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of Life Sciences and Technologies**

PROVENTUS PRO PATRIA

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Scientific Conference

Research for Rural Development 2018

Latvia University of Life Sciences and Technologies

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FOREWORD

The three independent reviewers estimated each paper and recommended 84 articles for publishing at the proceedings consisted of 2 volumes, which started life as presentations at the Annual 24th International Scientific Conference 'Research for Rural Development 2018' held at the Latvia University of Life Sciences and Technologies, in Jelgava, on 16 to 18 May 2018. The Annual 24th International Scientific Conference 'Research for Rural Development 2018' was special and dedicated to the *Latvia a 100 years* since became an independent state, *155th Anniversary* of Latvia University of Life Sciences and Technologies (LLU) and *280th Anniversary* of Jelgava palace, where is located the main building of university.

In the retrospect of four months later, we can count the Conference as a great success as interdisciplinary studies. The theme – Research for Rural Development - attracted participation more than 167 researchers with very different backgrounds. There were 139 presentations from different universities of Estonia, Poland, Kazakhstan, Lithuania, Ukraine, Sweden, South Africa, Indonesia, Russia and Latvia.
Thank you for your participation! We are sure that you have learned from the presentations and discussions during the conference and you can use the outcomes in the future.

The interdisciplinary proceedings of the Annual 24th International Scientific Conference 'Research for Rural Development 2018' (two volumes since 2010) are intended for academics, students and professionals. The subjects covered by those issues are crop production, animal breeding, agricultural engineering, agrarian and regional economics, food sciences, veterinary medicine, forestry, wood processing, water management, environmental engineering, landscape architecture, information and communication technologies. The papers are grouped according to the sessions in which they have been presented.

Finally, I wish to thank Organizing and Scientific Committee for their great support to the conference and proceedings.

On behalf of the Organizing Committee
of Annual 24th International Scientific Conference
'Research for Rural Development 2018'

Ausma Markevica
Latvia University of Life Sciences and Technologies

CONTENTS

BARBAREA ARCUATA AS A POTENTIALLY EXPANSIVE SPECIES IN AGRICULTURAL LANDSCAPES IN LATVIA

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Abstract
The distribution and abundance of *Barbarea arcuata* (Opiz ex J. et C. Presl) Rchb. were investigated throughout the territory of Latvia. The field survey was carried out to estimate the abundance patterns, and the herbarium materials were used to compile a distribution map. In total 411 localities were recorded in the period from 2015 to 2017. The species has been commonly found on roadsides, which accounts for 66% of the localities. Seventeen percent of the localities occurred in grasslands, 10% – in croplands, 4% – in fallows, 2% – on road embankment slopes, and 1% – on railway embankments. The highest density of *B. arcuata* were found in new fallows where it forms large populations. Whole field localities account for 5% of the total localities. Medium-sized stands are found in about 20% of localities and are mostly found in grasslands, roadsides, as well as croplands which include cereal fields and oilseed rape fields. Individual specimens are mostly found on roadside habitats and grasslands and account for 75% of the total number of localities. As dominant weed species it is found on fields of oilseed rape, cereal fields and fallows. Herbarium data and the Institute of Biology, University of Latvia lists of species show that *B. arcuata* distribution was frequent during the period from 1970 to 2014.
Key words: *Barbarea arcuata*, distribution, habitats, weeds.

Introduction

Weed species and weed control has been significant for several hundred years. Some weed species are becoming less common or even disappearing, while some other are becoming very frequent and expansive. Weed species composition is determined both by the agricultural crop and by the way of cultivating the land. Factors affecting the composition of weed species cannot be properly investigated without the consideration of temporal patterns (Lososová *et al.*, 2004). Weed vegetation on arable land can change rapidly over time and vary between fields and regions (Andersson & Milberg, 1998). Weeds have numerous interactions with other organisms and some of these interactions can have direct, either negative or positive, effects on the functioning of the agro-ecosystem (Petit *et al.*, 2011). Cropland is one of the most important weedy habitat, where many annual and perennial weeds grow with disturbing regularity (Zimdahl, 2018).

Barbarea arcuata (Opiz ex J. et C. Presl) Rchb. as native species is distributed in Europe and Asia (Котов, 1979). As for the flora of Latvia, *B. arcuata* was first mentioned in 1846 (Müller, 1846). In the subsequent literature sources it is also mentioned that the species is frequent (Klinge, 1882; Lehmann, 1895; Bickis, 1920; Фатаре, 1988) and locally abundant in Latvia, and also in Estonia and Lithuania (Kuusk, Rasiņš, & Jankevičienė, 1993). As mentioned by A. Rasins (1954), in Latvia *B. arcuata* was biennial or perennial weed occurring on arable land, clover fields, grasslands and weedy places.

A short life cycle and large seed production is a typical strategy of plants inhabiting highly disturbed habitats (Grime, 2001). *Barbarea arcuata* is characterized by a large number of seeds, ranging from 1,000 to 10,000 to one individual (Rasiņš, 1947) and the seed size is about 1.5 mm long and 1 – 1.25 mm wide (Eleksis, 1955). As the rosettes can grow in low temperature, the growing season extends (MacDonald & Cavers, 1991), thus contributing species presence in habitats. The flowering time for the species takes place during May and June (Kuusk, Rasiņš, & Jankevičienė, 1993).

In 2015, in eastern and central parts of Latvia, a large population of *B. arcuata* was observed on cereal fields one year after abandonment and on the edges of newly built roads, where species has not been observed before. This observation originated the question if there was a similar situation with this species in other regions of Latvia?

Barbarea R. Br. genus belongs to *Cruciferae* Juss. family and includes about 20 species, which are present almost worldwide, although concentrated in Eurasia (Appel & Al-Shehbaz, 2003). Three species are recorded in Latvia. Some authors, e.g. Stace (1992) and Ball (1993) accept only a single species, *B. vulgaris* R. Br. in a wide sense. Other authors (Hegi, 1986; Suominen, 1986) accept *B. vulgaris* as a polytipic species with several subspecies or varieties. In a number of Central European floras, *B. vulgaris* is considered a polytipic species (Kirschner, Kirschnerová, & Štěpánek, 2007), while in Eastern Europe, several taxa are accepted at species rank (Eleksis, 1955; Котов, 1979; Kuusk, Rasiņš, & Jankevičienė, 1993; Цвелев, 2000), separating *B. vulgaris* s. str. from *B. arcuata* (Opiz ex J. et C. Presl) Rchb.

The aim of this study is to clarify *B. arcuata* distribution in Latvia.

Materials and Methods

Species distribution and abundance analysis was based on the field studies and herbarium materials. Field survey was carried out in the territory of Latvia from 2015 to 2017 and totally 411 localities of *B. arcuata* were recorded. In order to evaluate the population size in various habitats, field surveys were carried out. Surveys were conducted mainly along roads, railways, as well as populated areas where species were recorded in the habitat area and assessed habitats on both sides of the road.

The number of specimens of *B. arcuata* were noted using a relative scale by distinguishing three groups: individual specimens (1 – 10 specimens of the species have been observed), medium-sized stands (11 – 100) and whole field (dominant species in habitat). The habitat types in which the species was found were recorded. If different groups were found in one square, then the map shows the one with the higher number of specimens.

For distribution of *B. arcuata* in the territory of Latvia, an analysis of herbarium material and 503 Institute of Biology University of Latvia inventory lists of species were carried out. The sources of the analyzed herbarium materials were: the Herbarium of the Laboratory of Botany, Institute of Biology, University of Latvia (LATV); the Herbarium of the Museum of

Botany, University of Latvia (RIG); the Herbarium of Slītere National Park (SVR); the Herbarium of the Natural History Museum of Latvia (LDM); the Herbarium of Daugavpils University (DAU); the Herbarium of the Latvia University of Agriculture (LLU); as well as from the private collections of botanists Alfreds Rasins (RAS) and Austra Abolina (AB), 175 herbarium specimens in total.

To evaluate the distribution and abundance of *B. arcuat*a in habitats, maps were compiled. Distribution maps were prepared using the Biological inventory square network, based upon geographical coordinates and in which one square is approximately 7.6 × 9.3 km in size. In Latvia, the total number of squares is 1017, of which 822 fall entirely within the territory of Latvia, and 195 partly overlie national borders (Табака, Клявиня, & Фатаре, 1980). For species distribution, the evaluation scale accepted by the Laboratory of Botany, Institute of Biology was used: very rare (1 – 10 localities), rare (11 – 30), rather rare (31 – 100), not rare (101 – 250), rather frequent (251 – 500), frequent (501 – 750), very frequent (more than 751) (Fatare, 1992). The programm ESRI © ArcGIS Desktop 10.3.1 was used to create maps.

Results and Discussion

During the field survey, *B. arcuata* was commonly found on roadsides, which make up 66% of the detected localities (Figure 1). Seventeen percent of the localities were found in grasslands, whereas croplands make up
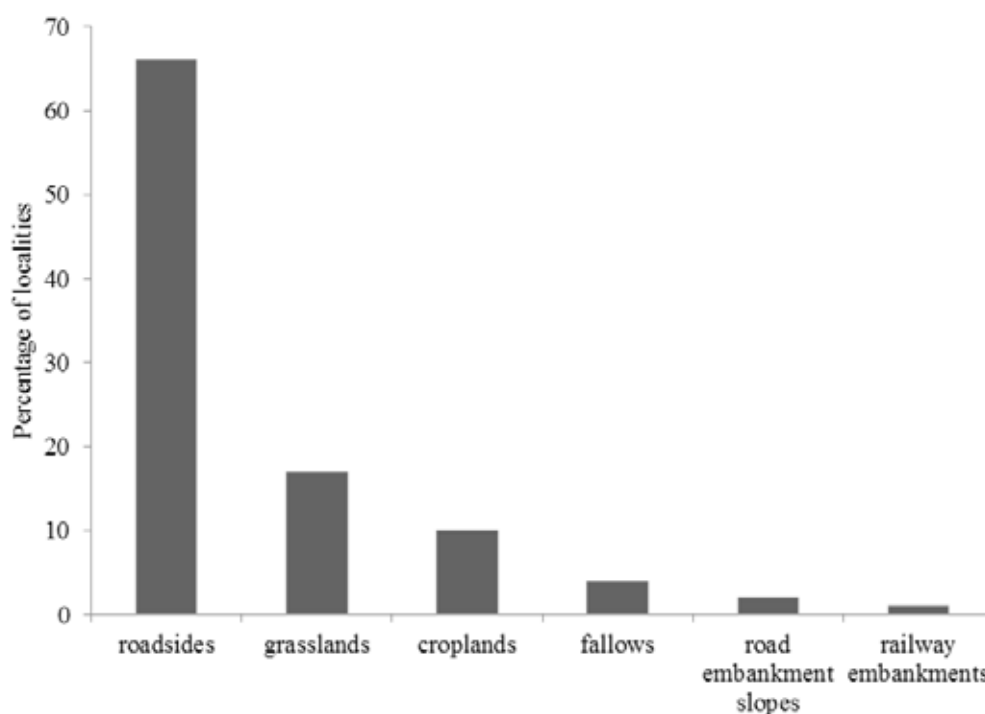
Figure 1. Habitats of *Barbarea arcuata* (Opiz ex J. et C. Presl) Rchb.
in Latvia in the observation period from 2015 to 2017.
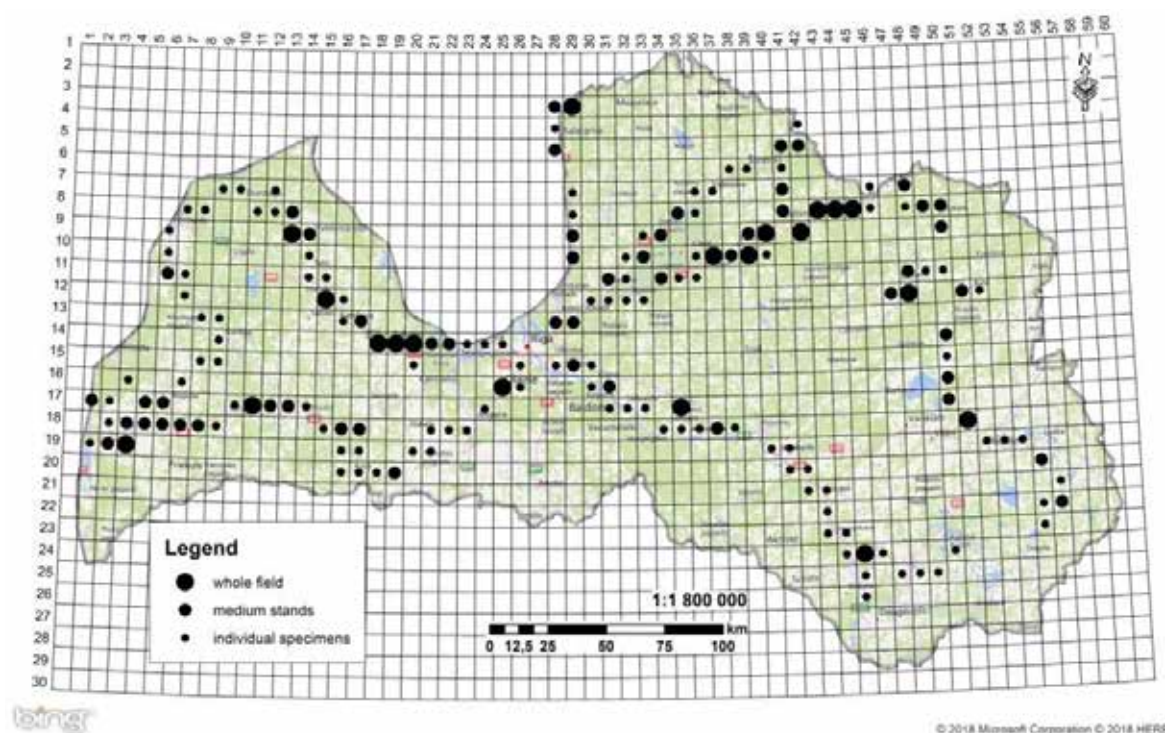
Figure 2. Abundance of *Barbarea arcuata* (Opiz ex J. et C. Presl) Rchb.
in Latvia during the observation period from 2015 to 2017.

10% of all localities, fallows – 4%, road embankment slopes – 2% and railway embankments 1%.

It can be concluded that *B. arcuata* has become a widespread weed in different habitats in Latvia. As it has become a rather common species in the roadside plant communities, it spreads also further away from roads in the fields and other habitats. As mentioned by Zimdahl (2018), few weed species grow exclusively in agronomic or horticultural crops or just in one crop. Also *B. arcuata* as weed is found in various agriculture-related areas.

Localities with individual specimens accounted for 75% of the total number of localities (Figure 2). The largest proportion of the localities were found on roadsides and grasslands, some also on railway embankments, oilseed rape fields and cereal fields, as well as in ditch margins. Localities of medium-sized stands are about 20% of whole localities and are found in grasslands, roadsides, cereal fields and oilseed rape fields. Whole field localities occur throughout the territory of Latvia and comprise 5%. Localities are found on cereal fields, oilseed rape fields and fallows.

The largest populations of *B. arcuata* were found on fallows. The species composition and density of weed seed in soil vary greatly and are closely related to the cropping history of the land (Rao, 2000).

Roads serve as corridors for the species distribution (Benedetti & Morelli, 2017) and also for *B. arcuata* contributes to reach new locations, where they establish as individuals or scattered stands which are quite frequent along roadsides. During road construction or reconstruction, the soil in use can derive from different places. As mentioned by Rao (2000), the seed bank in the soil is the primary source of new infestations of weeds each year. As soil for road reconstruction is transported from different locations, it is possible, if the soil has a large seed bank with *B. arcuata* seeds, that it will promote its establishment in new territories. In recent years, it is becoming more common in renovated or newly created road embankments, which are often dominated by *B. arcuata*.

B. arcuata forms a strong root system, which ensures the ability to absorb nutrients efficiently and creates competition for different crops. As mentioned by A. Rasins (1947), as weed grows on all kinds of soils in grasslands and fields. Short-lived root sprouts for this species have high fitness when regenerating from root fragments as well as when regenerating from seed (Rasiņš, 1954; Klimešová, Kociánová, & Martínková, 2008) and it is difficult to eradicate it in some habitats (Rollins, 1981).

After analyzing the herbarium material and the Institute of Biology, University of Latvia lists of species, it can be concluded that *B. arcuata* in the period from 1970 to 2014 is frequent (Figure 3) and occurs almost throughout Latvia. Herbarium data show that species is mainly found as individual
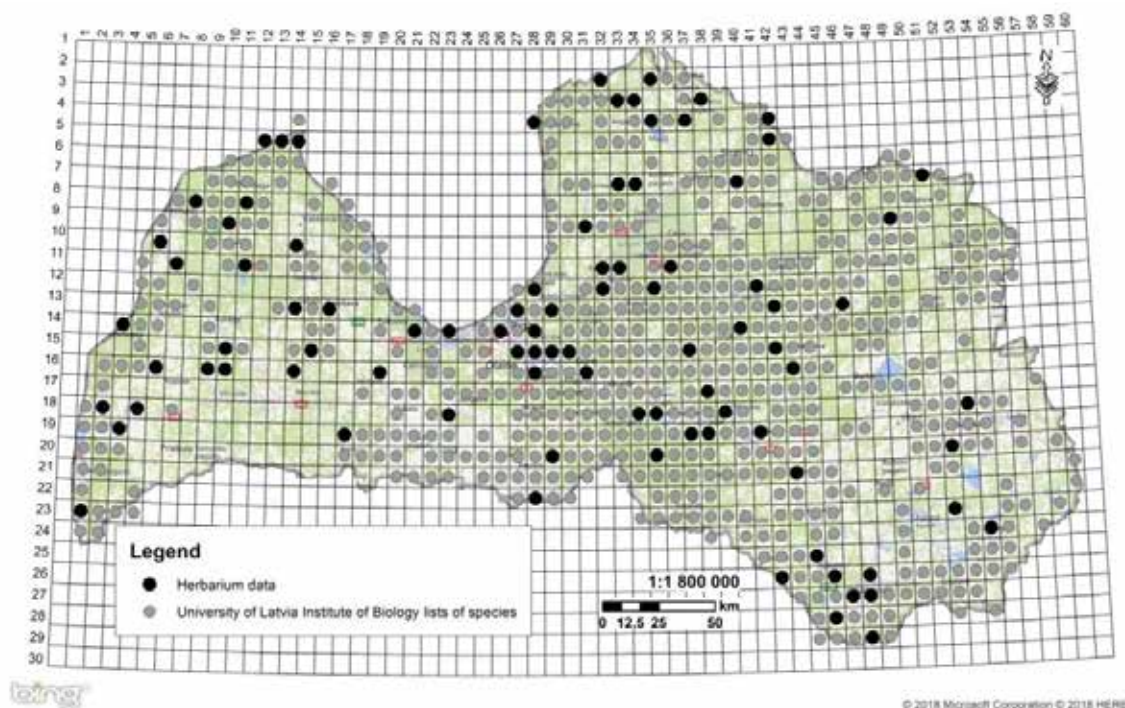
Figure 3. *Barbarea arcuata* (Opiz ex J. et C. Presl) Rchb. distribution in Latvia
in the period from 1970 to 2014.

specimens or as co-dominant species, without forming large populations.

Conclusions

B. arcuata is found on roadsides, grasslands, croplands, fallows, road embankment slopes and railway embankments. Roadsides are the most commonly found habitat type in this study and there are mostly found individual specimens. As *B. arcuata* forms large populations in croplands, fallows and grasslands, it can be considered as potentially expansive species in such habitats. Fields with high *B. arcuata* abundance are distributed throughout the country. This study shows current situation of *B. arcuata* distribution, but in order to estimate the changes in the distribution, it would be necessary to continue the research.

Acknowledgements

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BIODIVERSITY OF WEEDS AND SOIL SEED BANK IN ORGANIC AND CONVENTIONAL FARMING SYSTEMS

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Abstract
The aim of the study was to compare weed species diversity in organic and conventional farms in Poland. The study was carried out between 2012 and 2014 on production fields located in Lublin province, one of the easternmost regions of Poland. The results showed that diversity and abundance of weeds in spring cereals were generally higher in organic farming system than in conventional one. No significant differences between systems were found in 2013, because local flooding of fields in spring made impossible the execution of agricultural weed management treatment for some farmers. Both above-ground and soil seed bank weed communities were the mainstay of valuable weed species, which is confirmed by the presence of the species threatened with extinction, for example, summer pheasant's-eye (*Adonis aestivalis*), poorman's blue weatherglass (*Anagallis foemina)* and others in both tested farming systems. Dwarf everlast (*Helichrysum arenarium*) was the only found species that is subject to partial protection by Polish law. Both organic farms, run under CAP policy and support, and conventional extensive farms of the province of Lublin were the mainstay of biodiversity. Future rural development and CAP should be adapted and implemented regionally. Traditional extensive farms could contribute to the biodiversity and valuable plant species conservation.
Key words: biodiversity, weeds, farming systems, organic, conventional.

Introduction

Protection of biodiversity is one of the tasks of modern agriculture, which is reflected in the European Biodiversity Strategy (European Commission, 2011) that aims to halt the loss of biodiversity and ecosystem services in the EU by 2020. The abundance of animal and plant species is connected mostly with traditional extensive farming which is disappearing in modern, intensive agriculture of western Europe (Sutcliffe *et al.*, 2015). Such traditional farms are also disappearing in most parts of Poland, but are still common in easternmost parts of the country. The biodiversity in traditional extensive farms can have a positive impact on environment and it can also be beneficial to farmers. Conservation of biodiversity is crucial for maintaining ecological services that provide soil fertility and productivity of agricultural ecosystems (Clergue *et al.*, 2005). Biodiversity of rural areas is created mostly by the species and varieties richness of both cultivated and wild plants, but also by livestock and wild animals. It is well known that weeds have a negative impact on crop yields, mostly due to the competitiveness for all of environmental resources. Nowadays, it has become clear that weeds also play an important, positive role in the agricultural ecosystems. Those plants can create a number of various habitats for invertebrates. Pollinating insects and other insects that can provide biological pest control (e.g.: *Carabidae, Hymenoptera, Orthoptera*) are the examples of animals that live in the habitats created by weeds. Weeds are also a source of food for insects, small mammals; and also for farmland birds, which makes them important for the diversity of those groups of animals (Marshall *et al.*, 2003). Conservation of biodiversity of arable lands could be beneficial to farmers. It can help farmers get more stable yields and lower cost of chemical protection against pests and diseases. Moreover, biodiversity of segetal flora (weeds) increases the aesthetic value of rural areas, which is important for agri-tourism.

Intensification of agriculture, mostly by simplified crop rotation, high amounts of chemical fertilizer and plant protection products, is the most important threat to the biodiversity of rural areas. Herbicides, widely used in conventional farming system, are the main reason of biodiversity decrease. The surface of unproductive areas like field margins, shrubs, midfield trees and ponds is often reduced to minimum in intensive conventional farming. Modern, sustainable agriculture should combine the production goals with environment protection. Farming system that uses environmentally friendly cultivation methods and protects biodiversity is organic farming (European Commission, 2007). Lubelskie region, due to its specific characteristics (fragmented agriculture, low input of plant protection products and mineral fertilizers, high biodiversity) is one of the regions that is especially predisposed to implement low-input production systems, for example, like organic farming. All of this makes he number of organic farms in the province of Lublin still increasing, and the area is ranked 5th in terms of the number of organic production farms (1896 farms) and 7th in terms of surface of organic production (29585 ha) (Salach & Waszewska, 2016). Natural conditions of the province of Lublin favors the development of organic farming which produces food of high-quality but also has a positive impact on the environment, including biodiversity. The aim of the study was to compare weed species diversity in organic and conventional farms in Poland.

Materials and Methods

The three-year study was carried out in 2012, 2013 and 2014 as a part of KIK/25 project: 'Protection of species diversity of valuable natural habitats on agricultural lands on Natura 2000 areas in the Lublin Voivodeship'. Research was carried out in Poland, in the province of Lublin, one of the easternmost regions of Poland. Study sites were located in the vicinity of NATURA 2000 areas.

At the beginning of the research, 14 organic and 14 conventional study squares of the area of 9 ha were selected. Organic study squares had at least 50% of organic agriculture surface share (run as certified organic agricultural fields), while conventional squares had at least 50% of conventional agriculture surface share (conventional – without organic certification). The chosen study squares had to be at least 500 m apart from forests and shelterbelts to minimize the impact of forests and woodlands on biodiversity samplings. Pairs of organic-conventional squares were located in the vicinity to each other, to keep their soil and climate conditions as similar as possible. In each square, a field of spring cereals – wheat (*Triticum* L.), barley (*Hordeum* L.) oats (*Avena* L.) or cereals and cereal-legume mixtures - was located. Five test plots of the area of 0.5 m² (spacing between plots 10 m) were selected on each field. Above-ground weed species and their abundance were measured within every plot. Additionally, species found in the immediate vicinity of the test plots (2 m²) were also counted. Soil samples from the proximity of every test plot from 0–20 cm soil layer were taken in order to determine the species presence and their abundance in the soil seed bank, as well as to test soil parameters. Samples were placed in pots filled partially with sand (drainage) and placed in the greenhouse in order to evaluate seed species and their number present in the soil (ie. active seed bank). Exposure of soil seed bank lasted for 12 months. Both weed soil seed bank samples and above-ground evaluation took place annually, between 10th of June and 5th of July. The number of species, their abundance, as well as Shannon diversity index (H') (Shannon, 1948) and Simpson dominance index (SI) (Simpson, 1949) were counted to describe the biodiversity of weed communities. Shannon and Simpson indices were calculated using Past 3 software (Hammer, 2016). The statistical analysis was done on a basis of medians as most of variables had the distribution that was deviating from normal. A survey study with farm-holders was carried out to get knowledge about farms and agricultural practices performed on the tested fields. Weather conditions (precipitations and temperature) during the study period were similar to the long-term average for the region, with the exception of the year of 2013, in which rainfall in May was about twice as high as normal (Figure 1).

Results and Discussion

Characteristics of organic and conventional farms. The study squares and farms were randomly selected. The main features of the tested farms are given in Table 1. The tested organic and conventional farms differed significantly only on features linked with NPK fertilization, which was significantly higher in conventional farms, and the average grain yield – which also was significantly higher in conventional farms (3.0 t ha⁻¹) than in organic farms (2.0 t ha⁻¹). Moreover, the tested farms had slightly larger farm areas than the regional average (average organic farms in Lublin region 18.5 ha, average conventional farms 38.5 ha; (GUS, 2016), which probably was a consequence of the study square selection criteria (at least 500 m away from the forest and other shelterbelts) which promoted larger fields. The tested organic farms relied mainly on the use of organic fertilizers
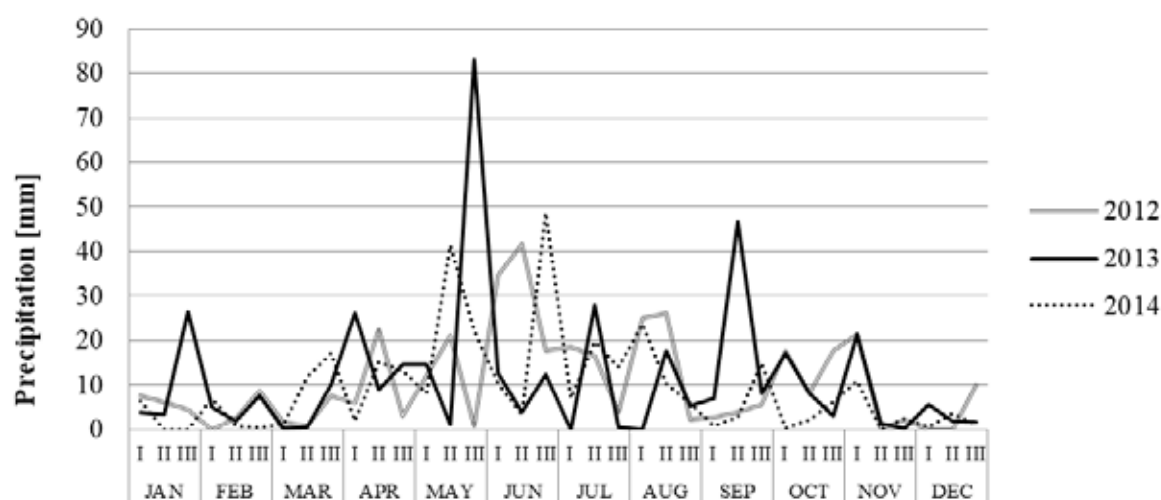
Figure 1. Precipitation (mm) in the study area during the study period (2012, 2013 and 2014).

Table 1

The main features of the tested organic (ORG) and conventional (CONV) farms

Feature	Median	
	ORG	CONV
Area of the farm (ha)	27.1[a]	26.7[a]
Soil class (I – best; VI – worse)	IV and V	IV and V
pH in KCl	4.57[a]	4.93[a]
Organic carbon (Corg) content (%)	0.60[a]	0.58[a]
NPK mineral fertilization (kg ha^{-1})	0[a]	32[b]
NPK organic fertilization (kg ha^{-1})	0[a]	36[b]
SUM of NPK (kg ha^{-1})	0[a]	120[b]
Number of harrowing (mechanical weed control)	1[a]	1[a]
Number of sprayings with Plant Protection Products	0[a]	1[a]
Share of fields with herbicide use (%)	0[a]	70[a]
Share of fields with use of PPPs other than herbicides (%)	0[a]	10[a]
Average yields of cereal grains (t ha^{-1})	2.0[a]	3.0[b]

[a,b] different letters in same row indicate significant differences between farming systems ($p<0.05$).

or catch crops as they used no mineral fertilizers, while conventional farms used minimal amounts of mineral fertilizers (Table 1). The number of harrowing was the same in both groups of farms. Conventional farms used low amounts of Plant Protection Products. Mechanical weed control (harrowing) was carried out only once a year in both farming systems (Table 1).

Above-ground weed species community and their abundance. There were 151 weed species found in total in spring cereals during the studies. Significantly more (131) weed species occurred in the organic farming system than in conventional farming system (116) (Table 2). Thirty-five species occurred only in organic farming system while next 20 – only in conventional farming system. Ninety-six species (63%) were common for both farming systems. The study showed a larger number of species and their abundance in organic than in conventional farming system in two of three years of the study (Table 2). There were no significant differences between the farming systems only in 2013, when weather conditions were unfavourable and made weed control impossible for some farmers (local inundations of fields). Biodiversity of weeds in organic farming system is usually greater than in other intensive farming systems, which is well described in the literature (Edesi *et al.*, 2012; Berbeć *et al.*, 2013; Jastrzębska *et al.*, 2013; Tuck *et al.*, 2014; Kolářová, Tyšer, & Soukup, 2015). Feledyn-Szewczyk and Duer (2007) found on average 17 species of weeds in organic spring wheat and 29 in organic spring barley, while in conventional farming the number of species was significantly lower (12 and 18, respectively). The abundance of weeds in the presented study was

significantly greater in organic than in conventional farming system. This dependence was confirmed by other authors (Feledyn-Szewczyk & Duer, 2007; Koocheki *et al.*, 2009; Edesi *et al.*, 2012; Salonen *et al.*, 2013), whooften found the weed infestation of organic cereals many times higher than conventional. Feledyn-Szewczyk (2012) found, on average, from 78 to 116 pcs m[-2] of weeds in organic spring wheat while in conventional spring wheat there was only between 13 to 48 pcs m[-2] of weeds depending on the year of the study. In the presented study, the differences between farming systems were not so large, but the infestation rate of spring cereals was generally greater (198–398 pcs m[-2]) in organic spring cereals than in conventional spring cereals (65–258 pcs m[-2]). Greater infestation rate of weeds was most likely due to the extensive crop production on farms, both organic and conventional. The relatively high abundance of weeds in the conventional farming system might be caused by the low efficacy of the herbicides, which was the result from wrong selection, inappropriate application or inadequate weather conditions during the application. Skrzyczyńska and Rzymowska (2000) investigated weed infestation in organic and traditional extensive farms and found that weed infestation was significantly greater in organic farming system.

Soil seed bank weed communities and their abundance. During the study, a total of 96 species of weeds were found in soil seed bank weed community. Significantly more species were found in organic (83) than in conventional farming system (78) (Table 3). Eighteen species were found only in organic farming system, while other 13 only in conventional farming system. The number of species in soil seed bank was

Table 2

Number and abundance of above-ground weed species in spring cereals in organic (ORG) and conventional (CONV) farming systems in the years 2012 – 2014

Parameters	ORG	CONV
Total number of species in above-ground weed communities	131[a]	116[b]
Species unique for system	35	20
Median of number of weed species per field		
2012	19[a]	10[b]
2013	28[a]	22[a]
2014	30[a]	18[b]
Median of abundance of weed flora (pcs·m^{-2})		
2012	198[a]	65[b]
2013	296[a]	258[a]
2014	398[a]	188[b]

[a,b] different letters in the same row indicate significant differences between the farming systems (p<0.05).

significantly greater in organic than in conventional farms in 2012 and 2014. The abundance of seeds in the soil seed bank was also significantly greater in organic than in conventional farming system in each year of the study (Table 3.) In 2013 there were no differences between two systems in the number of species. The reason behind that is the fact that soil seed bank is closely related to actual weed infestation. The scattering of seeds from the same phytocoenosis is the main source of their inflow to the soil (Murphy *et al.*, 2006; Wortman *et al.*, 2010). Since the weed infestation in 2013 was high (even in the conventional farming system), and soil samples were collected in June and July, most of weed species were able to produce seeds and deposit them in the soil seed bank. This had major impact on conventional farming

system, as even species rarely found in soil seed bank were able to germinate, grow and release seeds and increase seed reserve in the soil. Weed population on arable lands consists mainly of seeds in the soil, which was confirmed by the presented study (usually several thousand seeds per 1 m^2 in soil seed bank versus several hundred plants per 1 m^2 in the above-ground weed communities in the most abundant cases). Soil seed bank is an important reservoir of segetal flora. Chemical weed control is the main reason of differences in weed infestations between organic and conventional farming systems. Herbicides limit the population of sensitive weeds, however they often do not have any limiting effect on species not sensitive to them (Graziani *et al.*, 2012). Soil seed bank is also affected by crop rotations. Organic farming often

Table 3

Number of species and seeds in soil seed bank in spring cereals in organic (ORG) and conventional (CONV) farming systems in the years 2012 – 2014

Parameters	ORG	CONV
Total number of species (soil seed bank weed communities)	83[a]	78[b]
Species unique for system	18	13
Median of number of weed species per field		
2012	22[a]	15[b]
2013	20[a]	17[a]
2014	22[a]	15[b]
Median of number of weed seeds (pcs·m^{-2})		
2012	10,600[a]	5,400[b]
2013	9,300[a]	5,600[b]
2014	8,400[a]	4,400[b]

[a,b] different letters in the same row indicate significant differences between farming systems (p<0.05).

Table 4

Values of Shannon diversity (H') and Simpson dominance (SI) indices for above-ground and soil seed bank weed communities in organic and conventional farming systems

Farming system		Organic	Conventional
Year	index		
Above-ground biodiversity			
2012	Shannon (H')	2.553[a]	2.311[b]
	Simpson (SI)	0.165[a]	0.182[b]
2013	Shannon (H')	2.994[a]	2.637[b]
	Simpson (SI)	0.133[a]	0.181[b]
2014	Shannon (H')	2.727[a]	2.599[b]
	Simpson (SI)	0.166[a]	0.160[b]
Soil Seed Bank biodiversity			
2012	Shannon (H')	3.036[a]	2.546[b]
	Simpson (SI)	0.074[a]	0.146[b]
2013	Shannon (H')	2.845[a]	2.676[b]
	Simpson (SI)	0.086[a]	0.122[b]
2014	Shannon (H')	3.169[a]	3.080[b]
	Simpson (SI)	0.072[a]	0.074[a]

[a,b] different letters in same row indicate significant differences between farming systems ($p<0.05$).

has more complex crop rotation. Different crops are associated with different weed species, which enrich the soil seed bank.

Graziani *et al.* (2012) found that biodiversity of soil seed bank of weeds in organic farms is often similar to the biodiversity of seeds in traditional extensive farms. According to the authors, this is due to the 'integrated' (mechanical + chemical) weed control of low intensity performed in traditional farms. Weather conditions can also have a significant impact on the weed biodiversity. In the presented study, weather conditions in late spring of 2013 (heavy rains) resulted in local inundations of fields. This made performing of weed control practices impossible for some farmers, and thus greatly increased weed infestation and increased inflow of seeds to the soil. As a result, no differences between systems in 2013 in the number of species and abundance of weeds in above-ground weed communities were found. At the same time, soil seed bank was more stable and resistant to external disturbances (significant differences in abundance of seeds between these two tested farming systems were found).

Biodiversity assessment with Shannon diversity and Simpson dominance indices. Shannon diversity index (H') showed significantly higher values in organic than in conventional farming system both in above-ground and in soil seed bank weed communities in each year of the study. The values of Simpson dominance (SI) index were significantly

lower in organic than in conventional farming system in each year of the study for the above-ground weed communities. In the soil seed bank, Simpson dominance index was significantly lower in 2012 and 2013, while in 2014 there were no differences between those two farming systems (Table 4).

Shannon diversity and Simpson dominance indices showed better condition of biodiversity in organic than in conventional farming system. Nevertheless, Shannon diversity index for above-ground and soil seed bank had high values not only in organic (H'=2.6–3.2), but also in conventional farming system (H'=2.3–3.1), which indicates an important role of traditional extensive farms in biodiversity conservation. Armengot *et al.* (2013) found that Shannon diversity index had high values in organic weed communities found in cereals (H'=2.5), while its values for conventional farming system were lower (H'=1.5). Feledyn-Szewczyk & Duer (2007) confirmed that conditions of biodiversity were the best in organic and integrated farming system, worse in conventional farming system, and the worst in the long-term monoculture. Moreover, the authors found that Simpson dominance index for above-ground weed communities in organic farming system was low (0.25), while in the conventional farming system its values were higher (>0.25). In the presented study, Simpson dominance index was low in both farming systems, and even in the conventional farming system its values did not exceed 0.18, which indicates that

Table 5

Endangered weed species in organic and conventional spring cereals

Species name and endangerment category	Above-ground		Soil seed bank	
	ORG	CONV	ORG	CONV
Bromus secalinus [v]	×	–	–	–
Ranunculus arvensis [v]	×	×	–	–
Anagallis foemina [v]	×	×	–	–
Adonis aestivalis [v]	–	×	–	–
Myosurus minimus [v]	–	–	×	×
Helichrysum arenarium [p]	×	×	–	×

[v] – vulnerable according to Polish Red List of Plant and Fungi
[p] – subject to partial legal protection in Poland

weed communities were not dominated by single species. Moreover, in the presented study Shannon diversity index for soil seed bank differentiated the two tested farming systems, but was high for both farming systems (2.55–3.17). Graziani *et al.* (2012) found that Shannon diversity index for soil seed bank was lower than 2.0, and there were no significant differences between organic and conventional farms.

Endangered species. The presented study confirmed the positive impact of organic farming on biodiversity of weeds. It was also found that traditional extensive conventional farms, which are typical to eastern Poland, are of great importance in the protection of species diversity and, like organic farms, are the mainstay of valuable weed biodiversity. Confirmation of this is the fact that species enlisted in Red List of Plant and Fungi in Poland (Mirek, 2006) were found during the study in both organic and conventional farming systems. Those species included *Ranunculus arvensis L.*, *Anagallis foemina* Mill. and *Helichrysum arenarium* (L.) Moench. Other endangered weed species, all marked as 'vulnerable', were found in organic or conventional farming systems (Table 5). Other rare species as *Agrostema githago* L., *Veronica dillenii* Crantz, *Arnoseris minima* L., *Euphorbia exigua* L., *Geranium sanguineum* L., *Lathyrus tuberosus* L., *Campanula rapunculoides* L. and *Consolida regalis* S.F. Gray were also found during the study. *Helichrysum arenarium* (L.) Moench was the only found species that is a subject to partial legal protection in Poland. Those species are disappearing under intensive conventional agriculture conditions but are still present in extensive farms of eastern Poland. The presence of rare and endangered species of segetal flora in both organic and conventional farms

of eastern Poland is proof of the high environmental value of agro-ecosystems and the importance of organic and traditional extensive farming systems in biodiversity protection.

Conclusions
1. Studies have shown significantly higher species diversity and abundance of above-ground and soil seed bank weeds in organic than in conventional farms.
2. For both types of farms, the Shannon diversity index was higher for the soil seed bank than for above-ground flora, which indicates the importance of seeds in the soil as a reservoir of biodiversity.
3. Both organic and conventional farms of the province of Lublin are the mainstay of valuable segetal plant species, which is confirmed by the presence of the species threatened with extinction, as well as many other rare species.
4. The study showed that among the tested conventional farms there are also small family farms with low use of chemical inputs, which seems to be beneficial for weed biodiversity. Supporting such farms in further pro-ecological production seems necessary. Thus, rural development strategies and CAP should be adapted and implemented regionally to suit the local characteristics of agricultural production.

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PRODUCTIVITY OF CROP ROTATION MEASURED AS ENERGY PRODUCED BY INCLUDED PLANTS: A REVIEW

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Abstract
The most important reason for growing field crops is food consumption. Only some of the total amount of field crop species are mostly used for cultivation in the largest part of arable land. These crops ensure high economic income. This is the reason why biological diversity has decreased. Crop rotation is considered to be an instrument of sustainable cropping system and this is confirmed again nowadays. Higher cereal yields have been gained by including oil crops or pulses in the rotation. Each field crop has its own calorific value (MJ kg^{-1}). Grains / seeds and above-ground biomass may have different calorific values because of their chemical composition. Research results from literature confirm that the average net calorific value of winter wheat (*Triticum aestivum*) and triticale (*Triticosecale*) grain and straw are ~17 MJ kg^{-1}, but the net calorific values for oilseed rape (*Brassica napus* ssp. *oleifera*) seeds and straw are – 25.70 MJ kg^{-1} and 16.37 MJ kg^{-1}, respectively. Oilseed rape is also known as energy-rich crop. It is reported that diversified crop rotations also have greater energetic productivity from above-ground biomass (grain / seed yield and by-products) if compared with crops grown in repeated sowings or in monoculture. Crop rotation in combination with different tillage methods (conventional tillage, reduced or minimum tillage and no-tillage) is the way to improve soil quality, but it is not clear whether the soil treatment method has a significant impact on the overall crop rotational energy productivity.
Key words: crop rotation, yield, calorific value, energetic productivity.

Introduction

The main benefit of field crop cultivation in agriculture is the part of harvest intended for the main purpose – mostly it is food. In order to calculate the total yield of arable crops, by-products or post-harvest residues, such as straw, should also be taken into account. Farmers usually choose to grow crops which are profitable, despite the large investments needed for repeated sowings for several years or growing crops even in monoculture. The arable land in Europe is taken up with cereals – 54% (wheat (*Triticum*), barley (*Hordeum vulgare*), maize (*Zea mays*)), plants harvested green – 20%, industrial crops – 12% (oilseed rape (*Brassica napus* ssp. *oleifera*), turnip rape (*Brassica rapa*), sunflower (*Helianthus annuus*), soya (*Glycine max*)), and only 7% is taken up with dry pulses, root crops and vegetables (EUROSTAT, 2016). According to the data of Central Statistical Bureau of Latvia, the arable land in 2016 was used for growing the following crop groups – wheat (*Triticum aestivum*) (39%), oilseed rape (8%), barley (8%), oats (*Avena sativa*) (5%), pulses (3%) (main crop – faba bean (*Vicia faba*)). A particularly high prevalence of wheat over other species suggests that wheat is often grown in Latvia in repeated sowings, or among other cereal species, because other important crop rotation components, such as leguminous plants and oilseed crops, occupied just 11% of the total arable land (Use of Agricultural..., n.d.). A similar distribution of crops is also found in Germany where in the region of Lower Saxony in 2011 more commonly used crops were maize (>30%), winter wheat (25%), winter barley (10%), oilseed rape (8%) and rye (*Secale cereale*) (6%) (Stein & Steinmann, 2018).

Because some crops are more profitable than others and they are able to adapt to different growing conditions, the diversity of crops in farms has decreased. Crop rotations with small diversity of plants are used. We can usually observe cereal monoculture fields; legumes or oil crops are grown once per three to four years of cereal rotation. However, a well-considered plant change is an important cropping tool. Therefore, it is important to confirm again that crop rotation is a relevant part of crop production even nowadays. Employing other species instead of cereals as fore-crops may result in higher grain yields (Rosenberger *et al.*, 2001).

The benefits of crop cultivation are often compared by calculating economic returns. Different crops can also be compared by the produced energy. The total energy of crop rotation is also studied in the world as energy output from various crops' grain / seed yields (Zentner *et al.*, 2004) or from the total biomass (including grain / seed and straw) (Hülsbergen, Feil, & Diepenbrock, 2002).

Different field crops can be compared by determining the energy value (MJ kg^{-1}) of each individual product. Different crops have different energy or calorific value (Alluvione *et al.*, 2011). Similarly, different energy values are characteristic for different crop parts (grains / seeds, straw, roots) because their chemical composition differs. The calorific value is mainly influenced by the composition of the material, but various substances accumulated in the product can be influenced by various external factors, including those that can be partially affected by humans (seed material, fertilizer, etc.) (Zhang, Xu, & Champagne, 2010). Determined energy value can

be attributed to the harvested yield t ha⁻¹, in order to calculate the total energy output from the cultivated area.

Energy difference between the energy output and the energy input (both direct and indirect) is called net energy, and it has been studied extensively in the world. Besides, energy intensity (yield against energy input) and energy ratio (output energy against input energy) are also widely studied (Hülsbergen, Feil, & Diepenbrock, 2002; Zentner *et al.*, 2004; Strašil, Vach, & Smutný, 2015).

Agricultural products and by-products can be variously applied for food, fodder, energy and bioenergy due to their energy values. Also, post-harvest residues are valuable as they improve soil organic matter content.

Other solutions for profitability and productivity increase of crops is the reduction of costs by minimizing the expenses of soil treatment – traditional soil tillage with a minimum tillage or no-tillage is replaced.

The aim of this literature review is to compare how the total energy value of crop rotation is influenced by crops included in it and by soil tillage method.

Materials and Methods

Review summarizes the research findings on the energetic values of winter wheat and other crops in different crop rotations and in different tillage systems. Literature from different scientific journals all around the world has been used. It includes information from studies conducted in Latvia, Germany, Poland, Czech Republic, Austria, Canada, Japan and others. Monographic method was used in this study.

Results and Discussion

Crop rotation

Crop rotation is a part of cropping system. Crop rotation is also a way to ensure crop diversity in farms (Dury *et al.,* 2013). If the same crop has been cultivated using the same management for many years, negative effects on soil quality can be observed, and infection risk with harmful organisms like diseases, weeds and pests increases (Bennett *et al.,* 2012; Stein & Steinmann, 2018). Conventional crop rotations had been researched in the world trying to clarify whether any advantages can be observed, including energy crops in rotation. For the temperate climate of Northern Europe the best choice for species in rotation is oilseed rape, cereals, flax (*Linum usitatissimum*) and legumes, due to the increased yields, better control of diseases, and efficient use of soil resources (Zegada-Lizarazu & Monti, 2011). A way to ensure biodiversity in cereal-based crop rotation can be the use of catch-crops. Small differences of soil quality may also be provided, caused by the prevention of nutrient leaching by catch-crops (Nemecek *et al.,* 2015).

Crop rotations researched in Latvia consist of three treatments (1) wheat in repeated sowings, (2) rotation that includes winter wheat, oilseed rape, barley and faba bean, and (3) oilseed rape that is followed by wheat for two years (Konavko & Ruža, 2017). A long-term trial with similar crops has also been conducted in Canada with the following variants: (1) wheat in repeated sowings, including a fallow period once in four years, (2) spring wheat – spring wheat – flax – winter wheat, and (3) spring wheat – flax –winter wheat – pea (*Pisum sativum*) (Lafond *et al.,* 2006). Farms focusing on crop rotation designing get a stable farm management plan in the longterm, but it is more difficult for them to adapt to changing conditions in cropping (Dury *et al.,* 2013).

Yield and productivity of oilseed rape (Rathke, Christen, & Diepenbrock, 2005) and wheat (Freeman, Raun, 2007) mostly depend on crops' supply with nitrogen, which increases growing input costs. Inclusion of legumes in crop rotation ensures a possibility to reduce the N rate for the next crop due to the biological nitrogen fixation. Break crop also reduces the need for pesticides (Petersson *et al.,* 2007).

In a study in Germany, it was found that winter wheat yields increased when they were sown in the crop rotation after peas, in comparison with the rotation including only cereals. In a two-season long study with three different intensity growing systems, the following wheat yields were obtained: when grown after peas: 5.22 – 7.63 t ha⁻¹, and when grown after cereals: 2.86 – 6.55 t ha⁻¹. Straw yields of winter wheat in all cases were also the highest when wheat was grown after peas, if compared with growing after cereals: 7.77 – 10.35 t ha⁻¹ and 2.96 – 7.35 t ha⁻¹, respectively. Such tendency was observed also when triticale was grown after peas and cereals (Rosenberger *et al.,* 2001). When wheat was grown after faba beans, it was possible to obtain grain with higher protein and gluten content if compared to wheat grown in repeated sowings (Konavko & Ruža, 2017). In Canada, it has been concluded that there is no significant difference between wheat yields and energy yields if fore-crop was pea or rape (Nagy *et al.,* 2000).

The results of five-year field experiments in Sweden with five year rotation of cereal crops showed no difference between the effect of ploughless tillage and mouldboard ploughing on winter wheat yield in good conditions. Yield loses of winter wheat were observed in one of trial years in repeated winter wheat sowings where reduced tillage and direct drilling was used. Nevertheless, these losses can be attributed more to inappropriate wet conditions during tillage (Arvidsson, 2010).

Yield, biomass and energetic productivity

The increasing world population makes a challenge for food and energy production and provision of other basic needs. Land, soil and water resources are limited and exposed to climate changes. Agriculture needs to get higher yields and productivity of cropping systems (Cacho *et al.*, 2018).

In different sources of literature, crop yield and by-products (altogether – biomass) are often divided into different materials. Biomass components (cellulose, hemicellulose, lignin, lipids, simple sugars, water, carbon, ash and other components) are presented in different structures and ratios depending on species and different types of biomass (e.g., grain / seed, straw) (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The concentration of biomass components varies according to the tissue type, plant development phase in which the biomass is harvested, and growing conditions (Zhang, Xu, & Champagne, 2010).

Various mathematical models can be selected when determining the energetic values of different biomass materials named as calorific value or heating value (Friedl *et al.*, 2005; Erol, Haykiri-Acma, & Küçükbayrak, 2010; Vargas-Morenoa *et al.*, 2012). Calorific value can also be determined by automatic equipment (bomb calorimeter) (Erol, Haykiri-Acma, & Küçükbayrak, 2010). Calorific value is divided in gross calorific value or higher heating value (Friedl *et al.*, 2005) and net calorific value or lower heating value (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The difference between gross calorific value (HHV) and net calorific value (LHV) is in the amount of water vapour. In HHV it is included as condesated water, but in LHV water vapour remains as vapour; however, in the first one more heat is recovered. The gross calorific value can be determined by bomb calorimetry (Friedl *et al.*, 2005). Both mentioned values have been used in different studies, but it is not mentioned which of them are better for comparing energy output per hectare.

Biomass is an important renewable energy source that can be used for heat generation from burning. Biomass as fuel has economic and ecological benefits (Erol, Haykiri-Acma, & Küçükbayrak, 2010). The use of materials derived from plant biomass for the production of thermal energy is advisable as they do not emit more carbon dioxide in the atmosphere if compared with the amount plants absorb during the photosynthesis. Plants continue also to assimilate this carbon dioxide, so it does not have a significant impact on the greenhouse effect (Sakalauskas *et al.*, 2011; Qi *et al.*, 2018).

Energy value of different plants has been studied in Turkey. One of the studies has shown that the heating value is directly affected by the ash content. If the plant parts have high ash content, less heat is produced. Demirbas (2002) has also compiled literature on

earlier studies to calculate the heating value. Morrison and Boyd in 1983 wrote that the amount of heat increases with higher carbon and hydrogen quantities, and the proportion of mentioned elements to oxygen (cited from Demirbas, 2002). The same researcher also found a close correlation between the heating value and lignin content in biomass (Demirbas, 2001).

The most widely cultivated crops in Latvia are various species of cereals and oilseed rape. The usage directions of these species and energy values have been studied in Latvia and in the world. The main end product of cereals is grain used for food production, mainly for the production of flour. Grains that do not meet the food requirements are mostly used for forage production. Grains, due to their high energy value, can also be a source for bioenergy, for example, bioethanol, where the result is directly determined by the amount of starch; therefore, low protein content is preferable for bioethanol production (Jansone & Gaile, 2012; 2013). Wheat straw is also used for bioenergy production, e.g. for bioethanol, thanks to its energy value and cellulose content (Dai *et al.*, 2016; Townsend, Sparkes, & Wilson, 2017) and as a heating material, etc. Energy value of grain yield and biomass depends on the growing technology, which should be selected according to the desired cultivation purpose – food, feed, bioenergy.

In Canada, the average energy value of winter wheat grain set in a long-term experiment with three different soil treatments was – 18.71 MJ kg^{-1} (Zentner *et al.*, 2004). In Germany, the following HHV were established for cereals in a long-term experiment: winter wheat grain – 18.6 MJ kg^{-1}; winter wheat straw – 17.7 MJ kg^{-1}; spring barley grain – 18.4 MJ kg^{-1}; spring barley straw – 18.1 MJ kg^{-1} (Hülsbergen, Feil, & Diepenbrock, 2002). In Hungary, considerably lower heating values (determined with a bomb calorimeter) of winter wheat straw were established if compared with the above mentioned – HHV 16.4 MJ kg^{-1}, and LHV 14.9 MJ kg^{-1}; there is no information about the wheat yield and its growing technology (Sebestyén *et al.*, 2012). In Latvia, after determining the heating value of different winter cereal species, it was concluded that dry matter of winter cereal straw has a higher energy value if compared with dry matter of grains. At the same time, higher dry matter yield of grain, if compared with that of straw, was established and therefore more energy per ha was produced by grain (Jansone & Gaile, 2015). In Germany also it was established that straw of cereals has a higher heating value if compared with grains. Energy value of wheat and triticale grain dry matter was 17.0 and 16.9 MJ kg^{-1}, respectively, but that of straw – 17.2 un 17.1 MJ kg^{-1}, respectively (Boehmel, Lewandowski, & Claupein, 2008). In Poland, the energy efficiency of winter oilseed rape was studied

in a three-year trial. It was concluded that by using an intensive cultivation technology (by energy input) the highest amount of generated energy was obtained: 268.5 GJ ha⁻¹. Intensive cultivation technology included soil tillage treatments before sowing, hybrid seed material, soil fertilization (501 kg ha⁻¹ NPKS), weed control, and three insecticide and three fungicide sprays. Energy value obtained from the oilseed rape seed yield and oil yield when the intensive cultivation technology was used was significantly higher in comparison with other technologies. The calorific value was determined using adiabatic combustion calorimeter. Straw did not show significant differences in the energy output, depending on the intensity of farming activities. Specified net energy values for rape were: seed – 25.7 MJ kg⁻¹, straw – 16.4 MJ kg⁻¹. Energy obtained from seeds under intensive growing conditions were 100.2 GJ ha⁻¹, but in low-input conditions – 81.1 GJ ha⁻¹. In this study, the seed mass was about 30% of the total surface biomass (4.17 t ha⁻¹ seed, 10.31 t ha⁻¹ straw) (Budzyński, Jankowski, & Jarocki, 2015). In Germany, it was also found that the lower heating value for oilseed rape seeds is much higher than the value of straw – 26.5 and 17.1 MJ kg⁻¹, respectively (Boehmel, Lewandowski, & Claupein, 2008).

After researching the gross energy of the field crops in crop rotation, it is concluded that there is a big difference between various crops in energy value, e.g. gross energy for maize grain was 18.9 MJ kg⁻¹, for wheat grain 18.4 MJ kg⁻¹, for soybean – 23.65 MJ kg⁻¹ (Alluvione et al., 2011), for rape seed – 26.5 MJ kg⁻¹ (Boehmel, Lewandowski, & Claupein, 2008), for sugar beet – 17.4 MJ kg⁻¹, for potato – 17.6 MJ kg⁻¹ (Koga, 2008). Energy values of cereals, oilseeds and pulses straw did not differ significantly (Alluvione et al., 2011; Strašil Vach, & Smutný, 2015), but energy value of crop residues was lower for such crops as sugar beet (16.6 MJ kg⁻¹) and potatoes (13.6 MJ kg⁻¹) (Koga, 2008).

Since the total energy value obtained per ha depends on the total biomass and grain yield, it can also be affected by grain – straw ratio. Similarly, the ratio of grains / seeds and straw differs for various species and varieties within the species. In the USA, the relationship between straw yield and harvest index (HI) was studied in different wheat growing regions (eight states) and for different wheat grades. The average HI was 0.45. The results showed that soft white wheat had the highest grain (7.6 t ha⁻¹) and straw (9.4 t ha⁻¹) yields (HI – 0.49), soft red winter wheat had the highest HI (0.61) and lowest straw (3.4 t ha⁻¹) yield and lowest above-ground biomass (8.6 t ha⁻¹). HI does not suggest that the higher grain yield is always related to a high harvest index and low straw yield. Biotic stresses may also impact HI (Dai

et al., 2016). Researchers from the United Kingdom (UK) consider the possibility to create new varieties of wheat with an increased straw yield. As discussed above, wheat straw is used to produce bioenergy. UK farmers, producing livestock products in addition to crop production, are also interested in growing such varieties. Greater straw yield can be obtained mainly by extending the stalk. Increase in straw mass should not lead to the reduction in grain yield (Townsend, Sparkes, & Wilson, 2017).

The by-products of cereals, legumes and oilseeds can be used for bioenergy production because of their composition, but it is not a reasonable long-term solution, as straw is necessary for improvement of the soil organic matter and nutrient uptake in the soil (Bauer et al., 2007; Hernanz et al., 2014).

Total productivity of crop rotations affected by included plants and soil tillage

In the study in Canada (Zentner et al., 2004), winter wheat was grown in repeated sowings on heavy clay soil with pH 6.7 – 7.0. Winter wheat grain yield energy output was on average 45.7 GJ ha⁻¹ (for yield in the trial < 3 t ha⁻¹, straw was not taken into calculation, as they were incorporated in the soil). If wheat was grown after flax, energy increase was about 22%; Zentner et al. believe that this effect is due to inhibition of root and leaf disease thanks to plant change. In this study, a significant increase in energy output was obtained through the diversification of plants in crop rotation. Analysing the effect of soil tillage method on growing winter wheat, it was concluded that zero tillage (ZT) does not influenced the energy output of winter wheat if compared to conventional tillage (CT). In the same study, oilseeds (flax) and legumes (peas), included in the crop rotation after cereals, provided higher energy yields in conservation soil tillage (minimum tillage (MT) and ZT) variants (by 13% for flax and by 7% for peas) if compared to CT. In this experiment, the soil tillage method had a small effect on energy yield of cereals grown in monoculture and in rotation of cereals, legumes and oilseeds. However, the energy yield was significantly higher in the rotation of cereals and oilseeds when MT was used if compared to CT and ZT treatments. Energy produced by growing winter wheat after cereals (wheat or barley) did not differ significantly between the soil tillage treatments (42.2 GJ ha⁻¹ CT, 39.7 GJ ha⁻¹ MT, 41.5 GJ ha⁻¹ ZT), but it was significantly higher when wheat was grown after oilseed rape (51.0 GJ ha⁻¹ CT, 50.7 GJ ha⁻¹ MT, 48.8 GJ ha⁻¹ ZT) with no-till technology (ZT). Results of this study showed that the use of conservation soil tillage showed small reductions in the energy produced using minimum and zero treatments if compared to the traditional soil tillage method. Authors concluded that by diversifying plants in the crop rotation and by using

different soil cultivation techniques, more efficient yields can be produced and also the efficiency of non-renewable energy use increased (Zentner *et al.*, 2004).

Earlier studies in Canada (Nagy *et al.*, 2000) did not show a significant effect of soil tillage method on crop yields. However, the average energy output of a four-year crop rotation significantly differed between the crop rotations. The highest total productivity was obtained by the crop rotation which included oilseed rape followed by three years of cereals (oilseed rape–wheat–barley–barley) (57.1 GJ ha^{-1}). A slightly lower energy output was obtained from the crop rotation with oilseed rape–barley–peas–wheat – 54.7 GJ ha^{-1}, but significantly lower it was for crop rotation with two oil-crops included: oilseed rape–peas–flax–barley – 44.9 GJ ha^{-1}. In this experiment, grain / seed yields were as follows: barley 2.6 – 3.8 t ha^{-1}, wheat 2.8 – 5.0 t ha^{-1}, oilseed rape 1.8 – 2.1 t ha^{-1}. Straw was not considered in the energy calculation (Nagy *et al.*, 2000).

Insignificant effect of soil tillage methods was found on winter wheat, spring barley and white mustard (*Sinapis alba*) yields and energetic outputs also in Czech Republic. Three crop rotations were used in combination with three soil tillage systems (CT, MT, and ZT). Gross calorific value of the total biomass was 175.35 GJ ha^{-1} for winter wheat, 149.11 GJ ha^{-1} for barley and 87.27 GJ ha^{-1} for white mustard. Winter wheat also had the highest grain and residue yields (Strašil, Vach, & Smutný, 2015).

In Germany, Hülsbergen and Kalk (2001) established that continuous winter wheat sowings showed lower net energy output (168 GJ ha^{-1}) if compared with the situation when winter wheat was grown after clover (218 GJ ha^{-1} per year in rotation with 20% clover), and after lucerne (226 GJ ha^{-1} per year in crop rotation with 40% lucerne) (cited from Hülsbergen, Feil & Diepenbrock., 2002).

Energy output from the crop rotation is also studied in Japan, in the main agricultural region – Tokachi. Traditional crop rotation in this region is winter wheat–sugar beet–beans–potatoes (*Solanum tuberosum*). Calorific value of dry matter yield and post-harvest residue samples were measured with an automatic bomb calorimeter. The greatest energy output per hectare was gained from sugar beet – 252 GJ ha^{-1} (in total, including residues – 346 GJ ha^{-1}), dry biomass yield was 20 t ha^{-1}. In this research, calorific value of winter wheat was established 19.1 MJ kg^{-1} for grain and – 18.4 MJ kg^{-1} for straw; the same values were calculated for beans (*Vigna angularis* (Willd)). Potato and sugar beet showed a lower energy value per kg, but they had higher yields than cereals and legumes. Dry biomass yield of sugar beet in this experiment was 2.5 times higher than that of winter wheat, but energy output was 2.3 times higher (Koga,

2008). Sugar beet has shown the highest energy output per hectare also in another research with other crop rotations (Hülsbergen, Feil & Diepenbrock, 2002). Thus, by including the sugar beet or potato in crop rotation between the cereals, it is possible to obtain higher total energy from crop rotation, as these plants ensure higher energy output per hectare if compared to cereals (Koga, 2008).

Potential of energy output from specially designed crop rotations, including energy crops and traditional crops – used for food, feed and energy, have been explored in Austria. Intercrops (clover (*Trifolium* sp.) and lucerne (*Medicago sativa*)) before spring crops (spring barley and grain maize) were included in these crop rotations in order to obtain the maximum total energy yield from the crop rotation (Bauer *et al.,* 2007).

In Germany, traditional field crop rotation versus energy crop repeated and perennial sowings were compared. Traditional field crop rotation included oilseed rape with cereals – winter wheat and triticale. The average annual energy yield from this rotation was from 100 GJ ha^{-1} with no nitrogen fertilizer and with no-till technology to 262 GJ ha^{-1} with nitrogen rate – 160 kg ha^{-1} for winter wheat, and 240 kg ha^{-1} for oilseed rape in both soil tillage technologies – ploughing and no-till technology. If annual energy yields were compared in high nitrogen level between energy crops and field crop rotation, field crop rotation gave a higher energy output than switchgrass (*Panicum virgatum*); while significant difference was not found between average annual energy output of traditional crop rotations and willow (*Salix alba* L.), and miscanthus (*Miscanthus* sp.) energy yields (Boehmel, Lewandowski, & Claupein, 2008).

The effect of soil tillage on energy production by crop rotation was studied in a long-term experiment (1983 – 2002) in Latvia. The six-field crop rotation included the following species: winter wheat, oat, barley, barley undersown with perennial grass-clover mixture, perennial grass-clover mixture (2 years). Soil tillage treatments included (1) yearly deep ploughing; (2) yearly shallow ploughing + deep ploughing once per rotational cycle before winter wheat; (3) similar treatment to the 2nd, except deep ploughing was performed before sowing grasses. It was shown that the average energy productivity of the crop rotation was higher in the variant, where ploughing was carried out every year (1st treatment), but it was not significantly lower if deep ploughing was carried out once per rotational cycle – before winter wheat sowing. In general, from agronomical point of view, the reduction in yield and energy value between soil tillage treatments was not high (Kroģere *et al.*, 2005).

Conclusions

Crop rotation and soil tillage method affect crop yield and energy output. The total energy output per hectare depends on crops included in the rotation, their yield and total biomass, and calorific value of harvested yield and by-products. In different studies, for the same species the calorific values were different depending on growing conditions and varieties. It is possible to increase the total energy value, or it is possible to create benefits for the following plant by plant diversification.

It is possible to gain higher energetic productivity from the crop rotation if cereals are grown in rotation with oil crops, pulses, root crops and vegetables, but not in monoculture.

This literature review did not prove that any of the soil treatment methods could be the most suitable for higher energy output by yield. Significant differences were not found in yield parameters depending on soil tillage method in most part of articles reviewed, only in some cases the energy value was higher or lower depending on the soil type and conditions during tillage.

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AMINO ACIDS CONTENT IN TRITICALE GRAIN DEPENDING ON METEOROLOGICAL, AGROTECHNICAL AND GENETIC FACTORS

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Abstract
The field studies were conducted in the years of 2011 and 2014 at the Experimental Station in Osiny, Poland. Triticale (*Triticosecale*) is a valuable fodder cereal with a high nutritional value of grains. It can also gain importance as a consumer cereal, providing the body with the necessary amino acids. The aim of the study was to determine the influence of precipitation and temperature conditions in the harvest year, agronomic factors (intensive or integrated type of production) and the percentage of cereals in crop rotation (50, 75 and 100%) on the amino acid content of two winter triticale cultivars ('Pizarro' and 'Pigmej') as well as to determine the nutritive value of the protein: chemical score (CS) and essential amino acid index (EAAI). Our studies have shown that although the amino acid content of winter triticale is strongly genetically determined, it also depends on weather and agrotechnical factors. Precipitation and temperature factors had the biggest effect on the tyrosine (Tyr) content. The contents of essential and non-essential amino acids in triticale grains and EAAI value were higher under intensive technology, with 50% of cereal grains in the crop rotation, and in the traditional cultivar 'Pizarro' as compared to the dwarf one 'Pigmej'. The most important amino acids that limit the quality of protein in the grain are lysine (Lys) and tryptophan (Trp). Using intensive technology, reducing the cereal percentage of cereals in the crop rotation and selecting a proper cultivar, it is possible to maximize the content of the desired essential and non-essential amino acids in the triticale grains, and thereby improve their feed and consumer value.
Key words: crop rotation, cultivar, intensity of technology.

Introduction

Triticale (*Triticosecale*) is one of the most widely distributed cereals in Europe and Asia. According to FAOSTAT (2016), in 2014 this species was cultivated in 37 countries on the area of 4.1 million ha, its production amounting to 17.1 million tons. Major triticale producers include Poland, Germany, Belarus, France and Russia. Triticale grains are mainly used as valuable feed for animals, but they are becoming more and more popular as consumer grain (Coffey & Gerrits, 2009). Triticale has a high nutritional value due to its high content of protein in grains and a better amino acid composition than wheat (Alijošius *et al.*, 2016). The quality of cereal grain is shaped by the complex activity of habitat, agronomic and genetic factors (Djekić *et al.*, 2014; Järvan *et al.*, 2017). It is therefore advisable to find out the response of triticale to these factors in terms of the content of individual amino acids. One of the most important aspects of such an analysis should be the concentration of essential amino acids that are not synthesized, or synthesized in unsatisfying quantities, by human and animal organisms. Few studies on triticale indicate the differentiation of amino acid content in grains under the influence of agronomic factors such as terminal water stress (Fernandez-Figares *et al.*, 2000), sowing density, herbicides (Stankiewicz, 2005), and fertilization (Brzozowska, Brzozowski, & Hruszka, 2009). The aim of our study was to evaluate the impact of cereal percentage in the crop rotation (50, 75 and 100%), technology of cultivation (integrated, intensive) and a cultivar (dwarf and traditional)

on the amino acid concentration in the grains of winter triticale in different growing seasons, varying precipitation and temperature condition.

Materials and Methods

The studies were conducted in the years 2011 and 2014 at the Experimental Station in Osiny (51°27′ N; 22°2′ E), Poland. The experiment was located on a lessive soil (*Luvisol*), on plots with the area of 45 m^2, in 4 replicates. The soil had a slightly acidic pH (pH KCL 6.5) and contained 1.73 mg of P, 1.81 mg of K and 1.08 C_{org} g·kg^{-1}. Each year, an experiment was set up on the existing long-term field experiments with a 100% (spring barley (*Hordeum L.*), winter wheat (*Triticum aestivum L.)*, winter triticale (*Triticosecale)*), 75% (spring barley, winter rapeseed (*Brassica napus L.*), winter wheat, winter triticale) and a 50% share of cereals in crop rotation (winter rapeseed, winter wheat, faba bean (*Vicia faba L.*), winter triticale). Two technologies - integrated and intensive - were investigated within each crop rotation. They differed in terms of the rates of mineral fertilizers and the intensity of chemical plant protection (Table 1).
Two Polish winter triticale cultivars: 'Pizarro' and 'Pigmej' were studied. The dwarf cultivar 'Pigmej' forms a straw of the length of 95 cm. The traditional cultivar 'Pizarro' has a longer straw (115 cm) and, moreover, it is more resistant to powdery mildew (*Blumeria graminis*) and septoriosis (*Septoria tritici*) (Variety Descriptive List, 2017).

Sowing was carried out September 26 – 29 with the Amazone drill. The sowing density of triticale was

Table 1

Characterization of applied technologies for triticale production

Specification	Technologies	
	Integrated	Intensive
Fertilization (kg ha^{-1})		
N (ammonium nitrate)	50 (stage of spring tillering) 50 (BBCH 31)	60 (stage of spring tillering) 60 (BBCH 31) 30 (BBCH 51)
P (superfhosphate)	29 P$_2$O$_5$	35 P$_2$O$_5$
K (potassium salt)	59 K$_2$O	76 K$_2$O
Pesticides		
Herbicides	BBCH 31: 2,4 D + dikamba (3.0 l·ha^{-1})	BBCH 25: diflufenican, iodosulfuron-metyl-sodium, mesosulfuron- metyl (0.8 l ha^{-1}) BBCH 31: 2,4 D + dicamba (3.0 l ha^{-1}) BBCH 34: clopyralid (0.4 l ha^{-1})
Fungicides	BBCH 45: difenokonazol + paclobutrazol (0.8 l ha^{-1})	BBCH 31: flusilazol+carbendazim BBCH 45: difenoconazole +paclobutrazol (1.0 l ha^{-1})
Insecticides	-	BBCH 47: deltamethrin + dimethylcyclopropanecarboxylate (0.4 l ha^{-1})
Retardants	BBCH 32: trinexapak etylu (0.3 l ha^{-1})	BBCH 32: trinexapak etylu (0.3 l ha^{-1})

4 mln ha^{-1}. Harvesting was carried out in the middle of August. Immediately after the harvesting, grain samples were collected. Amino acid content in winter triticale grains, with the exception of tryptophan (Trp), was detected by ultrasonic liquid chromatography with spectrophotometric detection (UPLC-UV) on Waters Acquity apparatus. Tryptophan was determined using high performance liquid chromatography with fluorescence detection (HPLC-FLD).

The nutritive value of the protein was determined on the basis of the chemical score and essential amino acid indices, taking the whole chicken egg protein as the standard protein. The chemical score (CS) of restrictive amino acid(s) was calculated by comparing the amount of individual essential amino acids contained in the test protein (ai) with their content in their standard protein (as): chemical score = (ai/as) × 100 (FAO, 1985). The essential amino acid index (EAAI) was calculated as the geometric mean of all essential amino acids against the content of these amino acids in the standard. The obtained results were statistically worked out using the software *Statistica*, with the method of the analysis of variance ANOVA, and the differences were estimated with Tukey's test at α = 0.05. The relation of the amino acid content to the proteins in the grain and the thousand kernel weight was expressed by Pearson's correlation coefficients.

Weather conditions from the BBCH 31 to BBCH 87 (May – July) during the study years were different (Table 2). In May and, especially in June 2011 the temperatures were higher and the rainfall in these months was more than half lower in comparison to

Table 2

Weather conditions at the experimental site

Month	Year					
	2011	2014	1981 – 2010	2011	2014	1981 – 2010
	Temperature (°C)			Precipitation (mm)		
March	3.0	6.7	1.6	11	31	30
April	10.7	10.7	7.8	27	58	40
May	14.6	14.3	13.5	60	172	57
June	19.2	16.5	16.8	54	93	70
July	18.7	20.9	18.5	250	68	84
Mean / sum	13.2	13.8	11.6	402	422	281

the year 2014. Particularly large rainfall-related differences in the years of research occurred in July (BBCH83-BBCH89). In 2011 this month was much cooler and the total precipitation was 3.7 times higher compared to 2014.

Results and Discussion

The amino acid content in winter triticale was dependent on hydrothermal conditions during the study years, percentage of cereals in the crop rotation, cultivation technology, and the cultivar (Table 3). In 2011, the total of essential and non-essential acids in the grains were higher than in 2014, by respectively

8.6% and 10.7%. It was promoted by the abundant rainfall during the BBCH 73 - BBCH 89 (July 2011) (Table 2), which caused a significant increase in the content of almost all amino acids. Only in the case of Valine (Val), Proline (Pro) and Glysine (Gly), the differences between the years were not significant. The interaction analysis showed that Val and Pro showed no differences between the years of the study, only under intensive technology (data not shown). Among essential amino acids, the reduction in the amino acid content in 2014 was the biggest for Lysine (Lys) (by 12.7%), while among non-essential ones, for Tyrosine (Tyr) (by 36.9%). A similar relationship between the

Table 3

The contents of essential amino acids in grains of winter triticale depending on harvest year, production technology and a cultivar (g kg⁻¹)

Amino acid*	The year of harvest		Percentage of cereals in the crop rotation (%)			Production technology		Cultivars		Mean
	2011	2014	50	75	100	integrated	intensive	Pizarro	Pigmej	
Thr	3.84a	3.54b	3.88a	3.68b	3.51c	3.60b	3.78a	3.81a	3.56b	3.68
Val	5.01a	4.95a	5.19a	5.01b	4.74c	4.87b	5.09a	5.10a	4.85b	4.97
Ile	4.07a	3.63b	4.05a	3.82b	3.69c	3.74b	3.96a	3.91a	3.78b	3.84
Leu	7.69a	7.08b	7.75a	7.34b	7.07c	7.18b	7.59a	7.61a	7.26b	7.43
Phe	5.47a	5.07b	5.70a	5.14b	4.99c	5.03b	5.51a	5.33a	5.21a	5.27
His	2.83a	2.58b	2.87a	2.67b	2.57c	2.61b	2.80a	2.75a	2.65a	2.70
Lys	3.95a	3.45b	3.75a	3.77a	3.59b	3.71a	3.69a	3.88a	3.51b	3.69
Arg	5.44a	5.07b	5.59a	5.21b	4.98c	5.11b	5.41a	5.48a	5.13b	5.30
Met	2.29a	2.05b	2.29a	2.19ab	2.04b	2.13a	2.21a	2.31a	2.13b	2.22
Trp	1.13a	1.05b	1.11a	1.10a	1.07a	1.04b	1.15a	1.12a	1.07a	1.09
Total	41.82a	38.51b	42.18a	39.93b	38.02c	39.02b	41.19a	41.3a	39.15b	40.19

a, b, c – different letters denote statistically significant differences (α = 0.05).
* – Thr (threonine), Val(valine), Ile(isoleusine), Leu(leusine), Phe(phenylalanine), His(histidine), Lys(lysine), Arg(arginine), Met(methionine), Trp(tryptophan), Ser(serine),Asp(asparanine), Glu(glutamine), Pro(proline), Gly(glysine), Ala(alanine), Tyr(tyrosine), Cys(cysteine).

Table 4

The contents of non-essential amino acids in grains of winter triticale depending on harvest year, production technology and a cultivar (g kg⁻¹)

Amino acid*	The year of harvest		Percentage of cereals in the crop rotation (%)			Production technology		Cultivars		Mean
	2011	2014	50	75	100	integrated	intensive	Pizarro	Pigmej	
Ser	5.54a	5.23b	5.68a	5.37b	5.10c	5.20b	5.56a	5.47a	5.29b	5.38
Asp	8.10a	6.74b	7.62a	7.57a	7.07b	7.42a	7.42a	7.67a	7.17b	7.42
Glu	31.65a	28.44b	31.73a	30.08b	28.33c	29.17b	30.92a	29.82a	30.26a	30.04
Pro	10.86a	10.23a	11.30a	10.55b	9.88c	10.19a	10.96a	10.5a	10.65a	10.57
Gly	4.75a	4.69a	4.98a	4.70b	4.50c	4.58b	4.86a	4.90a	4.55b	4.72
Ala	4.89a	4.30b	4.75a	4.66a	4.37b	4.55a	4.64a	4.78a	4.40b	4.59
Tyr	3.06a	1.93b	2.71a	2.41b	2.39b	2.48a	2.51a	2.58a	2.42b	2.50
Cys	2.25a	1.89b	2.18a	2.09a	1.94b	2.04a	2.11a	2.16a	1.99b	2.07
Total	71.1a	63.45b	70.95a	67.43b	63.58c	65.63b	68.98a	67.88a	66.73b	67.29

a, b, c, * – see Table 3

amino acid content and weather was also presented by Stankiewicz (2005), who in comparable precipitation conditions, found an increased concentration of essential amino acids (by 10.6 – 13.4%) in spring triticale. However, in the studies of Brzozowska, Brzozowski & Hruszka (2009), heavy rainfall in the maturing stage of winter triticale increased the content of only four amino acids: Lysine, Phenylalanine (Phe), Histidine (His) and Arginine (Arg). In the study involving 15 cultivars of winter wheat, weather conditions had the biggest impact on Lysine and Isoleusine (Ile) (Spychaj-Fabisiak *et al.*, 2014).

Growing triticale in a crop rotation with lower cereal percentage is better for growth and development of this plant and its yields mainly due to a lower pest pressures. Also, it is more beneficial for the soil than using cereal monocultures which damage its physicochemical conditions (Gałązka *et al.*, 2017). In our studies, under the reduced, down to 50%, amount of cereals in the crop rotation, we recorded a higher amount of the sums of both essential and non-essential amino acids in the grain in comparison with a 75% share of cereals, while the concentration of the two groups of amino acids was the lowest in cereal monoculture (with a 100% cereal share) (Table 3, 4). However, the response of certain amino acids to cereal percentage in the crop rotation was weaker. The contents of Lys, Asp, Ala and Cys were similar under 50% and 75% shares of cereals; Tyr content was not significantly different at 75% and 100%, while Trp content was similar at 50, 75 and 100% of cereal share in the rotation. The decrease in the percentage of cereals from 100% down to 50% caused an increase in the content of essential amino acids from 3.7% (Trp) to 14.2% (Phe), while of the non-essential ones, from 7.8% (Asp) to 14.4% (Pro).

Our previous work has shown that triticale grown under intensive technology that uses higher doses of NPK fertilizers and a bigger number of pesticide treatments (intensive technology), tends to have higher total protein content than triticale in the integrated technology (Jaśkiewicz & Szczepanek, 2016). In this study, the analysis of amino acid content showed that the production technologies (intensive and integrated) differentiated the total content of essential and non-essential amino acids to the advantage of intensive technology (Table 3, 4). The highest increase in amino acid content under the intensive technology (with higher doses of NPK and pesticides) was noted for Trp (10.6%). However, the reaction of some amino acids was different. In the case of essential amino acids, the technology applied did not affect the contents of Lys and Met, while among non-essential amino acids, no response was recorded in the case of Asp, Pro, Ala, Tyr and Cys. Interaction analysis showed that the difference in the contents of Met and Asp between

the compared technologies was significant only in the case of cultivar 'Pigmej' (data not shown). Marczak *et al.* (2001), comparing the impact of N fertilization in rates of 50, 100 and 150 kg·ha⁻¹ on the amino acid content in triticale, showed that the highest values of essential amino acids, with the exception of Lys, were obtained under 100 kg N kg·ha⁻¹. In the studies of Brzozowska, Brzozowski & Hruszka (2009), differences in the rate and division of the dose of mineral nitrogen differentiated the content of amino acids in the proteins only in the case of Met, Val and Glu. Few studies on the effect of chemical protection on the content of individual amino acids in triticale grains show no significant differences after herbicide application compared to control (without using the product) (Brzozowska, Brzozowski, &Hruszka, 2009).

In our studies, the sum of essential and non-essential amino acids in winter triticale cultivar 'Pizarro' was significantly higher than in cultivar 'Pigmej'. However, the content of amino acids such as Phe, His, Trp, Glu and Pro in the grains was similar in both cultivars. In turn, Fernandez-Figares *et al.* (2000) showed varietal differences in the concentration of amino acids in triticale only for two amino acids: Lys and Met. Alijošius *et al.* (2016), in their studies involving 7 winter triticale genotypes showed variation in the concentration of all 16 amino acids tested, with the difference being the highest for Met, followed by Phe, Glu and Pro.

In our study, we found a negative correlation between the total content of essential amino acids and the thousand kernel weight, but in the case of non-essential amino acids, no such relationship occurred (Table 5).

The total protein content in the grains was positively correlated to the content of almost all essential (except for Lys) and non-essential (except for Asp and Cys) amino acids (Table 5). Fernandez-Figares *et al.* (2000) reported that the percentage of amino acids in the grain increased linearly with grain-protein content, but this relationship was not non-linear in the same degree for all amino acids. According to Biel & Jacyno (2013), the coefficients of nutritive value of barley grain protein does not improve with an increased level of protein, which is most often due to increases in the lysine-poor prolamines.

The relationship of amino acid content and grain yield was small (Table 5). Only the content of two amino acids (Tyr and Cys) was negatively correlated with the yield. The greatest variation coefficient was found for the content of Tyr, while the lowest, for Val.

It is commonly known that cereals have a low Lys content (Stankiewicz, 2005; Shewry, 2007). Similarly, in our studies, based on the value of the limiting amino acid (CS), we found that Lys was the most

Table 5

The relationship between the contents of amino acids, the grain yield of winter triticale, a thousand kernel weight and the total protein content in the grains (Pearson's simple correlation coefficient) and variation coefficient

Amino acid	Grain yield	Thousand kernel weight	Total protein content	Variation coefficient V (%)
Essential amino acids				
Thr	-0.29	-0.09	0.58*	10.0
Val	-0.25	-0.12	0.51*	8.9
Ile	-0.18	-0.16	0.48*	11.1
Leu	-0.13	-0.15	0.51*	9.8
Phe	-0.05	0.05	0.67*	11.7
His	-0.08	0.05	0.69*	10.2
Lys	-0.38	-0.16	0.20	11.7
Arg	-0.28	0.06	0.64*	10.3
Met	-0.22	-0.17	0.41*	10.5
Trp	-0.09	-0.12	0.42*	10.6
Total	0.39	-0.42*	0.57*	–
Non-essential amino acids				
Ser	-0.09	-0.08	0.61*	9.7
Asp	-0.32	-0.09	0.37	12.9
Glu	0.10	-0.18	0.43*	11.9
Pro	0.12	-0.09	0.53*	11.3
Gly	-0.25	-0.04	0.63*	9.2
Ala	-0.37	-0.18	0.40*	11.2
Tyr	-0.68*	0.03	0.40*	26.1
Cys	-0.43*	-0.16	0.29	12.8
Total	-0.15	-0.15	0.66*	–

* – significant at $\alpha = 0.05$

important amino acid shaping the nutritional value of the grain (Table 6).The second limiting amino acid was Trp. However, according to Stankiewicz (2005), the most important amino acid limiting the biological value of triticale protein is Lys, followed by Val. Other studies have confirmed the role of Lys, but they also indicated the importance of Ile and Met (Brzozowska, Brzozowski, & Hruszka, 2009).

The value of essential amino acid index (EAAI) determined against the hen egg standard was 60.4% (Table 7). For wheat, the EAAI is 63%, for rye 59%, while for oats 57% (Biel & Maciorowski, 2012). In our

study, weather conditions significantly differentiated the value of the integrated EAAI. In 2011, which saw heavy rains in the BBCH 73 BBCH 89 stage (Table 2), the EAAI was higher in comparison with the year 2014. Similarly, Zhang *et al.* (2017), based on their studies with winter wheat, indicated that under rainfed conditions improving essential amino acid index can be achived.

In our studies, under 50% of cereals in the crop rotation, the EAAI was higher than under cereal monoculture (a 100% of cereals in crop rotation). Growing triticale under the intensive technology

Table 6

Chemical score (CS) of restrictive amino acid(s) (%)

Amino acid	Thr	Val	Ile	Leu	Phe + Tyr	His	Lys	Arg	Met + Cys	Trp
CS	78	75	71	86	84	123	53	76	75	64

Table 7

Essential amino acid index (EAAI) of winter triticale grains depending on the year of harvest, production technology, and a cultivar (%)

The year of harvest		Percentage of cereals in the crop rotation, %			Production technology		Cultivar		Mean
2011	2014	50	75	100	integrated	intensive	Pizarro	Pigmej	
62.7a	58.4b	62.0a	60.8ab	58.6b	59.3b	61.7a	61.6a	59.4b	60.4

a, b – different letters denote statistically significant differences (α = 0.05).

increased the EAAI compared to the integrated technology. The value of this index was higher for cultivar 'Pizarro' than for 'Pigmej'.

Conclusions

The content of amino acids in winter triticale is a strongly genetically-determined trait, however, it also depends on the production technology (the amount of fertilizers and pesticides used), the percentage of cereals in the crop rotation and on weather conditions (precipitation and temperature).

The contents of essential and non-essential amino acids in triticale grains and the nutritive value of the protein (EAAI) are higher under intensive technology (where high doses of NPK and pesticides are used), and with 50% of cereal grains in the crop rotation as compared to 75% and 100%, and in the traditional cultivar 'Pizarro' as compared to the dwarf one 'Pigmej'. Abundant rainfall during the BBCH 73- BBCH 89 stage causes the increase in the content almost all essential and non-essential amino acids (except Val, Pro and Gly). The greatest influence of weather conditions on the content of amino acids in triticale grains was noted in Tyr. The main amino acid which limited the quality of protein in the triticale grains is lysine. This amino acid showed a high variability in years and cultivars but weak response to the agrotechnical factors (production technology and the percentage of cereals in the crop rotation).

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THE INFLUENCE OF AUTUMN SOWING DATE ON THE PRODUCTIVITY OF SPRING WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract
The greatest interest in the cultivation of spring wheat is in regions with an increased intensity of late fallow. However, there are also stronger tendencies to limit the area of its cultivation (similarly to other spring cereals), which is mainly due to a lower level of yielding. Farmers decide on the sowing date of varieties mainly after plants that leave the field late, e.g., potatoes, beets and maize. That is why these varieties are usually called „alternative wheat".The aim of the research was to determine the effect of autumn sowing date on the yield and the technological value of the grains of selected spring wheat varieties. A two-factor field experiment was established using a split-plot design at the Experimental Station of Cultivar Testing (ESCT) in Bezek (51°12′06″N 23°16′06″E), the Lubelskie voivodeship, Poland (2008/2009, 2009/2010, 2010/2011). Experimental factors were as follows: A) sowing date – I - October, II - November, III - spring, B) spring wheat variety: 'Tybalt', 'Cytra', 'Bombona', 'Monsun', 'Parabola'. It was found that grain yields of spring wheat sown in the autumn were higher than those sown in the spring term. Without regard to the sowing term, the highest grain yields were obtained from 'Tybalt' cultivar.
Key words: spring wheat, alternative wheat, yield, productivity, sowing term.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal species in the world. In world production, this species ranks third after rice and maize. Great advantage of wheat cultivation results from the high level of yield, valuable chemical composition, wide possibilities of grain use for consumption purposes, in particular for the production of flour, and for baking and feed purposes. Two forms of wheat are grown in the world: winter and spring wheat (Jasińska & Kotecki, 2003). The greatest interest in the cultivation of spring wheat is in regions with an increased intensity of late fallow. However, there are also stronger tendencies of limiting the area of its cultivation (similarly to other spring cereals), which is mainly due to a lower level of yielding. The yield of spring wheat, reduced in relation to the winter form, results mainly from a shorter growing season and less resistance to spring drought. A very important asset of spring wheat is its higher grain quality than of winter wheat (Kocoń, 2005; Cacak-Pietrzak *et al.*, 2014). However, it should be emphasized that this fact is now less important than in previous decades, when, in terms of quality, spring wheat clearly dominated over winter varieties. Among the registered varieties of winter wheat, only some were characterized by genetically determined high quality of grain.

In the first decade of this century, some breeders have started to advertise the bread spring varieties they have grown, as also suitable for autumn sowing term. In research centers, field experiments were carried out to study the suitability of spring wheat forms for autumn sowing. They pointed out, among other things, that sowing spring forms at the autumn term has many advantages, which in particular cause a prolongation of the growing season, especially at the start of tillering (BBCH – 22) and shooting (BBCH – 32) phase (Rudnicki, Jaskulski, & Dębowski, 1999; Grocholski *et al.*, 2007; Kurowski & Bruderek, 2009; Kardasz, Bubniewicz, & Bączkowska, 2010). According to these authors, an important advantage of autumn sowing term of spring wheat is also the increase of plant resistance to spring drought.

The articles in popular and popular-science press show that the group of producers which sow spring varieties in the autumn term is relatively large. Farmers decide on the sowing date of varieties mainly after plants that leave the field late, e.g., potatoes, beets and maize. That is why these varieties are usually called „alternative wheat". Such a term in relation to these varieties is also used by the authors of scientific papers (Hnilička *et al.*, 2005; Grocholski *et al.*, 2007; Weber & Kaus, 2007; Wenda-Piesik & Wasilewski, 2015). There are a few scientific papers dealing with the subject, but they do not fully cover the problem of sowing the varieties of spring cereals during the autumn. In the world cultivation of cereals we can distinguish spring forms sown in spring, winter forms sown in autumn, and transitional forms, sown both in autumn and spring (Listowski, 1963). A significant difference between winter and spring genotypes lies in the fact that spring plants require a higher temperature during the development period than winter cereals (Gumiński, 1977). According to Listowski (1963), the winter and spring wheat differs in the requirements for the development stage, and particularly at the stage of vernalization. The winter wheat seeds can withstand short-term temperature decrease in the range from -4 °C to -12 °C (Listowski, 1963). Seeds of winter cereals sown in spring germinate normally, but they do not bloom. Thus, they do not release seeds despite the fact that external conditions are

Marta Wyzińska, Jerzy Grabiński

THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

beneficial. Winter wheat without passing through the winter period (vernalization) are not capable of a fully normal development (Gumiński, 1977). Very important is freezing tolerance that is the result of physiological, chemical and physical reactions and modifications of plant cell structure, which take place at appropriate developmental stages and under suitable environmental conditions. This process is called hardening or acclimation. Acclimation proceeds in two stages, dependent on the sequential action of chilling (more than 0 °C) and freezing (-3 ° to -5 °C) temperatures (Braun & Saulescu, 2002). In addition to winter and spring forms, there is also an intermediate form – transitional, which can be sown both in autumn and spring (Listowski, 1963). According to Stelmakh (1998), such varieties are characterized by higher light requirements, smaller requirements in terms of vernalization, and lower tolerance to low temperatures. They start earlier spring vegetation and blooming. They occur both as spring and winter genotypes. Variations included in the intermediate form have their country-specific terms. In Russia, these are 'dwurutschki', in Hungary – 'jaro', in Germany – 'die Wechselweizen' (Hnilička *et al.*, 2005). In former Yugoslavia, they are called 'intermediete' or 'dual purpose', and in France 'le ble alternative' (Hnilička *et al.*, 2005).

The aim of the research was to determine the effect of autumn sowing date on the yield and the technological value of the grains of selected spring wheat varieties.

Materials and Methods

Field trials were conducted during three vegetation seasons 2008/2009, 2009/2010, and 2010/2011 at the Experimental Center for Variety Testing in Bezek, (51°12′06″N 23°16′06″E), the Lubelskie voivodeship, Poland, belonging to the Central Research Center for Varieties of Cultivated Plants (COBORU).The basis for the research were two-factor field experiments, in split-plot design, with four replications. The first-order factor (A) was the sowing time: I – autumn (after 2–3 weeks later than specified in IUNG – PIB (Institute of Soil Science and Plant Cultivation – State Research Institute) agronomical recommendations, as deliberately delayed for winter wheat), II – autumn (delayed from the first by 1–3 weeks), III – spring (indicated according to the agrotechnical guidelines of IUNG – PIB for spring wheat as the earliest possible). The second order factor (B) was the spring wheat variety: 'Tybalt', 'Cytra', 'Bombona', 'Monsun', 'Parabola'. All tested cultivars had increased frost resistance compared to the standard spring genotypes. The experiments were located on Calcaric Leptosols, soil quality class III b. The plot area was 15 m².

Table 1

Dates of spring wheat sowing in growing seasons

Growing season	Dates of sowing		
	I	II	III
2008/2009	24.10.2008	14.11.2008	3.04.2009
2009/2010	4.11.2009	21.11.2009	31.03.2010
2010/2011	6.11.2010	20.11.2010	25.03.2011

The content of K_2O in the soils on which the experiments were established, was at a high and very high level, and also the P_2O_5 content was at a very high level (Table 2). The soil was characterized by high magnesium content. The analysis showed that soil was alkaline. Soil pH value was 7.5. The soil was suitable for wheat growing.

Table 2

Soil content

Vegatation season	P_2O_5	K_2O	Mg
2008/2009	45.9	37.3	1.7
2009/2010	35.0	28.0	2.7
2010/2011	46.5	28.0	3.2

Mineral fertilization with phosphorus and potassium was applied depending on soil nutrient content, while nitrogen was used depending on the predicted level of grain yields. The amounts of doses used for individual components are shown in Table 3.

Table 3

Mineral fertilization dose in particular vegetation seasons

Vegetation season	N (kg·ha⁻¹)	P_2O_5 (kg·ha⁻¹)	K_2O (kg·ha⁻¹)
2008/2009	150	64	96
2009/2010	150	64	96
2010/2011	148	60	90

The seeding rate of wheat was 500 grains·m⁻². After reaching full maturity, the harvest was collected using a combine harvester. The following values were determined: grain yield at 14% of moisture, weight of 1000 grains, number of grains per plant, number of grains per ear, grain yield per plant and grain yield per ear. Plant material samples were collected from the 1m² and based on biometric measurements the following parameters - number of grains per plant, number of grains per ear, grain yield per plant and grain yield per ear – were determined.

THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

Marta Wyzińska, Jerzy Grabiński

Statistical evaluation was carried out using the Statgraphics Centurion v. XVI. Analysis of variance was performed with Tukey's confidence interval at a significance level of α=0.05.

Results and Discussion

Meteorological conditions during the research period varied depending on the year of research (Table 4). In all vegetation seasons weather conditions at the time of wheat sowing were good in terms of both temperature and precipitation. The most dangerous were the low temperatures in the winter months, because the wheat could not have survived during this time. In the 2009/2010 growing season, the average January temperature was -9.9 °C, but the plants did well. Weather conditions were also favorable for the wheat maturity.

Sowing date significantly influenced the yield of the spring wheat grain (Table 5). The highest yield was obtained when wheat was sown in the first autumn term (the third decade of October). The average yield from plots where wheat was sown in November (Term II) was similar to wheat sown in Term I. (6.98 and 7.26 t·ha^{-1}, respectively). The average yield of spring-sown wheat (Term III) was significantly lower compared to autumn-sown wheat (Terms I and II). Significant differences were also observed among the studied cultivars in grain yields. On average, 'Tybalt' cultivar was characterized by the highest grain yield and 'Cytra' cv. by the lowest grain yield. A relatively small number of plants of the 'Cytra' cv. per unit area had a large impact on the lowering of the average value of this variety with the first sowing date. Higher yielding of spring wheat from autumn sowing term is undoubtedly the effect of better resistance of plants to the stress of the spring period, mainly related to water shortages. Our own research did not concern the root system, but it should be assumed that it was the better rooting of plants at the time when there was a precipitation shortage (which in Polish climate is the norm and so occurred in each year of research) better to survive this stress. Greater resistance to drought stress also means better use of nutrients by plants. Visual evaluation of wheat crops during the growing season indicated this very clearly.

The genetic factor and variety had a significant impact on the level of obtained grain yields. The authors dealing with the issues of alternative wheat drew attention to this (Weber & Kaus, 2007; Kardasz, Bubniewicz, & Bączkowska, 2010). Some varieties of spring wheat ('Olimpia' and 'Helia') tended to have higher yields during late autumn seasons compared to the effects of spring sowing, while others ('Zebra', 'Torka' and 'Nawra') showed a reverse tendency in this respect, and thus have been identified by the authors as unsuitable for autumn sowing. One of the varieties, despite the increased frost resistance ('Olimpia'), was also included in the group not suitable for autumn sowing, and the reason for this was a high instability of yielding. In these studies, winter wheat varieties were used for comparisons. None of the tested varieties of spring wheat matched the yield of winter wheat varieties (Weber & Kaus, 2007). Sowing of alternative varieties in the late autumnal period increased the yield by approximately 37% compared to the results of spring sowing (Ozturk, Caglar, & Bulut, 2006). Research conducted by other authors (Grocholski *et al.*, 2007) indicate that the advantage of autumn over

Table 4

Meteorological conditions in individual growing seasons

Month	Temperature (°C)				Rainfall (mm)			
	2008/ 2009	2009/ 2010	2010/ 2011	Long term average	2008/ 2009	2009/ 2010	2010/ 2011	Long term average
October	9.8	6.8	4.8	7.8	60.3	92.1	14.3	40.0
November	4.2	4.9	6.0	2.6	26.7	74.4	45.0	32.0
December	0.3	-1.9	-4.7	-1.6	28.0	40.6	34.6	30.0
January	-2.1	-9.2	-1.2	-3.4	15.5	29.4	30.5	24.0
February	-1.8	-3.1	-4.9	-2.4	21.5	30.4	24.9	23.0
March	0.9	2.5	2.2	1.7	52.5	20.8	10.1	25.0
April	10.4	9.0	9.9	7.9	10.1	20.4	30.6	40.0
May	13.9	14.5	14.2	13.7	86.8	72.4	40.8	59.0
June	19.0	17.6	18.2	16.5	180.5	94.4	88.5	76.0
July	19.5	20.8	18.8	18.4	50.8	156.0	178.9	82.0
August	18.0	19.7	18.4	17.8	46.9	141.9	38.5	65.0
Mean (October–August)	8.37	7.42	7.43	7.18	52.69	70.25	48.79	45.1

Marta Wyzińska, Jerzy Grabiński

THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

Table 5

Yield of spring wheat (t·ha⁻¹) in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	8.00	6.49	7.13	7.59	7.08	7.26
II	7.49	6.29	6.79	7.18	7.14	6.98
III	6.95	5.36	5.77	6.07	6.42	6.11
Mean	7.48	6.05	6.56	6.94	6.88	–
$LSD_{0.05}$ for A = 0.403; B = 0.405; B/A = n.s.						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

Table 6

Number of plants per 1m² in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	364	280	350	356	350	340
II	319	343	334	354	339	338
III	325	317	336	326	341	329
Mean	336	313	340	346	343	–
$LSD_{0.05}$ for A = n.s.; B = n.s.; B/A = 62.0						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

spring sowing in wheat yielding was very high. Very large yield increase due to autumn sowing instead of spring wheat was obtained by Kardasz, Bubniewicz, & Bączkowska (2010); it was within 43.2–65.6% depending on the variety. The favorable effect of the autumn sowing date on the yield of wheat grain from the east has also been indicated by Sułek, Nieróbca, & Cacak-Pietrzak (2017). Also in the research conducted by Ozturk, Caglar, & Bulut (2006), the spring wheat sown in the first week of September had a higher grain yield than the delayed autumn and spring-sown wheat. The optimum time of sowing was winter for the facultative cv. 'Kirik'. Grain yields from delayed autumn and spring sowing were low, which was largely the result of hastened crop development and high temperatures during and after anthesis.

The number of plants per 1 m² did not depend significantly on the sowing date of wheat (Table 6). There was only a tendency to reduce the number of plants when wheat was spring sown. The role of the variety in developing the number of plants was also not significant, and the smallest number of plants per 1m² was found in the 'Cytra' cultivar. Some authors (Kardasz, Bubniewicz, & Bączkowska, 2010) have drawn attention to the cases of reverse dependence – a larger number of plants in autumn

Table 7

Number of ears per 1m² in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	616	496	516	549	535	542
II	461	489	535	612	526	544
III	537	457	592	484	551	524
Mean	538	481	547	548	537	–
$LSD_{0.05}$ for A = n.s.; B = 57.9; B/A = 104.8						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

Marta Wyzińska, Jerzy Grabiński

Table 8

Productive tillering of spring wheat in Bezek

Years	Sowing term (A)	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
2009	I	1.76	2.17	1.48	1.70	1.73	1.73
	II	1.84	1.60	1.74	1.70	1.66	1.70
	III	1.81	1.53	1.65	1.62	1.70	1.66
Mean		1.80	1.72	1.62	1.67	1.70	–
LSD$_{0.05}$ for A = n.s.; B = 0.170; B/A = 0.500							
2010	I	1.63	1.65	1.47	1.38	1.55	1.53
	II	1.31	1.19	1.43	1.50	1.45	1.38
	III	1.44	1.40	1.52	1.46	1.45	1.45
Mean		1.46	1.40	1.47	1.45	1.49	–
LSD$_{0.05}$ for A = 0.120; B = n.s.; B/A = n.s.							
2011	I	1.68	1.35	1.67	1.65	1.62	1.60
	II	1.67	1.26	1.77	1.75	1.51	1.60
	III	1.47	1.16	1.69	1.57	1.46	1.59
Mean		1.60	1.26	1.71	1.66	1.53	–
LSD$_{0.05}$ for A = n.s.; B = 0.300; B/A = n.s.							

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

sowing, which has been explained by a smaller fallout of better-rooted and more resistant to moisture deficiencies of plants from autumn sowing. According to other authors (Sułek, Nieróbca, & Cacak-Pietrzak, 2017), a smaller number of plants per unit area was obtained when the wheat was sown in autumn.

The impact of experimental factors on the number of ears per unit area was similar over the years. A selection of cultivars significantly affected the number of ears per unit area (Table 7). The largest ear density was found in 'Monsun' and 'Bombona' cultivars, and significantly lowest in 'Cytra' cv. However, the sowing date did not significantly affect the density of spikes per unit area. It should be noted, however, that there was an interaction of experimental factors, which was associated with a larger number of spikes in the Monsun cultivar at the second sowing date and Tybalt cultivar sown in the first sowing term. Similar results were obtained by Kardasz, Bubniewicz, & Bączkowska (2010), because the spring wheat sown in the autumn also developed a larger number of ears per unit area in comparison with the one sown in the spring time. Fotyma (2003) compared the number of spikes per unit area in winter wheat in spring time, and he found a larger number of spikes in the winter form of this species. However, this regularity was subject to modifications over the years, which was caused by the frost of plants in the winter. A productive tillering is a factor that significantly affects the number of spikes (Wenda-Piesik & Wasilewski, 2015). Wheat sown

in autumn begins the phase of tillering in the early spring, which lasts longer than in the case of wheat sown in the optimal spring time.

The influence of tested experimental factors on productive tillering of spring wheat depended on the year of research (Table 8). In 2009 and 2011, this feature of plants did not depend on the date of sowing, however, in 2010 the propagated plants sown in the second period (in November) were significantly weaker than those sown 2 weeks earlier (in October). According to other authors (Sułek, Nieróbca, & Cacak-Pietrzak, 2017), plants of wheat sown in spring are characterized by a better productive tillering to those sown in autumn.

The synthesis of research results from the three years of experiments carried out in Bezek showed that the weight of 1000 grains significantly depended on experimental factors (Table 9). With the delay of sowing time, the weight of thousand grains decreased. On average, 'Cytra' cultivar was characterized by a significantly smaller (than the other varieties) weight of 1000 grains (WTG). Among all the tested cultivars, the greatest 1000 grain weight (WTG) was achieved by the 'Parabola' cv. Between these two cultivars, the difference was 25%. Studies conducted by other authors also indicate that wheat sown in autumn is characterized by a higher weight of 1000 grains compared to spring sown wheat (Grocholski *et al.*, 2007; Kardasz, Bubniewicz, & Bączkowska, 2010; Sułek, Nieróbca, & Cacak-Pietrzak, 2017).

Marta Wyzińska, Jerzy Grabiński

THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

Table 9

Thousand grain weight (g) (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	43.17	38.57	40.90	43.86	50.96	43.49
II	42.38	36.48	41.99	42.46	49.79	42.62
III	42.64	35.92	37.27	40.53	47.00	40.67
Mean	42.73	36.99	40.05	47.00	49.25	–
LSD$_{0.05}$ for A = 2.030; B = 2.450; B/A = 3.450						

I – October, II – November, III – Spring

Conclusions

1. A positive effect of the autumn sowing term on the yield of spring wheat grain was found. Grain yield of wheat sown in the first autumn sowing date was statistically significantly higher than wheat sown in spring (the difference was 1.15 t·ha^{-1})

2. The number of plants per area unit did not depend significantly on the factors of the experiment, which means that the plants sown in autumn perfectly survived the winter period. Thus, it can be stated that there were no harmful effects of frost on plants.

3. No significant effect of the sowing date on the number of spikes per unit area was found. Only the selection of the cultivar affected this. The largest number of ears was found in the following cultivars: 'Monsun', 'Bombona', 'Parabola' and 'Tybalt', while the lowest in the 'Cytra' cv.

4. The production distribution depended on the years of research. In 2009 and 2011, the sowing date did not affect this. However, in 2010, by sowing wheat in the first date, the largest production spreading was achieved.

5. The weight of a thousand grains depended heavily on the experimental factors. The later sowing date resulted in a lower weight of 1000 grains. Cultivar 'Parabola' was characterized by the highest WTG.

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THE INFLUENCE OF AUTUMN SOWING
DATE ON THE PRODUCTIVITY OF SPRING
WHEAT (*TRITICUM AESTIVUM* L.)

Marta Wyzińska, Jerzy Grabiński

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THE INFLUENCE OF PRODUCTION TECHNOLOGY ON YIELD AND SELECTED QUALITY PARAMETERS OF SPRING WHEAT CULTIVARS

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Abstract
The field experiments were conducted at the Institute of Soil Science and Plant Cultivation – State Research Institute Experimental Station in Osiny in the years of 2015 – 2016. The aim of the study was to compare spring wheat (*Triticum aestivum* L.) yield depending on an integrated and intensive technology. The used production technologies differed as regards the nitrogen fertilization level, chemical protection against weeds, diseases, pests and the way of straw utilization. The following cultivars were selected for the research: 'Arabella' and 'KWS Torridon'. The weather conditions differentiated the yield of spring wheat in individual years. A higher effectiveness of intensive technology, expressed with a higher grain yield compared to the integrated one, was recorded in 2015 – on average by 18.0%. The yield increase between intensive and integrated technologies resulted from a higher 1000 grain weight. Spring wheat cultivars showed a varied response to the production technologies used. Under the intensive technology, a significant yield increase was recorded for the cv. 'KWS Torridon', while the production technologies did not differentiate the yield of cv. 'Arabella'. The quantity and quality of protein substances and the activity of amylolitic enzymes in grains were more dependent on the cultivar than on the production technique used. In the case of spring wheat cultivars 'Arabella' and 'KWS Torridon', the integrated production technology ensures obtaining grains of the quality suitable for processing.
Key words: spring wheat, integrated technology, intensive technology, grain yield, grain quality.

Introduction

Common wheat (*Triticum aestivum* L.) is one of the most important cereal crops grown worldwide. This is due to its valuable chemical composition and exceptional technological properties. The harvesting of wheat depends to a large extent on the production technology used, therefore this cereal is cultivated in an intensive way, which is connected to a high consumption of industrial means of production, such as mineral fertilizers and plant protection products. Increased wheat production most often results in an increase in yields, but at the same time it poses many risks to both the environment and consumer health security. Organic and integrated production systems have been promoted in recent years as alternative, environmentally and human-friendly ways of management. The integrated production system limits the use of plant protection products to the necessary minimum, and adjusts the use of mineral fertilizers to the soil nutrient content and plant nutrition status. In this production system, a skillful combination of all technologies with a reduced consumption of industrial means of production should ensure efficiency of inputs incurred and minimize the negative impact of agriculture on the natural environment. The production system influenced the quality of the grain obtained and its possible use. Wheat grains from the integrated cultivation, in which nitrogen fertilization is reduced, may contain less protein substances than grains from the intensive cultivation, which may adversely affect their usefulness for processing (Jańczak, Pruszyński, & Bubniewicz, 2002; Jańczak, Bubniewicz, & Pruszyński, 2003; Jończyk, Kuś, & Stalenga, 2007;

Korbas & Mrówczyński, 2009; Kuś & Jończyk, 2009; Cacak-Pietrzak, 2011).

The aim of the research was to analyze yields and selected parameters of technological value of two spring wheat cultivars grown under varied intensity of production technology.

Materials and Methods

The research was conducted in the years of 2015 – 2016 at the Experimental Station in Osiny (51º27'N; 22º2'E), Poland. The experiment was located on lessive soil (Luvisol), on plots 45 m² in size, in four replications. The soil had a slightly acid pH KCL (6.76) and included 1.66 mg of P, 1.71 mg of K, and 1.08 of C_{org} g kg^{-1} of the soil. The first factor was the type of the technology: integrated and intensive (A), which was diversified in terms of the doses of mineral fertilizers and the intensity of plant chemical protection. The specification of treatments is given in Table 1. The second factor was 'Arabella' and 'KWS Torridon' (B) cultivars. Sowing was carried out after winter rape, from 17 – 24 March with the Amazone drill. Sowing density was 400 seeds per 1 m². Grain samples were collected directly after the harvest. The harvested area of plots for estimation of yield was 22.50 m². Directly before the harvest, plant samples from the 1m² were taken and, based on biometric measurements, the number of ears per m², the number of grains per ear and 1000 grain weight were determined.

The protein content was determined according to the Kjeldahl method with a Kjel-Foss Automatic (N·5.83) instrument of the AACC Method 46-11.02

Characterization of applied technologies for spring wheat production

Specification	Technologies	
	Integrated	Intensive
Previous crop	winter rape	
Fertilization (kg·ha⁻¹) N (ammonium nitrate)	50 (in spring before sowing) 40 (at BBCH 31) 20 (at BBCH 51)	60 (in spring before sowing) 60 (at BBCH 31) 40 (at BBCH 51)
P (superphosphate) K (potassium salt)	50 P_2O_5 105 K_2O	80 P_2O_5 100 K_2O
Herbicide	At BBCH 31: florasulan, aminopyralid 2.4 (0.8 l·ha⁻¹)	At BBCH 31: florasulan, aminopyralid 2.4 (0.8 l·ha⁻¹)
Fungicide	At BBCH 57: azoksystrobin (0.6 l·ha⁻¹)	At BBCH 41: protiokonazol, spiroksamin (1.0 l·ha⁻¹) BBCH 57: azoksystrobin + propikonazol cyprokonazol (0.6 l·ha⁻¹ + 0.4 l·ha⁻¹)
Growth regulator	-	At BBCH 31: trineksapak etylu (0.4 l·ha⁻¹)
Insecticide	At BBCH 51: zeta-cypermetryn (0.1 l·ha⁻¹)	At BBCH 51: zeta-cypermetryn (0.1 l·ha⁻¹)

(AACC 2010). The wet gluten content and gluten index of the samples were determined using Glutomatic 2200 of the AACC Method 38-12.02 (AACC 2010). The sedimentation value was obtained by the Zeleny of the AACC Method 56-61.02 (AACC 2010). The falling number was determined using the Falling Number Test Apparatus type 1400 of the AACC Method 56-81.03 (AACC 2010). The results were statistically analyzed using the two-factor variance analysis (Anowa) and Statgraphics Centurion XVI computer program. The significance of differences between the means was assessed using Tukey test at the significance level of p=0.05.

Weather conditions during the development of spring wheat varied from year to year. The vegetation period in 2015 saw a higher amount of rainfall, similar to the mean of 1950 – 2000. Particularly favorable humidity and thermal conditions prevailed in May (during tillering, shoot formation) (Figures 1, 2). The growing period in 2016 was characterized by 1.6 °C higher average air temperature and by 31 mm lower precipitation than the mean for many years. In the year of the study, particularly high air temperatures occurred in May and June, which was unfavourable for the development of wheat (Figures 1, 2).
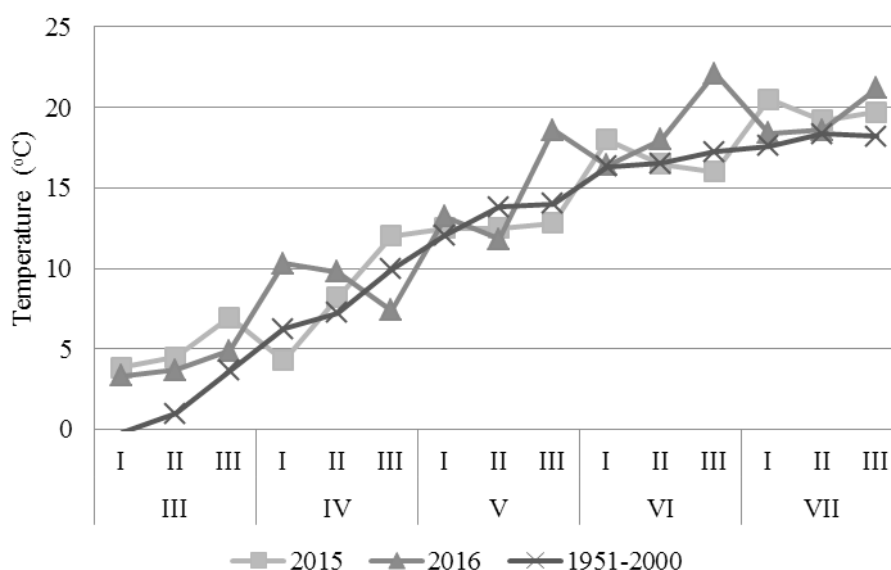
Figure 1. Monthly average temperatures in 2015 – 2016 compared to the long-term average (1951 – 2000).
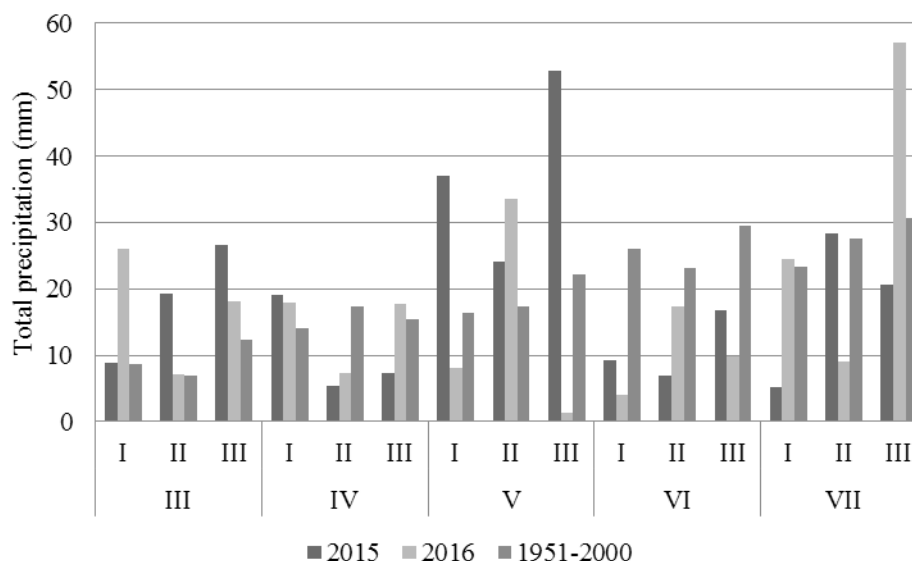
Figure 2. Monthly precipitation in 2015 – 2016 compared to the long-term average (1951 – 2000).

Results and Discussion

The yield of spring wheat grain depended on the weather conditions in the years of research, intensity of production technology, and the cultivar (Table 2).

In 2015, wheat yielded by 1.80% higher compared to 2016. The high impact of weather conditions on spring wheat yields has been confirmed by the results of studies by other authors (Jaskulski, 1999; Rudnicki, Jaskulski & Dębowski, 1999). The authors point to a significant correlation between grain yield, the amount of precipitation in May and June, and the total precipitation in the period April – July. The optimum precipitation rate for wheat cultivated in heavy soil conditions from April to July is 151 – 200 mm (Panek, 1987). In 2015, no significant influence of production technologies on the yields of the tested spring wheat cultivars was found. In this year of the studies, spring wheat cultivars yielded at a similar level, with a tendency of higher yields of cv. 'KWS Torridon'. Wheat cv. 'Arabella' grown under the integrated technology yielded higher compared to the intensive technology, but this difference was not statistically significant. In the case of cv. 'KWS Torridon', the grain yield increased by 1.05 t·ha^{-1} (14.6%) due to the intensification of cultivation. In 2016, spring wheat cultivars gave higher yields under the intensive production technology, but these differences were not statistically proven. In this year of the research, the grain yield of cv. 'KWS Torridon' was by 1.27 t·ha^{-1} higher in relation to cv. 'Arabella' (Table 2). Kołodziejczyk & Szmigiel (2014) found that the application of higher nitrogen fertilization and fungicide protection contributed to an increase in grain yields on average by 1.49 t·ha^{-1} (26.5%). The varied reaction of spring wheat cultivars to the intensity of production technology, shown in this paper, had been confirmed in previous research (Cacak-Pietrzak & Sułek, 2007; Kołodziejczyk, Szmigiel, & Oleksy, 2007; Kołodziejczyk, Szmigiel, & Kulig, 2009; Sułek & Podolska, 2012).

The effect of intensity of production technology on the value of 1000 grain weight of spring wheat cultivars was noted in the year of higher yields (2015). In addition, in this year, the grain was the most mature. Wheat cv. 'KWS Torridon', cultivated under intensive technology, showed a significant increase in its 1000 grain weight (by 6.4%) in relation to the integrated technology. In the case of cv. 'Arabella', no significant difference in this value was found among the different production techniques. In 2016, no effect of production technology on the 1000 grain weight was noted. In each year of the research, cv. 'KWS Torridon' was found to have a higher 1000 grain weight compared to cv. 'Arabella' (Table 2). In the studies of Dziki et al. (2017), spring wheat grain from the integrated production showed a higher 1000 grain weight in comparison with the grain from intensive cultivation, whereas in the studies of Cacak-Pietrzak & Sułek (2007) and Marzec, Cacak-Pietrzak, & Gondek (2011), the impact of production intensity on this quality of grain depended on the cultivar.

A significant increase in the ear density per unit area due to the intensification of production technology was found for cv. 'KWS Torridon'. However, the increase in intensity of production technology did not have a significant impact on the number of ears of cv. 'Arabella' (Table 2). Kołodziejczyk, Szmigiel, & Oleksy (2007) indicate that the use of higher nitrogen fertilization and fungicide protection contributed to an increase in the number of ears per unit of area by, on average, 12.3%. In our research, this increase was about 11.1%.

Table 2

Grain yield of spring wheat cultivars depending on production technology in 2015 – 2016

Technology production (A)	2015			2016		
	Cultivars (B)					
	Arabella	KWS Torridon	Means	Arabella	KWS Torridon	Means
Grain yield (t·ha⁻¹)						
Integrated	7.51	7.15	7.33	5.57	6.80	6.18
Intensive	7.18	8.20	7.50	5.89	7.21	6.55
Means	7.34	7.67		5.69	7.10	
LSD$_{0.05}$ for A – n.s.; B – n.s.; A/B – 0.542			LSD$_{0.05}$ for A – n.s.; B – 1.257; A/B – 0.392			
1000 grain weight (g)						
Integrated	40.0	43.7	41.8	33.4	40.8	37.10
Intensive	39.7	46.5	43.1	33.3	41.3	38.32
Means	38.8	45.1		34.4	41.0	
LSD$_{0.05}$ for A – n.s.; B – 0.41; A/B – 1.89			LSD$_{0.05}$ for A – n.s. B – 4.21; A/B – n.s			
Number of ears per m²						
Integrated	566	468	517	604	449	526
Intensive	572	510	530	614	556	585
Means	569	489		609	502	
LSD$_{0.05}$ for A – n.s.; B – 37.8; A/B – 39.3			LSD$_{0.05}$ for A – 52.6; B – 63.8; A/B – 71.2			
Number of grains per ear						
Integrated	36.5	35.0	35.5	27.6	37.1	32.3
Intensive	31.6	34.6	33.3	29.3	31.4	30.3
Means	34.0	34.8		28.4	34.2	
LSD$_{0.05}$ for A – n.s.; B – n.s.; A/B – n.s.			LSD$_{0.05}$ for A – n.s.; B – 3.92; A/B – 4.77			

n.s. – not significant

The presented research results concerning the number of grains per year show that the production technology did not influence this trait in 2015. In 2016, cv. 'KWS Torridon' grown under intensive technology (Table 2) showed a significantly higher number of grains. Earlier studies (Sułek & Podolska, 2012) showed no relationship between the number of grains per ear and the intensity of production technology. These authors have shown that this feature depends on the cultivar. According to the research conducted by Kołodziejczyk, Szmigiel, & Kulig (2009), using the intensive production technology results in a significant increase in the number of ears and grains per ear, whereas it has a negative impact on the 1000 grain weight.

The production technology of spring wheat did not significantly (p>0.05) affect the quality traits of grains, whereas the cultivar used shaped most traits of the grain quality, apart from the sedimentation index (Table 3). In both years of the research, the grains of cv. 'KWS Torridon' contained more total proteins than the grains of cv. 'Arabella' (Table 3). The influence of the cultivar features on the protein content in spring grains of wheat cultivars was also demonstrated by Uhlen et al. (2015). In 2015, the total protein content of grains was on average by 0.6 percentage points higher than in 2016, due to the weather conditions more favorable for the accumulation of protein. The use of intensive production technology resulted in an increase in the total protein content of grains of the tested wheat cultivars, but these changes were not statistically significant (p>0.05). Cacak-Pietrzak & Sułek (2007), Marzec, Cacak-Pietrzak, & Gondek (2011) and Dziki et al. (2017) demonstrated a beneficial effect of intensification of production on the total protein content in the grains of spring wheat cultivars. In this work, irrespective of the production technology used, the grain of both wheat cultivars met the requirements for the production of baking flour in terms of their total protein content (min. 11.5% of total protein).

The content of gluten proteins, similarly to total proteins, depended significantly on the cultivar features (Table 3). Significantly more gluten was

Table 3

Quality traits of spring wheat grains depending on production technology in 2015 – 2016

Technology production (A)	2015			2016		
	Cultivars (B)					
	Arabella	KWS Torridon	Means	Arabella	KWS Torridon	Means
Protein content (% s.s.)						
Integrated	12.1	13.5	12.8 a	11.5	12.8	12.2
Intensive	12.8	13.9	13.3 a	11.8	13.7	12.7
Means	12.5	13.7		11.7	13.2	
$LSD_{0.05}$ for A – n.s.; B – 0.85; A/B – n.s.			$LSD_{0.05}$ for A – n.s.; B – 0.71; A/B – 0.82			
Gluten content (%)						
Integrated	26.0	31.2	28.6	24.0	29.1	27.1
Intensive	28.5	31.0	29.7	25.0	31.7	27.8
Means	27.2	31.1		24.5	30.4	
$LSD_{0.05}$ for A – n.s.; B – 2.05; A/B – 2.02			$LSD_{0.05}$ for A – n.s.; B – 3.93; A/B – 4.03			
Gluten index						
Integrated	99	79	89	99	86	93
Intensive	98	68	83	98	85	92
Means	99	74		99	86	
$LSD_{0.05}$ for A – n.s.; B – 19.3; A/B – 10.3			$LSD_{0.05}$ for A – n.s.; B – n.s.; A/B – n.s.			
Sedimentation value (cm^3)						
Integrated	38	37	38	38	34	36
Intensive	40	35	38	38	36	37
Means	39	36		38	35	
$LSD_{0.05}$ for A – n.s.; B – n.s.; A/B – n.s.			$LSD_{0.05}$ for A – n.s.; B – n.s.; A/B – n.s.			
Falling number (s)						
Integrated	379	374	376	281	389	335
Intensive	355	367	361	309	381	345
Means	367	370		295	385	
$LSD_{0.05}$ for A – n.s.; B – n.s.; A/B – n.s.			$LSD_{0.05}$ for A – n.s.; B – 60.7; A/B – n.s.			

n.s. – not significant

removed from the grains of wheat cv. 'KWS Torridon' than from cv. 'Arabella'. Weather conditions in 2015 promoted the accumulation of gluten proteins in wheat grains more than in 2016. The use of intensive cultivation technology generally increased the amount of gluten proteins in the grains of the wheat cultivars studied, but the changes were not statistically significant. In previous studies (Cacak-Pietrzak & Sułek, 2007), the amount of gluten proteins in spring wheat grains increased with the intensification of production technology, but at the same time their quality deteriorated. In this work, the deterioration of gluten quality was found only in the case of cv. 'KWS Torridon' grains from the 2015 harvest. Regardless of the year of research and the production technology used, the grain of both wheat cultivars were a suitable raw material for the production of baking flours in terms of the quantity and quality of gluten proteins.

The values of Zeleny's sedimentation index did not significantly depend on weather conditions in the years of research, the intensity of production technology, or cultivar (Table 3). In the previous studies (Cacak-Pietrzak & Sułek, 2007), the values of this indicator depended on the cultivar, intensity of production technologies, and the interaction between these factors.

The activity of amylolitic enzymes in the grains of the tested wheat cultivars was generally at a low level (Table 3). An exception were the grains of cv. Arabella under the integrated cultivation, harvested in 2016, as they showed an average amylolitic activity. In the case of this cultivar, in 2016, intensification of the

cultivation process significantly decreased the activity of amylolitic enzymes. In the previous studies (Cacak-Pietrzak & Sułek, 2007), the intensity of production technology did not have a significant impact on this characteristic of the grain, but, similarly as in the studies of Uhlen & *et al*. (2015), it depended on the cultivar.

Conclusions

1. A higher effectiveness of intensive wheat production technology, expressed by the increase in grain yield (on average by 18.0%) compared to the integrated technology, was noted in 2015. An increased grain yield was the result of a higher 1000 grain weight.
2. Spring wheat cultivars responded differently to the production technologies used. In the conditions of intensive production technology, cv. 'KWS Torridon' yielded significantly more, while the yields of cv. "Arabella" did not significantly differ.
3. The total protein content of the grains, including gluten proteins, depended on the cultivar characteristics. The grains of wheat cv. 'KWS Torridon' contained more of this component than the grains of cv. 'Arabella'. Using intensive production technology resulted in an increase in the content of protein substances of the analyzed wheat cultivars, but these changes were not statistically significant.
4. The activity of amylolitic enzymes in the grains of both analyzed wheat cultivars was at a low level, with the exception of 'Arabella' cultivar grown under the integrated system in the 2016 harvest. In this study, the use of intensive production technology significantly decreased the amylolitic activity of the grains.
5. The research showed that the use of integrated production technology did not adversely affect the quality characteristics of the grains of the tested cultivars of spring wheat. The intensification of production technology can only be justified in the case of wheat cv. 'KWS Torridon' due to its higher yields under this system.

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RESPONSE OF BARLEY ON SEAWEED BIOSTIMULANT APPLICATION

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Abstract
In some regions of the world, there is a risk of limiting crop production due to the growing pressure of biotic and abiotic factors. It is mostly connected with the forecasted climatic changes. Hence, alternative methods for supporting plant growth are sought for, and among them, biostimulants can play a significant role. The three-year (2009 – 2011) field experiment with spring barley (*Hordeum vulgare* L.) was conducted in Poland to assess the response of grain yield, yield components, as well as the content and uptake of N, P and K in grain to differentiated times and to a dose of seaweed (*Ecklonia maxima* Osbeck) biostimulant Kelpak application. Preparation was applied in a dose of 2 L ha^{-1} at BBCH 22 (early treatment) or in a dose of 2 L ha^{-1} at BBCH 31 (late treatment), as well as two times, 1.5 L ha^{-1} each, in both phases. The study indicated that the biostimulant had a favourable effect on the root weight, grain number per spike, thousand grain weight and seed yield in early treatment as compared with the control. Early application also had a positive effect on N and P uptake in the grain yield. Favourable response of barley to the application of biostimulant shows the usefulness of the seaweed extract in the cultivation technology of this crop.
Key words: root weight, yield component, grain yield, macroelements.

Introduction

Barley (*Hordeum vulgare* L.) is among the most economically vital cereal crops. It is used mostly as a raw material for feed production. An increase in the meat production generate an increasing demand for grain of fodder cereals (FAOSTAT, 2018). At the same time, there is a risk of limiting grain production due to the growing pressure of environmental factors, mostly connected with an increased risk of drought and heat stress (Sharma *et al*., 2014). Hence, alternative methods for supporting plant growth and hardiness are sought for, and among them, biostimulants are highly promising (Craigie, 2011; Khan *et al*., 2009; Kocira *et al*., 2017; Kotwica *et al*., 2014; Sangha *et al*., 2014; Sharma *et al*., 2014; Szczepanek, Wszelaczyńska, & Pobereżny, 2018). Agricultural biostimulants are organic substances that are applied to plants or soils to increase crop tolerance to stress, and the quantity and quality of yield (EBIC, 2018). Among the preparations from this group, biostimulants produced from marine algae (e.g. *Ascophyllum nodosum, Ecklonia maxima, Laminaria digitate, Fucus serratus, Durvillaea potatorum*) constitute a significant part (Craigie, 2011; Sharma *et al*., 2014). Currently, it is known that the use of macroalgal extracts can bring many benefits in the cultivation of agricultural crops, but the reasons for the positive results are not fully understood (Sharma *et al*., 2014). Nowadays, the economics of crop production limit the use of biostimulants mainly to high-value horticultural crops. However, high prices for fertilizers and pesticides may change this situation, and these preparations exhibiting activity for promoting plant growth and stress tolerance will become commonly used in many agricultural crops (Shanga *et al*., 2014; Sharma *et al*., 2014). Learning the effects for use of alga biostimulants requires

research concerning the method of application, which forms the basis for increasing the effectiveness of those preparations. The aim of the study was to assess the response of spring barley yield and yield components, as well as the content and uptake of macronutrients in grain to differentiated times (cereal developmental stages) and a dose of algae (*Ecklonia maxima* Osbeck) biostimulant Kelpak application.

Materials and Methods

The current study was based on two strict field experiments located in Poland, in Kuyavian-Pomeranian voivodeship (53°13'N; 17°51'E), carried out for three years (2009, 2010 and 2011). Most of the time, the rainfall and thermal conditions in the area of the study are favourable for wheat and barley cultivation. The cereal growing period begins on the first days of April and ends on the last days of July. The long-term mean of total precipitation in this period amounted to 197 mm. In 2009, the lowest precipitation was recorded in April (0.4 mm) and in 2010 in June (18.1 mm). In 2011, the rainfall during the growing period of barley (from April to July) was the lowest (59.2 mm).

Field experiments were located on the Haplic Luvisol (Cutanic) soil (IUSS Working Group WRB). The soil at experimental fields was characterized by a low content of organic carbon 7.55 – 7.8 g kg^{-1} (PN-ISO 10694) and a low content of the total nitrogen 0.69 – 0.75 g kg^{-1} NH$_4$ – N and NO$_3$ – N (PN-R-04028). The content of available phosphorus (PN-R-04023) and potassium (PN-R-04022) were 190 – 210 mg kg^{-1} (high) and 95 – 150 mg kg^{-1} (medium), respectively. The content of magnesium (PN-R-04020) was very low (<20.0 mg kg^{-1}). The soil was characterised by a slight acidic reaction (pH in 1 mol KCL 5.7 – 6.1) (PN-ISO 10390).

The field study was conducted as strict one-factorial experiment, in four replications. The plots had an area of 12 m². The subject of the study was the spring barley (*Hordeum vulgare*) cultivar 'Nuevo'. In the experiment, the seaweed biostimulant Kelpak was used during three successive growing seasons. Biostimulant Kelpak is obtained from macroalga (*Ecklonia maxima* Osbeck) belonging to the division of brown algae (*Phaeophyta*), collected on the south coast of Africa. In the processing of algae, Cold Cellular Burst Technology is used, thanks to which the full physiological activity of all substances is preserved. The bioproduct Kelpak contains phytohormones like auxins (11 mg L^{-1}) and cytokinins (0.031 mg L^{-1}), alginians, amino acids, and brassinosteroids. Kelpak was applied as an early treatment (in a single dose of 2 L ha^{-1}, at tillering - two tillers detectable, BBCH 22) or as a late treatment (in a single dose of 2 L ha^{-1}, at stem elongation, first node at least 1 cm above tillering node, BBCH 31), as well as a sequential treatment (two times, 1.5 L ha^{-1} in each of both growth stages, BBCH 22 and BBCH 31). Preparation was applied as aqueous solution in a dose of 300 L ha^{-1}. The three kinds of applications of the seaweed biostimulant were compared with the control (without treatment) group.

The spring barley was sown on 2 – 4 April in germinate able seeds of 430 per 1 m². Pre-sowing fertilization was used in an amount of 31 kg P, 66 kg K and 80 kg N ha^{-1}. At the beginning of the stem elongation, the second dose of N was applied in dose of 30 kg N ha^{-1}. For weed control, Lintur 70 WG in a dose of 150 g ha^{-1} (dicamba, 988 g ha^{-1} + triasulfuron, 61.5 g ha^{-1}) was used at BBCH 22 – 24. To protect the barley against fungal diseases, Capalo 337.5 SE in a dose of 1.5 L ha^{-1} (metrafenone, 112.5 g ha^{-1} + epoxiconazole, 93.8 g ha^{-1} + fenpropimorph, 300 g ha^{-1}) was used at BBCH 34 – 39 and Alert 375 SC in a dose of 1 L ha^{-1} (carbendazim, 250 g ha^{-1} + flusilazole, 125 g ha^{-1}) at BBCH 51 – 59. For pest control, Bi58 400 EC in a dose of 0.5 L ha^{-1} (dimethoate, 200 g ha^{-1}) was used at BBCH 59. The harvest of barley grain was performed at the beginning of August.

At flowering stage (BBCH 75), the generative tiller number on the area of 1 m² and generative tiller length on 30 randomly chosen tillers were determined. At the same time, the dry matter of roots was determined based on 20 successive plants in a row. At the end of ripening (BBCH 89) on 30 randomly selected spikes from each plot the number of grains per spike was determined. The grain yield and moisture were determined directly after harvest. The straw weight was measured 6–8 days after the grain harvest. One to two months after the grain harvest the 1000 grain weight was also assessed according to the method PN-68/R-74017. The yield of spring barley grain and straw weight were converted to the determined humidity of 14%. For each plot, the harvest index was calculated (the dry matter of grain yield divided by the sum of the dry matter of grain and straw yields). Mineralization of grain was performed by wet combustion with sulphuric acid and perhydrol (PN-91/R-04014). The content of P, N and K were made using the following methods: PN-ISO 6491, PN-EN ISO 2048, and PN-EN ISO 6869, respectively. The uptake of phosphorus, nitrogen, and potassium was calculated for each plot as the product of grain dry matter yield and the microelement content in grain.

The results were analysed using the 'Analysis of variance' statistical program by the UTP University of Science and Technology. The differences between the means were verified with Tukey's test and the significance level p=0.05. Pearson's correlation analyses were carried out using the *Statistica* for Windows.

Results and Discussion

Preparations produced from algae may have a favourable effect on barley growth. In the study by Möller & Smith (1999) it was indicated that priming in seaweed (*Ascophyllum nodosum*) suspension was beneficial to seed germination. Seaweed (*Ecklonia maxima*) application at later developmental stages may also be favourable, though there are few studies on this subject (Featonby-Smith &Van Staden, 1987; Matysiak & Adamczewski, 2006).

In the current study, the early application of biostimulant at the tillering (BBCH 22), in a dose of 2 L ha^{-1}, and sequential, in two doses of 1.5 L ha^{-1} at the tillering and shooting stages (BBCH 22 and 31), resulted in an increase in the barley root weight in comparison with the control group (Table 1). Barley root growth after the application of extract from algae (*Ascophyllum nodosum*) has also been reported by other scientists (Steveni, Norrington-Davies, & Hankins, 1992). Horoszkiewicz-Janka & Jajor (2006), however, did not observe a difference in the root weight after the use of algae (*Ecklonia maxima*) biostimulant in comparison with the control group, but in that study, the biopreparation was used for seed dressing. Stimulation of the root system development can be attributed to phytohormones contained in algae, and particularly to auxins (Tarakhovskaya, Maslov, & Shishova, 2007; Kurepin, Zaman, & Pharis, 2014). Apart from that, Kelpak also contains other active compounds including cytokinins, polyamines and brassinosteroids (Stirk *et al*., 2014; Stirk & Van Staden, 2014).

In the current study no significant effect of the use of biostimulant on density or generative tiller length was observed (Table 1). The straw yield increase, in

Table 1

**Biometric features and yield of barley depending on biostimulant
rate and growth stage during application, means from 2009 – 2011**

Characteristics	Biostimulant rate and growth stage of barley			
	2 L ha⁻¹ BBCH 22	1.5 L ha⁻¹ BBCH 22 1.5 L ha⁻¹ BBCH 31	2 L ha⁻¹ BBCH 31	Control
Root weight[†], g	14.2a[‡]	14.4a	12.8b	12.3b
Generative tiller length, cm	57.5a	56.7a	57.4a	57.0a
Generative tiller density, no m⁻²	975a	980a	981a	956a
Grain number per spike, no	21.3a	21.1a	21.1a	20.5b
Thousand grain weight, g	41.3a	40.9a	40.0b	39.6b
Grain yield, kg ha⁻¹	6141a	5975b	5912b	5909b
Straw yield, kg ha⁻¹	5726b	5936b	6162a	5820b
Harvest index	0.507a	0.489b	0.475b	0.491ab

[†]dry root weight from 20 plants; [‡]within a row for each characteristic, values followed by different letters are significantly
different according to LSD (0.05).

turn, was recorded for the late application (2 L ha⁻¹ at BBCH 31). The early use of the biostimulant resulted in a significant increase in the harvest index in comparison with the late and sequential treatment. The early application of the biostimulant (BBCH 22) in a dose of 2 L ha⁻¹ resulted in an increase in the grain yield in comparison with the control group. This application method also resulted in an increase in the thousand grain weight. Positive effects of application of the extract from algae were also obtained for the number of grains per spike, for which a positive correlation with grain yield was proved (Table 2). Featonby-Smith & Van Staden (1987) also have indicated stimulation of traits connected with shaping the barley grain yield as affected by the seaweed concentrate. They showed an increase in grain weight per plant, largely due to a greater number of fertile spikelets per spike. An increase in the spring barley

grain yield under the influence of foliar application of the biostimulant from algae was also reported by Matysiak & Adamczewski (2006).

In our study, the grain yield of spring barley was positively correlated with the root weight, tiller length and their density, and negatively with the thousand grain weight (Table 2). A positive correlation was seen between the number of grains per spike with the root weight, straw yield and generative tiller length, and a negative correlation between the number of grains per spike with the thousand grain weight. The thousand grain weight, in turn, was negatively correlated with the root weight and the tiller length. The correlation between the tiller length and the root weight was also positive. The straw yield was positively correlated with the generative tiller length, root weight and grain yield. There was a negative correlation of the harvest index with the thousand grain weight and positive with

Table 2

Pearson's correlation coefficients for the relation between biometric features and yield of barley

Characteristics	1.	2.	3.	4.	5.	6.	7.
1. Root weight, g							
2. Generative tiller length, cm	0.64*						
3. Generative tiller density, no m⁻²	-0.09 ns	0.08 ns					
4. Grain number per spike, no	0.69*	0.95*	0.19 ns				
5. Thousand grain weight, t ha⁻¹	-0.47*	-0.83*	0.20 ns	-0.74*			
6. Grain yield, kg ha⁻¹	0.57*	0.82*	0.40*	0.88*	-0.47*		
7. Straw yield, kg ha⁻¹	0.54*	0.82*	0.20 ns	0.79*	-0.64*	0.73*	
8. Harvest index	0.50*	0.71*	0.38*	0.80*	-0.38*	0.94*	0.47*

* significant at p<0.05; ns – non significant

Table 3

**Content and uptake of N, P, K in barley grain depending on biostimulant
rate and growth stage during application, means from 2009 – 2011**

Macroelement	Biostimulant rate and growth stage of barley			
	2 L ha⁻¹ BBCH 22	1.5 L ha⁻¹ BBCH 22 1.5 L ha⁻¹ BBCH 31	2 L ha⁻¹ BBCH 31	Control
Content, g kg⁻¹				
N	16.3a‡	16.3a	16.6a	16.4a
P	3.57b	3.60a	3.56b	3.57b
K	3.65c	3.68b	3.71a	3.70a
Uptake, kg ha⁻¹				
N	84.4a	81.9b	81.8b	81.5b
P	19.1a	18.6b	18.2b	18.4b
K	18.5a	18.1a	17.8a	18.0a

‡within a row for each macroelement, values followed by different letters are significantly different according to LSD (0.05).

the root weight, generative tiller length and density, as well as with the number of grains per spike and with the grain and straw yield.

No significant effect of the seaweed biostimulant on N content in the spring barley grain was indicated (Table 3). Sequential use of the preparation resulted in an increase in P content in the grain, as compared with the control group and the other application variants. The early and sequential applications of the biostimulant resulted in a decrease in K content in the spring barley grain, as compared with the control group and late treatment. The uptake of N and P in grain was the highest after a single application of the preparation at the tillering stage (early treatment). No significant effect of the biostimulant application on K uptake was indicated.

In the current study, N and P uptake in barley grain was determined mainly with the grain yield quantity. Due to the lack of influence of the preparation on N content or a small effect on P concentration, the uptake of those elements in the grain was the highest after the application, resulting in the growth of yield (single early treatment). Potassium uptake, in spite of smaller concentration in grain in early and sequential treatments, was similar to the application of biostimulant and in the control group. The lack and even a negative response of the macroelement N, P and K content in the barley grain to the biostimulant application may result from genetic traits of the studied barley cultivar. According to Carvalho *et al.* (2014), the effect of the use of extracts from algae depends not only on the dose, method, and time of application, but also on the cultivar sensitivity. The integration of cultivation methods and improvement of varietal traits may bring about a significant increase in the effectiveness of nutrient utilization,affecting barley grain yield quantity and quality (Anabessa & Juskiw, 2012).

Conclusions
1. The response of spring barley to the foliar application of seaweed (*Ecklonia maxima* Osbeck) biostimulant Kelpak depended on the dose and developmental stage of plants during the application.
2. Early application of biostimulant (in a dose of 2 L ha⁻¹ at BBCH 22) had a favourable effect on the number of grains per spike, thousand grain weight, and grain yield of spring barley. This application method stimulated the growth of root weight and resulted in an increase in N and P uptake in grain.
3. Favourable response of the grain yield and nutrient uptake gives grounds for recommendations of the foliar application of seaweed biostimulant Kelpak in early treatment for spring barley. There is a need for further field studies on the effect of the preparation application in conditions of growing biotic and abiotic stress.

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THE EFFECT OF SUPERABSORBENT POLYMER APPLICATION ON YIELDING OF WINTER WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract
Superabsorbents are hydrophilic polymers that can absorb large amounts of water. These studies show that the use of superabsorbent may significantly reduce the negative effects of drought stress on plants. However, their use in the field cultivation has so far been minimal. The price of hydrogels has recently decreased significantly. This was the reason for starting research described in this work, in which the experimental plant was the winter wheat cultivar 'Lucullus' - the cereal which is the most intensively cultivated in Poland. The field experiment was conducted in the years of 2014 – 2016, in the Agricultural Experimental Station (AES) in Osiny, Poland, in 4 repetitions. TerrahydrogelAqua was evaluated in the following doses: 1) control without hydrogel, 2) 10, 3) 20 and 4) 30 kg·ha^{-1}. Before harvesting, the plant samples were taken to determine the yield structure elements. After harvesting, grain yield at 15% moisture content was determined. The influence of hydrogel on winter wheat grain yield varied in individual years. On average, the yield of wheat grain from the treatment with a dose of 30 kg·ha^{-1} of hydrogel was significantly higher than from the control treatment or the treatment with a dose of 10 kg·ha^{-1} of hydrogel. The mean values of yield structure features, i. e. ear grain yield and weight of thousand grain were the highest at the dose of 30 kg·ha^{-1} of hydrogel. The effect of hydrogel on the average number of plants and ears per unit area and on the number of grains per ear was not found.
Key words: winter wheat, superabsorbent, hydrogel, yield.

Introduction

Superabsorbents, also known as hydrogels, are hydrophilic polymers that can absorb large amounts of water (Junping, An, & Aigin, 2006). In the dry state, they have the form of compact clusters, while under the influence of water, their functional groups become solvent and dissociate. Cations get separated and negative charges connected with polymer chains repel under the influence of electrostatic forces. This loosens the polymer and results in the possibility of water absorption. This process ends when the polymer chains are maximally elongated (Bereś & Kałędowska, 1992). One gram of hydrogel can absorb up to 1000 g of water, although according to Dąbrowska & Lejcuś (2012), absorbents with an absorbent capacity greater than 600 g·1g^{-1} are not used in practice.

The most commonly used hydrogels are the ones formed on the basis of polyacrylamide, polyacrylic acid, polymethyl acid and the derivatives of these compounds.

Superabsorbents have already started to be used in land reclamation (Bereś & Kołędowska, 1992) or forestry (Dąbrowska & Lejcuś, 2012). A number of studies have also been carried out on the effects of superabsorbents on the soil (Lejcuś *et al.*, 2006). In this case, these compounds are treated as moisture buffers. Studies have shown that by retaining water, superabsorbents can limit the leaching of nutrients and plant protection products to the deeper layers of the soil profile. Water retained by superabsorbents can be easily utilized as the binding forces of the water in the superabsorbent are lower than the suction force of roots. According to Lejcuś *et al.* (2006), the utilisation rate exceeds 90%.

Despite many studies, it is not yet clear to what extent superabsorbents affect the soil structure (de Boodt, 1993). However, some authors believe that hydrogeogels may cause the soil to become loosened due to repeated swelling and shrinking. Thus, they can have a positive effect on soil aeration under water excess (Nowosielski, 1996). According to Helia, El-Amir, & Shawky (1992), as a result of hydrogel action, micropores are interrupted and evapotranspiration decreases. However, interrupting the micropores does not affect the porosity of the soil, and therefore anaerobic root rot does not occur. This suggests that superabsorbents can play a role not only in light soils but also in heavy soils, where water scarcity is rare.

The absorption of water in the superabsorbent occurs within a very wide range of pH from 4 to 11, so soil acidity is not a limiting factor for effective action. Water hardness has some influence on water absorption by the hydrogels. With increased hardness, this absorption is lower. But even in the case of very hard water, i. e. exceeding 700 mg $CaCO_3$, the absorption of water by hydrogels does not stop (Malisz & Kałędowska, 1994).

The improvement of water and air relations by superabsorbents causes the treatment with these substances show better root formation, faster development and growth of plants, and thus a higher drought resistance of vegetables (Jabłońska-Ceglarek & Cholewiński, 1998), grasses (Sady & Domagała, 1994), tobacco (Kościk & Kowalczyk-Juśko, 1998), and trees (Lejcuś *et al.*, 2006).

Most frequently it is proposed to use polymers by mixing them with the soil (Lejcuś *et al.*, 2008). A positive effect of hydrogels on plants is generally

Jerzy Grabiński, Marta Wyzińska

THE EFFECT OF SUPERABSORBENT
POLYMER APPLICATION ON YIELDING OF
WINTER WHEAT (*TRITICUM AESTIVUM* L.)

not questioned in literature. However, their use in the field cultivation has so far been minimal. The price of hydrogels has recently decreased significantly. According to the data from 2011, 1 kg of hydrogel can be bought for about USD 5 per kilogram (Mao *et al.*, 2011). If we consider that the dose per 1 ha, as proposed by producers, is between 10 and 15 kg ha^{-1}, that is to say, the cost of its application per 1 ha does not exceed the cost of using good quality fungicide in cereal sowing, and is therefore relatively low. It should be added that in Poland, field crop producers (especially of quality wheat) are starting to use superabsorbents by importing them directly from China.

To sum up, knowledge of superabsorbents is relatively broad, but the amount of information on the effects of using these substances in field crops, is low.

The aim of the study was to determine the influence of superabsorbent on the yield and yield component traits of the structure of winter wheat yield.

Materials and Methods

The field experiment was carried out in the years of 2014–2016, in AES Osiny (51°27'N 22°2'E), the Lubelskie voivodeship, Poland, in the crossed sub-block design, in 4 replications. TerrahydrogelAqua (crosslinked acrylic, potassium polymer) evaluated during the experiment was assessed at the following rates: 1) control – without hydrogel, 2) 10, 3) 20 and 4) 30 kg·ha^{-1}. The size of the plot at the set-up and harvesting was 100.0 m^2. The experiment was carried out on the Albic Podzols soil, sandy loam, suitable to winter wheat production. The experimental plant was a winter form of wheat cultivar 'Lucullus'. The sowing date and all agronomic treatments were applied according to the recommendations specified in the latest instructions issued by the Institute of Soil Science and Plant Cultivation – State Research Institute for the respective species. During the vegetation period, dates of the plant development stages were noted. Prior to the harvest, samples of plants were taken in order to determine the elements of yield structure: number of plants and ears per area unit, grain yield per ear, weight of thousand grains, and the number of grains per ear. Harvesting was carried out at full maturity stage (BBCH 97). The yield has been calculated at 15% moisture content.

The experiment was conducted using annually the hydrogel described in Table 1.

The results were statistically analyzed using a one-way ANOVA and the Statgraphics Centurion XVI computer program. Significance of differences between means was evaluated using the Tukey test at the level of significance p=0.05.

Results and Discussion

Data from a meteorological station located in the AES in Osiny, where the research was conducted, were used to describe the weather conditions in subsequent

Table 1

Characteristics of TerrahydrogelAqua (crosslinked acrylic, potassium polymer)

moisture (%)	6 – 10
degree of absorption of distilled water	350 – 550 g·1g^{-1} of gel
degree of absorption of brine	40 – 70 g·1g^{-1} of gel
speed of absorption	0.5 – 2 h
Granulation	20 – 40 mesh
Biodegradation	3 – 5 years
pH	6 – 8
Commercial form	Granulated
registration	REACH

Table 2

Soil nutritional status (mg·100 g^{-1}) and pH in individual years of the study

Year	pH	Soil nutritional status		
		P$_2$O$_5$	K$_2$O	Mg
2014	6.59	17.8	16.9	2.1
2015	6.02	15.8	12.7	3.4
2016	6.44	21.9	14.5	4.5

Table 3

Meteorological conditions in individual growing seasons (2014 – 2016)

Month	Year			
	2013/2014	2014/2015	2015/2016	Long– term average
Temperature (°C)				
September	14.5	15.1	15.3	13.3
October	7.2	10.1	7.3	8.0
November	5.2	4.9	5.2	2.8
December	4.1	0.6	4.0	-1.3
January	-3.5	1.2	-3.3	-3.3
February	3.6	1.0	3.7	-2.3
March	4.0	4.1	4.3	1.6
April	9.2	8.6	9.6	7.8
May	14.7	13.9	15.6	13.5
June	18.9	17.9	19.8	16.8
July	19.4	20.4	20.1	18.5
Rainfall (mm)				
September	41	12	118	51
October	5	22	27	43
November	49	21	38	39
December	14	36	27	37
January	49	43	33	31
February	24	5	64.5	30
March	42	21	53	30
April	73	28	38.4	40
May	189	108	72.2	57
June	121	32	27.9	70
July	63	55	86.6	84

growing seasons. They varied significantly over the years. In the first year of the study (Table 3) there was a relatively large total rainfall and relatively favorable rainfall distribution, especially in the spring growing period. In the second year of the study, the weather conditions were less favorable for wheat development – the rainfall was significantly lower than usually in May and July during the period of intensive plant growth (May–BBCH 32–65) and ripening (July–BBCH 83–89). On the other hand, in the 2015/2016 research season meteorological conditions were not favorable as well, due to much lower precipitation in May and June, when wheat plants underwent flowering (BBCH 61-69) and grain-filling stages (BBCH 71–77) (Table 3).

In each year of the study, winter wheat grain yield significantly depended on the dose of superabsorbent. In 2014, significantly higher yields of wheat were obtained from the treatment with the highest dose of hydrogel compared to the treatments with the lowest

dose of hydrogel and the control. In the following year of the study (2015), the highest winter wheat grain yield was obtained using hydrogel in the amount of 30 kg·ha^{-1}, whereas a significantly lower yield was obtained from the control object and with the lowest dose of hydrogel (10 kg·ha^{-1}). On average from three years of research, wheat yielded the highest at the treatment with a dose of 30 kg·ha^{-1} of hydrogel, while significantly lower at the control treatment and one with a dose of 10 kg·ha^{-1} (Table 4).

The analysis of the yield structure from this experiment showed that the use of hydrogel did not have a significant impact on the number of plants and ears per area unit (Fig. 1, Fig. 2), while it had a positive effect on the grain yield per ear. In the years 2014 and 2015, the highest value of this trait was found in the treatments where hydrogel was used at the highest dose, while significantly lower in the control treatment (0 kg·ha^{-1}). In the last year of the study, no statistically significant differences were found between the

Jerzy Grabiński, Marta Wyzińska

THE EFFECT OF SUPERABSORBENT
POLYMER APPLICATION ON YIELDING OF
WINTER WHEAT (*TRITICUM AESTIVUM* L.)

Table 4

Yield of winter wheat (t·ha⁻¹) depending on superabsorbent dose in Osiny

Dose of superabsorbent (kg·ha⁻¹)	Year			Mean
	2014	2015	2016	
0	8.72	7.34	8.22	8.09
10	9.42	6.43	8.25	8.03
20	9.48	7.57	8.96	8.67
30	9.46	9.56	8.86	9.29
LSD$_{0.05}$	0.715	2.128	0.718	1.156

treatments in terms of ear grain yield, although the tendency of significantly lower ear grain yield from the ears in the control treatments and ones treated with the lowest dose of 10 kg of hydrogel was quite clear (Table 4). On average, in the three years of the study, the grain yield from ears treated with hydrogel applied at a dose of 30 kg·ha⁻¹ was significantly higher than in the control (without hydrogel).
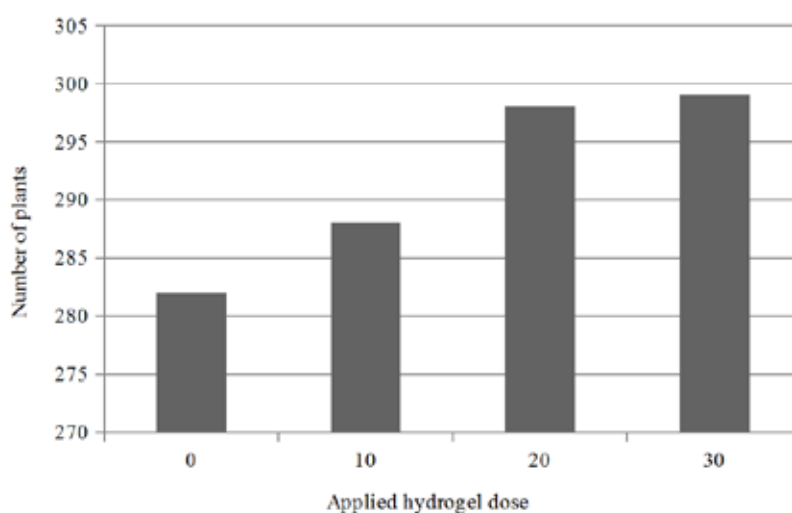

Figure 1. Number of plants per 1m² in Osiny depending on superabsorbent dose
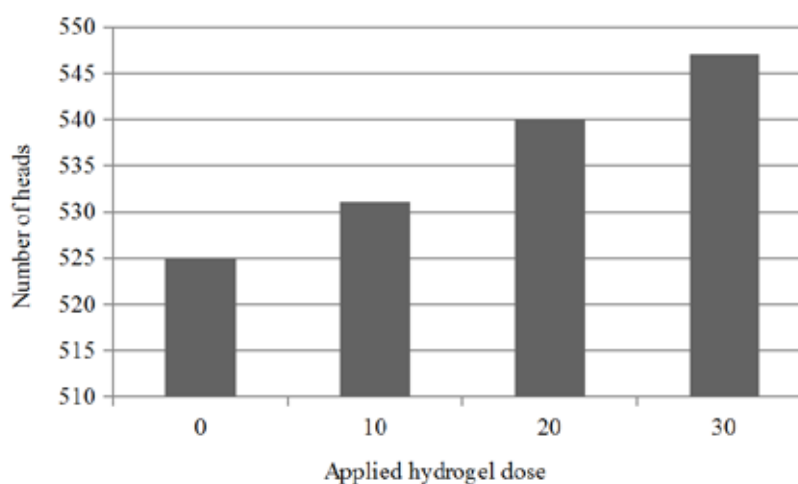(mean in the years 2014 – 2016) (p>0.05).

Figure 2. Number of head per 1m² in Osiny depending on superabsorbent dose
(mean in the years 2014 – 2016) (p>0.05).

THE EFFECT OF SUPERABSORBENT
POLYMER APPLICATION ON YIELDING OF
WINTER WHEAT (*TRITICUM AESTIVUM* L.)

Jerzy Grabiński, Marta Wyzińska

Table 5

Yield of grain per head (g) depending on superabsorbent dose in Osiny

Dose of superabsorbent (kg·ha⁻¹)	Year			Mean
	2014	2015	2016	
0	1.62	1.56	1.52	1.567
10	1.69	1.56	1.54	1.597
20	1.71	1.67	1.64	1.673
30	1.74	1.89	1.66	1.763
LSD$_{0.05}$	0.120	0.227	n.s.*	0.183

* – p>0.05

Table 6

Weight of thousand grain (g) depending on superabsorbent dose in Osiny

Dose of superabsorbent (kg·ha⁻¹)	Year			Mean
	2014	2015	2016	
0	42.67	44.67	42.13	43.16
10	43.15	45.57	42.11	43.61
20	43.43	45.56	44.34	44.44
30	44.19	46.27	44.23	44.90
LSD$_{0.05}$	1.303	n.s.*	1.830	1.466

* – p>0.05

A trait which define the grain filling degree is the weight of thousand grains (WTG). The highest WTG in 2014 was achieved by wheat grain from the treatments where hydrogel was applied at a dose of 30 kg·ha⁻¹, while significantly lower from the control treatments. In the subsequent year of the study, the value of this trait did not significantly depend on the dose of hydrogel, however, a tendency to a higher value of the WTG was noted in the variants where superabsorbent was applied. In 2016, WTG was significantly higher in the treatments with the doses 20 and 30 kg of hydrogel per 1 ha, compared to the treatments with the lowest dose or the control. The mean of three years of the above trait of yield structure achieved the highest value in the treatment with a dose of 30 kg·ha⁻¹ and decreased as the dose decreased, whereas statistically significant differences were found for the highest dose and the control treatment (Table 6).

A significant influence of hydrogel on the number of grains per ear was observed in the first two years of the study. However, in the first one, the value of this trait in treatments where hydrogel was used (regardless of a dose) was similar, whereas in the control, it was significantly lower. In the second

Table 7

Grain number per head depending on superabsorbent dose in Osiny

Dose of superabsorbent (kg·ha⁻¹)	Year			Mean
	2014	2015	2016	
0	36.63	32.82	36.08	35.18
10	39.17	34.23	36.57	36.66
20	39.37	36.65	36.99	37.67
30	39.38	40.85	36.17	38.80
LSD$_{0.05}$	2.126	1.328	n.s.*	n.s.

* – p>0.05

Jerzy Grabiński, Marta Wyzińska

THE EFFECT OF SUPERABSORBENT
POLYMER APPLICATION ON YIELDING OF
WINTER WHEAT (*TRITICUM AESTIVUM* L.)

year of the study, the differences of this feature were relatively large. As the dose of hydrogel decreased, the number of grains per ear decreased significantly as well. The difference in the number of grains in the treatment with the highest dose and the control was as high as 8. In 2016, no differences in the amount of grains per ear were found. On average, the number of grains per ear decreased markedly over three years together with the decrease of the hydrogel dose, and it was the lowest in the control treatment. However, it was not a statistically significant difference (Table 7).

A certain reference to presented on studies could be research works, in which the effect of various levels of drought stress on cereals was measured. Usually in these papers the increasing of available water influences the increase of thousand kernels of grain and grain number per head (Kilic & Yagbasanlar, 2010), as in this paper in the objects with larger doses of superabsorbent.

Due to the lack of literature on the use of superabsorbents in field crops, particularly in cereals, our studies were of recognition nature. They showed that the use of superabsorbent may lead to significant yield increases, which gives grounds for making a hypothesis about the necessity to continue these studies under other soil or weather conditions. In subsequent years of the study, there were some rain shortages, but these were not very large. It seems that if they had been larger, the effect of superabsorbent could have been more significant. It should also be noted that the doses used were in a relatively narrow range in order to perform a realistic assessment of the possibility of using the superabsorbent, taking into account its current price. It cannot be excluded that if the price falls, then it will become justified to examine the effects of higher doses than those included in this work.

Conclusions

1. The effect of hydrogel on winter wheat yield varied throughout the years. A stronger positive impact was observed in years with bigger rainfall deficit.
2. On average for three years, the application of the superabsorbent at a dose of 30 kg·ha⁻¹ resulted in a significant increase in wheat grain yield.
3. The use of hydrogel did not affect the number of plants and ears of winter wheat per area unit but, in general, it significantly increased the number of grains per ear and the weight of 1000 grains, and thus the grain yield per ear.

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TEMPORAL VARIABILITY OF DROUGHT IN FIELD CROPS IN THE REGION OF KUJAWSKO-POMORSKIE, POLAND

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Abstract
The objective of the work, carried out as part of research programme on current change of the regional climate, was to confirm the hypothesis about the increasing frequency and intensity of droughts in May and June in the region of Kujawsko-Pomorskie (central Poland) in the years 1981 – 2010. Furthermore, the aim was to confirm a significant relationship between indicators characterizing meteorological and agricultural droughts. Material for the research was the data from five meteorological measuring points located in the region. Atmospheric precipitation and air temperature in the period of high water needs of cereals and rapeseed (May – June) were used. Statistical methods widespread in climatological studies were applied, particularly the method of trends. The average multiannual totals (1981 – 2010) of rainfall in May – June allow ranking the region of Kujawsko-Pomorskie into the area of the lowest rainfall in Poland. The frequency of meteorological drought in May and June is 23.3 – 30.0% in the region. In the analyzed period there were no significant changes in the frequency and intensity of these droughts with the passage of years. Rainfall shortages in cereal crops and rapeseed production range on average from -19 to -35 mm, and extend to maximum of -93 to -117 mm. The values of shortages did not show any significant changes in the years of the study. The significant dependence between the indicators of meteorological and agricultural droughts allows for determination of the rainfall shortages in crop production on the basis of the SPI values.
Key words: meteorological and agricultural drought, cereal, rapeseed, atmospheric rainfall shortage.

Introduction

The region of Kujawsko-Pomorskie, which is located in the northern part of central Poland, is mainly the area of agricultural production. Agricultural land in this region covers over 1 million ha, of which cereal crops and rapeseed are grown on 700.000 hectares (Statistics Poland, 2018). Production of these crops is associated with climatic risk resulting from the frequent occurrence of droughts during the period of high water needs, spanning May and June (Łabędzki, 2007; Doroszewski *et al.*, 2012; Łabędzki & Bąk, 2014; Żarski *et al.*, 2017).

The main feature of droughts is their irregularity, resulting from a high variation of atmospheric precipitation in time. This variation, which consists of the occurrence of radically different weather conditions in the same calendar periods of particular years, is the most important feature characterizing the climate of central Poland, referred to as temperate and transitional between oceanic and continental climates. According to the forecasts of climate change, the main symptom of which is the increase in the air temperature, in the temperate latitudes the frequency of extreme weather conditions and thus the occurrence of droughts are to increase (Kundzewicz & Kozyra, 2011; IPCC, 2014). Under the projections and simulations of climate change for the years 2050–2060, the determined probabilities for occurrence of extremely dry periods in central Poland indicate on average their two-, three- and fourfold increase depending on the scenario of climate change (Kuchar *et al.*, 2015). Many research results indicate that these changes are already taking place. Somorowska (2009) stated that during the last two decades of the 20th century, dry months occurred in the most of analyzed regions in Poland. Jania & Zwoliński (2011), Wibig (2012), Skowera (2014), and Ziernicka-Wojtaszek (2015) have come to similar conclusions.

The basic objective of the work, carried out as part of research programme on current changes in the regional climate, was to confirm or deny the hypothesis about the increasing frequency and intensity of droughts in May and June in the region of Kujawsko-Pomorskie in the years 1981 – 2010. The work was also aimed at confirming a significant relationship between indicators characterizing meteorological and agricultural droughts.

Materials and Methods

Material for the research was meteorological data of standard measurements of atmospheric precipitation and air temperature in the period of high water needs of cereals and rape, spanning May and June. The meteorological data were derived from three local branches of the Central Research Center for Cultivar Testing located in Chrząstowo, Głębokie and Głodowo. Also data of meteorological measurements carried out at the Research Station of UTP University of Science and Technology in Bydgoszcz, located in Mochełek rural area, were used. In order to check the homogeneity of rainfall data from the four measuring points, they were compared to the sole reference station in the region, operating in the national network of the Institute of Meteorology and Water Management (IMGW–PIB), located in Toruń. All measuring points are located in the region of Kujawsko-Pomorskie. Chrząstowo and Mochełek are located in the northern part of the region in the Pojezierze Krajeńskie, and

Figure 1. Location of the meteorological measuring points.

Drought classes according to the standardized precipitation index SPI (Łabędzki & Bąk, 2013)

Type of period	SPI	Graphic designation
Extremely dry	≤-2.00	
Very dry	-1.99 ÷-1.50	
Moderate dry	-1.49 ÷-1.00	
Slightly dry	-0.99 ÷-0.50	

the other two are located in the southern part of the province: Głębokie in Pojezierze Gnieźnieńskie (Równina Inowrocławska) and Głodów in Pojezierze Dobrzyńskie (Wysoczyzna Płońska) (Figure 1). The geographical location of the listed sites is presented in the Results section (Table 2). They all are located in poorly urbanized and industrialized areas, which decreases the impact of urban anthropogenic factors to a minimum. To ensure the homogeneity of the meteorological data series, following the recommendations of the World Meteorological Organisation (WMO), only the totals of rainfall in the 30-year normal period were statistically analysed (1981–2010). Next to the representativeness of the data, it is also important, whether rules of comparability of meteorological measurements and observations provided by WMO are respected. Failure to comply with those rules often leads to erroneous conclusions due to the lack of comparability of measurement sites, measuring instruments, or data averaging procedures (Kuśmierek-Tomaszewska, Żarski, & Dudek, 2012).

Droughts were identified on the basis of the standardized precipitation index (SPI) (Bąk & Łabędzki, 2002). The SPI was calculated separately for each location; 30-year data series of two-month precipitation totals were normalized by the transforming function $f(P) = (P)^{1/3}$. Based on the

calculated values of the SPI, the drought level was determined (Table 1) according to the scale stand in rainfall monitoring in Poland, run by the Institute of Technology and Life Sciences (Łabędzki & Bąk, 2013).

The indicator SPI is used to identify meteorological drought only on the basis of rainfall data. To determine the agricultural drought (RS), an index of deficiency of real rainfall (Pr) was compared to the optimum rainfall totals (Po) elaborated by Klatt for plants grown on soil of medium compactness (Schwarz, 1970). For cereal crops and rapeseed, the optimum rainfall is 65 mm in May at the average air temperature of 13 °C, and 70 mm in June at the average temperature of 16 °C. The temperature difference in relation to the stated increases or decreases the optimum rainfall of 5 mm for every 1 °C of the difference (Schwarz, 1970).

The following statistical methods commonly used in climatological studies were applied (Garnier, 1996): analysis of regression and correlation, and analysis of trends that employ linear regression equations in relation to the 30-year measurement period.

Results and Discussion

Multiannual averages (1981–2010) of atmospheric precipitation in the period of high water needs of cereals and rapeseed (from May to June) calculated

Table 2

The average multiannual (1981 – 2010) total of rainfall in the period of May – June in the region of Kujawsko-Pomorskie and statistics defining their temporal variability

Location	Latitude	Longitude	Avg. rainfall (mm)	Max. rainfall (mm) (year)	Min. rainfall (mm) (year)	CV (%)
Mochle	53°13' N	17°51' E	102.1	178.6 (2007)	27.0 (2008)	39.3
Chrząstowo	53°11' N	17°35' E	110.4	195.2 (2007)	32.8 (1989)	40.0
Toruń	53°03' N	18°36' E	108.6	182.0 (2010)	35.0 (1989)	34.7
Głodowo	52°50' N	19°15' E	119.7	208.7 (2009)	54.3 (2000)	32.3
Głębokie	52°39' N	18°27' E	111.2	187.9 (1985)	48.5 (1989)	33.9

for particular locations proved very strong consistency and compliance with reference data obtained from the station of The Institute of Meteorology and Water Management – National Research Institute (IMGW–PIB) in Toruń (Table 2). The lowest rainfall totals were in Mochle, and the highest in Głodowo - set in Wyżyna Płońska (100 m a. s. l.). These results are consistent with the existing studies carried out in the national (Czarnecka & Nidzgorska-Lencewicz, 2012) or regional scale (Żarski *et al.*, 2014). The long-term rainfall in the period of May–June for the analyzed locations, on average amounted to 110.4 mm (Table 2), which makes the region of Kujawsko-Pomorskie the area with the lowest atmospheric precipitation in Poland (compared to Lorenc, 2005).

Far greater than the spatial variation of rainfall in the analyzed period was their variation in time, which is distinctive of the climate of Central Poland. This is evidenced by both extreme values of totals and high coefficients of variability (CV), amounting to 32.3 – 40.0%, depending on the locality. The difference between the maximum and minimum rainfall in May and June in the years 1981 – 2010 was on average around 150 mm, so it exceeded the optimum rainfall for plants in the stages of their high water needs.

A high temporal variability but less spatial variability were also related to the frequency of occurrence of meteorological drought in the period of high water needs of cereals and rapeseed (Table 3). In the analyzed multiannual period, 7 to 9 meteorological droughts occurred in particular locations of the Kujawsko-Pomorskie region, which means a frequency of 23.3 to 30.0%. This result is fully consistent with the study of Łąbędzki (2007), made for central Poland. Noteworthy is the high consistency of drought occurrences in the analyzed locations. The entire region experienced drought in the years 1983, 2000 and 2008. In four of the analyzed locations, drought occurred in 1989, 1992 and 2006, and in three locations in 2003. The adverse effect of the evidence of drought is the reduction in yields and deterioration of their quality (Doroszewski *et al.*, 2012; Żarski *et al.*,

2013; Łabędzki & Bąk, 2017). According to the study by Żarski *et al.* (2017), regional losses in yields and harvests of barley, due to the occurrence of drought in May and June, are on average 14%, and the maximum of 23%. Minimizing the effects of agricultural droughts is associated with the development of plant irrigation. According to many studies on agricultural and horticultural plants, irrigation contributes to the regular rhythm of plant growth and development as well as the intensification of physiological processes. As a result, it increases yields and stabilizes them in subsequent years, and also positively affects the yield quality (Żarski *et al.*, 2013). According to Żarski *et al.* (2017), the application of irrigation in dry periods not only prevents yield decreases, but also ensures a higher level of yield, compared to the average one achieved without using this treatment.

In the years 1981 – 2010, there was no evidence of increasing frequency and intensity of meteorological drought in the period covering May and June in the selected locations of the Kujawsko-Pomorskie region (Figure 2). Nosignificant changes were observed in the SPI values over the period of time. The coefficients of determination characterizing these relationships were low, so it is difficult to point to a trend of changes over time. However, a great temporal variability of the SPI values was found, which is typical for the climate of central Poland.

A similar absence of significant trends and tendencies was also seen regarding the agricultural drought indicators expressed as the difference of the real and optimum rainfall, calculated for cereal plants and rapeseed, grown on soils of medium compactness (Figure 3). This deficit, as well as SPI values, were characterized by a very high time variability. They were on average from -19 to -35 mm depending on the location, which means that the production of cereals and rapeseed in the region of Kujawsko-Pomorskie is limited by the shortage of rainwater. The maximum rainfall deficit ranged from -93.2 mm in Głodowo and -22.3 mm in Głębokie (2000) to -111.6 mm in Chrząstowo and -117.0 mm in Mochle (2008). In

Table 3

The occurrence of meteorological droughts in the period of high water needs of cereal crops and rapeseed (May – June) in the years 1981 – 2010 in the region of Kujawsko-Pomorskie

Year	Mochle	Chrząstowo	Toruń	Głodowo	Głębokie
1981	▒	░			
1982					
1983	▒	░		▓	▓
1984					
1985					
1986	░			░	
1987					
1988				░	
1989	▒	■	■		▓
1990	░				░
1991					
1992	░	▒	░	▒	
1993					
1994				▒	
1995			░		
1996					
1997					
1998					▒
1999					
2000	▓	▓	▓	■	▓
2001					
2002		░			
2003	▒	░	▓		
2004					
2005				░	
2006		░	░	░	▓
2007					
2008	■	■	▒	■	■
2009					
2010					
■ (black)	1	2	1	1	0
▓ (dark)	1	1	2	2	5
▒ (medium)	4	1	1	2	1
░ (light)	3	5	4	4	1

White cells indicate periods without drought

the case of such high deficit, substantial losses in the regional crop production occur.

There are many indicators for quantitative assessment and drought monitoring, but despite identifying and expressing the intensity of the phenomenon in different units, they indicate a great compliance of the course from statistical point of view (Tokarczyk & Szalińska, 2013; Łabędzki & Bąk, 2014; Żarski *et al.*, 2017). The confirmation of this statement is the high coefficients of determination characterizing the relationship between SPI indices and rainfall shortages for cereals and rape (Figure 4). These coefficients were at a level exceeding 90%. The regression equations allow for an assessment of

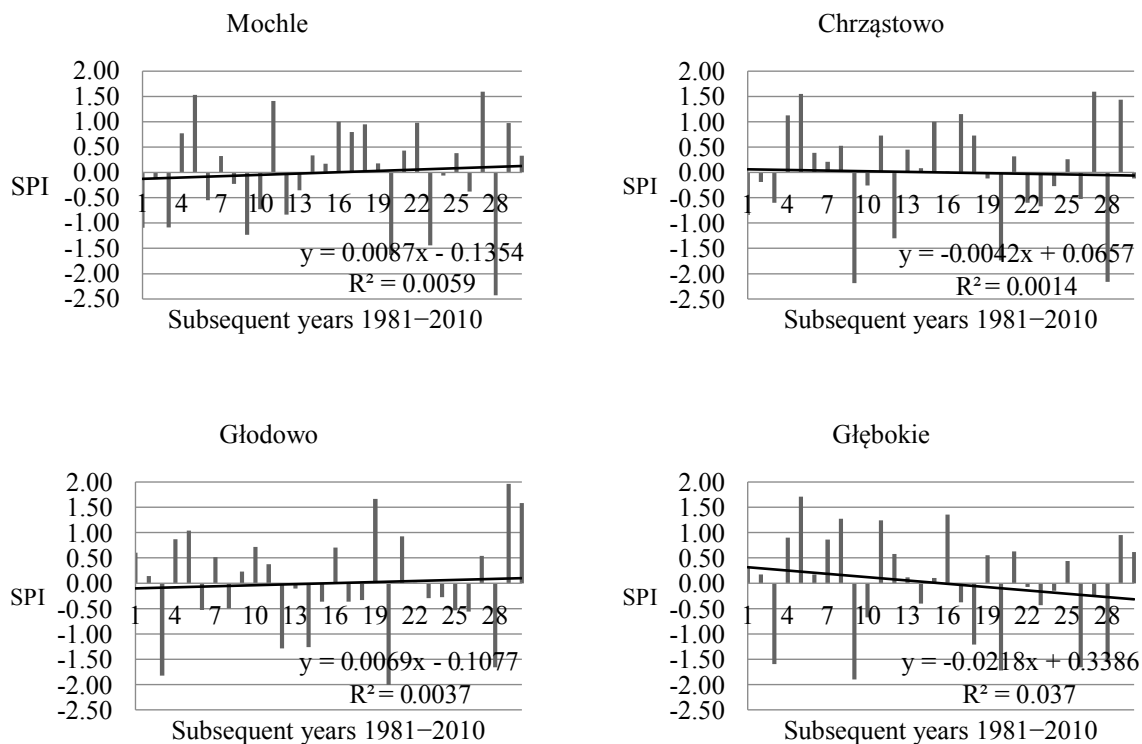Figure 2. Temporal variation of the meteorological drought index (SPI) in the period of high water needs of
cereals and rapeseed (May – June) in the locations of Kujawsko-Pomorskie in the years 1981 – 2010.
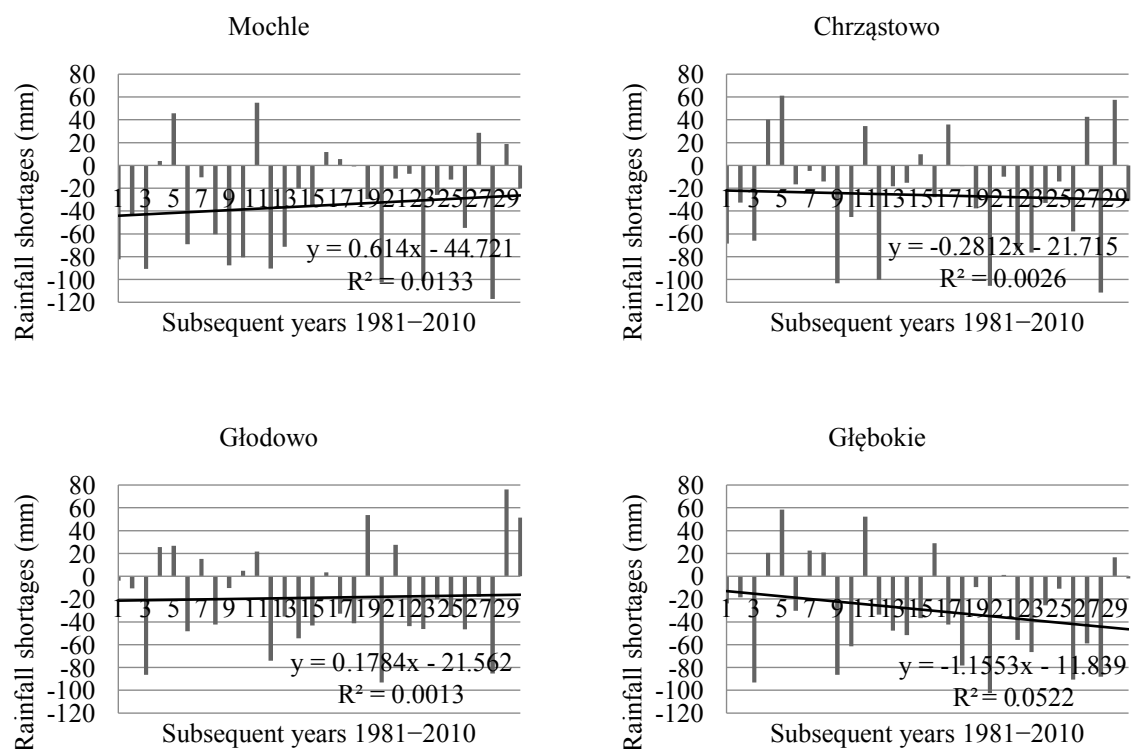

Figure 3. Temporal variation of the agricultural drought index (RS) in the period of high water needs of
cereals and rapeseed (May – June) in the locations of Kujawsko-Pomorskie in the years 1981 – 2010.
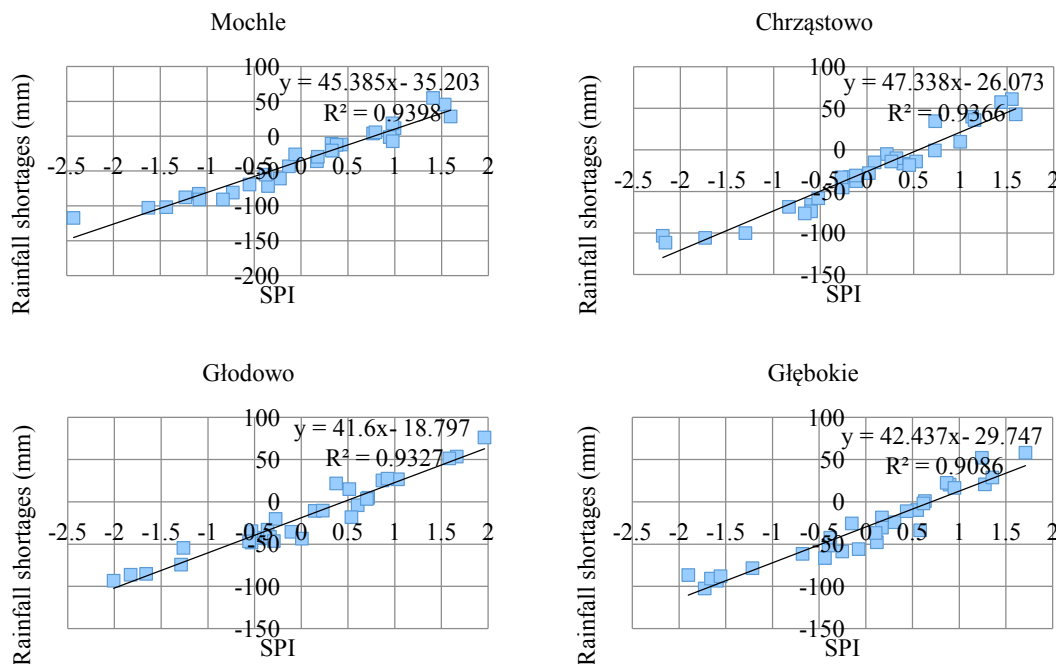
Figure 4. Relationship between the meteorological and agricultural drought indices in the period of high water needs of cereals and rapeseed (May – June) in the locations of Kujawsko-Pomorskie in the years 1981 – 2010.

rainfall shortages during the growing season based on SPI, so only on the basis of rainfall data. These shortages of rainfall determine the irrigation needs of the tested plants in the analyzed region, as well.

Conclusions

1. The average multiannual (1981 – 2010) totals of atmospheric precipitation in May – June, in particular locations allow ranking the region of Kujawsko-Pomorskie into the area of the lowest rainfall in Poland.

2. The frequency of meteorological drought in May and June is 23.3 – 30.0% in the region of Kujawsko-Pomorskie. In the analyzed period, there were no significant changes in the frequency and intensity of these droughts with the passage of years. The hypothesis about the increasing frequency and intensity of droughts in May and June in the region of Kujawsko-Pomorskie (central Poland) was not confirmed.

3. The production of cereals and rapeseed in the region of Kujawsko-Pomorskie is carried out under the conditions of atmospheric rainfall shortages, which on average range from -19 to -35 mm, and extend to maximum of -93 to -117 mm, depending on the locality. The values of shortages did not show any significant changes in the years of the study of 1981 – 2010.

4. The significant interdependence between the indicators of meteorological and agricultural droughts allows for determination of the rainfall shortages in plant production on the basis of the SPI values.

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CHARACTERIZATION OF YELLOW RUST
(*PUCCINIA STRIIFORMIS* WESTEND.): REVIEW

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Abstract

Yellow rust caused by *Puccinia striiformis* is a significant wheat disease in cereal growing areas worldwide. On average, yellow rust can cause 50% big yield damages resulting in economic losses. Yellow rust damages wheat leaves, leaf sheaths, awns, and glumes. *Puccinia striiformis* is divided into four lineages – *P. striiformis sensu stricto*, *P. pseudostriiformis*, *P. striiformoides*, *P. gansensis*. Different races of yellow rust have been determined. After 2000 three new aggressive races – 'Warrior', 'Kranich' and 'Triticale aggressive' have been identified. New races are characterized by shorter latent period, extended spore germination and tolerance to a high temperature in comparison with the races determined before 2000. These characteristics allowed the new races to replace races dominant before 2000. Yellow rust is a biotrophic heteroecious fungus with a complicated life cycle. For successful development, *Puccinia striiformis* requires cereals as primary hosts and *Berberis* spp. as alternate hosts. The history of studies regarding yellow rust is more than two hundred years old but only in 2010 the ecidiospores of yellow rust were found on the alternate host *Berberis* spp. Two types of resistance – seedling (or all-stage) resistance and adult plant resistance (APR) were discovered. Since 2000 multiple severe epidemics of yellow rust have been observed in cereal growing areas with warmer climate. In recent years, the incidence of yellow rust in Latvia has increased. Particular studies about the biology, distribution, and races of *Puccinia striiformis* in Latvia are necessary. This article summarizes the information about the classification, biology and harmfulness of the yellow rust.
Key words: *Puccinia striiformis*, races, diversity, control.

Introduction

Yellow rust *Puccinia striiformis* Westend. (*Pst*) is one of the most harmful wheat pathogens in cereal growing areas present in all continents except Antarctica (Chai *et al*., 2014). Chen (2005) reported that at early infection on susceptible varieties yield losses can reach 100% but on average yield losses can vary 10 – 70% during the epidemics. The amount of damaged yield is measured in millions of tons and causes significant financial losses (Wan *et al*., 2004; Wellings, 2007). Wellings (2011) concluded that *Pst* is the most significant threat to wheat production.

Pst is a biotrophic heteroecious fungus (Chen *et al*., 2014; Hovmøller *et al*., 2016). Cereals as primary hosts and *Berberis* spp. as alternate hosts are necessary for successful development of yellow rust (Jin, Szabo, & Carson, 2010). Yellow rust has been investigated since the 18th century (Stubbs, 1985) but only after 2000 harmful epidemics were observed. Nowadays new aggressive races of *Pst* have been identified.

Yellow rust is widespread in major wheat producing regions like the Middle East, China, US, Australia (Chen, 2005; Yahyaoui *et al*., 2002; Wan *et al*., 2004; Wellings, 2007). Hassebrauk (1965, cited by Hovmøller *et al*., 2011) reported that 320 grass species from 50 genera can be infected with *Pst* with artificial or natural infection. Yellow rust can cause epidemics on barley in Europe and America (Brown *et al*., 2001; Macer & Driessche, 1966). Epidemics on rye are not frequent nowadays (Stubbs, 1985).

Wheat infection at the seedling stage usually results in reduced root growth, plant height, and dry matter production, size and number of flowering spikes, and the size of grains also is less than expected. Infection during anthesis reduces root weight and the amount of yield (Wellings, 2011). Yield losses in wheat from *Pst* infections are usually the result of reduced grain number per spike, low test weight and reduced grain quality (Roelfs, Singh, & Saari, 1992).

Information about the incidence of *Pst* and influence on the yield in Latvia is not clear. Eglitis (1938) reported that yellow rust in Latvia is harmful only on wheat. On barley, until 1938 one observation was registered in Priekuli but on rye yellow rust was not observed. In 1970–80, periodic observations of the *Pst* were made in the breeding fields in Stende (Strazdina, 2017, personal communication). Systematic observations about the incidence of *Pst* in Latvia have not been performed, sporadic observations of the pathogen have been made (Bankina, Jakobija, & Bimsteine, 2011). In 2010 severe infection was observed on winter wheat in Stende. In 2015, extensive infection was observed on winter and spring wheat in Kurzeme near the coast of the Baltic Sea. In 2016 yellow rust was observed in the whole territory of Latvia (Strazdina, 2017, personal communication).

The aim of this article is to summarize the information from literature about *Puccinia striiformis* Westend. with emphasis on classification, biology, and harmfulness of the yellow rust.

Materials and Methods

Monographic method has been used for this study. Scientific literature from different countries

regarding to wheat pathogen causing yellow rust *Puccinia striiformis* Westend, its biology, evolution and distribution has been summarized.

Results and Discussion

Symptoms

Yellow rust damages wheat leaves, leaf sheaths, awns and glumes. Chlorotic flecks on primary host leaves can be observed 6 – 8 days after inoculation (Chen *et al*., 2014). In these flecks, 0.4 – 0.7 mm long and 0.1 mm wide uredinial pustules that can contain thousands of dikaryotic uredospores are located. Uredospores visually remind yellow to orange powder, each spore has an ellipse to obovoid form with the size of 24.5 × 21.6 μm. Sporulation starts from 12 to 14 days after inoculation (Chen *et al*., 2014), depending on temperature, moisture, and host resistance. During the development, yellow rust can be observed as orange, narrow stripes usually between leaf veins. Approaching the host senescence or when the temperature is high, telia are produced. Telia usually are pulvinate to an oblong form, 0.2 – 0.7 mm long, 0.1 mm wide. Teliospores are dark brown, rounded, flattened at the vertex from 24 – 31 until 56 – 65 μm long and from 11 – 14 – until 25 – 29 μm wide (Chen *et al*., 2014).

During severe epidemics, awns and glumes can be infected. On resistant plants, *Pst* appears as small flecks with chlorosis, necrosis and limited spore production or do not show any visual symptoms. On seedlings, *Pst* does not appear as narrow stripes between leaf veins but covers all leaf surface as small spots (Chen *et al*., 2014).

On the upper side of the alternate host *Berberis* spp. leaves yellow to orange flask-shaped pycnia with oblong-shaped pycniospores can be observed. On the lower side of the alternate host *Berberis* spp. leaves sunflower-shaped aecia with spherical-shaped aeciospores can be found.

Taxonomy

The common names of *Puccinia striiformis* Westend. are yellow rust, stripe rust, and glume rust. In literature, the first time yellow rust was mentioned in 1777 by Gadd but taxonomically named as *Uredo glumarum* in 1827 by Johann Carl Schmidt (Eriksson & Henning, 1896 cited by Stubbs, 1985).

Several synonyms of *Pst* have been used in the past like *Uredo glumarum* J.C. Schmidt, *Trichobasis glumarum* Lév, *Puccinia neglecta* Magnus, *Puccinia tritici* Oerst, *Puccinia glumarum* (J.C. Schmidt) Erikss & Henning, *Puccinia lineatula* Bubák, *Dicaeoma glumarum* (J.C. Schmidt) Arthur & Fromme, *Puccinia rubigo-vera* (Erikss) Carleton, *Pleomeris glumarum*

(J.C.Schmidt) Syd, *Puccinia striformoides* M. Abbasi, Hedjar & M. Scholler[1].

Puccinia striiformis is classified in kingdom *Fungi*, phylum *Basidiomycota*, class *Urediniomycetes*, order *Uredinales*, family *Pucciniaceae*, genus *Puccinia*. *Puccinia* is notable genera in *Pucciniaceae* that includes more than 4,000 different species (Cummins & Hiratsuka, 2003 cited by Sørensen, 2012).

Pst infects different species of wheat – common wheat *Triticum aestivum* L., durum wheat *Triticum turgidum* var. *durum* L., cultivated emmer wheat *Triticum dicoccum* Schrank, wild emmer wheat *Triticum dicoccoides* Korn, triticale x *Triticosecale*, rye *Secale cereale* L., barley *Hordeum vulgare* L. and pasture grass species like *Elymus canadensis* L., *Leymus secalinus* Hochst, *Agropyron* spp. Garetn, *Hordeum* spp. L., *Phalaris* spp. L. and *Bromus unioloides* Kunth (Chen *et al*., 2014).

Pst isolates can differ by morphological characters and peculiarities of an epidemic. Eriksson (1894 cited by Hovmøller *et al*., 2011) based on host specialization divided *Puccinia striiformis* in five special forms (*formae speciales*): *P. striiformis* f. sp. *tritici* on wheat, *P. striiformis* f. sp. *hordei* on barley, *P. striiformis* f. sp. *secalis* on rye, *P. striiformis* f. sp. *elymi* on *Elymus* spp., and *P. striiformis* f. sp. *agropyron* on *Agropyron* spp. Extra *formae speciales* were divided: *P. striiformis* f. sp. *dactylidis* (*Psd*) on orchard grass (*Dactylis glomerata* L.) (Manners, 1960; Tollenaar, 1967), *P. striiformis* f. sp. *poae* (*Psp*) on Kentucky bluegrass (*Poa pratensis* L.) (Tollenaar, 1967), *P. striiformis* f. sp. *leymi* on *Leymus secalinus* (Georgi) Tzvel. (Niu *et al*., 1991 cited by Chen *et al*., 2014) and *P. striiformis* f. sp. *pseudo-hordei* (*Psp-h*) on *Hordeum* spp. in Australia (Wellings, 2007).

Liu & Hambleton (2010) based on DNA sequence polymorphisms and different morphological qualities divided *Puccinia striiformis* into four lineages and declared them as diverse species. The first lineage called *P. striiformis sensu stricto* infects *Triticeae*, host range – *Aegilops, Elymus, Hordeum, Triticum* (Chen *et al*., 2014). The second lineage *P. pseudostriiformis* previously named as *P. striiformis* f. sp. *poae* infects *Poa* spp., the third lineage *P. striiformoides* previously known as *P. striiformis* var. *dactylidis*) infects *Dactylis* spp. The fourth lineage – *Puccinia gansensis* was found in China and infects *Achnatherum inebrians* (Liu & Hambleton, 2010; Chen *et al*., 2014).

It is considered that the center of origin of yellow rust is Transcaucasia (Hassebrauk, 1965, cited by Hovmøller *et al*., 2011) where yellow rust was present on grasses and later spread to other territories. The west part of China and Central Asia (Ali *et al*., 2010) also is considered to be the center of origin. Isolates

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[1] Species Fungorum. *From: CABI databases*. [Online] [viewed 8 March 2018]. Available: http://www.speciesfungorum.org/GSD/ GSDspecies.asp?RecordID=227064

taken in these territories produce more telia and have a higher genetic diversity (Chen *et al*., 2014) with frequent recombination (Vallavielle-Pope *et al*., 2012 cited by Chen *et al*., 2014) than isolates from other territories. Yellow rust has the clonal population structure in Europe, Australia and America (Hovmøller *et al*., 2016), resulting from asexual reproduction. The evolution of sex as an ancestral trait was used in the searches of origin (Hovmøller *et al*., 2011). Despite many researches and recent discoveries, the center of origin of *Pst* and diversity of population have not been clarified yet. Research in this field continues and information about the race composition and DNA diversity in separate geographical regions will improve scientific knowledge about the pathogen diversity.

Races

The most significant traits in relation to gene and genotype diversity are virulence and race. In the process of mutation (genetic variation) new alleles and genotypes are derived. Flor (1956 cited by Sørensen, 2012) defined the gene-for-gene hypothesis that was the basics for race identification. Gene-for-gene hypothesis is based on host resistance genes related to pathogen avirulence genes, if they make pairs, the host is resistant and vice versa.

Between 1975 and 2000 mutations that resulted in the loss of avirulence were determined 16 times (Hovmøller & Justesen, 2007).

The concept of races – a pattern of pathogen responses to inoculation onto differential lines, was proposed by Allison & Isenbeck (1930 cited by Hovmøller *et al*., 2011).

The first race of yellow rust was identified in 1979 (Wellings & McIntosh, 1990). Detailed research about races in Europe and the USA started in the late 1960s (Line & Qayoum, 1992, cited by Hovmøller *et al*., 2011) when several epidemics of yellow rust were recorded on wheat in California (Tollenaar & Houston, 1967). Since the 1960s up to 300 samples of yellow rust are collected and race-analyzed every year (Chen *et al*., 2009). Similar researches were carried out in Australia (Wellings, 2007), China (Wan *et al*., 2004; Chen *et al*., 2009), India (Prashar *et al*., 2007) and South Africa (Boshoff, 2002). Since 1990s, studies of *Pst* population structure and diversity have been successfully applied because of the development of biotechnology and molecular marker techniques (Hovmøller *et al*., 2011).

Since 2000 epidemics of yellow rust have been observed in warmer cereal growing areas where *Pst* had not been found previously. In 2000 yellow rust caused epidemics in the South, Central and Eastern United States. In these territories, yellow rust has been rare because of high temperatures during the growing season (Chen *et al*., 2000). These epidemics were caused by pathogen isolates that were different from isolates identified before 2000 in terms of AFLP and virulence phenotype (Markell & Milus, 2008).

In 2000 in Central Europe, an aggressive strain of yellow rust PstS2 was determined (Hovmøller *et al*., 2011). PstS2 is related to PstS1, these strains were found in many areas within five continents. In the Mediterranean / Middle East region on several wheat cultivars epidemics were observed but most of the cultivars stayed resistant (Abbasi *et al*., 2004). Between 2000 and 2002 fast and broad spread of yellow rust was observed (Hovmøller *et al*., 2008). To compare these strains with North American races and typical northwestern European races (races typical before 2010) different virulence phenotypes were found but the evolutionary origin was common (Hovmøller *et al*., 2011). After 2011 new races – 'Warrior', 'Kranich' and 'Triticale aggressive' were identified. In Europe, yellow rust race 'Triticale aggressive' was detected in 2006 on the island of Bornholm in the Baltic Sea. 'Warrior' replaced races found before 2011, 'Kranich', 'Triticale aggressive' were found in certain regions and/or crop types. All three races had spread in large areas within one or a few years. Races of non-European origin have been found in different areas 1-2 years after the first detection (Hovmøller *et al*., 2016).

Only a few of the European races recognized between 2000 and 2010 were found from 2011 to 2014. New aggressive races have different molecular characteristics, higher genetic diversity in comparison with the existing European population. New races produce a lot of telia which indicates that aggressive races have evolved from sexual populations (Hovmøller *et al*., 2016). The composition of races changes quickly; research about the incidence of specific races in different geographic regions is necessary to understand the possibilities of development and distribution of new races.

Resistance

Host resistance plays an important role in successful disease control. Development of new resistant cereal varieties is the main task for plant breeders and scientists (Singh *et al*., 2004). The largest *Pst* research centres are located in Denmark, France, UK, USA, China and Mexico. In Eurowheat database http://www.eurowheat.org data about *P. striiformis* virulence dynamics in Europe and disease control measures are published (Jørgensen *et al*., 2010). Resistance to *Pst* as a genetic trait has been known since 1905 when Biffen crossed yellow rust immune and susceptible wheat species (Hovmøller *et al*., 2011). During 1980s in European wheat breeding programs *Yr17*-resistance was established.

Yr17 resistant cultivars were introduced in the early 1990s and stayed resistant to yellow rust until 1994. Then a new *Yr17* – virulent race with different AFLP fingerprint appeared in the UK (Justesen, Ridout, & Hovmøller, 2002).

Yellow rust can infect susceptible wheat varieties at any plant growth stage while the plant parts are green. There are two main types of resistance – seedling (or all-stage) resistance and adult plant resistance (APR) (Chen *et al.*, 2014).

Seedling resistance is race specific (Johnson, 1992). It is qualitatively inherited and expressed during all plant growth stages. Seedling resistance is controlled by single genes with major effects or simple combinations of single genes. Changes in single-genes increase the virulence in *Pst* populations. Single genes resistant to yellow rust are called *Yr*-genes. 41 from 55 catalogued *Yr* genes refer to seedling resistance and 14 to APR genes (Chen *et al.*, 2014).

Adult plant resistance is commanded by one or several quantitative trait loci. In prevalence with some exclusions, APR is described as quantitatively inherited, non-race specific and provides durable resistance (Chen, 2005, 2013). During the seedling stage, plants with APR are susceptible to yellow rust, resistance comes effective at post-seedling development (Boyd, 2006). APR shows better yield protection if it starts in early growth stages in comparison with resistance starting from flag leaf emergence (Chen *et al.*, 2014). APR is influenced by temperature and crop nutritional status; high nitrogen level can provoke more serious disease expression (Chen, 2005, 2013). High-temperature adult plant resistance (HTAP) becomes more effective with increasing temperature (Chen, 2005).

Plant resistance and its reaction – virulence/ avirulence to pathogen isolates are traditionally evaluated on seedlings. For assessment of virulence or avirulence by phenotyping method differential sets are used. They consist of different wheat varieties with known resistance genes. Inoculation of wheat varieties with spores of *Pst* is performed under controlled conditions. Two different scales – from full resistance (specific resistance genes are present) to full susceptibility (specific resistance genes are not present) are used to assess the level of leaf damages. The 0 – 9 scale (McNeal, 1971, cited by Chen, 2005) is widely used in Europe, North America, Syria, and Lebanon (Chen *et al.*, 2014). The 0 – 4 scale (Gassner & Straib, 1932a, b cited by Chen *et al.*, 2014) is used in Australia (Wellings & McIntosh, 1990), China (Chen *et al.*, 2009), India (Prashar *et al.*, 2007), South Africa (Boshoff *et al.*, 2002) and Pakistan (Ali *et al.*, 2010). Scales are divided by ranging from no visible symptoms, chlorosis and necrosis to density of spore-bearing pustules (Chen, 2005). If the interaction is compatible, it is scored as a high infection type, if interaction is incompatible – a low infection type on differential lines (Hovmøller *et al.*, 2017). The present differential set for *Pst* race identification is composed of 20 wheat lines (Chen *et al.*, 2009). In different regions various differential lines are used (Bayles *et al.*, 2000; Wan *et al.*, 2007; Wellings, 2007), depending on commercial wheat cultivars but race nomenclature system has stayed similar since the 1960s.

Life cycle

Until 2010 it was assumed that *Pst* is an autoecious micro-cyclic pathogen. In the last century efforts to identify the alternate host of *Pst* by infecting different plant species with germinating teliospores have failed (Jin et al., 2010) and detailed information about the sexual host of yellow rust stayed a mystery (Wellings, 2011). *Berberis* spp. and *Mahonia* spp. were suspected to be the alternate hosts of *Puccinia striiformis* because of related rusts found on these plants (Mains, 1933, cited by Stubbs, 1985). The sexual stage of yellow rust on *Berberis* spp. and *Mahonia* spp. was described by Jin, Szabo, & Carson (2010). He observed pycnia on *Berberis* spp. leaves when aecia were developed on the bottom side of the leaf. Jin, Szabo, & Carson (2010) proved that *Berberis* spp. is the alternate host of yellow rust by successful infection of wheat with aeciospores from *B. chinensis* that resulted in uredinia. Molecular analysis – real-time polymerase chain reaction and DNA sequence – affirmed the identity of *P. striiformis* (Jin *et al.*, 2010). It has been found that alternate hosts are barberry – *Berberis chinensis*, *B. koreana*, *B. holstii*, *B. vulgaris*, *B. shensiana*, *B. potaninii*, *B. dolichobotrys*, etc. Wang & Chen, 2013 proved that Oregon grape *Mahonia aquifolium* can also serve as an alternate host of *Puccinia striiformis* (Chen *et al.*, 2014). Alternate hosts help pathogen to survive between cropping seasons. As the global distribution of *Berberis* spp. is not clear, it is difficult to predict the influence of sexual reproduction on the dynamics in *P. striiformis* populations at global scale (Hovmøller *et al.*, 2011). Although the sexual stage of *Pst* has been proved (Jin *et al.*, 2010), the influence of sexual reproduction on *Pst* dynamics (Hovmøller *et al.*, 2011) and origin of epidemics is not known.

Previously it was assumed that yellow rust is a low-temperature pathogen and is distributed in temperate climate zones with cool and moist weather conditions (Chen *et al.*, 2014) or in warm territories with cold nights (Stubbs, 1985). To compare with other rusts, *Pst* is more sensitive to meteorological conditions such as moisture and air temperature that play a significant role in germination and infection processes (Chen *et al.*, 2014).

A suitable temperature for germination of uredospores is from 8 °C to 12 °C (Vallavieille-Pope

et al., 1995) and comfortable temperature for infection is 8 °C (Dennis, 1987). Chen *et al.*, 2014 observed that the minimum temperature for germination of uredospores is 0 °C and maximum 20 – 26 °C.

For successful inoculation moisture on leaf surface is necessary. Relative humidity should reach more than 50% for sporulation to occur (Zadoks, 1961; Rapilly & Fournet, 1968, both cited by Chen *et al.*, 2014). Cereal density influences moisture level between the plants. The development of yellow rust is slower if the length of the day is shorter or the light intensity is lower (Wellings, McIntosh, & Hussain, 1988). Stubbs (1985) reported that light intensity during the seedling tests should be over 10,000 lux. Yellow rust is sensitive to UV light and air pollution that negatively influences the germination of uredospores (Sharp, 1967, cited by Chen *et al.*, 2014).

Pst can migrate long distances and spread spores with the help of wind (Chen *et al.*, 2014; Hovmøller *et al.*, 2016; Hovmøller *et al.*, 2017) and human-assisted transport (Brown & Hovmøller, 2002). If the winter is severe, spores of yellow rust can die and wind is the only way how to spread (Hovmøller, Justesen, & Brown, 2002). Uredospores can spread thousands of kilometers from the primary infection areas (Chen *et al.*, 2014). Stubbs (1985) reported that uredospores have spread more than 1,200 km from northern France to Algeria by wind blasts. Justesen, Ridout, & Hovmøller (2002) by comparing AFLP lineages found that migration of *Pst* occurred between the UK, Germany, France and Denmark, and some *Pst* populations in Denmark arrived from France and/or Germany by the wind. In the US Pacific Northwest yellow rust infected spring wheat from winter wheat and opposite (Chen, 2005). *Pst* can stay on wild grass species.

Milus, Seyran, & McNew, 2006 reported that *Pst* has adapted to high temperatures. New yellow rust races are characterized by shorter latent period and 2 – 3 times bigger spore production per day, tolerance to high air temperature, extended aggressiveness in high and low temperatures (Milus, Kristensen, & Hovmøller, 2009) in comparison with the races identified in Europe and North America before 2000 (Milus *et al.*, 2009). Races with the ability to cause infection faster than before have been found in North America in 2000 (Milus, Seyran, & McNew, 2006). Only spores of new races can germinate at high temperature (Volin & Sharp, 1973). At the temperature of 10 °C, during the night and 18°C during the day

new, aggressive races showed 16% shorter latent period, 71% more spores per mm^2 of a sporulating lesion and the pathogen grew 18% faster. At 12 °C – 28 °C, isolates of new races showed by 26% shorter latent period, produced 159% more spores during the day, pathogen grew 18% faster (Markell & Milus, 2008; Milus *et al.*, 2009). Hovmøller, Walter, & Justesen, 2010 defined this aggressive strain as PstS1 (Hovmøller *et al.*, 2008; Markell & Milus, 2008).

Pst has a complicated life cycle with five various stages (Hovmøller *et al.*, 2011) and it requires an alternate host to complete a full growth cycle (Jin, Szabo, & Carson, 2010). Uredospores, teliospores and basidiospores infect primary host (Hovmøller *et al.*, 2011) on alternate host pycniospores, and aeciospores of *Pst* are formed.

Uredospores are dikaryotic and can be formed asexually (Buller, 1950, cited by Rodriguez-Algaba *et al.*, 2017). Each uredinium produces spores over the period of several days and causes epidemics on the primary host. Uredospores can be produced several times during the season. In later host growth stages telia are formed that produce two-celled teliospores. Teliospores have two thick-walled cells each containing diploid in karyogamy formed nucleus. In similar conditions, the capability to develop telia can be different between isolates (Chen *et al.*, 2012).

Teliospores can germinate immediately without a dormancy period. Germinating teliospores through karyogamy meiosis produces haploid basidiospores (Leonard & Szabo, 2005) that infect alternate host *Barberry* spp. After a pycnia with pycniospores is formed on the upper side of the leaf. After fertilization a mycelium is formed, it grows through the leaf, and aecia with dikaryotic aeciospores is formed on the lower side of the leaf (Chen *et al.*, 2012). When climatic conditions are favourable – a high level of humidity – aecia crack, unclose and exempt aeciospores that can infect gramineous hosts if they are near. The full life cycle can continue for two growing seasons of the primary host (Hovmøller *et al.*, 2011).

Conclusions

Life cycle of *Puccinia striiformis* Westend. has changed and it has been revealed only over the last two decades.

New aggressive races of yellow rust have adapted to high temperatures and can spread more effectively in cereal growing areas.

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FORECASTING PRODUCTION EFFECTS OF IRRIGATED FABA BEAN (*VICIA FABA* VAR. *MINOR*) DEPENDING ON DROUGHT LEVELS

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Abstract
The aim of the article was to develop formulas, which can be used to model forecasts of production and economic effects of irrigated faba bean (*Vicia faba* var. *minor*), depending on drought severity level in a growing season. For the analysis we used data of ten-year (2005 – 2014) production effects of irrigated faba bean and indices calculated on the basis of meteorological data from the measuring point set in the vicinity of the experimental site in region of Bydgoszcz city, central Poland. Based on them, the most relevant relationships between irrigation productivity and chosen drought indices, calculated for a period of high water needs of the plant, were searched. Presented results have demonstrated that the non-irrigated faba bean yields depended significantly on drought severity level and showed very high variability in time. Irrigation contributed to a significant 49% increase in yields and their stability in the years. Due to this treatment, the coefficient of variation of the yield decreased from 55.1 to 19.6%. The production effects of irrigation depended significantly on moisture conditions over the period of high water needs of faba bean. In wet seasons, the increases in yields due to irrigation were insignificant and about three-fold lower, while in the dry periods – more than a half higher (57%) than the average increases. The results presented in the work are of great importance because they can be used to model forecasts of production, as well as to plan the development of irrigation systems in the given area.
Key words: drip irrigation, faba bean, yield, drought index, atmospheric precipitation, evapotranspiration.

Introduction

Faba bean is a leguminous plant whose seeds are widely used as a component for blends with other livestock feeds. An important feature of faba bean is a high protein content of 25 – 30%, the ability to bind atmospheric nitrogen in the process of symbiosis with Rhizobia. This plant has also a structure-creating effect by enriching the soil with organic matter and nutrients, and improving its physical and chemical properties (Podleśny, 2005). All this causes faba bean to be a desirable forecrop for cereals, especially for winter wheat *(Triticum aestivum)*, which is dominant in the structure of sowings. Despite these advantages, the area of cultivation of legumes in Poland, including faba bean, in the first decade of the 21st century was only about 100 thousand hectares (Podleśny, 2005) and only after receiving special subsidies under the EU Common Agricultural Policy it exceeded 400 thousand hectares in 2015 (Adamska *et al.*, 2016). The ecological importance of this plant, confirmed by many EU research programs (Święcicki, Chudy, & Żuk-Gołaszewska, 2007), indicates that this trend will be perpetuated.

The main disadvantage of all legumes, including faba bean representing the coastal climate plants, is lower yielding in dry growing seasons, when atmospheric precipitation totals are considerably reduced. In the transitional climate in central part of Poland, atmospheric droughts that turn into soil droughts, and in some cases even into hydrological ones, are frequent and irregular (Łabędzki, 2007). Their severity and range were observed in the last 30 years in the growing seasons of 1989, 1992, 2000, 2003, 2008 and 2015 (Żarski *et al.*, 2017). The occurrence of drought during increased water needs of faba bean, coinciding with the reproductive phase, contributes to the deterioration of yield, not only in terms of quantity, but also quality (Szukała *et al.*, 2007; Dudek, Żarski, & Kuśmierek-Tomaszewska, 2011; 2013; Di Paolo, Garofalo, & Rinaldi, 2015; Rokosz & Podsiadło, 2015).

An effective treatment, applied to prevent the negative effects of drought in plant production, is irrigation. The use of irrigation systems in Poland, despite the rapid development of the country, is still a future solution. However, this creates an alternative for theprogress in agricultural production in the future. Factors that accelerate the development of irrigation in agriculture, apart from providing higher and more stable, good quality yields, include the noticeable progress in modernity of farms and a raise of their competitiveness, as well as the forecasted climate change (Łabędzki, 2009; Rzekanowski, Żarski, & Rolbiecki, 2011).

The aim of the article was to develop formulas for a model determining production effects of irrigated faba bean, depending on a drought severity, based on meteorological indices representing moisture conditions.

Materials and Methods

For the analysis we used meteorological data from the agrometeorological monitoring, gained from the measuring point owned by the Department of Land Reclamation and Agrometeorology (UTP University of Science and Technology in Bydgoszcz, Poland) and the yields of irrigated and non-irrigated faba bean. The

procedures used in the meteorological measurements were compliant with the World Meteorological Organization (Guide to Meteorological Instruments and Methods of Observation, 2014) measuring standards. The experimental site is located in Mochełek village, about 20 km away from Bydgoszcz city center, on the south-eastern edge of the Krajeńska Upland (53°13'N, 17°51'E, 98.5 m. a. s. l.); in the zone of the highest average precipitation deficit and high needs for supplementary irrigation in Poland in terms of the climate criterion (Łabędzki, 2007; Rzekanowski, Żarski, & Rolbiecki, 2011; Żarski *et al.*, 2017). The experiment was set up in Luvisol (LV) with a fine sandy loam texture (World reference base for soil resources 2014). In terms of compaction, it is a sandy soil on compact subsoil.

Data obtained from the long-term field experiment of sprinkler irrigated faba bean grown for seeds, carried out in 2005 – 2014 were used in the study. Considering the soil conditions of the experiment, irrigation was, typically for Poland's climate conditions, used in emergency, supplementing the seasonal precipitation deficit over the period of high water needs of the crop tested. The plants were optimally irrigated, ensuring the reserve of readily available water throughout the period of high water needs, which span the phases from the beginning of flowering BBCH 60 to the technical maturity of seeds 89 BBCH, in the soil layer with controlled moisture level, which means that water needs of plants during the growing season were fully covered (the soil moisture was maintained in the range of pF-value of 2.0 – 2.5). Faba bean was irrigated with a portable system with low-pressure Nelson type sprinklers, withthe unit capacity of 200 dm^3 h^{-1}. The irrigation dates were determined based on information from continuous soil root layer moisture monitoring, by balancing the reserve of readily available water based on the weather parameters and direct soil moisture measurements using Fieldscout TDR 300 Soil Moisture Meter probe. The number of disposable irrigation doses and the total seasonal dose depended on the weather conditions, mainly on the amount and distribution of atmospheric precipitation. Detailed information on the factors, the pattern of experiment, and faba bean agrotechnics can be found in the works of Dudek *et al.* (2011, 2013).

In order to determine the most significant relationships between the production effects of irrigated faba bean in the subsequent years and selected indicators characterizing the moisture content during the period of high water needs of faba bean from 1 June to 31 July, a correlation and regression analysis was applied. The critical value of the correlation coefficient for a number of paired observations n=10 at the significance level p=0.05 is 0.6319. The following indicators were considered

for the analysis: absolute precipitation (P), relative precipitation index (RPI) (Bąk & Łabędzki, 2002), standardized precipitation index (SPI), described by Guttman (1999), as well as the ratio of precipitation to potential evapotranspiration (ET), calculated on the basis of the Grabarczyk's formula:

$$ET = 0.32\left(d + \frac{1}{3}t\right) \qquad (1)$$

where d – mean vapor pressure deficit in hPa, t – mean air temperature in °C. According to the studies by Grabarczyk & Żarski (1992), the value of potential evapotranspiration calculated for grass according to the Grabarczyk's formula correlated stronger with real evapotranspiration compared to the ET values calculated on the basis of the Penman's equation. The season of 2010 was excluded from the regression analysis due to the extremely unevenly distributed rainfall. In June and July of 2010, the total rainfall was 125.5 mm, but as much as 100.2 mm fell only in the last week of July. As a result, the yield of non-sprinkled faba bean was much lower, and the effects of sprinkler irrigation were significantly higher than those determined by regression equations.

Results and Discussion

In respective years, taken for the analysis, weather conditions in the period of high water needs of faba bean (growth phases BBCH 61-89), varied a lot. The average rainfall total was 140.7 mm, changing from 46.0 mm in 2006 to as much as 249.4 mm in 2012. The RPI ranged from 38 to 203%, SPI from -1.66 to 1.87, and the level of coverage of evapotranspiration by precipitation – from 0.12 to 1.26. Three dry, three normal and four wet seasons were recorded. Therefore, in such rainfall conditions, irrigation was applied in emergency cases, which is typical for the climate of central Poland (Rzekanowski, Żarski, & Rolbiecki, 2011; Żarski *et al.*, 2017) (Table 1).

In central Poland, the irrigation's role is to supplement precipitation deficit, unlike in the dry and semi-dry climate zones, where it is a basic and indispensable yield-forming practice. This treatment is applied mainly in the case of long periods without rain. In the temperate climate of Poland, there occur periods and even whole growing seasons when it is used very rarely or it is not applied at all. In our research, such a situation took place in 2007 (faba bean was irrigated only once) while in 2009, due to evenly distributed rainfall in June and July, application of irrigation was not necessary. National research aiming at the improving irrigation in central Poland cover primarily the aspects of its advisability in various crop cultivations by determining the production and economic efficiency and changes in the quality of yield (Rolbiecki *et al.*, 2000; Dudek *et al.*, 2011;

Table 1

**Moisture content indicators and the total irrigation rates over the period of high water needs
in faba bean from June to July**

Year	Drought level acc. to SPI	P mm	RPI %	SPI	ET mm	P/ET	D mm
2005	moderately dry	64.1	52	-1.11	290	0.22	140
2006	very dry	46.0	38	-1.66	372	0.12	110
2007	moderately wet	210.2	171	1.42	224	0.94	25
2008	mild dry	74.2	61	-0.85	277	0.27	200
2009	wet	175.4	143	0.97	186	0.94	0
2010	normal	125.5	102	0.20	268	0.47	180
2011	very wet	233.3	190	1.69	221	1.06	65
2012	very wet	249.4	203	1.87	198	1.26	65
2013	normal	128.3	105	0.24	223	0.58	120
2014	normal	100.3	82	-0.27	211	0.48	140
Average	normal	140.7	115	0.45	247	0.57	104

P – absolute precipitation, RPI – relative precipitation index, SPI – standardized precipitation index, P/ET –precipitation to potential evapotranspiration ratio, D – total irrigation rate.

2013; Żarski *et al.*, 2013; Rolbiecki *et al.*, 2015; Wszelaczyńska *et al.*, 2015), as well as optimizing irrigation doses in relation to the water needs of plants (Kuśmierek-Tomaszewska, Żarski, & Dudek, 2012). In climatic zones where irrigation plays the main role as a factor shaping the yield, the prospects and effects of partial coverage of plant's demand for water are examined, due to the need to save water. In reference to the species *Vicia faba* L., such research was conducted inter alia by Bryla, Banuelos, & Mitchell (2003), Di Paolo, Garofalo, & Rinaldi (2015), Ouji *et al*. (2017) and S. Sarkar, A. Sarkar, & Zaman (2017).

The results indicate that the yield of non-irrigated faba bean was, on average, in the research years 3.21 t ha^{-1} (Table 2). In respective years, the yields showed a very high variation – from 0.58 to 5.55 t ha^{-1}. The coefficient of variation (CV) for them accounted for 55.1%. The regression analysis (Figure 1) demonstrated that yielding depended significantly on moisture content over the period of high water needs in faba bean growth stages from 60 to 89 according to the BBCH spanning June – July. Of all the indicators analyzed, the strongest correlation with the seed yield in non-irrigated faba bean referred to the P/ET

Table 2

Seed yields and sprinkler irrigation effectiveness in faba bean depending on drought level

Year	SPI	Drought level acc. to SPI	Seed yield at 15% moisture content (t ha^{-1})		Seed yield increase under irrigation		
			O	W	t ha^{-1}	%	kg·mm^{-1}
2005	-1.11	moderately dry	2.05	4.23	2.18	106	15.6
2006	-1.66	very dry	1.44	3.52	2.08	144	18.9
2007	1.42	moderately wet	4.14	5.01	0.87	21	34.8
2008	-0.85	mild dry	0.58	3.70	3.12	538	15.6
2009	0.97	wet	5.26	5.38	0.12*	2	0.0
2010	0.20	normal	1.23	4.89	3.66	298	20.3
2011	1.69	very wet	3.44	3.84	0.40	12	6.2
2012	1.87	very wet	5.55	6.27	0.72	13	11.1
2013	0.24	normal	4.58	5.88	1.30	28	10.8
2014	-0.27	normal	3.83	5.10	1.27	33	9.1
Average	0.45	normal	3.21	4.78	1.57	49	15.0

O – non-irrigated plants, W – irrigated plants; *– the difference insignificant at the level of p=0.05.
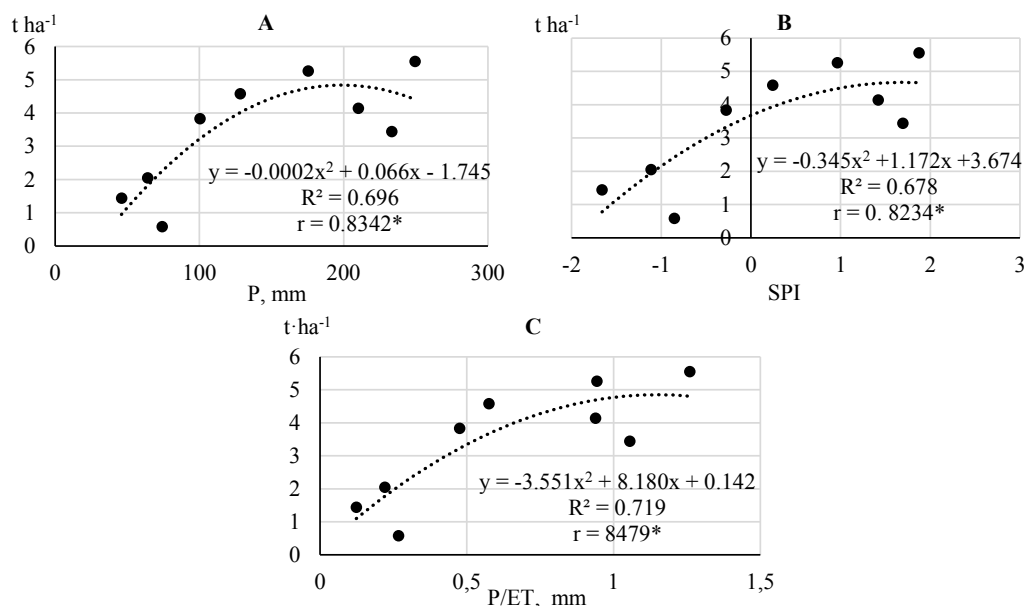
Figure 1. Relationship between the seed yield of faba bean grown without irrigation and moisture
conditions over the period of high water needs: A – precipitation, B – standardized precipitation index SPI,
C – precipitation to evapotranspiration ratio.

ratio (Figure 1); however the other indicators, i.e. absolute precipitation and SPI determined the yield to a comparable statistical significance. The polynomial regression equations (Figure 1) show that the optimal precipitation for faba bean in the period from June to July was 190 – 210 mm, and the P/ET ratio – 1.10–1.20.

Seed yields of irrigated plants were on average 4.78 t ha^{-1}, ranging in respective years from 3.52 to 6.27 t ha^{-1} (Table 2). Irrigation enhanced the yield stability since the coefficient of variation of the seed yield in irrigated faba bean accounted for 19.6%.

Irrigation ensured the adequate plant growth and development, as well as intensified physiological
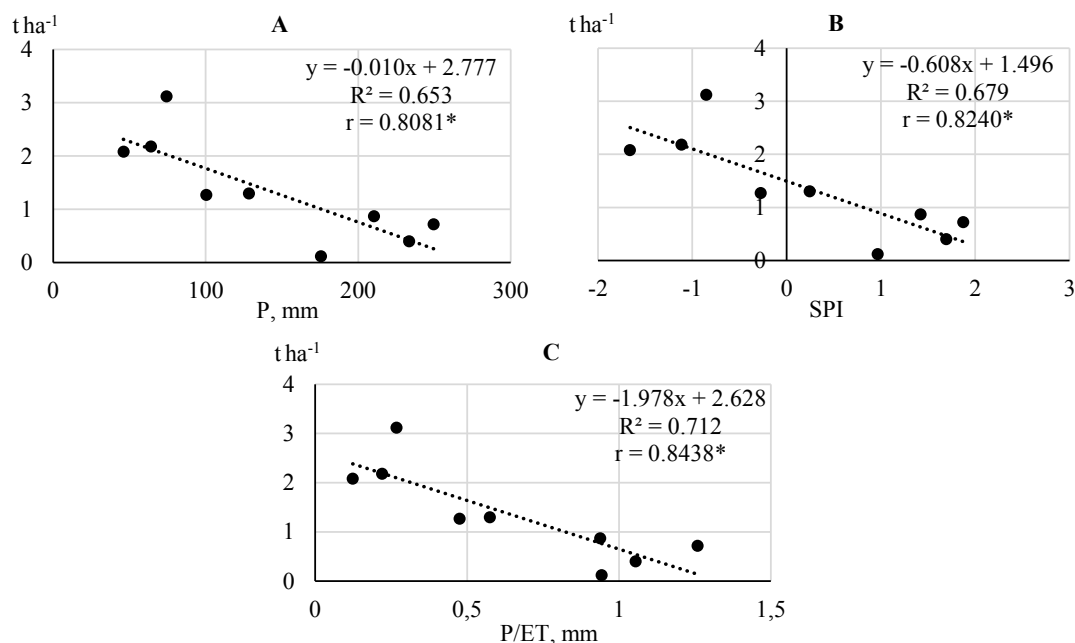

Figure 2. Linear relationship between faba bean seed yield increases due to irrigation and moisture
conditions over the period of high water needs: A – precipitation, B – standardized precipitation index SPI,
C – precipitation to evapotranspiration ratio.

processes. As the result, the average multiannual production effect of irrigated faba bean was 1.57 t·ha⁻¹, which accounted for a 49% increase in seed yield. One mm of water used for irrigation caused an average increase in seed yield at the level of 15.0 kg·mm⁻¹·ha⁻¹. In particular growing seasons, the irrigation production effects depended significantly and linearly on indices representing moisture conditions during the periods of high water needs of faba bean (Figure 2). The best indicator of those effects was absolute precipitation (R^2=0.712). The regression equation shows that increases in yields due to sprinkler irrigation are insignificant only when precipitation in June through July exceeds 250 mm and the P/ET ratio exceeds the value of 1.20.

The average production effects of faba bean irrigation presented in this work point to a great potential of increasing the production of faba bean in central Poland, provided that the water factor is optimized. Therefore, it can be concluded on the basis of the obtained results that the application of irrigation in the production of faba bean is a justified treatment. However, in agricultural practice, making that treatment common will depend to a great extent on the economic conditions, which have an impact on seed prices (Adamska *et al.*, 2016), as well as on infrastructural conditions – mainly the availability of water sources for irrigation purpose (Rzekanowski, Żarski, & Rolbiecki, 2011; Żarski *et al.*, 2013).

Conclusions

Presented results, based on the data from multiannual field experiment with sprinkler irrigation in faba bean grown in central Poland have demonstrated that the non-irrigated faba bean yields depended significantly on indicators characterizing moisture conditions. The results demonstrated a very high temporal variation. Irrigation contributed to a significant 49% increase in yields and their stability over the years. Due to that treatment, the CV of the yield decreased from 55.1 to 19.6%. The production effects of irrigation depended significantly on moisture conditions over the period of high water needs of faba bean, spanning the growth stages from flowering to full reap (BBCH 60-89) that occur in the period June – July. In wet seasons, the increases in seed yields due to irrigation were insignificant and about three-fold lower, while in the dry periods – more than a half higher (57%) than the average increases. The results presented in the work are of great importance because the formulas can be used to model forecasts of production and its economic effects, as well as to plan the development of irrigation systems in a given area.

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INCIDENCE OF FRUIT ROT ON JAPANESE QUINCE (*CHAENOMELES JAPONICA*) IN LATVIA

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Abstract
Japanese quince (*Chaenomeles japonica*) is cultivated as a fruit crop because its fruit possesses valuable properties. The total area of Japanese quince in Latvia is continuously increasing; therefore, fruit rot can become an important reason of yield loss. The aim of this study was to clarify the fruit rot incidence in Japanese quince plantations in Latvia and explore the influencing factors of rot development in the year 2017. The evaluation of fruit rot was carried out during the fruit development in eight places of different regions of Latvia where Japanese quince is grown commercially. Three plantations of different Japanese quince cultivars in Dobele and seven plantations where Japanese quince is grown from seedlings were observed. Fruit rot incidence among plantations had no significant differences. Statistically significant differences in fruit rot incidence depending on quince growth stage ($p<0.05$) were found. Significant differences in fruit rot incidence were found between cultivars in Dobele.
Key words: fruit crop, seedlings, growth stage, plantation, fungal diseases, evaluation.

Introduction

Japanese quince (*Chaenomeles japonica* (Thumb.) Lindley ex Spach) is one of the four species in the genus *Chaenomeles* Lindl. belonging to the subfamily *Maloidae* of the family *Rosaceae* (Weber, 1964; Phipps *et al*., 1990; Ling-Ti *et al*., 2003). The natural growth area of Japanese quince is the central and southern part of Japan (Weber, 1964). Japanese quince (hereinafter quince) is cultivated as an ornamental crop in China (Ling-Ti *et al*., 2003) and in many other countries of the world. Quince as a fruit crop is cultivated in Latvia and Lithuania (Mierina *et al*., 2011), several regions of Russia (Fedulova, Skripnikova, & Mezhenskiĭ, 2009; Федулова, Куклина, & Каштанова, 2017), Poland (Nahorska, Dzwoniarska, & Thiem, 2014), Belarus (Panteev, Batchilo, & Grakovich, 1995), Sweden (Rumpunen, 2002), and in southern Finland (Kauppinen & Weckman, 2002). According to the information of Ministry of Agriculture of the Republic of Latvia (2016), the total area of quince plantations was 102 ha in 2013, 116 ha in 2014, and 200 ha in 2015; and this increase still continues.

Mierina *et al*. (2011) found that quince fruit was the major source of minerals in comparison with other pome fruits. Results of the analysis conducted by Baranowska-Bosiacka *et al*. (2017) showed that quince fruit was rich in valuable nutrients, ascorbic acid, phenols, and fibre and had a low oxalate content. Quince fruits are considered a perspective source for use in medicine (Nahorska, Dzwoniarska, & Thiem, 2014; Banaś & Korus, 2016), cosmetics and food industry (Nahorska, Dzwoniarska, & Thiem, 2014).

Kaufmane *et al*. (2013) quoting Tics (1992) reported that the first studies of breeding quince as a fruit crop in Latvia were carried out in the 1950s. Several investigations in *C. japonica* growing and breeding were performed in 1999 – 2001 in

cooperation with scientists from Latvia, Sweden, Finland, Lithuania, France, and Spain (Kaufmane *et al*., 2013). However, few studies of fungal diseases in quince are performed in Europe, and even less in Latvia. From 1998 to 2001, studies of pests and diseases were performed in Sweden, including also a few samples of quince leaves collected in Dobele, Latvia (Norin & Rumpunen, 2003). From 2009 to 2011 the evaluation of phytosanitary conditions of the pomological collections of quince in Lithuania was conducted (Grigaliūnaitė, Žilinskaitė, & Radaitienė, 2012). Norin and Rumpunen (2003) concluded that quince does not have significant pests. However, if the areas of quince increase, some of the fungi common in other crops from the family *Rosaceae* will also attack the Japanese quince. Fungal diseases dominate in *Chaenomeles* spp., which may cause fruit spots, rotting of fruits, and die-back of shoots and plants (Norin & Rumpunen, 2003).

Botrytis cinerea, *Monilinia fructigena*, and *Penicillium expansum* were detected and identified as causal organisms of fruit rot in quince during the monitoring carried out in Tambov region of Russia from 2010 to 2016 (Федулова, Куклина, & Каштанова, 2017). *B. cinerea*, *Fusarium* spp., and *P. expansum* as causal agents of fruit rot were detected in Lithuania (Grigaliūnaitė, Žilinskaitė, & Radaitienė, 2012). From 1998 to 2001, Norin and Rumpunen studied fungi on quince in Sweden. They identified several genera of fungi involved in fruit rots. *B. cinerea* causal agent of grey mould and *P. expansum* were found on young and mature rotten fruits as well as on fruits kept in cold storage. Brown rot caused by *M. fructigena,* bitter rot caused by *Colletotrichum gloeosporioides*, and bull's-eye rot caused by *Cryptosporiopsis curvispora* (teleomorph *Neofabraea malicorticis*) and *Phlyctema vagabunda* (teleomorph *Neofabraea alba*) were

observed on mature fruits. Several other *Penicillium* species such as *P. brevicompactum*, *P. islandicum* and *P. rugulosum* were also isolated from mature fruits. Rot caused by *Fusarium* spp. was found on young fruits (Norin & Rumpunen, 2003). Fruit rot caused by *Diplodia seriata* has been reported as a pathogen of quince in Serbia (Vico *et al*., 2017). Observations of quince in Latvia showed that this crop was damaged by fruit rot, but systematic assessments have not been performed yet.

The aim of this study was to clarify the fruit rot incidence in Japanese quince plantations in Latvia and explore the factors influencing the rot development.

Materials and Methods
Monitoring sites and meteorological conditions
The evaluation of diseases in quince fields was carried out in the vegetation period of 2017. Observations were done in eight places that grow quince commercially (Fig. 1). In all of the places observed, quince was grown using the biological management method; the exception was Dobele, where the integrated management method was used.

The most critical periods in the development of fruit rot depending on the environmental conditions are flowering (the middle to end of May), fruit development (June to July) and time closer to harvesting (August). Meteorological conditions in the vegetation period of 2017 mostly differed from the data of long-term observations. In May, June, and July, the mean air temperature and precipitation were below long-term average. In August, when

quince fruits reached the beginning of ripening GS 81 (Growth stage (hereinafter GS) in each assessment was determined using the international decimal code scale BBCH (*BiologischeBundesanstalt, Bundessortenamt und CHemistreIndustrie*) for pome fruits, the amount of precipitation and air temperature rose above long-term average. The first decade of September or the harvest time of quince was warm and moist. Meteorological conditions in August and the beginning of September created favourable conditions for the development of fruit rot. Information about the meteorological situation in Latvia was sourced from the website of Latvian Environment, Geology and Meteorology Centre. Meteorological data of the 2017 vegetation period in Dobele (Fig. 2) was collected from a stationary meteorological station placed directly in the area of the Institute of Horticulture in Dobele. Meteorological conditions in Dobele were similar to those in other observation places but had some differences. At the end of May, during flowering, the precipitation level was comparatively lower but the mean air temperature was above long-term average. In June, during the beginning of fruit development, precipitation was higher than long-term average but the mean air temperature was moderate, although rose above long-term average.

Evaluation methods of fruit rot
Assessments of fruit rot incidence started at the beginning of Japanese quince fruit development (GS 71), i.e., on June 15, 2017 and lasted until fruit ripening (GS 87), i.e., September 13, 2017. Hereinafter in the

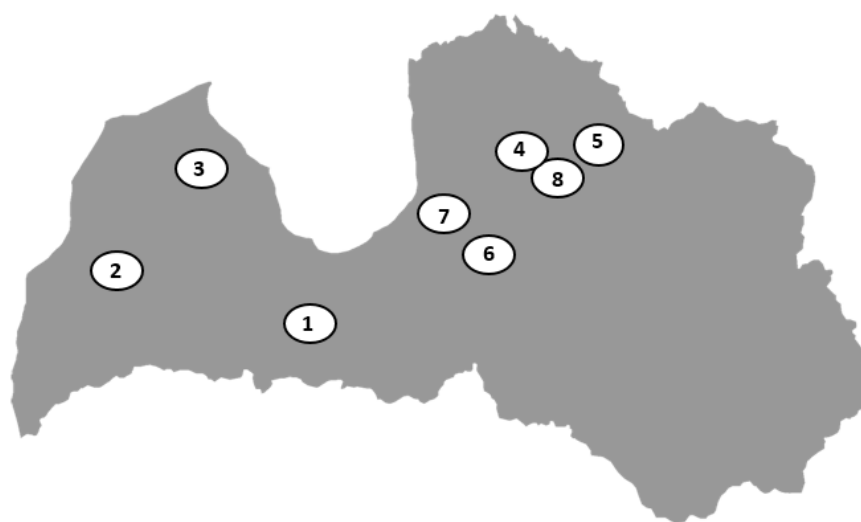Figure 1. Location of the places observed:

1 – Institute of Horticulture (hereinafter Dobele); 2 – farm 'Mežvidi' (hereinafter Mežvidi); 3 – 'Lubeco' Ltd. (hereinafter Lubeco); 4 – 'Cooperative' Ltd. (hereinafter Cooperative); 5 – farm 'Buliņi' (hereinafter Buliņi); 6 – farm 'Elianda' (hereinafter Elianda); 7 – 'Rāmkalni' Ltd. (hereinafter Rāmkalni); 8 – farm 'Lejaskārkli' (hereinafter Lejaskārkli).
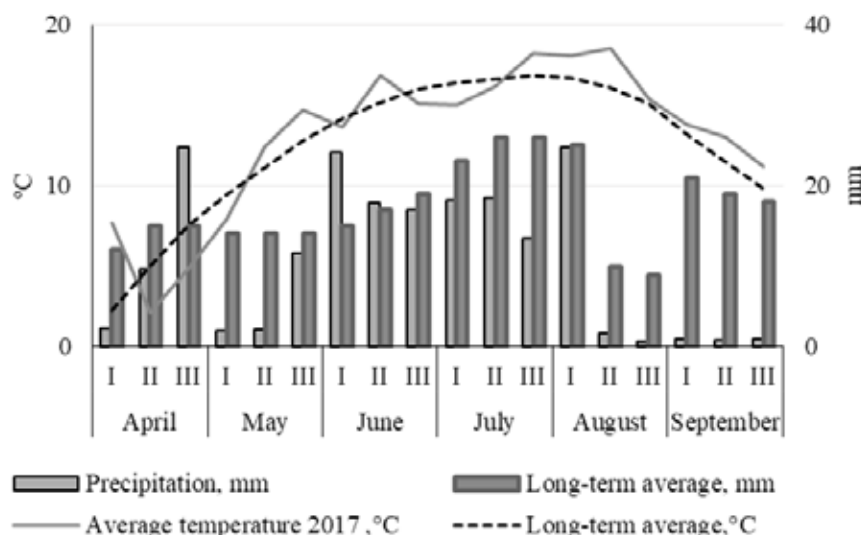
Figure 2. The average temperature and the amount of precipitation in 2017, and long-term data in Dobele.

text the number of assessment times are assigned by 'n=x (number of assessments)'. Assessments were conducted once a month or with an interval of 28 days in Mežvidi (n=4), Buliņi (n=4), Elianda (n=4), Rāmkalni (n=4), and Lejaskārkli (n=3) and twice a month or with an interval of 14 days in Dobele (n=7), Lubeco (n=7), and Cooperative (n=7). Three plantations with different quince cultivars – 'Rondo', 'Rasa' and 'Darius' – were observed in Dobele (each of these n=7); in other plantations, quince grown from seedlings was observed.

The disease incidence was evaluated diagonally across the field by inspecting 20 randomly selected plants; on each shrub 15 fruits were evaluated. In Cooperative, where the field was too small, evaluation was made in a zigzag pattern throughout the field. The outer edges of the field were avoided. In case there were not enough fruits on the selected shrub, the missing fruits were replaced with fruits from the nearby shrub. In total, 300 fruits were examined in one survey. Fruit rot was recognized visually and rotten fruits recorded in the observation form intended for this purpose.

Statistical processing of data

The incidence was calculated with the formula:

$$I = \frac{n}{N} \times 100$$

where I – Incidence, %;
  n – number of infected fruits;
  N – all assessed fruits.

For statistical processing of data, the analysis of variance (ANOVA) was used. The significance level of α=0.05 was used. For data processing, the programs 'R' (version 3.4.3.) and 'RStudio' were used.

Results and Discussion

Symptoms of rot

Young fruits of quince from the first to second fruit drop (GS 71–73) turned yellow but did not fall off the plants immediately, which should be typical for this growth stage interval. The first rot signs on these yellow and weakened young fruits were observed. Fruits turned brown, and rot covered all or part of the young fruit.

Fruit remained erect (the underside of fruit and stalk forming a T) until fruits reached half of the final size (GS 74–75), rot development continued and grey mycelium or tan spore sporodochia appeared on rotten fruits in moist conditions. Similar signs have been described also by other authors, for example, Norin and Rumpunen (2003) associated them with gray mould and Fedulova, Kuklina, & Kashtanova (2017) with brown rot, respectively.

During the sizing process when fruits reached 60–80% of their characteristic size (GS 76–78), the development of the above-described rot was observed and other symptoms appeared. Brown irregular sunken spots which covered 30 – 50% of fruit surface were noticed. Rot-damaged areas were rounded with a noticeable red to purple border in some samples. Norin and Rumpunen (2003) reported that the red border around rot damage could be associated with plant resistance to pathogens.

Up to the next observations, when quince fruits had reached 90% of their characteristic size and ripening had started (GS 79–80), a large number of rotten fruits had fallen down. Different symptoms of rot, as described before, continued to progress.

During the last times of observations (from the beginning of ripening till the fruits were ripe for picking (GS 81–87), different disease symptoms were found, such as concentric rings in the rotten parts
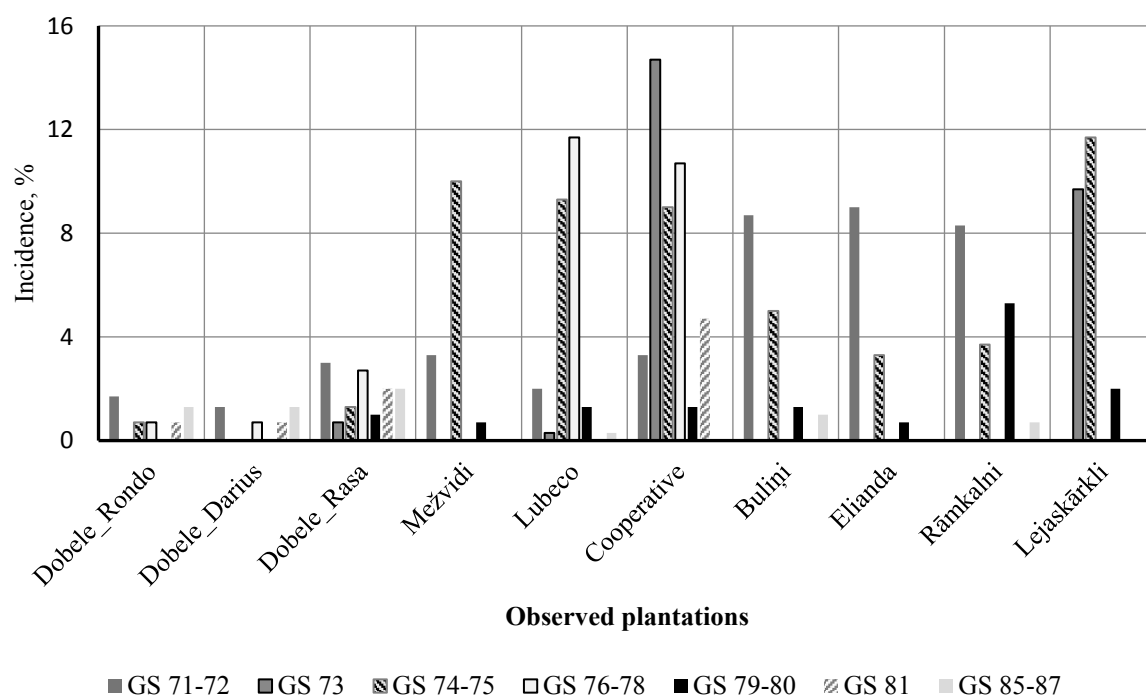
Figure 3. Incidence of fruit rot depending on the plantation at different growth stages of Japanese quince.

of some samples. These symptoms could be a sign of bull's-eye rot caused by *Neofabraea* species and described by Hortova, Novotny, & Erban (2014) on apples in the Czech Republic. Fully rotten fruits in this observation period were detected more often than in previous observations.

Symptoms of fruit rot differed depending on meteorological conditions as well as, possibly, also on cultivar and growth stages; therefore, further investigations are required for precise description of symptoms and identification of causal agents.

Incidence of rot

The first symptoms of rot on young fruits of Japanese quince were observed in all observed plantations in the middle of June (GS 71–72); the incidence of rot fluctuated between 1.3% and 9.0% depending on the plantation (Fig. 3).

In the next observations (GS 73), in some plantations (e.g. Dobele Rondo and Dobele Darius), rot was not found on the fruit, which could be explained with the first or second fruit drop when rotten fruits had fallen down and, therefore, could not be included in further assessments. However, incidence of rot mainly in different observation places continued to increase during GS 74–75 and GS 76-78. At this stage, in some plantations (e.g. Mežvidi, Lubeco, Cooperative and Lejaskārkli), rot incidence exceeded 10%, which can be considered an agronomically significant level. Subsequent assessments until fruit maturing showed a decrease in rot incidence: at GS 79–80 it varied from 0 to 5.3% depending on the location; and at

GS 81 and GS 85–87 it varied from 0 to 1.3%. This fact can be explained with abundant mass falling of rotten fruits after GS 76–78. A similar situation was described in Sweden, where a large number of rotten young fruits had fallen on the ground. *B. cinerea* infection was recognized as the most important reason for fruit falling (Norin & Rumpunen, 2003). Further investigations are required to clarify whether fallen infected young fruits affect fruit rot incidence during fruit ripening. No statistically significant differences (p>0.05) in rot incidence among the plantations were found; however, there was a tendency for the incidence of rot in Dobele to be lower than in the plantations of other places. One of its possible reasons is that in Dobele quince cultivars were grown, whereas in all other places quince was grown from seedlings. Also, management methods in Dobele were different and more intensive than in the observation places where organic management was used. This means that quince plants in Dobele received balanced fertilization and were more resistant to unfavourable conditions. Consequently, a hypothesis is proposed that the origin of the planting material and quince growing management are important factors influencing fruit rot incidence.

Mean incidence of fruit rot varied in different growth stages of quince (Fig. 4). Statistically significant differences in fruit rot incidence depending on growth stages (p<0.05) were found.

A significantly higher incidence of rot was detected at growth stage intervals 74–75 and 76–78 in comparison with later stages of quince development.
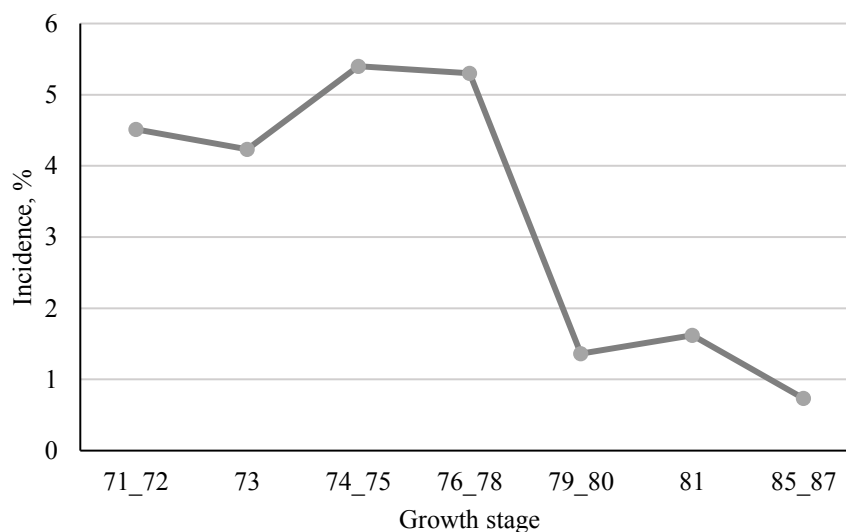
Figure 4. Incidence of fruit rot depending on growth stages of Japanese quince (average data).
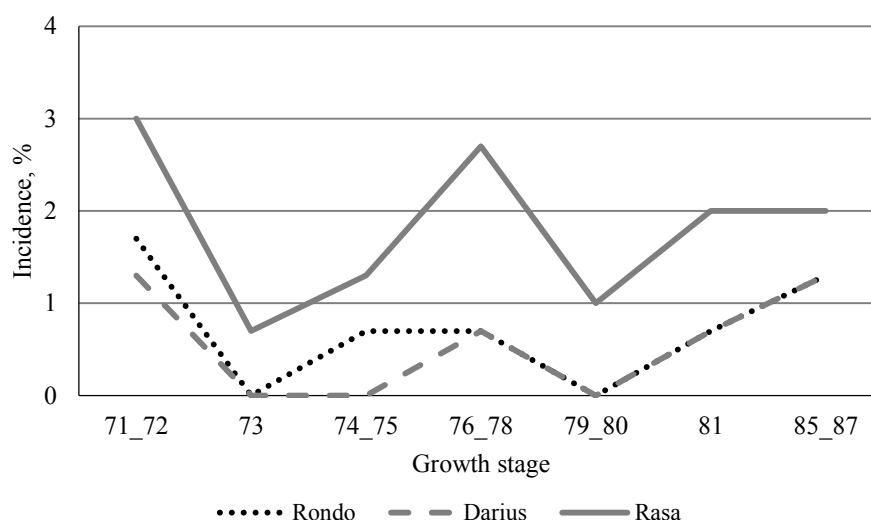

Figure 5. Development of fruit rot incidence depending on quince cultivar in Dobele.

This suggests that young infected fruits identified at GS 71–73 were an important source for further fruit rot development. Furthermore, the time of the significant fruit rot increase coincided with the occurrence of relatively high precipitation and air temperatures. This could mean that weather conditions had an important influence on fruit rot development during the fruit growth. It is considered that precipitation and moderate air temperatures during flowering have an impact on fruit rot development. Quince flowering in Dobele in 2017 was observed from the middle to the end of May. This period was characterized by moderate air temperatures, but precipitation level was low and notably below the long-term data in full flowering, which can explain the comparatively low fruit rot incidence in quince plantations in Dobele. Further investigations are required to clarify whether the remaining fruits and fallen infected young fruits affect fruit rot incidence during fruit ripening.

Studies in Tambov region of Russia also showed differences in the susceptibility of quince cultivars to diseases including fruit rot (Федулова, Куклина, & Каштанова, 2017). In Dobele, the impact of quince cultivars on rot incidence was studied in the plantations of three cultivars registered in Latvia (Fig. 5), and significant differences in fruit rot incidence ($p<0.05$) were determined.

Although differences among cultivars were significant, the disease progress curves were similar. After GS 79–80, differences in rot development occurred, and a tendency of a faster increase in rot incidence in 'Rondo' and 'Darius' was observed if compared to cultivar 'Rasa'. This can be explained with differences in the ripening process of cultivars.

Fruits of 'Rondo' and 'Darius' had a faster and more regular ripening process, but fruits of 'Rasa' ripened unevenly, which had an impact on the development of fruit rot as well.

Conclusions
1. Fruit rot incidence in Japanese quince varied among the plantations but significant differences were not found. However, there was a tendency that the origin of the planting material and quince growing management importantly influenced fruit rot incidence.
2. Growth stages had a significant impact on fruit rot incidence in Japanese quince during fruit development. The significantly highest fruit rot incidence was detected in the middle of vegetation period when fruits reached 40–80% (GS 74–78) of their characteristic size.
3. Cultivars of Japanese quince showed different susceptibilities to fruit rot.
4. Further investigations are required to identify the pathogens causing rot in Japanese quince to better explain the biological properties of fruit rot development in quince plantations.

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LEAF OPTICAL PROPERTIES REFLECT CHANGES OF PHOTOSYNTHETIC INDICES IN APPLE TREES

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Abstract
The impact of light penetration into crown and the effect of rootstocks and distance between trees on photosynthetic behaviour were analysed. Apple cultivar 'Auksis' was grafted onto dwarfing rootstock P60 and super-dwarfing rootstock P22 and planted at different distances (3 × 1 m, 3 × 0.75 m and 3 × 0.5 m). Nitrogen balance index and photochemical reflectance index were measured at two heights: 0.8 m above ground inside the canopy and 1.5 m above ground outside the canopy; specific leaf area, fresh and dry weight were evaluated from all canopy. The significantly positive effect of dwarfing rootstock P60 on all tested indices was observed comparing to P22 rootstock. Increasing density between trees lead to a decreased specific leaf area and increased nitrogen balance index. The dry and fresh weight ratio and photochemical reflectance index were also significantly affected, but no general tendency was identified. Photochemical reflectance index was not affected by light penetration into canopy, but the nitrogen balance index significantly decreased in the upper part of the canopy. Summarizing, it can be stated that decreasing light penetration into the crown results in an increase in the specific leaf area and photochemical reflectance index, and leads to a decrease in dry and fresh weight ratio and nitrogen balance index.
Key words: apple tree, specific leaf area (SLA), nitrogen balance index (NBI), Photochemical Reflectance Index (PRI).

Introduction

The plant growth and photosynthetic productivity are strongly influenced by environmental factors. The light is the essential source of energy and an external signal for regulating processes in plants. Photosynthetic productivity depends on many factors, such as light, water, CO_2, nutrients and other elements like leaf canopy size and architecture (Long *et al.*, 2006). During photosynthetic processes, solar energy is bounding to dry matter, thus it is possible to estimate photosynthetic behaviour of the plant. An increase in leaf photosynthesis translates into an increase in biomass. The productivity of the biomass also depends on the optimal plant photosynthesis system work (Long *et al.*, 2006; Hüner *et al.*, 2016).

Specific leaf area (SLA), which is defined as the leaf area per unit of dry leaf mass, is an important component linking plant carbon and water cycles as well as quantifying plant physiological processes. SLA regulates plant physiological processes, such as light capture, growth rates and life strategies (Ali *et al.*, 2017; Yao *et al.*, 2016).

Non-destructive methods determining plant leaf area are useful instruments in physiological, ecological and agronomic research. Reflectance indices offer non-intrusive tools for rapidly inferring several functionally important leaf and canopy properties (Sala *et al.*, 2015; Gamon & Surfus, 1999). Photochemical reflectance index (PRI) is related with photosystem II (PSII) via the xanthophyll cycle and can be used as a proxy for light use efficiency. Thus, PRI was also applied as an active probe of pigment conversion (Gamon & Surfus 1999). Weng *et al.* (2010) found that both PRI and PSII efficiency decreased in *Mangifera*

indica leaves with the increase in illumination. Moreover, the PSII efficiency-PRI relationship varied with temperature and leaf colour. Chlorophyll index (Chl) and the nitrogen balance index (NBI) describes the relative chlorophyll and nitrogen content of the same leaves. Nitrogen index is capable of assessing N dynamics in apple tree systems (Cerovic *et al.*, 2012; Overbeck *et al.*, 2018). Moreover, such methods allow repeat sampling of changing optical properties during leaf development.

It was reported that optical properties and photosynthetic indices were affected by seasonal changes in mango, *Phlomis fruticosa* (Weng *et al.*, 2010; Stagakis *et al.*, 2014), depending on the water status in woody perennial plants (Hmimina *et al.*, 2014) and light penetration into crown for *Zea mays* and *Phlomis fruticosa* (Cheng *et al.*, 2013; Stagakis *et al.*, 2014). However, there is no data about leaf optical property relationship with photosynthetic indices in apple trees. Thus, the aim of the study was to find out the impact of light penetration into crown and the effect of rootstocks and distance between trees on photosynthetic behaviour of apple trees.

Materials and Methods

Plant material and growing conditions
A field experiment was carried out in an intensive orchard at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry, Lithuania. The apple (*Malus domestica* Borkh.) cultivar 'Auksis' was grafted on rootstocks P22 and P60. Trees were planted in 2001 in single rows spaced 1 m, 0.75 m and 0.5 m apart with 3 m between rows. Pest and disease management was carried out

according to the integrated plant protection practices, and the orchard was not irrigated. Soil conditions of the experimental orchard were as follows: clay loam, pH 7.3, humus 2.8%, P_2O_5 255 mg kg^{-1}, K_2O 230 mg kg^{-1}. Three single trees were fully randomized. Measuruments and leaf samples were taken in 2017 in the middle of July (beginning of apple maturity) and at the end of August (harvest time).

Optical leaf indices
Photochemical reflectance index (PRI)

PRI was evaluated using non-destructive method (CI-710 Leaf spectrometer, USA) from five leaves from each tree at two heights: 0.8 m above ground inside the canopy and 1.5 m above ground outside the canopy. The PRI combines reflectance at 531 nm (R531) with a reference wavelength insensitive to short-term changes in light energy conversion efficiency (R570) and normalizes it:

PRI = $(R_{531} - R_{570})/(R_{531} - R_{570})$
Nitrogen balance index (NBI)

NBI was evaluated using non-destructive measurement of leaf chlorophyll and flavonoid content in the epidermis (Dualex ®4, USA) from five leaves from each tree at two heights: 0.8 m above ground inside the canopy and 1.5 m above ground outside the canopy.

Biometric measurements

To determine the leaf area (cm^2), twenty leaves were randomly sampled from the whole tree canopy and measured with a leaf area meter (AT Delta – T Device, UK). The dry mass of twenty leaves was determined by drying apple leaves at 105 °C (Venticell 222, Medcenter Einrichtungen, Gräfeling, Germany) to constant weight. SLA was defined as the leaf area per unit of dry leaf mass, usually expressed in cm^2 g^{-1}.

Statistical analysis

The data were processed using two-way and three-way analysis of variance (ANOVA) at the confidence levels P≤0.05 and P≤0.01.

Table 1

The effect of light penetration into the canopy, rootstock, the distance between trees and seasonality on the photochemical reflectance index (PRI) and nitrogen balance status (NBI) in 'Auksis' apple tree leaves

Rootstock	Distance	Photochemical Reflectance Index		Photochemical Reflectance Index		Nitrogen Balance Index		Nitrogen Balance Index	
		0.8 m above ground	1.5 m above ground	0.8 m above ground	1.5 m above ground	0.8 m above ground	1.5 m above ground	0.8 m above ground	1.5 m above ground
		Beginning of apple maturity		Harvest time		Beginning of apple maturity		Harvest time	
P22	3×1	0.096	0.097	-0.003	-0.004**	35.00	30.05	38.34	30.61
	3×0.75	0.094	0.108	0.046**	0.036	39.88	29.65	38.67	31.10
	3×0.5	0.111	0.101	0.054**	0.048	33.34	24.41	31.58	26.73
P60	3×1	0.152**	0.179**	0.040**	0.062**	42.15	33.57	42.88	24.40
	3×0.75	0.160**	0.115	0.054**	0.054**	39.84	31.82	50.92**	37.63
	3×0.5	0.127	0.150**	0.060**	0.062**	40.78	25.05	39.38	37.48
LSD$_{0.5AB}$		0.026	0.032	0.021	0.025	8.911	5.481	9.813	7.030
LSD$_{0.1AB}$		0.035	0.043	0.028	0.033	11.83	7.277	13.028	9.334
F actual									
Factor A (rootstock)		**		**		*		**	
Factor B (Distance)		ns		**		*		**	
Factor C (Measuring height)		ns		ns		**		**	
Interaction AB		*		**		ns		*	
Interaction AC		ns		ns		ns		ns	
Interaction BC		ns		ns		ns		*	
Interaction ABC		**		ns		ns		ns	

LSD – Fisher's protected least: *P<0.05; **P<0.01 shows significant differences, ns – no significant differences.

Table 2

The effect of rootstock, the distance between trees and seasonality on Specific leaf area and dry and fresh weight ratio in 'Auksis' apple tree

Rootstock	Distance	Specific leaf area, cm² g⁻¹		Dry/Fresh weight ratio, g	
		Beginning of apple maturity	Harvest time	Beginning of apple maturity	Harvest time
P22	3×1	60.01	63.05	36.32	36.36
	3×0.75	62.70	67.45	36.64	34.80
	3×0.5	69.34	93.21*	35.37	33.92
P60	3×1	121.08**	101.58**	38.09	38.68*
	3×0.75	121.71**	128.32**	38.92	38.53*
	3×0.5	134.78**	128.33**	37.75	36.39
LSD$_{0.5AB}$		36.965	23.277	2.39	2.01
LSD$_{0.1AB}$		52.579	33.109	3.40	2.85
F actual					
Factor A (Rootstock)		**		**	
Factor B (Distance)		ns		**	
Factor C (Season)		*		ns	
Interaction AB		ns		ns	
Interaction AC		ns		ns	
Interaction BC		ns		ns	
Interaction ABC		ns		ns	

LSD – Fisher's protected least: *P<0.05; **P<0.01 shows significant differences, ns – no significant differences.

Results and Discussion

The impact of light penetration into crown and the effect of rootstocks and distance between trees on photosynthetic behaviour were analyzed. Thus, the NBI and PRI were measured at two heights inside and outside the canopy to assess how these indices change in different lighting conditions. According to the obtained results, the NBI inside the canopy was significantly higher for all treatments compared to fully lightened leaves outside the canopy (Table 1). This data corresponds to the findings by Cronin & Lodge (2003), as they found that low light availability increased the nitrogen content of leaf tissue by 53%. It was found that NBI increased by about 10% in apple tree leaves grafted on P60 rootstock compared with the rootstock P22. According to the results, the planting distance had the most significant impact on the NBI. Increasing the density between trees lead to the decrease of NBI inside and outside the canopy. Twice lower density between the trees resulted in NBI decreased by about 15%. A significant impact on NBI was also found in apple tree cultivar 'Ligol' (Samuolienė et al., 2016).

PRI was about 1.5 times bigger in the leaves of apple tree grafted on P60 rootstock compared with the rootstock P22 in July compared to the harvesting time. P22 rootstock and 3×1 m planting distance between trees resulted in the decrease of PRI. Weng et al. (2006) say that PRI can serve as an indicator of the seasonal variation of potential PSII efficiency. In our research, PRI from middle of July till the end of August decreased by a half and more.

Both the distance between the trees and rootstock significantly affected the specific leaf area. The specific leaf area of trees with rootstock grafted on P60 was two times larger compared to the trees grafted on P22 rootstock in all treatments (Table 2). Decreasing the distance between apple trees lead to an increased specific leaf area, but dry and fresh weight ratio (DW/FW) decreased. On the other hand, DW/FW was significantly affected by the rootstock and the distance between trees, but seasonality had no significant effect. DW/FW of trees with rootstock grafted on P60 had increased by about 6% compared with rootstock P22. Meanwhile, there were no significant differences

between the interactions of factors. Thus, the increase of specific leaf area was caused by dry mass decrease, which was effected by lower light penetration into canopy. Similar results have been obtained by other authors, who have stated that when increasing the density of fruit trees, the dry mass decreases (at the same time DW/FW decrease has been observed), but it results in the increase of SLA (Sims *et al.*, 1994; Poorter & Nagel, 2000). According to Evans and Poorter (2001), an increase in SLA lead to a decrease of NBI. Moreover, lower light penetration decreases the dry mass and NBI (Cronin *et al.*, 2003). The same tendency was obtained in our research (Table 2).

Conclusions

1. Decreasing light penetration into the crown results in the increase in SLA and PRI, and leads to a decrease of DW/ FW and NBI.

2. The rootstock has the greatest influence on the photosynthesis indices compared to the planting density and seasonality. The significantly positive effect of dwarfing rootstock P60 on all tested indices was observed compared to P22 rootstock.

3. The distance between the fruit trees significantly increased the specific leaf area and nitrogen balance index, but no general tendency was identified for changes of dry and fresh weight ratio and photochemical reflectance index.

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THE EFFECTS OF LED LIGHTING ON NITRATES, NITRITES AND ORGANIC ACIDS IN TATSOI

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Abstract

Progressive type of controlled environment horticulture, such as plant factories, enables the precise control of cultivation environment parameters. The experiments were performed at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry in the year of 2017. The aim of this study was to evaluate the effects of different irradiance levels produced by solid state light-emitting diodes (LEDs) on nitrates, nitrites and organic acids contents in tatsoi (*Brassica rapa* var. *rosularis*), cultivated in the controlled environment chambers. Plants were cultivated under combinations of red (640, 660 nm), blue (445 nm) and far red (731nm) LEDs at photosynthetic photon flux density (PPFD) level of 200 µmol m^{-2} s^{-1}. At the pre-harvest stage, PPFD was increased to 300 µmol m^{-2} s^{-1} by elevating the fluxes of different spectral components for 3 days. The contents of nitrates, nitrites and organic acids were evaluated. The results propose the metabolic interface between nitrates, nitrites and organic acids in green vegetables, sensitive for lighting conditions. The higher intensity of LED light at pre-harvest stage led to decreased contents of nitrates in tatsoi. The increased intensity of blue 455 nm light led to lower contents of nitrates and higher of organic acids in comparison to red 640 nm. In addition, the increased intensity of red 640 nm led to significantly higher (p≤0.05) contents of nitrites. The target management of LED light spectra and intensity at pre-harvest stage could be used to reduced nitrates and increased organic acids in tatsoi.
Key words: *Brassica rapa*, controlled environment, light emitting diodes.

Introduction

Light is one of the most important environmental factors necessary for the growth and development of plants. The technology of light-emitting diodes (LEDs) is one of the largest potential advantages in horticultural lighting in the last few decades (Morrow, 2008). Solid-state lighting systems have many unique advantages over existing horticultural lighting. LED lighting systems have the ability to control their spectral output, produce more light than incandescent lamps, they have high light output levels with low heat emission, when cooled properly, and the ability to maintain useful light output for years without replacement (Bourget, 2008; Morrow, 2008). LEDs emit narrow-band wavelengths from UV (~250 nm) to infrared (~1000 nm) (Bourget, 2008). This promising technology gives new possibilities to analyse the effects of lighting parameters on biochemical processes in green vegetables produced in growth chambers.

Light intensity and spectra affect plant growth and nutritional quality. Light intensity is known as the main factor affecting the accumulation of nitrates and nitrites in plants. Vegetables are the main source of nitrates and nitrites, accounting for between 72% and 94% of the total human nitrate intake (Hord, Tang, & Bryan, 2009; Reinik, Tamme, & Roasto, 2009; Yuming *et al.*, 2017). Nitrate accumulation in plants depends on nitrate reductase (NR) activity, which can be caused by red light (Vaštakaitė & Viršilė, 2015). Nitrate accumulation in vegetables can be also affected by genetic and environmental factors such as plant variety, type and composition of soil, air

temperature, harvesting time, storage (Boroujerdnia, Ansari, & Dehcordie, 2007; Konstantopouloua *et al.*, 2010; Bahadoran *et al.*, 2016). The consumption of high amounts of nitrates may increase the risk of developing stomach cancer or other diseases (Zhou, Liu, & Yang, 2012).

Vegetables cultivated under controlled environment conditions have a higher nitrate and nitrite content, but they also accumulate higher concentrations of useful substances for the human body, such as amino acids, vitamins, minerals, proteins, and organic acids (Wang *et al.*, 2014; Yuming *et al.*, 2017). Organic acids, depending on the concentration, provide the taste and smell of green vegetables (Flores *et al.*, 2011; Wang *et al.*, 2014).

Green vegetables are one of the main sources of vitamin C. Previous studies have shown that over 90% of vitamin C is consumed daily by vegetables and fruits (Hermsdorff *et al.*, 2012). It has been noticed that ascorbic acid synthesis in plant tissues is caused by higher light intensity (Zhou, Liu, & Yang, 2012). Ascorbic acid molecules are found in various plant organs. Higher levels of ascorbic acid are found in photosynthetic plant organs (Gest, Gautier, & Stevens, 2013). Ascorbic acid performs many functions in the plant cell such as the synthesis of ethylene and gibberellins and is a co-factor for many enzymes (Arrigoni & De Tullio, 2000).

The aim of this study was to investigate how different light intensity and spectrum of light emitting diodes (LEDs) affect the level of nitrates, nitrites and organic acids in tatsoi (*Brassica rapa* var. *rosularis*).

Materials and Methods

The experiments were performed at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry. Tatsoi were grown in a peat substrate (Profi 1, Durpeta, Lithuania) (pH 5–6) in plastic trays for 23 days. The average amounts of nutrients (mg L^{-1}) in the substrate were: N, 110; P_2O_5, 50; K_2O, 160; microelements Fe, Mn, Cu, B, Mo, and Zn. Electrical conductivity was $0.5 - 0.7$ ms^{-1} cm^{-1}. Trays were arranged randomly and were systematically rotated every day to improve the uniformity of the light environment. Plants were watered with tap water when needed. Experiments were performed in controlled environment growth chambers. Day/night temperatures of $21/17 \pm 2$ °C were established with a 18-h photoperiod and a relative air humidity of $50 - 60\%$. As a light source, the different combinations of red (R; 640 nm, 660 nm), blue (B; 445 nm), far-red (FR; 731 nm) light emitting diodes were used. Three days before the harvest, the intensities of different spectrum components were increased seeking for improved parameters of nutrition quality (Table 1).

Nitrate and nitrite contents were evaluated according to the spectrophotometric method of Merino (2009). To prepare the dry material (DM) for determination of nitrates and nitrites, plant tissue samples were dried in the drying oven (Venticell, MBT, Czech Republic) at 70 °C for 48 h. Initial nitrite concentration and total nitrite after zinc reduction were determined by Griess reaction at 540 nm (M501, Camspec, UK). Nitrate and nitrite contents (mg kg^{-1}) were determined by the calibration method.

Determination of organic acid contents. Conjugated biological samples of fresh matter (FM) from randomly selected plants were used for biochemical analyses. Samples were taken from the central part of the tray, leaving plants at the edges of the tray as a guard. 0.3 g of FM was homogenized with liquid nitrogen, diluted with deionized water and placed in ultra-sonic bath for 30 min. The contents of organic acids in samples were determined according to the method of Wang *et al.* (2014) with modifications**.** The extracts were analysed using HPLC Shimadzu (10A) system with diode array detector. Column used Lichrosorb RP – 18, 5u, 4.6 mm×250 mm, 5 μm (Phenomenex, USA). Mobile phase – 0.01mol L^{-1} sulfuric acid in deionized water. The chromatogram was monitored by the photodiode array detector at 230 nm for ascorbic acid; and at 210 nm for citric acid, oxalic acid, malic acid and succinic acid. The concentrations of organic acids in FM samples were calculated according to the calibration curve of standards.

Photosynthetic photon flux density (PPFD) was measured daily by photometer-radiometer RF 100 (Sonopan, Poland).

All data are expressed on a FM basis. All measurements were evaluated for significance by an analysis of variance (ANOVA) followed by the least significant difference (LSD) test at the $p \leq 0.05$ level. Correlations were calculated by STATISTICA 7.

Results and Discussion

The results of nitrate, nitrite and organic acids in tatsoi influenced by different light treatments are shown in Table 2.

LED light treatments differentially affected the nitrate, nitrite and organic acid contents in tatsoi. The nitrate content was affected by an increased intensity of B 455 nm to PPFD level at 300 μmol m^{-2} s^{-1} treatment – it was ~4.2-fold lower in comparison to control (a PPFD level at 200 μmol m^{-2} s^{-1}). The increased intensity of R 640 nm LEDs resulted in a higher content of nitrates in comparison to B 455 nm, but slightly lower than in control. Moderate nitrate reduction was observed in the treatment, where all spectral components were proportionally increased to PPFD 300 μmol m^{-2} s^{-1}. However, other authors also confirm that a higher light intensity results in lower nitrate contents in various green vegetables. According to Vaštakaitė & Viršilė (2015), the higher LED light irradiation resulted in an increase of the nitrate content in tatsoi and mustard, red

Table 1

LED lighting parameters

Light treatment	PPFD, μmol m^{-2} s^{-1}									
	During the growing					3 days before the harvest				
	FR 731nm	B 445nm	R 640nm	R 660nm	P/ PPFD	FR 731nm	B 445nm	R 640nm	R 660nm	P/ PPFD
Control PAR 200 μmol m^{-2} s^{-1}	4	20	88	88	16/200	4	20	88	88	16/200
All up to PAR 300 μmol m^{-2} s^{-1}						6	30	132	132	16/300
450 nm to PAR 300 μmol m^{-2} s^{-1}						4	120	88	88	16/300
640 nm to PAR 300 μmol m^{-2} s^{-1}						4	20	188	88	16/300

FR – Far red, B – Blue, R – red, P – photoperiod, PPFD – photosynthetic photon flux density.

Table 2

The contents of nitrates, nitrites and organic acids tatsoi cultivated under different LED light treatments

Light treatment	Nitrate content mg^{-2} kg^{-1}	Nitrite content mg^{-2} kg^{-1}	Ascorbic acid content mg^{-2} g^{-1}	Citric acid content mg^{-2} g^{-1}	Oksalic acid content mg^{-2} g^{-1}	Malic acid content mg^{-2} g^{-1}	Sucinic acid content mg^{-2} g^{-1}
Control PAR 200 µmol m^{-2} s^{-1}	205.63	0.94	0.19	0.78	1.83	2.06	0.08
All up to PAR 300 µmol m^{-2} s^{-1}	**83.04***	0.73	0.19	**2.27****	**0.86***	**1.3***	**0.21****
450 nm to PAR 300 µmol m^{-2} s^{-1}	**48.39***	0.91	**0.11***	**2.56****	**1.09***	**1.06***	0.11
640 nm to AR 300 µmol m^{-2} s^{-1}	**193.47***	**7.52****	**0.13***	**2.38****	**0.96***	**1.33***	0.14
LSD $_{0.05}$ =	7.91	0.48	0.06	0.08	0.19	0.11	0.05

*the value is significantly (p≤0.05) lower than control; ** the value is significantly (p≤0.01) higher than control.

pak choi microgreens, while Samuolienė *et al.* (2013) stated that the lowest investigated (100 µmol m^{-2} s^{-1}) LED light intensity resulted in the highest nitrate contents in *Brassica* microgreens.

Nitrite content in tatsoi was determined ~ 8-fold higher, when R 640 nm LED light intensity was increased to PPFD 300 µmol m^{-2} s^{-1}, compared to the control plants. No significant differences were determined when B 455 nm or all spectral components were increased to PPFD level at 300 µmol m^{-2} s^{-1} (Table 2). Wanlai, Liu &, Qichang (2013) also reported decreased nitrate contents in lettuce, a few days before the harvest was exposed to high intensity of red and blue LED light.

The data of organic acid analysis in tatsoi leaves showed that ascorbic acids and other organic acid contents in tatsoi can be changed by tailoring LED lighting parameters (Table 2). Ascorbic acid content was significantly affected by increased B 450 nm and R 640 nm spectral components (to PPFD 300 µmol m^{-2} s^{-1}): it was determined ~1.7, ~1.4-fold lower than control, respectively. The increased light intensity due to proportionally elevated intensity of all spectral components had no effect comparing to control. Several studies have observed the increase in ascorbic acid contents in tatsoi microgreens grown under a higher intensity of LED light (Vaštakaitė &

Viršilė, 2015; Brazaitytė *et al.*, 2016). In our study, the accumulated ascorbic acid content was not only affected by the light intensity, but also by the wavelengths of LED light. The variation of ascorbic acid contents in plant tissues is affected by the complex relationships among effects of light stress and plant genetics, according to Solfanelli *et al.* (2006).

The LED light treatments affected the contents of citric acid in tatsoi. The significantly higher contents of citric acid in tatsoi grown under the treatments of all spectra components to PPFD level at 300 µmol m^{-2} s^{-1}, B 455 nm and R 640 nm on PPFD level at 300 µmol m^{-2} s^{-1} were determined in comparison to control (~2.9, ~3.2, ~3 -fold, respectively). On the contrary, the higher intensity of LEDs led to lower contents of oxalic acid and malic acid contents in tatsoi. The contents of oxalic acid were found to be ~2.1, ~1.6, ~1.9-fold and malic acid ~1.5, ~1.9, and ~1.5-fold lower in comparison to control. Succinic acid content was significantly affected by lighting treatment, where the intensity of all lighting components was increased to PPFD 300 µmol m^{-2} s^{-1} proportionally. The significantly higher (~2.6-fold) content of succinic acid in tatsoi grown under increased intensity of all LED components to 300 µmol m^{-2} s^{-1} were determined in comparison to plants grown under PPFD level at 200 µmol m^{-2} s^{-1}.

Table 3

The correlation among nitrates, nitrites and organic acid

Variable	Nitrate	Nitrite	Oxalic acid	Malic acid	Ascorbic acid	Succinic acid
Nitrite	0.52	1				
Oxalic acid	0.54	-0.32	1			
Malic acid	0.76	-0.15	**0.87**	1		
Ascorbic acid	**0.23**	-0.39	0.32	**0.59**	1	
Succinic acid	-0.37	0	**-0.68**	-0.38	0.37	1
Citric acid	**-0.65**	0.30	**-0.92**	**-0.98**	-0.56	0.47

Bolded correlations are significant at p≤0.05.

The correlation analysis revealed interdependencies between nitrate, nitrite and organic acid contents (Table 3). Strong, statistically significant negative correlation was determined between nitrate and citric acid contents, and weak positive, but statistically significant – between nitrate and ascorbic acid contents. Strong correlation was found between the contents of oxalic acid and malic, succinic and citric acid.

Conclusions

Our study revealed that increased LED light intensity at pre-harvest (3 days before harvest) resulted in decreased nitrate contents in tatsoi. The increased intensity of blue 455 nm LED light had a more pronounced effect compared to elevated R 640 nm light. However, this negatively affected ascorbic acid content in plant leaves. Oxalic and malic acid contents were the most sensitive to the differences in the light spectrum. Further analysis of nitrate and organic acid metabolism under different LED light spectrum and intensity should be explored seeking to develop strategies for reduced nitrate and increased ascorbic acid contents in tatsoi.

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EFFECTS OF DIFFERENT FERTILIZER TREATMENTS ON GRAIN YIELD AND YIELD COMPONENTS OF SPRING WHEAT

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Abstract
The present research was carried out to investigate the effects of different fertilizer treatments on grain yield and yield components of spring wheat (*Triticum aestivum* L.) 'Harenda' cultivar. The five treatments were as follows: control (standard NPK fertilization), standard NPK fertilization plus liquid NPK (10-11-11) fertilizer, standard NPK fertilization plus liquid NPK (10-11-11) fertilizer with microelements, standard NPK fertilization plus calcium micronized suspension fertilizer, and standard NPK fertilization plus Cu, Mn, Zn, Ca micronized suspension fertilizers. The field trials were conducted in 2017 at the Experimental Site of Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy, Poland. Applications of calcium micronized suspension foliar fertilizer and a mixture of Cu, Mn, Zn, Ca micronized suspension fertilizers significantly increased grain yield of spring wheat, respectively by 44.5% and 38.6% in comparison with control (standard NPK fertilization). These fertilizer treatments also enhanced yield components of spring wheat. Moreover, micronized suspension fertilizers (Ca and the mixture of Cu, Mn, Zn, Ca) had a significant effect on ear number and thousand grain weight of spring wheat compared to control and NPK fertilizers. Liquid NPK and micronutrient-enriched NPK fertilizers had a significant effect on thousand grain weight compared to control.
Key words: liquid fertilizer, micronized suspension, microelement, fertilization.

Introduction

Spring wheat (*Triticum aestivum* L.) is an important grain crop in Poland and in the world. Because of the increase in the rate of population growth and the decrease of areas of arable land, improving the grain yield is the way to meet food demand. Grain yield of cereals is the product of the following components: the number of spikes per unit area, the number of kernels per spike and thousand kernel weight (Bulman & Hunt, 1988). It can be increased due to the use of improved cultivars and nutrient management. Optimal fertilizer management is necessary to maintain sustainable yields, improve nutrient use efficiency of fertilizers, and save fertilizer resources (Chuan *et al.*, 2016). The macro- and micronutrients play an important role in the crop nutrition and thus they are important for achieving higher yields, better growth and development of plants (Imran & Gurmani, 2011). Nitrogen (N), phosphorus (P), and potassium (K) are primary nutrients in crop nutrition. N is a primary constituent of proteins, enzymes, chlorophyll, and metabolic processes involved in the synthesis and transfer of energy (Raun & Johnson, 1999). P is a component of energy compounds (e.g., ATP and ADP) and thus it is involved in biochemical pathways. Orthophosphates play a role in plant metabolic processes such as photosynthesis and respiration (Plaxon & Tran, 2011). Potassium is vital for growth as an enzyme activator that promotes metabolism. K provides abiotic stress tolerance (e.g. under drought stress), regulate stomatal opening and helps plants adapt to water deficit (Hasanuzzaman *et al.,* 2018). Calcium (Ca) is a regulator of physiological and biochemical processes in plants, especially in response to abiotic stresses (Bowler & Fluhr, 2000). This element is known as a second messenger and can delay or promote leaf senescence (Bowler & Chua, 1994), which is a terminal stage of leaf development (Thakur, Sharma, & Kishore, 2016). Ca is also believed to have an influence on the development of heat shock proteins that help the plant tolerate the stress of prolonged heat (Goswami *et al.*, 2014). Foliar calcium applications enhanced wheat yield and its components, increased transpiration rates, photosynthesis rate, stomatal conductance and chlorophyll content in spring wheat (Dolatabadian *et al*., 2013). Micronutrients (i.e., Fe, Cu, Zn, B, Mn, and Mo) are required for growth of plants (Welch *et al.*, 1991). According to Stępień & Wojtkowiak (2016), micronutrients such as Cu, Mn, and Zn are mostly needed by plants. Many studies have showed that small quantities of foliar-applied micronutrients (solitary or in association with others) significantly increase yield, its components and enhance growth and quality of wheat grain (Ziaeian & Malakouti, 2001; Asad & Rafique, 2002; Ali *et al*., 2009; Ali, 2012; Raza *et al*., 2014; Gomaa *et al*., 2015; Rawashdeh & Sala, 2015). Zinc (Zn) is responsible for the formation of growth hormones (auxin), seed and grain formation, plant height, protein syntheses, transformation and consumption of carbohydrates. Zn is known to have an important role as metal component of enzymes or as a functional, structural or regulatory cofactor of a wide number of enzymes (Hotz & Braun, 2004; Esfandiari *et al.*, 2016). Copper (Cu) is an enzyme activator, plays an important role in the metabolism of N compounds and indirect

role in chlorophyll production, and increases sugar contents. Micronutrients such as Mn and Zn have an effect on protein biosynthesis by adjusting the activity of peptidases and controlling protein metabolism (Ronen, 2007; Hänsch & Mendel, 2009). Iron (Fe) promotes formation of chlorophyll as well as enzyme mechanism which operates the respiratory systems of cells and is involved in reactions of cell division and growth (Ronen, 2007).

There are known several types of fertilizer applications. One of the methods is broadcasting of fertilizers over the soil surface (Finck, 1982). Another method is a foliar fertilization, also known as foliar feeding. It is a technique of feeding plants by applying liquid fertilizers directly on the leaves or the stem (Nasiri *et al.*, 2010). Fertilizers used for foliar applications are in solution or suspension. Because of the fast absorption of nutrients through the leaf cuticle or stomata, the deficiencies of macro- and microelements can be quickly corrected after being diagnosed by observation or foliar analysis. Low application rates and uniform distribution of nutrients are the main advantages of this type of application (Finck, 1982). Despite the fact that foliar fertilization is supplementary and cannot replace the basal fertilization, it is very effective. Foliar feeding should be done during periods of low temperature and relatively high humidity. The best results of feeding can be obtained during cloudy weather, in the early morning or in the evening. The application of foliar liquid fertilizers in concentrations above the recommended doses can cause leaf burning and necrosis.

The major types of fluid fertilizers are clear liquids and suspension fertilizers. Clear liquids are completely water-soluble while suspensions are partially dissolved in water, and the nutrients are suspended in the saturated solution. Suspension fertilizers are characterized by higher concentrations of nutrients than solutions of liquid clear fertilizers. Materials of low solubility are used for production of suspensions. The stability of the suspension is a major problem in this form of fertilizers. Gelling type clays (e.g., bentonite, aluminosilicates) are added in order to prevent the settling of solids and to keep the suspension stable. Nevertheless, prolonged storage of several months is not recommended for these type of fertilizers (Hagin & Tucker, 1982). One critical, although hard-to-predict, determinant of a successful foliar fertilization is the amount of ions taken up by the leaf *via* cuticular and stomatal pathways (Fernandez & Brown, 2013; Kaiser, 2014). In recent years, studies have shown that aqueous stomatal uptake under certain conditions is possible (Eichert & Burkhardt, 2001; Burkhard & Hunsche, 2013; Kaiser, 2014). Recently, new products for foliar applications containing

suspended mineral microparticles have emerged on the market (Kaiser, 2014). The latest direction of research on the intentional formation of fertilizer composition to obtain better quality characteristics of crops, is a search for a very specific composition of foliar fertilizers, which would act stimulatingly in the desired direction of changes in yield characteristics (Tripolskaja *et al.*, 2017).

The aim of the study was to compare the effect of different fertilizer treatments (standard NPK fertilization (control), standard NPK fertilization plus NPK foliar fertilizer, standard NPK fertilization plus NPK micronutrient-enriched foliar fertilizer, standard NPK fertilization plus calcium micronized suspension foliar fertilizer, and standard NPK fertilization plus the mixture of Cu, Mn, Zn, Ca micronized suspension foliar fertilizers) on grain yield and yield components of spring wheat (*Triticum aestivum* L.). Liquid NPK micronutrient-enriched fertilizer was applied once at the tillering phase of wheat, and other liquid fertilizers were applied at the tillering and stem elongation phases. These fertilizers were tested for the first time in field experiments.

Materials and Methods

The new innovative formulas of liquid fertilizers were used: liquid NPK fertilizer, liquid NPK micronutrient-enriched fertilizer, and Ca, Cu, Mn, Zn suspension fertilizers obtained at the Fertilizer Research Centre of New Chemical Syntheses Institute, Poland.

A field experiment was carried out in 2017 at the Institute of Soil Science and Plant Cultivation (IUNG-PIB) Experimental Site in Puławy, Poland. A spring wheat cultivar 'Harenda' was used in the experiment. A trial was set up in a randomized complete block design with five different fertilizer treatments with three replications. Treatments were as follows:

1. T_1 – Control – standard NPK fertilization: 50 kg $N \cdot ha^{-1}$ as 34% ammonium nitrate (AN), 80 kg $P_2O_5 \cdot ha^{-1}$ as granular triple superphosphate, 100 kg $K_2O \cdot ha^{-1}$ as potassium salt before sowing and 40 kg $N \cdot ha^{-1}$ as 34% ammonium nitrate at the stem elongation phase (BBCH 32);

2. T_2 – standard NPK fertilization plus liquid NPK (10-11-11) fertilizer at doses of 10 $L \cdot ha^{-1}$ at the tillering (BBCH 20) and 5 $L \cdot ha^{-1}$ at the stem elongation phase (BBCH 32) (foliar application);

3. T_3 – standard NPK fertilization plus liquid NPK (10-11-11) fertilizer with microelements (0.01% B, 0.03% Fe- EDTA, 0.01% Mn-EDTA, 0.001% Mo, 0.004% Zn-EDTA, 0.004% Cu-EDTA) at one dose of 5 $L \cdot ha^{-1}$ at the tillering phase (BBCH 20) (foliar application);

4. T_4 – standard NPK fertilization plus calcium micronized suspension fertilizer (19.5% Ca) at two

Table 1

Soil properties (layer 0-30 cm) at the IUNG-PIB experimental site

Parameter	Method	Unit	Value
pH(KCl)	potentiometrically	-	6.6
Nmin, DM	gravimetric method	%	85.9
N-NO$_3$	CFA with spectrophotometric detection	mg·kg^{-1}	5.0
N-NH$_4$	CFA with spectrophotometric detection	mg·kg^{-1}	2.4
available phosphorus (P$_2$O$_5$)	spectrophotometric method	mg·100g^{-1}	26.9
available potassium (K$_2$O)	FAES	mg·100g^{-1}	18.3
available Mg	FAAS	mg·100g^{-1}	7.4
Ca	FAAS	mg·kg^{-1}	921
Corg	titration method	%	0.59
organic matter	by calculation Corg x 1.724	%	1.02

doses of 5 kg Ca ha^{-1} (26 kg of Ca suspension per ha, respectively) at the tillering (BBCH 20) and at the stem elongation phase (BBCH 32) (foliar application);

5. T$_5$ – standard NPK fertilization plus Cu, Mn, Zn, Ca micronized suspension fertilizers (33% Cu, 23% Mn, 51%Zn, 19.5% Ca) at two doses of 100 g Cu·ha^{-1}, 300 g Mn·ha^{-1}, 400 g Zn·ha^{-1}, and 5 kg Ca ha^{-1} (a mixture of 0.303 kg of Cu suspension + 1.305 kg of Mn suspension + 0.785 kg of Zn suspension + 26 kg of Ca suspension per ha, respectively) at the tillering (BBCH 20) and at the stem elongation phase (BBCH 32) (foliar application).

Foliar solutions were sprayed with a hand held spray bottle at the rate of 400 L·ha^{-1} on plant foliage. Spring wheat was sown in an amount ensuring a density of 450 plants per m^2. The area of each plot was

1 m^2. The soil chemical characteristics at experimental site can be seen in Table 1. Data on the yield and yield components were recorded. Plants with roots were collected from each plot (1 m^2) by hand, then labelled and plant number per 1 m^2 was counted. After harvest, productive tillers from each plot were cut using scissors and then counted. Grain yield per plant, grain yield per ear, the number of kernels per plant, and the number of kernels per ear were mathematically calculated using Excel formulas. Exactly 100 kernels from each plot were counted and weighted in three replications and the results were multiplied by 10 in order to calculate thousand grain weight.

The spring wheat vegetation period in 2017 was characterized by much higher average monthly temperatures compared to long term averages (Figure
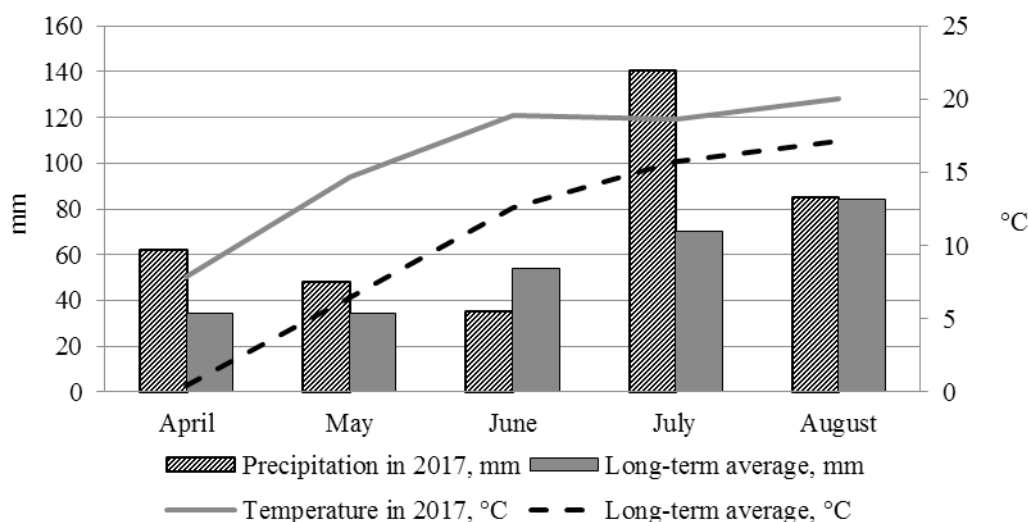

Figure 1. Weather conditions in 2017 and the long term average data (1971 – 2007).

1). In the growing season, the average temperature was 16 °C, and the sum of precipitation was 371 mm. In June, precipitations were lower (35.4 mm) than the long-term average precipitation data (54.2 mm). In contrast, the sum of precipitation in July (140.5 mm) was two-fold higher than the long term average value (70 mm).

The productive tillering coefficient (PTC) was calculated by the following formula:

$$PTC = \frac{number\ of\ produvtive\ tillers \cdot m^{-2}}{number\ of\ overwintered\ plants \cdot m^{-2}}$$

Statistical evaluation was carried out using the Statgraphics Centurion v. XVI. Analysis of variance was performed with Tukey's confidence interval at a significance level of $\alpha = 0.05$.

Results and Discussion

Analysis of the results showed a significant beneficial effect of micronized suspension and liquid clear fertilizers on grain yield of spring wheat. The highest grain yield was observed under applications of Ca and the mixture of Cu, Mn, Zn, Ca micronized suspension fertilizers (831.6 and 751.9 g·m^{-2}, respectively) increasing respectively by 369.9 g·m^{-2} (44.5%) and by 290.2 g·m^{-2} (38.6%) with respect to control. Between T_1, T_2, and T_3 treatments there were no statistically significant differences (p≥0.05). But, there was only a tendency of higher grain yield after the application of NPK liquid and NPK micronutrient-enriched liquid fertilizer compared to control (by 15.7 and 11.7%, respectively) (Fig. 2). This may be due to a better crop nutrition through foliar application of suspension and clear liquid fertilizers, and also due to important roles of macro- (N, P, K, Ca) and micronutrients (Cu, Mn, Zn, B, Fe, Mn, Mo) in

plant growth and development which may result in improved crop growth and increased production. Jarecki, Buczek & Bobrecka-Jamro (2017) reported that three foliar fertilizations increased grain yield in comparison with control. Ali (2012) reported that foliar application of Fe enhanced grain yield as compared to control. The highest grain yield per plant was observed under the application of the mixture of Cu, Mn, Zn, Ca micronized suspension fertilizers (T_5), followed by T_4, T_3, and T_2 treatments. Between T_1, T_2, T_3, and T_4 treatments, there were no statistically significant differences in grain yield per plant (p≥0.05). The highest grain yield per ear was observed under Ca micronized suspension fertilizer treatment (T_4), followed by T_5, T_3, and T_2 treatments.

Leszczyńska *et al.* (2007) reported that spring wheat cultivars require sowing of approximately 450 grains per m^2, because of their poor tillering. According to our study, the fertilizer treatments did not significantly affect the plant number of spring wheat per m^2 (p≥0.05). The plant number ranged from 251 to 313 plants per m^2 (Table 2) whereas the sowing density was 450 grains per m^2.

Analysis of the results showed a significant beneficial effect of micronized suspension and NPK liquid fertilizers on the ear number of spring wheat. The highest ear number was stated under T_5 and T_4 fertilizer treatments (micronized suspension fertilizers) as compared to control. Between the control (standard NPK fertilization), NPK fertilizer (T_2) and NPK micronutrient-enriched fertilizer treatments (T_3), there were no statistically significant differences in the ear number of spring wheat (p≥0.05) (Table 2). Bobrecka-Jamro, Jarecka & Jarecki (2015) confirmed that a higher NPK dose significantly increases the ear number per 1 m^2. Seadh *et al.* (2009)
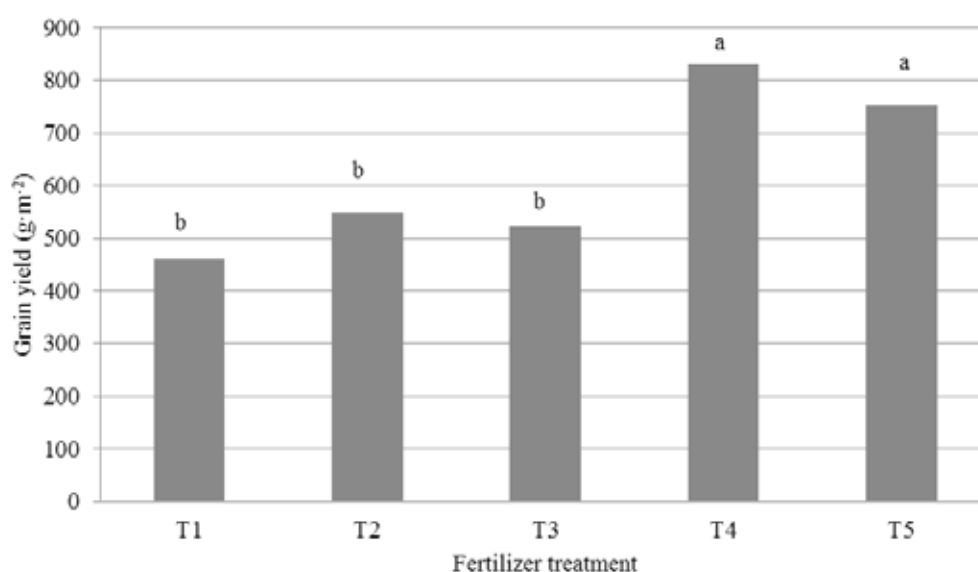

Figure 2. Grain yield (g·m^{-2}) of spring wheat in 2017.

Table 2

Yield components and a productive tillering coefficient of spring wheat

Treatment	PN	EN	TGW (g)	GYP (g·plant^{-1})	GYE (g·ear^{-1})	NKP	NKE	PTC
T1	251	442b	38.2c	1.87bc	1.04b	49	27	1.79
T2	312	473ab	41.5b	1.76bc	1.16ab	42	28	1.52
T3	262	453b	42.0b	2.01ab	1.17ab	48	28	1.73
T4	313	605a	45.7a	2.67ab	1.37a	58	30	1.94
T5	310	611a	46.2a	2.49a	1.23ab	55	27	2.01

Notes: PN – plant number per m^2, EN – ear number per m^2, TGW – thousand grain weight, GYP – grain yield per plant, GYE – grain yield per ear, NKP – number of kernels per plant, NKE – number of kernels per ear, PTC – productive tillering coefficient. For each variable, means followed by the same letter are not significantly different at p≥0.05 (Tukey HSD test).

reported that the application of a high nitrogen dose and a multi component foliar fertilizer has the most favourable effect on the number of ears per 1 m^2. The study by Tahir *et al.* (2009) did not indicate the effect of foliar application of boron on the ear density. Arif *et al.* (2006), in turn, after the application of three-time foliar spraying, obtained a significant increase in the number of ears per 1 m^2. Jarecki, Buczek & Bobrecka-Jamro (2017) reported that the use of higher NPK dose resulted in an increase in the number of ears of spring wheat per area unit in comparison with the lower dose.

The fertilizer treatments significantly affected thousand grain weight (TGW) (Table 2). The highest TGW was observed under micronized suspension fertilizer treatments (T$_4$, T$_5$), followed by NPK liquid fertilizer (T$_2$) and NPK with microelement liquid fertilizer (T$_3$) applications, and the lowest TGW was observed under standard NPK fertilization (T$_1$). Arif *et al.* (2006), Rawashdeh & Sala (2016) and Jarecki, Buczek, & Bobrecka-Jamro (2017) confirmed that foliar fertilization increases TGW in wheat, but on the condition of performing several sprayings during the growing season. Nadim *et al.* (2013) did not indicate the effect of microelements applied to soil or on leaves on TGW.

The fertilizer treatments had no significant effect on the number of kernels per plant (p≥0.05) (Table 2). The number of kernels per plant increased linearly with increased N availability (Oscarson, 2000).

Number of kernels per ear is one of the most important yield determinants. The fertilizer treatments had no significant effect on the number of kernels per ear (p≥0.05) (Tab. 2). On the contrary, Arif *et al.* (2006) and Zain *et al.* (2015) reported that foliar application of nutrients had a significant effect on the number of kernels per ear. Esfandiari *et al.* (2016) reported that the foliar zinc application at the stage of grain development significantly increased grain yield by increasing the number of kernels per ear.

The fertilizer treatments had no significant effect on the productive tillering coefficient (p≥0.05) (Table 2). But the tendency of having the highest productive tillering coefficients was observed only under T$_4$ and T$_5$ treatments (1.94 and 2.01, respectively).

Conclusions

The present research revealed that different fertilizer treatments had a significant effect on the grain yield and some of the yield components of spring wheat. The use of micronized suspension foliar fertilizers (T4 and T5) significantly enhanced grain yield and yield components of spring wheat as compared to control. Liquid NPK and micronutrient-enriched NPK fertilizers (T2 and T3, respectively) had a significant effect on thousand grain weight as compared to control (T1). To confirm the results of the study, the field trials are being continued in 2018.

Acknowledgements

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THE EFFECT OF LED LIGHTING DOSAGE ON PHOTOSYNTHETIC INDICES IN TATSOI

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Abstract

Plant factories provide possibilities to get optimal yield of green leafy vegetables entire year independent from the season. The technology of light-emitting diode (LEDs) light has become one of the most powerful tools in photophysiological researches of various horticultural plants. In order to manage plant physiology and improve productivity, it is necessary to develop new LEDs technologies in horticulture. The aim of the study was to investigate different lighting intensities and elevated red light (660 nm) effect on tatsoi photosynthetic parameters. All plants were grown under the same light sources where overall photosynthetic photon flux density (PPFD) varied from 200 to 300 µmol m^{-2} s^{-1}. Three days before harvesting red light intensity (640 and 660 nm) was increased until 132 µmol m^{-2} s^{-1} and 660 nm until 188 µmol m^{-2} s^{-1} at 16 hours photoperiod. In the last treatment merely 24 hours photoperiod was applied. The photosynthetic indices in tatsoi were determined by non-destructive methods using LI-6400XT portable photosynthesis system, OS5p fluorometer, DUALEX optical sensor and CID leaf spectrometer. Research was performed in 2017 – 2018 winter season. The obtained data revealed that the total photosynthetic photon flux density (PPFD) at level of 200 µmol m^{-2} s^{-1} was sufficient for optimal CO_2 assimilation in tatsoi plants. The increased PPFD of LED light at pre-harvest stage resulted in reduced photosynthetic parameters of plants.

Key words: *Brassica rapa*, photosynthetic parameters, photosynthetic photon flux density, light-emitting diode.

Introduction

Light spectra and intensity are the main factors to promote efficient plant growth. The technology of light-emitting diodes (LEDs) provide possibility to change spectral characteristics and combine the desired light with respective wavelengths without unnecessary spectral parts (Olle & Viršilė, 2013). The solid-state lighting technology has become a tremendous innovative and alternative instrument in horticulture. LEDs have a broad light spectrum, which can be tailored in various proportions and produce high light levels. The feature and possibility for light and environment management and digital controlling is one of the most useful advantages in vertical farming (Cocetta *et al.*, 2017).

To promote and ensure effective and efficient photosynthetic process, the cultivation conditions should be optimized according to the plant natural needs. Different plant species and varieties have different optimal cultivation conditions (temperature, light intensity, light spectrum etc.) (Carvalho & Folta, 2014). Some authors state that mild stress conditions can improve the productivity or nutritional value of green vegetables (Jansen *et al.*, 2008; Rouphael *et al.*, 2018).

Optimal spectrum characteristics and suitable qualitative composition have a direct impact on photosynthetic process (Kang *et al.*, 2013; Wojciechowska *et al.*, 2015). Zhen & Van Iersel (2017) in experiments with lettuce observed spectrum quality impact on instantaneous photosynthetic intensity (Pn) and claimed far-red light influence on photosynthetic intensity. Moreover, red and far red light transfer energy to photosystem II (PS II) and excites electron transmission through energetic reactions (Muhoz & Quiles, 2003).

Previous studies with pre-harvest showed that supplemental LED lighting a few days before harvesting in greenhouses, resulted in improved nutritional value of different green vegetables. One of the most analysed effects was nitrate reduction (Samuolienė *et al.*, 2009; Samuolienė *et al.*, 2011; Bliznikas *et al.*, 2012). The decrease in nitrate contents was accompanied by increased levels of carbohydrates and ascorbic acid in vegetable tissues (Samuolienė *et al.*, 2012a; Zhou, Liu, & Yang, 2012; Wanlai, Liu, & Qichang, 2013). From the practical side, these research findings also propose the ways how to improve the value of green vegetables, cultivated in light deficiency conditions. Nevertheless, there are no accomplished studies with elevated red light component intensity three days before harvesting, and the effect on photosynthesis system acclimatization and response is still clearly unknown in tatsoi.

Chlorophyll is the main pigment participating in photosynthetic process, which allows plants to absorb energy (Hall & Rao, 1999). The nitrogen impact on photosynthesis is crucial. As the main component it promotes efficient photosynthetic process and improves all photosynthetic apparatus activity (Sun *et al.*, 2016; Basi, Menossi, & Mattiello, 2018). Photochemical reflectance index is used for tracking changes and variability in photosynthetic light use efficiency (Nakaji, Oguma, & Fujinuma, 2006).

The efficiency of electrical energy utilization for lighting is a key parameter evaluating the costs of vegetable production in greenhouses and vertical farming system (Kubota *et al.*, 2016). In addition to

this, it is possible to apply lower PPFD in various horticulture systems. This is enough in order to grow plants without losses and sufficient for physiology needs, as well as allows to save energy costs (Singh *et al*., 2015).

Materials and Methods

The experiment was conducted in closed controlled-environment growth chamber at the Institute of Horticulture, Lithuanian Research Centre for Agriculture and Forestry. The investigation was carried out in 2017–2018 winter season. Day and night temperatures were set at 21/ 17 °C ± 2 °C respectively, the 16 h photoperiod was established. The relative air humidity in the growth chamber was approximately 50 – 60%.

All plants were grown under the same spectral combination of light-emitting diode (LEDs) units at photosynthetic photon flux density (PPFD) levels at 200 and 300 μmol m^{-2} s^{-1} (Table 1). Three days before the harvest, the intensity of LED lighting was increased from 200 to 300 μmol m^{-2} s^{-1} by elevating the intensity of red light (660 nm) or of all spectral components proportionally at 16 h or 24 h photoperiod. The experiment scheme is presented below in Table 1.

All plants were grown in plastic trays (two trays per one treatment) of 28 cells and 70 mL volume of each. Tatsoi (*Brassica rapa* var. *rosularis*) was sown in a peat substrate (Profi 1, Durpeta, Lithuania) (pH 5 – 6). The average amounts of nutrients (mg L^{-1}) in the substrate were: N – 110; P$_2$O$_5$ – 50; K$_2$O – 160 supplemented with microelements Fe, Mn, Cu, B, Mo, and Zn. Electrical conductivity was 0.5 – 0.7 mS cm^{-1}. Three seeds were sown into each cell and watered according to the demand. The period of

experiment was 23 days from sowing (20 + 3 days of increased PPFD).

Non-destructive methods were used to evaluate the light effect of lighting treatments on tatsoi photosynthetic indices. The measurements of gas exchange were performed using a portable closed infrared gas analyser LI-6400XT (LI-COR, Lincoln, USA) with randomly selected, youngest fully expanded leaves on the last day of the treatment. The conditions for this measurement were set at 1000 μmol m^{-2} s^{-1} PPFD, block temperature was 21 °C, CO$_2$ concentration ~400 ± 6 μmol s^{-1} and 60 – 70% relative humidity.

Measurements of chlorophyll fluorescence were performed in closed environment growth chamber and fixed under LED lighting. In addition to this, before chlorophyll fluorescence measurements, all plants were dark adapted (Maxwell & Johnson, 2000) for 40 minutes using black hood. Fluorometer OS5p (Opti-Sciences, USA) was used to measure maximum yield and yield in PSII (quantum of yield).

The maximum quantum of yield can be calculated from equation:

$$Y_m = \frac{F_V}{F_m} \qquad (1)$$

where: *Fv* is variable fluorescence; *Fm* – maximal fluorescence (dark adapted sample)

Quantum of yield in PSII is calculated from equation:

$$Y_{(II)} = \frac{F_m{'}-F}{F_m} \qquad (2)$$

where: *F′m* – maximal fluorescence (light adapted sample)

Chlorophyll, flavanols and nitrogen balance index (NBI) were measured by DUALEX 4 (Dualex

Table 1

The spectral composition and PPFD of LED light treatments

| Light treatment | PPFD, μmol m^{-2} s^{-1} | | | | | | | | | |
| | during the growing | | | | | 3 days before the harvest | | | | |
	B 445 nm	R 640 nm	R 660 nm	FR 731 nm	P/ PPFD	B 445 nm	R 640 nm	R 660 nm	FR 731 nm	P/ PPFD
Control PPFD 200 μmol m^{-2} s^{-1}	20	88	88	4	16/ 200	20	88	88	4	16/200
PPFD 300 μmol m^{-2} s^{-1}	30	132	132	6	16/ 300	30	132	132	6	16/300
All up to PPFD 300 μmol m^{-2} s^{-1}	20	88	88	4	16/ 200	30	132	132	6	16/300
660 nm to PPFD 300 μmol m^{-2} s^{-1}	20	88	88	4	16/ 200	20	88	188	4	16/300
660 nm to PPFD 300 μmol m^{-2} s^{-1} 24h	20	88	88	4	16/ 200	20	88	188	4	24/300

*FR – Far red, B – Blue, R – red, P – photoperiod, PPFD – photosynthetic photon flux density.

Scientific, USA). Leaf reflectance indices: greenness (G) and photochemical reflectance index (PRI) were evaluated by leaf spectrometer CI–710 (CID, USA). Statistical analysis to evaluate significant differences was performed by an analysis of variance (ANOVA), the least significant difference (LSD) test at the $P \leq 0.05$ level. Correlation analysis was conducted by statistical software package STATISTICA 10 (StatSoft, USA).

Results and Discussion

The results using non-destructive methods to evaluate photosynthetic performance and interaction between photosynthetic rates and fluorescence indices in tatsoi (*Brassica rapa* var. *rosularis*) are presented in Tables 2, 3 and 4. According to the data obtained, the photosynthetic parameters of tatsoi grown under PPFD levels at 200 and 300 µmol m^{-2} s^{-1} did not differ significantly (Table 2).

The plants grown under 200 and 300 µmol m^{-2} s^{-1} LED light intensities demonstrated the same total photosynthetic rate (Pn) (12.41 µmol CO_2 m^{-2} s^{-1}). However, it was about 25% higher Pn than in tatsoi grown under the elevated red LED light (660 nm) intensity with total PPFD level at 300 µmol m^{-2} s^{-1}. When the light intensity was increased in the three days pre-harvest stage, photosynthetic rate decreased, and the decrease was more pronounced in treatments where sole red light (660 nm) intensity was elevated. This is associated to decreased stomatal conductance and transpiration rates in red light (660 nm) enriched treatments (strong positive correlation between these indices) (Table 4).

The most pronounced effect on photosynthetic indices was determined in the treatment, where tatsoi in pre-harvest stage was illuminated with increased red light (660 nm) intensity for 24 h per day (Table 2). This resulted in significantly lower stomatal conductance (Gs) (~3.29 times lower than control), intracellular CO_2 (Ci) concentration (~1.1 times lower than control), maximum quantum yield (Ym) (~1.26 times lower than control), quantum yield of PSII (~1.23 times lower than control) and Pn as well (~1.6 times lower than control).

The highest Ci in tatsoi (326.57 µmol CO_2 m^{-2} s^{-1}), grown under all elevated LEDs to PPFD level at 300 µmol m^{-2} s^{-1} three days before the harvest, was determined (not significant). The PPFD level at 300 µmol m^{-2} s^{-1} led to the highest transpiration rate (Tr) as well (Table 2).

Considering gas exchange measurements, PPFD level at 300 PPFD µmol m^{-2} s^{-1} had positive influence on tatsoi growth. Fluorescence measurements showed smaller differences among treatments, but in this case control treatments were performed most efficiently in photosystem II (PSII). The PPFD levels at 200 and 300 µmol m^{-2} s^{-1} showed the highest and reliable signal of resistance to environmental stress and efficient driving photosynthesis. About 25% lower results were measured in the last three treatments. Maximum quantum yield (Ym) decreased gradually (significantly), when all light components were increased until 300 µmol m^{-2} s^{-1} three days before harvesting for 16 or 24 hours photoperiod (Table 2), while PS II only decreased significantly (~1.23 times) at 300 µmol m^{-2} s^{-1} with elevated red light (660 nm) component for 24 hours photoperiod. This could be associated with PS II inactivation and increased energy dissipation (Adams *et al*., 2013). Significant changes in ETR were not observed.

Table 2

The effects of LED light treatments on photosynthetic parameters in tatsoi

Light treatment	Pn/µmol CO_2 m^{-2} s^{-1}	Gs/H_2O mol m^{-2} s^{-1}	Ci/µmol CO_2 mol^{-1}	Tr/mmol H_2O m^{-2} s^{-1}	Ym	Y$_{(II)}$	ETR/µmol e$^-$ m^{-2} s^{-1}
Control PPFD 200 µmol m^{-2} s^{-1}	12.41	0.46	322.95	1.07	0.67	0.69	31.00
PPFD 300 µmol m^{-2} s^{-1}	12.41	0.47	323.01	1.08	0.69	0.70	32.39
All up to PPFD 300 µmol m^{-2} s^{-1}	**10.01**[B]	0.32	326.57	0.90	**0.58**[B]	0.62	37.42
660 nm to PPFD 300 µmol m^{-2} s^{-1}	**6.22**[B]	**0.14**[B]	311.65	**0.51**[B]	**0.59**[B]	0.69	37.94
660 nm to PPFD 300 µmol m^{-2} s^{-1} 24h	**7.76**[B]	**0.14**[B]	**294.91**[B]	**0.54**[B]	**0.53**[B]	**0.56**[B]	28.34
LSD$_{0.05}$=	2.71	0.22	17.92	0.32	0.06	0.07	8.05

*Pn – Photosynthetic rate, Gs – Stomatal conductance, Ci – Intercellular CO_2 concentration, Tr – Transpiration rate, Ym – Maximum quantum yield, Y$_{(II)}$ – Quantum yield of PS II, ETR – Electron transport rate
B – The value is significantly ($P \leq 0.05$) lower than control.

Table 3

The effects of LED light treatments on leaf pigments and optical properties parameters in tatsoi

Light treatment	Chlorophyll index	Flavanols index	Greeness index	NBI	PRI
Control PPFD 200 μmol m^{-2} s^{-1}	37.44	0.81	49.21	1.41	–0.04
PPFD 300 μmol m^{-2} s^{-1}	**32.3^B**	**1.33^A**	**25.36^B**	1.38	**–0.06^B**
All up to PPFD 300 μmol m^{-2} s^{-1}	**28.75^B**	0.98	**32.74^B**	1.44	**–0.05^B**
660 nm to PPFD 300 μmol m^{-2} s^{-1}	38.85	0.94	44.25	1.24	–0.05^B
660 nm to PPFD 300 μmol m^{-2} s^{-1} 24h	33.23	**1.13^A**	**30.62^B**	1.42	–0.04
LSD$_{0.05}$ =	4.67	0.23	11.11	0.20	0.01

*NBI – Nitrogen balance index, PRI – Photochemical reflectance index
A – The value is significantly (P≤0.05) higher than control; B – The value is significantly (P≤0.05) lower than control

Plants grown under increased red light intensity (640 and 660 nm) until 132 and 188 μmol m^{-2} s^{-1} were affected by photoinhibition. Instantaneous photosynthesis and fluorescence parameters resulted in decreased response comparing with lower light intensity – 200 μmol m^{-2} s^{-1} PPFD. Light excess is a restrictive factor for efficient photosynthetic process and have a negative effect on photosynthesis system acclimatisation causing photoinhibition (Powles, 1984). In this case, 200 μmol m^{-2} s^{-1} PPFD was sufficient for efficient photosynthetic process in tatsoi.

The results of non-destructive leaf pigments and optical properties measurement confirm that different lighting conditions even for short three-day pre-harvest treatment have a significant effect on plant performance (Table 3).

Leaf pigments and optical properties analysis in tatsoi (Table 3) showed that light quantity and pre-harvest exposure three days before harvesting had a significant effect on plants. Chlorophyll and greenness indexes decreased (~1.16 and 1.94 times) when PFFD was 300 μmol m^{-2} s^{-1} or ~1.3 and ~1.5 times when all light components were elevated until 300 μmol m^{-2} s^{-1} three days before harvesting. However, flavanols index significantly increased when PPFD was 300 μmol m^{-2} s^{-1} at 16 hours photoperiod or 24 hours with elevated red light (660 nm) comparing with the control treatment. It can be claimed that rapid chlorophyll index degradation is related to flavanol index increase via changes in plants senescence physiology and reflect trends in photosynthetic activity (Mattilla *et al.*, 2018). Increased all light components or just red light (660 nm) intensity at 16 hours photoperiod had a significant effect on PRI reduction. However, the control treatment did not show differences comparing with other treatments. To sum up, it can be useful to apply longer photoperiod in order to promote photoprotective system reactions and xantophyll cycle changes.

Table 4

Correlation among photosynthetic parameters in tatsoi, grown under various LED light treatments

Variable	Pn	Gs	Tr	Ym	Y$_{(II)}$	ETR
Gs	**0.88**					
Tr	**0.98**	**0.83**				
Ym	**0.54**	**0.58**	**0.55**			
Y$_{(II)}$	0.24	**0.32**	**0.29**	0.25		
ETR	-0.09	-0.07	-0.02	-0.5	0.03	

*Pn – Photosynthetic rate, Gs – Stomatal conductance, Tr – Transpiration rate, Ym – Maximum quantum yield, Y$_{(II)}$ – Quantum yield of PS II, ETR – Electron transport rate

The lower chlorophyll index and photochemical reflectance index comparing in tatsoi, cultivated under PPFD 300 µmol m^{-2} s^{-1}, compared to PPFD 200 µmol m^{-2} s^{-1} confirm the obtained trend in photosynthetic rate. It shows that PPFD 200 µmol m^{-2} s^{-1} is sufficient light quantity for efficient photosynthesis and productivity of tatsoi and in economic cultivation system; there is no need to waste energy increasing PPFD to 300 µmol m^{-2} s^{-1}. Increased flavonol index in PPFD 300 µmol m^{-2} s^{-1} treatment and 660 nm to PPFD 300 µmol m^{-2} s^{-1} treatment of 24 h, show the photoprotective reactions of tatsoi antioxidant system. The reduced NBI index in higher PPFD 300 µmol m^{-2} s^{-1} during the cultivation stage and pre-harvest increased light intensity treatments show the excess light effect on the nitrogen assimilation processes.

The obtained results propose that excess light intensity is not efficiently utilized for photosynthetic processes and 200 µmol m^{-2} s^{-1} light intensity for growing period is sufficient for tatsoi cultivation. The pre-harvest treatment with an increased level of LED light also results in reduced photosynthetic parameters. This might be associated to mild photo-stress conditions and tatsoi adaptations to increased light intensity and/or shifted proportions of light spectral quality.

In addition to this experiment, the variability and correlations among all photosynthetic indices showed strong differences between instantaneous photosynthetic intensity and chlorophyll fluorescence values (Table 4). However, only among Pn, Gs and Tr strong positive correlations (r>0.7) were obtained comparing all values. According to the previous studies, these linkages were determined between photosynthesis and chlorophyll fluorescence indexes as well (Flexas *et al*., 2000; Zarco-Tejada *et al*., 2013; Yang *et al*., 2017).

These results agree with the statements of other authors that pre-harvest higher LED light treatments can evoke the response of antioxidant protective system and, therefore, resulted in an increased nutritional value of green vegetables (Samuolienė *et al*., 2012b; Zhou, Liu, & Yang, 2012; Wanlai, Liu, & Qichang, 2013). Samuolienė *et al*., (2009) proposed that the reduction of nitrates and increased ascorbic acid contents could be associated to provoked natural senescence and remobilization of nutrients. Our study showed that elevated light intensity three days before harvesting suppressed main photosynthetic indices in tatsoi, and 200 µmol m^{-2} s^{-1} is sufficient for the cultivation process. Further studies should be performed, seeking to balance the light conditions and strategies for different species and varieties of green leafy vegetables, aiming for increased economic efficiency of lighting, optimal photosynthetic performance of plants and high nutritional value.

Conclusions

A higher intensity of LED lighting of PPFD 300 µmol m^{-2} s^{-1} was not superior for plant photosynthetic performance, according to the measured indices, compared to PPFD 200 µmol m^{-2} s^{-1} light intensity. For efficient photosynthesis, it is enough to have 16 h photoperiod and PPFD 200 µmol m^{-2} s^{-1} light intensity for tatsoi. Plants treated under elevated PPFD can be affected by stress. Increased pre-harvest lighting intensity resulted in suppressed photosynthetic and optical leaf indices in tatsoi. Increased red light intensity of 660 nm three days before the harvesting reduced photosynthetic indices in plants. Tatsoi experienced mild photo stress conditions resulting in adaptive changes: increased flavanols, reduced chlorophyll and PRI.

Acknowledgements

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THE IMPACT OF *FUSARIUM GRAMINEARUM* INFECTION ON DIFFERENT PLANT SEEDS

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Abstract
Healthy seeds are essential for the optimal plant population and yield, but seed-borne pathogens, such as *Fusarium* spp., may reduce seed germination, quality and cause damping-off of the seedlings. *Fusarium graminearum* is a dominant pathogen of cereal crops and can cause significant losses of grain yield and quality. It is important to evaluate the role of alternative inoculum source in crop rotation. The aim of this study was to assess the impact of *F. graminearum* infection on different plant seed germination and seed infestation. The research was conducted at the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, in 2017. Visually healthy seeds of bean (*Vicia faba* L.), pea (*Pisum sativum* L.), lupine (*Lupinus angustifolius* L.), soybean (*Glycine max.* (L.) Merr.), lucerne (*Medicago sativa* L.), white (*Trifolium repens* L.) and red (*Trifolium pratense* L.) clover were inoculated with 10 mL of *F. graminearum* suspension, adjusted to 1×10^6 conidia per mL. Seed infection was counted 2 and 6 days after inoculation (DAI), seed germination energy and reduction rate – after 3 DAI and germination index – 6 DAI. Results showed that all inoculated seeds were covered with typical to *F. graminearum* red-purple mycelium. The results of inoculated seeds with *F. graminearum* showed red-purple mycelium growth on the seeds (infection from 21.25 up to 100%). The results showed that germination energy decreased on pea (2.56%) and lupine (7.79%) seeds. Our results suggest that various plant seeds differently react to *F. graminearum* infection. The highest infection of *F. graminearum* was obtained on pea, lupine seeds and the least on red clover.
Key words: germination, infection, inoculation.

Introduction

One of the important inputs for crop production is seeds. Healthy seeds are essential for the optimal plant population and yield. Numerous diseases are associated with seeds. Diseased seed often looks discoloured or shrunken, but there may be exceptions. Conventionally, the cereal seeds are treated with fungicides regardless of seed health and expected disease. Some of the diseases are controlled by sorting the seeds by size and seed density during seed cleaning. Seed-borne disease cause at least 10% of yield losses. The seed-borne pathogens may reduce seed germination, quality and cause damping-off of the seedlings. Seed-borne diseases are associated with a lack of adequate amount of fungicides to control diseases. The understanding of the seed-borne pathogens may be helpful in reducing losses and improving yields (Borgen, 2005; Leslie & Summerell, 2006; Cram & Fraedrich, 2010; Farrag & Moharam 2012; Yang *et al.*, 2013; Purahong *et al.*, 2014).

Fusarium spp. associated pathogens are important to cereal crops causing significant losses of grain yield and quality. *Fusarium* spp. infected seeds could look healthy but has fungus inside. *Fusarium graminearum* Schw. cause Fusarium head blight (FHB) of small grain cereals. The mycotoxin contamination and yield reduction make FHB primarily cereal disease. There are several *Fusarium* species which cause FHB, but *F. graminearum* is the most frequent species in many cereal-growing regions. The primary host plants *F. graminearum* are wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), rice (*Oryza sativa* L.), oats (*Avena sativa* L.), triticale (x

Triticosecale Wittm.), rye (*Secale cereale* L.), maize (*Zea mays* L.). There are several reports stating that this fungus causes symptoms on some non-graminaceous crops. *Fusarium* spp. also is associated with seed-borne diseases. The infected seed inoculum is a source of Fusarium foot rot (Ali *et al.*, 2005; Leslie & Summerell, 2006; Broders *et al.*, 2007; Burlakoti *et al.*, 2008; Xu *et al.*, 2008; Cram & Fraedrich, 2010; Yang *et al.*, 2013; Mourelos *et al.*, 2014; Purahong *et al.*, 2014). Seed-borne pathogens can be present on seeds without evident signs. Many factors are related to seed-borne diseases (Cram & Fraedrich, 2010). The detection of seed-borne diseases is an important aspect of its management. Therefore, it is important to use healthy seed material to have optimal and good quality yield. The increased spread of *F. graminearum* was recently noticed in Lithuanian cereals (Suproniene *et al.*, 2015). That could lead to an increased inoculum of *F. graminearum* in the primary source of infection – host plant residues remaining in the soil. Therefore, it is important to know the possible influence of this fungus on the other crop rotation plants, which could be susceptible to the pathogen. The aim of this study was to assess the impact of *Fusarium graminearum* infection on different plant seed germination and seed infestation.

Materials and Methods

The research was carried out at the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, in Central Lithuania (54º53'32.4 N 23º50'16.2 E) in 2017. The infection of *Fusarium graminearum* was assessed on different legume seeds:

bean (*Vicia faba* L.), pea (*Pisum sativum* L.), lupine (*Lupinus angustifolius* L.), soybean (*Glycine max.* (L.) Merr.), lucerne (*Medicago sativa* L.), white (*Trifolium repens* L.) and red (*Trifolium pratense* L.) clover.

F. graminearum 4vkv4 was isolated from spring wheat (FHB-infected head) in 2016. The isolate was identified morphologically as *F. graminearum* and verified by species-specific PCR, using the protocol and primer pairs suggested by Demeke *et al.* (2005). Before the experiments, *F. graminearum* isolates were cultured on Potato dextrose agar (PDA) at 25 °C for 7 days in the dark. Then isolate was transferred onto Spezieller Nährstoffarmer Agar (SNA) (Nirenberg, 1976), incubated at 25 ± 2 °C for 14 days, until the formation of a macroconidial mass.

The seed inoculation procedure was made based on a modified Petri-dish test suggested by Purahong *et al.* (2012) with some modifications. Each tested plant seed was inoculated with *F. graminearum* 4vkv4 isolate, in four replicates. One replicate consisted of 20 visually healthy seeds, inoculated with 10 ml of *F. graminearum* suspension. The *F. graminearum* macroconidial concentration was adjusted to 1×10^6 conidia per ml. All tested plant seeds before inoculation were surface sterilised in 2% sodium hypochlorite for 3 min and then rinsed 6 times with sterile distilled water. The control treatment was soaked only in sterile distilled water. Various plant seeds were laid out in 15 cm diameter glass Petri plates with sterile double-layer filter paper. To increase relative humidity, each replicate of Petri was put in a clear polyethylene bag and then incubated at 22 °C in the dark.

The infection of different plant seeds was counted 2 and 6 days after inoculation (DAI), germination energy after 3 DAI and germination index – 6 DAI. Seed germination was evaluated according to Aswathaiah *et al.* (1993). Germination reduction rate was calculated after 3 DAI according to Purahong *et al.* (2012). Germination index was calculated after 6 DAI according to Opio & Photchanachai (2016). Germination index was calculated after the seeds with normal germination were classified and recorded. The seeds were considered germinated when they had root and shoot. *F. graminearum* infected plant seeds were identified visually and/or by mycelium completely covering the seeds (Figure 1). The experiment was repeated. After the experiment, re-isolation of mycelium was done and morphologically identified.

Data analysis was performed using ANOVA, from the package SELEKCIJA. Duncan's multiple range test was used to determine the significant difference between different treatments (P<0.05) (Raudonius, 2017).

Results and Discussion

This study was carried out to evaluate the impact of *F. graminearum* on various plant seed germinations and infestations. The data was obtained by *in vitro* tests. In general, *F. graminearum* is an important pathogen causing Fusarium head blight (FHB) of small grain cereals. However, it causes diseases on other plants (Purahong *et al.*, 2012; Barros *et al.*, 2014; Suproniene *et al.*, 2016). Broders *et al.* (2007)

Bean   Pea   White clover

Figure 1. Symptoms on seeds inoculated with *F. graminearum* (4vkv4) compared with control (water) at 4 DAI. Figure shows inoculated bean, pea and white clover seeds. Each seed is presented on four (upper) inoculated and two (bottom) control plates.

Table 1

The germination of various plant seeds inoculated with *F. graminearum* 4vkv4

Seeds	Energy, %		Reduction, %	Index
	3 DAI		3 DAI	6 DAI
Bean	36	b	39	0.2
Lupine	8	ab	77	0.0
Soybean	85	c	78	1.3
Pea	3	a	78	0.0
Lucerne	94	cde	76	5.5
White clover	96	e	79	2.8
Red clover	90	cde	79	5.5

Note. Values with different letters in the columns are significantly different according to Duncan's test at P<0.05.

found out that *F. graminearum* is an important seed and seedling pathogen of maize and soybean.

The seeds were inoculated with a macroconidial suspension of *F. graminearum* to test for the probability to cause infection. The symptoms of *F. graminearum* infection showed up after 2 DAI and the germination index of bean, pea, lupine, soybean, lucerne, white and red clover seeds scored after 6 DAI (Figure 1). In an examination of inoculated seeds with *F. graminearum,* red-purple mycelium growth was detected on the seeds (infection from 21.25 up to 100%). The results show that the percent of seed infection and seedling germination depends on the plant species (Figure 2). Broders *et al.* (2007) evaluated 105 isolates of *F. graminearum* and found out the moderate and high level of pathogenicity on both maize and soybean.

The seed germination energy, after inoculation of different plant seeds with *F. graminearum,* showed variation between plant species (Table 1). The germination energy in inoculated seeds varied

from 2.56% in pea to 96.25% in white clover. The results showed that germination energy decreased on pea (2.56%) and lupine (7.79%) seeds. Very low germination energy shows high susceptibility to infection. Our results of nearly all tested seeds showed that germination reduction was observed by almost 80%. This study showed that germination index varied within different plant seeds. Purahong *et al.* (2012) found out that germinated wheat seeds after 2 DAI and healthy seedling inoculated with *F. graminearum* decreased compared with control. Farrag & Moharam (2012) reported that *F. oxysporum* and *F. solani* inoculated cucumber (*Cucumis sativus* L.) seed germination decreased compared with control.

The results of *F. graminearum* contamination on various plant seeds are provided in Figure 2. The symptoms of *F. graminearum* infection on seeds were observed on 2 and 6 DAI. The inoculated seeds with *F. graminearum* were accompanied by characteristic red–purple mycelium completely covering different plant seeds (Figure 1). The highest infection of *F.*
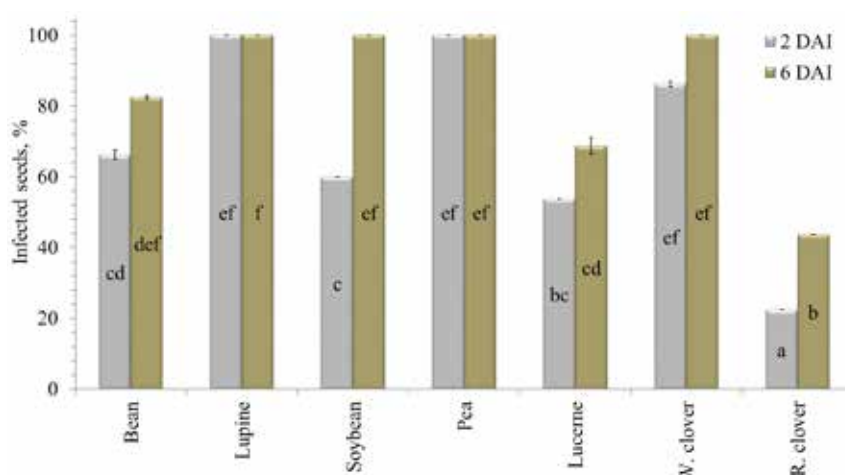

Figure 2. The infection of various seeds inoculated with *F. graminearum* isolate 4vkv4. Values with different letters in the columns are significantly different according to Duncan's test at P<0.05.

graminearum was obtained on pea and lupine seeds (100%). It was established that white clover (86%) seeds after 2 DAI were infected similarly as lupine and pea. Moderate infection after 2 DAI was on lucerne (53%), soybean (60%) and bean (66%). The lowest infection was seen on red clover at 2 DAI – 22%, as well as 6 DAI – 43%. This study shows that after 6 DAI a similar tendency of infection was observed as after 2 DAI. The results show that the highest susceptibility to *F. graminearum* had pea and lupine seeds and the least red clover. Purahong *et al.* (2012) found out different aggressiveness of *F. graminearum* isolates on wheat seeds. Farrag & Moharam (2012) reported dominance of *Fusarium* spp. (32%) pathogens followed by *Rhizoctonia* spp. (12%). This study demonstrated the *F. graminearum* capability to infect various plant seeds. Our data indicate that red clover is more suitable for cereal crop rotation, because of less susceptibility to *F. graminearum.* On the other hand, peas and lupines grown in cereal crop rotation could serve as an alternative host and source of inoculum, though leaving *F. graminearum* infected residues in the field. Therefore, further studies and monitoring are still required.

Conclusions

In our case, bean, pea, lupine, soybean, lucerne, white and red clover seeds showed susceptibility to *F. graminearum*. The results obtained in this study suggest that various seeds differently react to *F. graminearum* infection. As present research shows, red clover is less susceptible to *F. graminearum.* It was found that the highest susceptibility to *F. graminearum* had pea and lupine seeds. However, further studies and monitoring is still required.

Acknowledgements

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ANALYSIS OF MEASUREMENTS OF LATVIAN WARMBLOOD AND LATVIAN HEAVY WARMBLOOD SIRES

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Abstract
The objective of the study was to analyze measurements of the sires used in Latvian Warmblood (LWB) and Latvian Heavy Warmblood (LHWB) breeding programs in the period 2003 – 2017, two major horse populations in Latvia included in one studbook. The Latvian Warmblood has an open studbook for breeding sport horses, whereas the Latvian Heavy Warmblood is a partly closed studbook. Measuring information for all sires with at least one foal born (n=834) in the respective time period was retrieved from the Latvian horse database, with 673 stallions measured at least once. The data consisted of direct measurements – height at withers, chest circumference and cannon bone circumference – and two calculated indices – massivity index and boniness index. Average values of adult stallions were analyzed in four groups – LWB, LHWB, 'other warmbloods' and refining breeds, with LWB and 'other warmbloods' showing similar average values. Sires were divided by use in breeding into 3-year periods to observe a possible change in the breeding objective and stallion choice, however, no significant differences were found in LWB or LHWB. Average measurements of stallions used in the LWB breeding program (different breeds) were 168.6 ± 4.3 cm for height at withers, 194.4 ± 6.6 cm for chest circumference, 21.8 ± 1.0 cm for cannon bone circumference, massivity index 115.5 ± 3.1, boniness index 13.0 ± 0.5. Average measurements of stallions used in the LHWB breeding program (only LHWB stallions) were 167.6 ± 4.6 cm, 201.4 ± 7.3 cm, 23.7 ± 1.0 cm, respectively, and massivity index 120.0 ± 5.0, boniness index 14.1 ± 0.6. Significant differences between LWB and LHWB stallions were observed in all parameters, except height at withers, and between measurements at the age of 2, 3, 4 years and adult (5 and more years).
Key words: horse, body measurements, body indices, breed development.

Introduction

The Latvian Warmblood is a horse breed reared in the territory of Latvia. The Studbook includes two sections – the Latvian Warmblood (LWB, also called sport type) and the Latvian Heavy Warmblood (LHWB, also called carriage type). The LWB is a warmblood horse suitable for classic equestrian sports and is an open studbook. The Latvian Heavy Warmblood belongs to heavy warmblood breeds and is a partly closed studbook – influx of only a few other breeds is allowed and in a small percentage. The breeding of both LWB and LHWB is regulated by state breeding programs. The choice of stallion for mating is made by the mare owner solely and based on his or her preference, knowledge and financial resources (Orbidāne & Jonkus, 2016). Stallion approvals are organized by horse breeding organisations, but it is not forbidden to use non-approved stallions (Latvijas zirgu..., 2016). The use of LHWB stallions for breeding of LWB is permitted without restrictions, and several LWB stallions have been approved for use in LHWB if they conformed to several criteria. Artificial insemination has been barely available until 2016, therefore the influx of stallions stationed abroad is small, and Latvia-based stallions have been used by natural covering. The number of offspring per stallion is low and population is inhomogeneous, which is also a problem in other small studbooks with undeveloped artificial insemination like the Czech Warmblood (Makovská Krčová, 2012) and the Polish halfbred horse (Lewczuk, 2005).

Internationalization and the pursuit of current trends in global sport horse breeding are increasing in LWB because of availability of information and artificial insemination, thus making it more similar to other sport horse breeds/ studbooks. The same processes occur elsewhere, as described in the Swedish Warmblood, where 80% of mares are covered by foreign stallions or their semen (Thorén Hellsten *et al.*, 2008), and other European countries (Koenen, Aldridge, & Philipsson, 2004).

In a study concerning changes of measurements and indices in LWB and LHWB broodmares born in the years 1988 – 2013 (Veidemane & Jonkus, 2018), it was concluded that measurements of LWB broodmares significantly differ between years, with a tendency for younger mares to be of lighter sport horse type than older mares. The most significant parameters were cannon bone circumference and boniness index. Measurements of LHWB broodmares showed no influene of birth year on these parameters. Average heights at withers in LWB broodmares were 166.9 ± 4.1 cm and 166.1 ± 4.3 cm in LHWB.

Height at withers is one of the main criteria used by the potential horse purchasers, with the most desired value being at least 167 cm at withers for warmbloods in Germany (Gille & Spiller, 2010).

The objective of the study was to analyze measurements of sires used in LWB and LHWB breeding programs in 2003 – 2017.

Materials and Methods

Data about LWB and LHWB registered foals born in the years 2002–2017 (n=6721) and their respective sires (n=834) were retrieved from the Agricultural Data

Centre and the Latvian Horse Breeders Association's database. Only sires of breeds allowed for LWB and LHWB with ancestors known in 4 generations have been recorded.

For each stallion having at least one registered offspring during this time period, information about measuring was retrieved from the database of the Latvian Horse Breeders Association. Data included three direct measurements – height at withers, chest circumference and cannon bone circumference. From the direct measurements two indices were calculated, using formulas (1) and (2).

$$Boniness\ index = \frac{cannon\ bone\ circumference}{height\ at\ withers} \times 100 \quad (1)$$

$$Massivity\ index = \frac{chest\ circumference}{height\ at\ withers} \times 100 \quad (2)$$

Two hundred twenty five stallions were measured as adults (5 years old or older), while additional 50 stallions had records of height at withers as adult. 299 stallions were measured as two-year olds, 219 as three-year olds and 103 as four-year olds. One stallion was measured four times, 20 – three times, 180 – twice, 468 – once, but 165 stallions did not have any measurement record at all. As most stallions are approved as 3-year-olds (until 2015 as 2-year-olds), there are inssufficient measurements for older horses. Imported adult stallions constituted 34% of the adult stallions group.

An analysis of average values of stallions belonging to different breed groups at adult age was carried out. Stallions were arranged in 4 groups: LWB, LHWB, other warmblood breeds and refining breeds. Other warmblood breed group consisted of 23 Holsteiners, 10 Oldenburgers, 8 Hanoverians, 7 Westphalians, 7 Danish Warmbloods, 7 Dutch Warmbloods (KWPN), 2 Swedish Warmbloods, 1 Estonian Sport Horse, 1 Selle Francais, and 1 Rheinlander. The Refining breeds group consisted of 17 Trakehners, 9 Thoroughbreds and 3 Arabians.

The sires of registered LWB and LHWB foals born in the years 2003 – 2017 were grouped in periods of 3 years – 2003 – 2005, 2006 – 2008, 2009 – 2011, 2012 – 2014 and 2015 – 2017 – regardless of the exact number of foals. The data consisted of 165 full records with 50 more records of height at withers. Not all sires of warmblood foals born in Latvia in the respective year were included in the study, as some foals are registered with the Oldenburg or Zangersheide studbooks, or due to the sire's pedigree deficiencies (less than 4 generations, influx of non-allowed breeds). A measurement analysis for sires used in each 3-year period was conducted to calculate mean values and standard deviation and compared between 3-year periods to determine a possible change in choice of stallion in making a modern sport type horse.

The statistical analysis of average values of LWB and LHWB stallion measurements at the age of 2, 3, 4 and adult (age 5 and older) was carried out and compared. We examined the influence on measurements of two indepedents factors – breed (LWB or LHWB) and age at measuring – with a two-way analysis of variance.

The statistycal analysis was performed on 'R' and Microsoft Excel. For the analysis of impact of one influencing factor one-way ANOVA was used, but for the impact of two influencing factors we used two-way ANOVA.

Results and Discussion

The data analysis showed a difference between measurements in four breed groups (Table 1). LWB stallions and 'other warmblood breeds' (imported) stallions were similar in both direct measurements and body indices. Both groups are closely related and have the same breeding objective – a horse for the classic equestrian sports of showjumping, dressage and eventing. Higher variability in the LWB group can be explained by different selection – it includes non-approved stallions (too small or too refined/heavy to get the breeding approval), while most other warmblood breed stallions were selected, bought and imported for breeding at an adult age. It corresponds to the data of the Polish warmblood breeds, where offspring of the historic Polish warmblood breed Wielkopolski and Malopolski stallions showed greater variability in measurements than offspring of sport breed stallions (Lewczuk, 2005).

The LHWB has a significantly higher chest circumference, cannon bone circumference, massivity index and boniness index than other group stallions, but smaller height at withers than the LWB and other warmbloods. Height at withers is nevertheless higher than in other breeds belonging to the heavy warmblood group – Schweres Warmblut in Germany (minimum requirement 158 cm) (Zuchtprogramme..., 2009) and the Groningen horse in Netherlands, where the minimum requirement for a stallion is 158 cm at the age of 3 and 160 cm at the age of 4 (Keuringsreglement, 2014). When compared with the Silesian breed, LHWB has a higher height at withers (167.0 cm in LHWB versus 162.1 cm in the Silesian), a bigger chest circumference (201.2 cm versus 199.2 cm), a bigger cannon bone circumference (23.7 cm versus 23.2 cm), but smaller massivity index (120.5 versus 122.9) and boniness index (14.2 versus 14.3) (Walkowicz et al., 2013), which characterizes the LHWB as a taller heavy warmblood horse with some sport horse features. The fourth group, refining breeds, has lower average values for measurements and indices. Higher variability can be explained by the fact that several breeds were included in the group,

The average measurements of sires belonging to different breed groups

Breed groups	N	Height at withers		Chest circumference		Cannon bone circumference		Massivity index		Boniness index	
		cm	V, %	cm	V, %	cm	V, %	index	V, %	index	V, %
LWB	68	169.7 ± 3.6[c]	2.1	195.8 ± 6.1[b]	3.1	22.3 ± 0.9[b]	4.1	115.4 ± 3.3[a]	2.9	13.1 ± 0.5[b]	3.7
LHWB	59	167.0 ± 4.5[b]	2.7	201.2 ± 9.2[c]	4.5	23.7 ± 1.2[c]	4.9	120.5 ± 5.4[b]	4.5	14.2 ± 0.6[c]	4.3
Other warmblood breeds	68*	169.1 ± 3.0[c]	1.7	195.5 ± 5.2[b]	2.7	21.9 ± 0.6[b]	2.9	115.7 ± 2.9[a]	2.5	13.0 ± 0.4[b]	3.0
Refining breeds	29	164.3 ± 7.2[a]	4.3	188.9 ± 7.7[a]	4.1	20.6 ± 1.2[a]	5.9	115.0 ± 3.3[a]	2.9	12.6 ± 0.4[a]	3.3

* Height at withers, n=118
[a, b, c] – significant differences have been observed between breed groups, p<0.05.

with the Arabians being lower at the withers than the Trakehners and the Thoroughbreds.

An analyis of measurements of stallions used in each 3-year period was carried out to evaluate the mare owner's choice of stallions in the LWB and the LHWB. No significant differences between periods were observed (Table 2). The average height at the withers for breeding stallion in the LWB is 168.6 ± 4.3 cm, which coincides with studies in different sport warmblood breeds with the same origin as the LWB (Lewczuk, 2005; Catalano *et al.*, 2016). The average chest circumference was 194.4 ± 6.6 cm and the average cannon bone circumference was 21.8 ± 1.0 cm. However, there is a deficiency of information about current average measurements in many related sport horse breeds (Bene *et al.*, 2015), with most of it coming from Eastern and Central European small studbooks.

Although no signs of breeding progress or change of breeding objective by use of different types of stallion can be observed, these aims could be reached also by a change in preferences for broodmares. A gradual refinement of the LWB mare type was observed in our previous study (Veidemane & Jonkus, 2018), with younger mares having significantly lower average values for cannon bone circumference and boniness index. Furthermore, the time period used in this study (16 years) is probably too short for revealing a change in the breeding objective, even if this study concerns the actual use of stallions, not its results. The generation interval for warmblood sport horses is estimated to be longer than 10 years – 12.0 years for males, 11.5 for females in the Selle Francais (Dubois & Ricard, 2007), 11.1 years for males, 10.3 years for females in the Swedish Warmblood (Viklund, 2010), 10 ± 0.06 in Trakehner (Teegen, Edel, & Thaller, 2009).

No significant difference was found in measurements of LHWB sires used in the years 2003 – 2017 (Table 3). Average values have been 167.6 ± 4.6 cm for height at the withers, 201.4 ± 7.3 cm for chest circumference and 23.7 ± 1.0 cm for cannon bone circumference. These measurements make the LHWB potentially unique among other horse breeds as being the tallest from the heavy warmblood breed group, with the Alt-Oldenburger being the most similar

Comparison of measurements of sires used in 3-year periods in LWB breeding program

Period	Sires, n*	Sires, n**	Height at withers, cm	Chest circumference, cm	Cannon bone circumference, cm	Massivity index	Boniness index
2003-2005	87	233	168.2 ± 4.9	195.0 ± 6.9	21.7 ± 1.0	116.0 ± 3.3	12.9 ± 0.5
2006-2008	76	267	168.2 ± 5.3	194.4 ± 7.2	21.7 ± 1.2	115.8 ± 3.9	12.9 ± 0.4
2009-2011	72	266	168.6 ± 4.6	194.1 ± 6.5	21.7 ± 1.0	115.2 ± 3.2	12.9 ± 0.5
2012-2014	64	233	168.5 ± 5.6	192.9 ± 7.2	21.7 ± 1.2	114.6 ± 3.2	12.9 ± 0.5
2015-2017	43	189	169.2 ± 3.1	194.7 ± 4.8	21.9 ± 0.7	114.8 ± 2.7	12.9 ± 0.4
Average	165	707	168.6 ± 4.3	194.4 ± 6.6	21.8 ± 1.0	115.5 ± 3.1	13.0 ± 0.5

* Number of stallions with at least one foal in a 3-year period and adult measurement record.
** Total number of stallions with at least one foal in a 3-year period.

Comparison of measurements of sires used in 3-year periods in LHWB breeding program

Period	Sires, n*	Sires, n**	Height at withers, cm	Chest circumference, cm	Cannon bone circumference, cm	Massivity index	Boniness index
2003-2005	31	43	167.2 ± 4.9	201.3 ± 8.1	23.6 ± 1.3	119.9 ± 6.3	14.1 ± 0.7
2006-2008	42	63	167.6 ± 4.3	201.8 ± 7.1	23.7 ± 1.2	120.4 ± 4.6	14.2 ± 0.7
2009-2011	41	63	167.9 ± 4.5	201.0 ± 6.9	23.6 ± 1.0	119.8 ± 4.8	14.1 ± 0.6
2012-2015	31	45	168.8 ± 4.8	201.5 ± 6.2	23.7 ± 1.1	119.5 ± 4.1	14.0 ± 0.7
2015-2017	28	44	168.9 ± 4.6	201.1 ± 7.2	23.6 ± 1.1	119.1 ± 4.2	14.0 ± 0.6
Average	69	126	167.6 ± 4.6	201.4 ± 7.3	23.7 ± 1.0	120.0 ± 5.0	14.1 ± 0.6

* Number of stallions with at least one foal in a 3-year period and adult measurement record.
** Total number of stallions with at least one foal in a 3-year period.

in stallion measurement requirements (Übernahme des Orginal..., s.a).

A comparison with the results of the LWB and the LHWB mare measurement analysis (Veidemane & Jonkus, 2018), reveals clear sexual dimorphism, with mares having lower average height at the withers and cannon bone circumference, but a higher average value ofchest circumference. This difference has a secondary effect on both indices, with massivity index being higher in mares than stallions, but the boniness index being higher in stallions than in mares. Sexual dimorphism is concluded also by other studies, with mares being lower at the withers and exhibiting a smaller cannon bone circumference (Alagic *et al*., 2002; Kapron *et al.*, 2013).

The analysis of LWB and LHWB stallions was carried out for stallions aged 2, 3 and 4 years, with the adult group including all stallions measured at least 5 years old (Table 4). Significant differences between measurements of LWB and LHWB sires were observed in chest circumference, cannon bone circumference, massivity index and boniness index. The height at

the withers at different ages is similar in LWB and LHWB sires. The only peculiarity is in the adult horse group, as this measurement for LHWB is lower than in 4-year old LHWB horses. This could be explained by the influx of old stallions after the beginning of the preservation of the LHWB as a genetic resource in 2004. These stallions were first measured only as adults (Orbidāne *et al*., 2014). Significant differences were found between measurements and indices at different ages in both LWB and LHWB.

Conclusions

Comparison of measurements of adult stallions among Latvian Warmblood, Latvian Heavy Warmblood, other allowed warmblood breeds and refining breeds revealed that the Latvian Warmblood is similar in parameters to other warmblood breeds, but measurements of Latvian Heavy Warmblood and refining breed stallions were significantly different.

Possible signs of a change in the breeding objective and stallion choice were not reflected in the body measurements and indices of interest. Average values

Measurements of Latvian Warmblood and Latvian Heavy Warmblood stallions at different ages

Age, years	Sires by group	n	Height at withers, cm	Chest circumference, cm	Cannon bone circumference, cm	Massivity index	Boniness index
2	LWB	228	162.8 ± 4.5[a]	184.8 ± 7.4[Aa]	21.4 ± 0.9[Aa]	113.5 ± 3.5[Aa]	13.1 ± 0.5[Aa]
	LHWB	32	161.8 ± 3.5[a]	184.0 ± 7.9[Ba]	22.1 ± 1.0[Ba]	114.3 ± 4.4[Ba]	13.7 ± 0.5[Ba]
3	LWB	136	166.6 ± 4.0[b]	190.4 ± 6.4[Ab]	21.7 ± 0.9[Ab]	114.3 ± 3.0[Ab]	13.0 ± 0.4[Aa]
	LHWB	33	166.3 ± 3.1[b]	195.1 ± 7.2[Bb]	22.9 ± 0.8[Bb]	117.3 ± 3.3[Bb]	13.8 ± 0.5[Ba]
4	LWB	63	168.3 ± 3.7[c]	193.8 ± 5.5[Ac]	22.0 ± 0.8[Ab]	115.2 ± 3.1[Ab]	13.1 ± 0.4[Aa]
	LHWB	13	168.3 ± 4.4[c]	200.0 ± 4.6[Bc]	23.5 ± 0.6[Bb]	118.9 ± 2.4[Bb]	14.0 ± 0.4[Ba]
Adult	LWB	68	169.7 ± 3.6[d]	195.8 ± 6.1[Ad]	22.3 ± 0.9[Ac]	115.4 ± 3.3[Ac]	13.1 ± 0.5[Ab]
	LHWB	60	167.0 ± 4.5[d]	201.2 ± 9.1[Bd]	23.7 ± 1.1[Bc]	120.6 ± 5.4[Bc]	14.2 ± 0.6[Bb]

[A, B] – significant differences have been observed between breed types, $p < 0.05$.
[a,b, c, d] – significant differences have been observed between measuring age, $p < 0.05$.

of measurements of sires were similar in the period 2003 – 2017 and coincide with the recommendations in the breeding program.

The data on measurements in adult stallions is insufficient, many of them are entered in Studbook measured as 2- and 3-year-old horses. The recommendation is to measure breeding stallion repeatedly until at least 5 years old to obtain adult horse measurements for Studbook entry.

Further studies on growth dynamics in Latvian Warmblood and Latvian Heavy Warmblood should be done to determine the age of maturing in this breed.

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THE RUMEN BACTERIAL COMMUNITY OF *REINDEER* IN DIFFERENT AGE PERIODS FROM RUSSIAN ARCTIC REGIONS

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Abstract
Rangifer tarandus (reindeer) – is actively bred in the northern regions of different countries. Therefore, an urgent task is to deepen information about the features of reindeer adaptations. Rumen symbiotic microorganisms play an important role in the life of *Rangifer tarandus*, allowing animals to efficiently use scarce nutrient resources of the tundra and forest-tundra. The microbial community of the reindeer rumen, as well as its age-related changes, are the least studied compared to other ruminants. The comparative analysis results of rumen bacterial community composition of calf (4 months), young animals (1–2 years) and adults (3–6 years) *Rangifer tarandus* of the Russian Arctic are presented for the first time. The reindeer ruminal bacterial community composition was analyzed in the laboratory of the 'BIOTROF+' Ltd by T-RFLP method. In the ontogenesis, significant changes in the microorganism representation were noticed, the greatest of which was noted in microorganism involved in carbohydrate fermentation. The content of cellulolytic *Clostridia* and the acid-utilizing species of the *Negativicutes* (P<0.05) decreased with age, but bacteria with the amylo- and cellulosolytic properties of the phylum *Bacteroidetes* increased (P<0.05). A wide range of microorganisms which traditionally belong to the pathogens of various animals and humans diseases was revealed. With age, a tendency to increase the number of pathogens, including the bacteria of the families *Campylobacteraceae*, *Burkholderiaceae*, phylum *Fusobacteria*, and the genus *Staphylococcus* was noticed. The greatest percent of opportunistic microorganisms, including phylum *Actinobacteria* and the family *Enterobacteriaceae*, were detected in young animals.
Key words: reindeer, *Rangifer tarandus*, rumen bacterial community, T-RFLP-analysis, ontogeny, Russian Arctic regions.

Introduction

Providing the population of the Arctic regions with food is connected with reindeer (*Rangifer tarandus)* husbandry. The reindeer is a unique species of the animal, which as a result of expanding its habitat has acquired specific adaptations for life in the North. These are the only animals that can effectively use for nutrition meager plant resources of vast expanses of tundra, forest-tundra, northern taiga. So, for example, the share of lichen (*Cladonia, Nephroma*) carbohydrates assimilated by reindeer can reach 90% (Hungate, 1966).

Assimilation of plant fibers in reindeer, as in the rest of ruminant animals, is carried out by enzymes synthesized by rumen symbiotic microorganisms (Church, 2006). Among other representatives of the ruminant family *Bovidae*, the reindeer *Rangifer tarandus* are the least studied. The question of age-related changes in the microbial community of the reindeer scar is barely illuminated, although it is of considerable interest in connection with the study of adaptations of their organism to the unfavorable conditions of habitat and nutrition.

The most informative for the study of rumen microbiota are methods aimed at studying the structure of the community as a whole, for example, NGS-sequencing and T-RFLP-analysis. These methods allow to detect and determine the content of low-level microorganisms in the rumen community, as demonstrated in the studies on cattle (*Bos taurus taurus*) (Jami & Mizrahi, 2012; Veneman *et al*., 2015), sheep (*Ovis aries*) (de la Fuente e*t al.*, 2014; Snelling *et al*., 2014), deer (*Rangifer tarandus tarandus*) (Salgado-Flores *et al.*, 2016), and goats (*Capra aegagrus hircus*) (Han *et al.*, 2015; Wang *et al.*, 2016).

Previously, using T-RFLP analysis, we conducted detailed studies of age-related changes in microbiota in cattle rumen, which demonstrated the development of the microbial community, coupled with the growth of calves and changes in their nutritional diet (Laptev *et al*., 2016).

According to modern ideas obtained on the basis of molecular genetic studies, it has been established that the total diversity of symbiotic microorganisms in the rumen of ruminant animals can reach several thousand species, including bacteria, fungi, archaea, protozoa, most of which are strictly anaerobic, uncultivated and unidentifiable species (Hungate, 1966; Tarakanov, 2002).

In this study, for the first time on the basis of molecular genetic analysis, we studied the age-related changes in the bacterial community of the reindeer rumen of the Russian Arctic. The aim of the study was to compare the taxonomic composition of bacteria present in the rumen of calves, young and adult *Rangifer tarandus*.

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THE RUMEN BACTERIAL COMMUNITY OF
REINDEER IN DIFFERENT AGE PERIODS
FROM RUSSIAN ARCTIC REGIONS

Materials and Methods

The objects of the study were calves (4 months old), young animals (1–2 years old) and adults (3–6 years) of reindeer *Rangifer tarandus* of the Nenets breed. Samples of the contents of the rumen were selected in the summer-autumn period in 2017 from three animals from each age group in the Yamal-Nenets Autonomous Okrug (Harp, forest-tundra natural-climatic zone). On the average, the summer pasture ration of reindeer consisted of lichens (*Cladonia, Nephroma*) and plants (*Betula nana, Betula pendula, Salix polaris, Salix borealis, Vaccinium uliginosum* and others).

The composition of the bacterial community of the reindeer rumen was analyzed by T-RFLP (Terminal restriction fragment length polymorphism) (Laptev *et al.*, 2016).

The total DNA from the samples was isolated using the Genomic DNA Purification Kit (Fermentas, Inc., Lithuania) according to the manufacturer's recommendations. PCR amplification was performed on a Verity DNA amplifier (Life Technologies, Inc., USA) using eubacterial primers 63F (CAGGCCTAACACATGCAAGTC) labeled at the 5' end WellRed D4 fluorophore (Beckman Coulter, USA) D4 WellRed) and 1492R (TACGGHTACCTTGTTACGACTT), which allow the fragment of the 16S rRNA gene to be amplified at positions 63 to 1492 at 95 °C for 3 min (1 cycle);

Table 1

Ratio of bacterial taxa in the content of reindeer rumen (Yamalo-Nenets Autonomous District)

Microorganisms	Group of animals		
	Calf (4 months)	Young (1–2 years)	Adults (3–6 years)
Amount of phylotypes	91.50 ± 5.25	109.50 ± 4.15*	163.00 ± 7.20**
The proportion of the taxon, %			
Unclassified phylotypes	12.38 ± 0.57	28.33 ± 1.12*	13.77 ± 0.95**
Phylum *Actinobacteria*	8.89 ± 0.64	12.20 ± 0.52*	7.91 ± 0.30**
genus *Bifidobacterium*	0.26 ± 0.01	1.09 ± 0.06*	0.21 ± 0.02**
others	8.63 ± 0.35	11.11 ± 0.36*	7.70 ± 0.21**
Phylum *Bacteroidetes*	10.12 ± 0.42	18.32 ± 0.84*	13.45 ± 0.64**
Phylum *Proteobacteria*	7.11 ± 0.34	4.34 ± 0.21*	13.49 ± 0.34**
family *Enterobacteriaceae*	0.31 ± 0.02	1.83 ± 0.09*	1.00 ± 0.04**
family *Campylobacteriaceae*	5.99 ± 0.36	1.30 ± 0.05*	9.69 ± 0.35**
family *Pseudomonadaceae*	0.71 ± 0.05	0.32 ± 0.05*	0.48 ± 0.02
family *Burkholderiaceae*	0.11 ± 0.02	0.89 ± 0.04*	2.32 ± 0.08**
Phylum *Fusobacteria*	0.78 ± 0.25	0.18 ± 0.01*	1.65 ± 0.05**
Phylum *Cyanobacteria*	–	0.70 ± 0.03	0.75 ± 0.02
Phylum *Acidobacteria*	–	–	0.33 ± 0.01
Phylum *Firmicutes*	60.74 ± 2.14	35.93 ± 1.63*	48.65 ± 1.96**
class *Clostridia*	39.03 ± 1.98	15.12 ± 0.65*	26.86 ± 1.21**
family *Thermoanaerobacteraceae*	0.16 ± 0.02	0.24 ± 0.01	0.12 ± 0.01
family *Lachnospiraceae*	6.12 ± 0.22	2.30 ± 0.10*	2.72 ± 0.35
family *Eubacteriaceae*	21.04 ± 1.02	9.47 ± 0.34*	15.34 ± 0.48**
family *Ruminococcaceae*	–***	0.19 ± 0.01	–
family *Clostridiaceae*	11.61 ± 0.25	2.61 ± 0.20*	8.36 ± 0.38**
genus *Peptococcus*	0.11 ± 0.02	0.31 ± 0.02*	0.32 ± 0.01
genus *Lactobacillus*	0.40 ± 0.12	2.66 ± 0.12*	1.12 ± 0.06**
genus *Bacillus*	2.39 ± 0.19	4.37 ± 0.25*	5.03 ± 0.22
genus *Staphylococcus*	–	0.10 ± 0.01	0.31 ± 0.02**
class *Negativicutes*	18.92 ± 2.20	13.68 ± 0.54*	15.33 ± 0.63

* P<0.05 – differences between age groups, calves / young.
** P<0.05 – differences between age groups, young / adult.
*** – below the limit of reliable determination by the T-RFLP method.

THE RUMEN BACTERIAL COMMUNITY OF
REINDEER IN DIFFERENT AGE PERIODS
FROM RUSSIAN ARCTIC REGIONS

Larisa Ilina, Valentina Filippova,
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95 °C – 30 s, 55 °C – 40 s, 72 °C – 60 s (35 cycles), 72 °C – 5 min.

The concentration of total DNA in the solution was determined using a Qubit fluorometer (Invitrogen, Inc., USA) using 'Qubit dsDNA BR Assay Kit' (Invitrogen, Inc., USA), as recommended by the manufacturer.

The fluorescently labeled amplicones of the 16S rRNA gene were purified by a standard procedure (Maniatis *et al*., 1984). The restriction of 30 – 50 ng DNA was carried out with restriction enzymes HaeIII, HhaI and MspI following the manufacturer's recommendation (Fermentas, Lithuania) for 2 hours at 37 °C. The restriction products were precipitated with ethanol, then 0.2 μL of the Size Standard-600 molecular weight marker (Beckman Coulter, USA) and 10 μL of Sample Loading Solution formamide (Beckman Coulter, USA) were added. The analysis was carried out using CEQ 8000 (Beckman Coulter, USA) according to the manufacturer's recommendations. The error of the CEQ 8000 device was not more than 5%. The calculation of peak sizes and areas was carried out in the Fragment Analysis program (Beckman Coulter, USA), on the basis of which subtypes (filotypes) were distinguished with a 1-nucleotide error in the study and their relative content in the microbial community was determined.

The affiliation of bacteria to a specific taxonomic group was determined using the database (http://mica.ibest.uidaho.edu/trflp.php).

Statistical processing of the results was carried out using the analysis of variance using Microsoft Excel 2010 software.

Results and Discussion

For the first time we characterized the age-related changes in the composition of the rumen bacterial community for the Russian Arctic *Rangifer tarandus* using the molecular genetic method of T-RFLP. Analyses were made for calves of 4 months of age, young animals (1–2 years old) and adults (3–6 years). The first years of life are the most critical for reindeer. During this period the highest percentage of death is observed, which is probably due to the scarcity of the diet in the conditions of natural habitats (Samandas, Laishev, & Samoylov, 2011).

In the process of ontogenesis in *Rangifer tarandus*, the development of the bacterial community, the appearance of new taxa of microorganisms was observed (Table 1). The spectrum of bacteria detected in young animals and adults was more widespread than in 4-month-old calves – over 109.50 ± 4.15 (P<0.05). Most of the bacterial phylotypes, as a result of the assessment of taxonomic affiliation, were assigned to the *Firmicutes*, the total percentage of which was observed in 4-month-old calves (P<0.05). The bacteria

of the phylums *Bacteroidetes*, *Actinobacteria* and *Proteobacteria* were found in the *Rangifer tarandus* rumen community in a lesser extent. In a minor amount representatives of phylums *Tenericutes* and *Fusobacteria*, *Acidobacteria*, *Cyanobacteria* were identified.

The part of philotypes that could not be identified by databases was also significant. The largest proportion of unidentified taxa was observed in individuals 1–2 years old. The results are compatible with the results of researchers who reported the presence of a higher number of unidentified taxa in the rumen of the *Rangifer tarandus tarandus* of Norway, compared with cattle and Thompson's gazelles (Sundset *et al*., 2007). This indicates the need for a set of additional studies to establish the role of these microorganisms in the livelihoods of reindeer.

Therefore, in general, using T-RFLP-analysis, we obtained results comparable to modern ideas about the microbiota of rumen of ruminant animals (Hungate, 1966; Tarakanov, 2002; Church, 2006).

It is worth noting some differences in the composition of the bacterial community, found in the studied specimens of reindeer, from other ruminants. *Rangifer tarandus* almost completely lacked the cellulolytic bacteria of the family *Ruminococcaceae* traditionally detected in the rumen of cattle in significant quantities. In this case, the percentage of bacteria of the *Eubacteriaceae* family of *Clostridia* class with cellulose and saccharolytic properties was, on the contrary, higher than reported for cattle (Hungate, 1966). According to some authors, the unique ability of eubacteria, in particular *Eubacterium rangiferina*, is the ability to detoxify secondary lichen metabolites that are toxic to other ruminants (Sundset *et al*., 2008). The presence of *Cyanobacteria* – photosynthesizing microorganisms, which are cyanobionts of lichens, is also a point of interest in the microbiota of the reindeer rumen.

A comparative analysis of *Rangifer tarandus* rumen microbiota showed the presence of certain patterns in the development of the bacterial community associated with the age of the animals.

One of the indicators characterizing the microflora of the 'adult type' in ruminants is its ability to digest fiber (Nocek, 1997). The studies of rumen microbiota using T-RFLP-analysis showed that reindeer already at 4 months of age are able to digest significant amounts of fiber. It is based on the relative amount of bacteria involved in the fermentation of carbohydrates of plant feed. At the same time, with age, the proportion of these microorganisms in the rumen of animals did not increase significantly.

In contrast, in the process of ontogenesis in reindeer, there was a significant decrease in the total content of *Clostridia* (P<0.05), which potentially

Larisa Ilina, Valentina Filippova,
Andrey Dubrovin, Elena Yildirim,
Timur Dunyashev, Georgiy Laptev, Kasim Laishev

THE RUMEN BACTERIAL COMMUNITY OF
REINDEER IN DIFFERENT AGE PERIODS
FROM RUSSIAN ARCTIC REGIONS

have the ability to ferment polysaccharides of plants with the formation of VFA (volatile fatty acids). In 4-month-old calves, the percentage of bacteria of the *Clostridiaceae* family was significantly higher (P<0.05). The young reindeers have a tendency to decrease the level of representatives of the *Clostridia*, including the *Eubacteriaceae* and *Clostridiaceae*. The relative abundance of these microorganisms in 4-month-old calves and adults was significantly higher (P<0.05). The content of other microorganisms that have the ability to ferment starch, fiber, a number of other carbohydrates, proteins, and also deaminate amino acids from the phylum *Bacteroidetes* (including the genera *Bacteroides*, *Prevotella*) significantly increased (P<0.05) with the age of the animals.

Characterization of identified age-related changes requires clarification and additional studies, because the trends can be related to both the physiological characteristics of this stage of development of animals, and with other factors.

Representation in the rumen of the studied animals the microorganisms of the *Negativicutes* class, capable of utilizing the mono-, oligo-, polysaccharides, acids formed during fermentation, was high and tended to decrease in ontogeny (P<0.05). The reindeer have a reverse pattern between the content of bacteria of the *Negativicutes* class and microorganisms of the genus *Lactobacillus* (the main metabolite of which is lactate) which confirms the importance of acid-utilizing bacteria for ruminant animals.

The variety of pathogenic and opportunistic bacteria in the reindeer rumen is practically not described in the literature. The most studied in this regard are the causative agents of necrobacteriosis–*Fusobacterium necrophorum*. Necrobacteriosis in winter often causes the mass death of young animals. Thus, it is shown that in cattle *Fusobacteria* are able to penetrate into the blood, infecting the animal organism with the development of liver abscesses, hoof lesions, skin, and mucous membranes (Samandas, Laishev, & Samoylov, 2011; Laptev *et al.*, 2016).

Based on the results of the T-RFLP analysis, in the rumen of the investigated reindeer the presence of a wide range of microorganisms was found, which traditionally belong to the causative agents of various animal and human diseases. The highest in *Rangifer tarandus* was the abundance of phylum *Actinobacteria* and families of *Campylobacteriaceae* and *Enterobacteriaceae*. To a lesser extent the representatives of the families *Pseudomonadaceae*, *Burkholderiaceae*, genus *Staphylococcus* were identified in the reindeer rumen. At the same time there is a tendency to increase the representation of a number of the pathogenic and opportunistic bacteria in the rumen of animals during ontogeny.

Conclusions

The results of the conducted studies indicate the presence of significant age-related changes in *Rangifer tarandus* rumen microbiota. As part of the bacterial community of the reindeer rumen, a number of differences from other ruminants have been identified, which may be explained by the physiological characteristics of these unique animals and their adaptability to conditions in the Arctic regions. In general, the obtained results indicate an expansion of the taxonomic diversity of microorganisms during ontogenesis, accompanied by the gradual settlement of the rumen with new microorganisms.

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THE RUMEN BACTERIAL COMMUNITY OF
REINDEER IN DIFFERENT AGE PERIODS
FROM RUSSIAN ARCTIC REGIONS

Larisa Ilina, Valentina Filippova,
Andrey Dubrovin, Elena Yildirim,
Timur Dunyashev, Georgiy Laptev, Kasim Laishev

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PROJECTING PRODUCTIVITY IN AGRICULTURE IN LATVIA

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Abstract
The development of rural territories in the European Union (EU) plays an essential role, and agricultural development can largely contribute to this process. To project agricultural trends, a number of models have been developed in the EU, while in Latvia the LASAM model was developed in 2016 to generate projections for agricultural sector development in Latvia until 2050. In 2017, LASAM was extended by a module for socio-economic assessment that allows projecting productivity for various types of farming. The research aim is to develop a model for productivity simulation for various specialisation types of farms in order to project their development in Latvia. To achieve the aim, two specific research tasks were set: 1) to develop a model for productivity simulation for various specialisation types of farms in Latvia; 2) to identify the key results of the simulation of productivity for various specialisation types of farms in Latvia. The research found that in the period 2005 – 2016 the value added of agriculture tended to slightly increase in Latvia, whereas an opposite trend was observed for the number of persons employed in agriculture, which tended to decrease in the period of analysis. Both trends determine the agricultural productivity trend as well. A projection of productivity measured as value added per AWU for various farming types in Latvia by means of the LASAM model has revealed that it is different, and the highest level of productivity in 2030 and 2050 is projected for granivores as well as field crop farms.
Key words: projection, productivity, agriculture, types of farming.

Introduction

More than half of the population of the EU lives in predominantly or intermediate rural areas. These regions produce 45% of gross value added (GVA) and provide 53% of the employment of the EU-27. In land use terms, rural areas represent 93% of the EU-27 territory, with 20% of the population living in predominantly rural areas and 38% in significantly rural areas. Productivity is measured through two indicators: gross domestic product and GVA. The growth of GDP/capita in rural regions is higher than in urban regions since 2001, due to strong growth in the new Member States, especially from 2006 onwards. However, despite the positive trend that GDP/capita is increasing in rural areas, the gap between rural and urban is widening (ECORYS Nederland BV, 2010). These challenges create pressure on rural firms to increase productivity in order to be competitive with other firms that may be located closer to markets or have lower cost inputs near to them. Most importantly, for several decades rural regions have been impacted by the steady substitution of capital for labour in the natural resource sectors – agriculture, forestry, mining etc. that has increased productivity but reduced employment (OECD, 2015). The George Washington Institute (2011) stresses that we can grow the economy through increasing inputs or we can increase the productivity and efficiency of the regional economy (increase outputs per unit of input) – by improving the efficiency of market operations and governance; enhancing the interactions and synergies between different kinds of economic activity; and improving how the assets of the economy are organized and deployed spatially. Usually, technological change is

an important driver of global food prices, as it directly affects productivity of land and production costs. However, the productivity increase is not sufficient to meet the doubling demand for agricultural products by 2050 without expansion of agricultural area (Frank *et al.*, 2014). Producing more with less, while preserving and enhancing the livelihoods of small-scale and family farmers, is a key challenge for the future (Food and Agriculture Organization, 2017). For a number of reasons, the agricultural productivity increase has gained renewed interest. The European Commission has launched an ambitious programme towards a resource efficient Europe in 2020. As a consequence, the agricultural sector is challenged to achieve more with less (European Commission, 2016a).

Agriculture develops dynamically in the EU, and the Common Agricultural Policy (CAP) regulates and determines opportunities for the growth of it. For this reason, both the European Commission and the governments of other Member States track the growth of the agriculture. On the one hand, the current situation is extensively analysed, while on the other hand, various models are developed to project the growth of agriculture. The most well-known and most employed models in the EU are as follows: CAPRI and AGLINK-COSIMO (Adenauer, 2008; Britz & Witzke, 2012; Leip & Eiselt, 2013), GLOBIOM-EU (GLOBIOM model, 2012), AGMEMOD and ESIM (Antle, 2015; Grethe *et al.*, 2012; Chantreuil, Salputra, & Erjavec, 2013; Zeverte-Rivza, Nipers, & Pilvere, 2017).

Therefore, the **research aim** is to develop a model for productivity simulation for various specialisation types of farms in order to project their development

in Latvia. To achieve the aim, two specific research tasks were set: 1) to develop a model for productivity simulation for various specialisation types of farms in Latvia; 2) to identify the key results of the simulation of productivity for various specialisation types of farms in Latvia.

The **object of the research** is productivity on farms of various types of farming.

Materials and Methods

To generate projections for agricultural sector development in Latvia until 2050, Latvia University of Agriculture developed the LASAM model in 2016. LASAM is an econometric, recursive, dynamic, multi-period scenario model, which can also simulate GHG emissions. Most of the estimations within the model are done by performing linear regression, the regression models are evaluated by their statistical significance and the coefficient of determination (Nipers, Pilvere, & Zeverte-Rivza, 2017). In 2017, the LASAM model was extended by a module for socio-economic assessment that allows not only projecting and assessing the effects of policy measures on physical quantities produced in agriculture and its sectors but also analysing socio-economic effects (Zinātniskā pētījuma Lauksaimniecības …, 2017). The present research shows a projection of productivity in agriculture.

Value added in the agricultural sector divided by size of the agricultural labour force should be an appropriate measure of agricultural productivity (Dorward, 2013). Value added is the value of output minus the value of goods and services used up in the production. Value added shows an increase in the market value of a product (Centrālā statistikas pārvalde, 2017a) that has arisen in the result of an economic activity. The value of goods and services used in the production for consumption, excluding fixed assets, the consumption of which is accounted for as fixed capital consumption, represents intermediate consumption (Centrālā statistikas pārvalde, 2017b).

Value added (at producer prices, excluding subsidies) and employment data for various types of farming were acquired or calculated for the period 2005–2015 in Latvia from Farm Accountancy Data Network (FADN) (Datu bāze par.., 2016). Labour input in agriculture is measured in annual work units (AWU). One AWU corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis (Eurostat, 2017b). An AWU is measured in man-years, and it is equal to 1840 hours (Institute of Agricultural Resources and Economics, 2017). The FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the CAP. The rules applied aim to provide representative data for three criteria: region, economic size and type

of farming. Types of farming at the level of the EU are: 1) field crops; 2) horticulture; 3) wine; 4) other permanent crops; 5) milk; 6) other grazing livestock; 7) granivores (pigs and poultry); 8) mixed (European Commission, 2017). Six of the above-mentioned types of farms are the most important for Latvia (excluding wine and mixed farming). The present research made a projection of productivity for five types of farming, as it was not possible to perform accurate projection calculations for other grazing livestock because this type of farms featured a very high level of intermediate consumption (in 2013-2015, 1.006, 0.974 and 0.925, respectively), while the projection of value added was performed without considering support payments (Zinātniskā pētījuma Lauksaimniecības …, 2017).

Results and Discussion

Development of the model for productivity simulation for farms of various specialisation types in Latvia

The model computes **value added per person employed** based on FADN data on farms broken down by the specialisation type: field crops, vegetables, permanent crops, milk, as well as granivores (pigs and poultry).

A projection of value added per person employed by type of farming was made based on the projection of future value added per person employed, the present value of which was acquired from the FADN database.

A projection of value added per person employed for specialised *field crop farms* was made exogenously by analysing and comparing with the levels of other EU Member States.

A projection of value added per person employed for specialised *vegetable farms* was made based on a trend equation:

vegf_VA_AWU_vegfspec_reg<-lm(vegf_VA_AWU_vegfspec ~ vegf_VA_AWU_vegfspec_trend) (1),

where vegf_VA_AWU_vegfspec − value added per person employed in specialised vegetable farms;

vegf_VA_AWU_vegfspec_trend – trend.

The intercept of the regression equation was computed at 3.66596, coefficient 0.84895, p=0.000 (Table 1).

A projection of value added per person employed for specialised *permanent crops farms* was made based on a trend equation:

fr_VA_AWU_frspec_reg<-lm(fr_VA_AWU_frspec ~ fr_VA_AWU_frspec_trend) (2),

where fr_VA_AWU_frspec − value added per employed person for specialised permanent crop farms;

fr_VA_AWU_frspec_trend – trend.

The intercept of the regression equation was computed at 1.5469, coefficient 0.5125, p=0.029 (Table 1).

Table 1

Parameters of the regression equation for specialised vegetable and permanent crop farms in Latvia in 2015

Parameters of the regression equation	
Vegetable farms	Permanent crop farms
Coefficients: Estimate Std. Error (Intercept)　　　　3.66596　0.49764 vegf_VA_AWU_vegfspec_trend 0.84895　0.07337 　　　　　t value Pr(>|t|) (Intercept)　　　7.367 4.25e-05 *** vegf_VA_AWU_vegfspec_trend 11.570 1.05e-06 *** Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Residual standard error: 0.7695 on 9 degrees of freedom Multiple R-squared: 0.937, Adjusted R-squared: 0.93 F-statistic: 133.9 on 1 and 9 DF, p-value: 1.05e-06	Coefficients: Estimate Std. Error t value (Intercept)　　　1.5469　　0.5957　2.597 fr_VA_AWU_frspec_trend 0.5125　0.1530　3.350 　　　　　　　Pr(>|t|) (Intercept)　　　0.0603 . fr_VA_AWU_frspec_trend 0.0286 * Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Residual standard error: 0.6399 on 4 degrees of freedom Multiple R-squared: 0.7373, Adjusted R-squared: 0.6716 F-statistic: 11.22 on 1 and 4 DF, p-value: 0.02856

Source: authors' calculations based on Datu bāze par …, 2016; Zinātniskā pētījuma Lauksaimniecības …, 2017.

A projection of value added per person employed for specialised ***dairy farms*** was made exogenously by analysing and comparing with the levels of other EU Member States.

A projection of target value added per person employed for specialised ***granivore farms*** was made based on a trend equation:

pp_VA_AWU_ppspec_reg<-lm(pp_VA_AWU_ppspec ~ pp_VA_AWU_ppspec_trend) (3),

where pp_VA_AWU_ppspec – value added per person employed for specialised granivore farms;

pp_VA_AWU_ppspec_trend – trend.

The intercept of the regression equation was computed at 6.571, coefficient 1.407, p=0.003. The target value added acquired was exogenously equalised.

Key results of the simulation of productivity on farms of various specialisation types in Latvia

The EU-28 average farm net value added decreased by 5.8% from 2012 to 2013, mainly due to the increase in the agricultural input costs (linked mainly to the increased costs of feeding stuffs and crop protection), while output value remained nearly unchanged (-1.3%). The average farm net value added per annual work unit decreased by 4.6%, from EUR 19 000 in 2012 to EUR 18100 in 2013. On average, farms specialised in granivores, field crops, wine, milk and horticulture had the highest farm net value added per AWU, while the farm net value added per AWU of farms specialised in other permanent crops, grazing livestock (other than milk) and mixed activities remained below the EU-28 average (European Commission, 2016b). It has to be noted that farm net value added, which is a standard FADN indicator, slightly differs from the indicator used in the LASAM model (output minus intermediate consumption), yet development trends are possible to identify. Farm net value added takes into account subsidies and depreciation, while the LASAM model used derivative indicators in order to project the farm development easier.

According to the data from the Economic Accounts for Agriculture (EAA), a satellite account of the European system of national and regional accounts, adapted to the specific nature of the agricultural sector, providing complementary information and concepts (Eurostat, 2017a), in the period 2005 – 2016 in Latvia

Table 2

Parameters of the regression equation for specialised granivore farms in Latvia in 2015

Parameters of the regression equation	
Coefficients: 　　　　　Estimate Std. Error t value (Intercept)　　　6.571　　2.394　2.744 pp_VA_AWU_ppspec_trend　1.407　　0.353　3.984 　　　　　　Pr(>|t|) (Intercept)　　　0.02268 * pp_VA_AWU_ppspec_trend 0.00319 **	Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Residual standard error: 3.703 on 9 degrees of freedom Multiple R-squared: 0.6382, Adjusted R-squared: 0.598 F-statistic: 15.87 on 1 and 9 DF, p-value: 0.003185

Source: authors' calculations based on Datu bāze par …, 2016; Zinātniskā pētījuma Lauksaimniecības …, 2017.
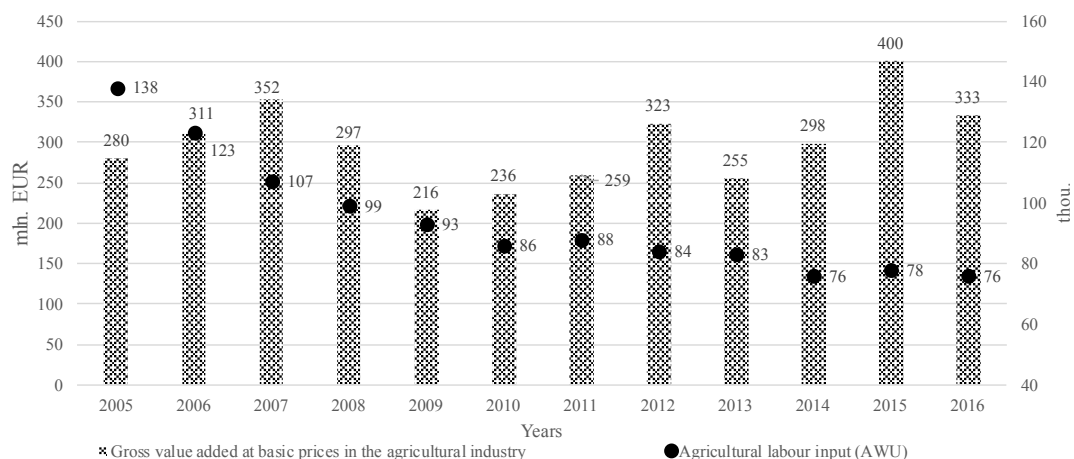
Source: Eurostat, 2017c.

Figure 1. Value added of the agricultural industry and the number of persons employed in
agriculture in Latvia in the period 2005 – 2016.

the value added of agricultural industry (at basic
prices, including subsidies on agricultural products)
increased from EUR 280 to 333 million (19%
increase), accounting for 2.2% and 1.4% of the total
value added of the national economy and indicating
a decrease in the significance of the agriculture in
terms of value added and its share in GDP (Figure 1).
The highest value added was reported in 2015 – EUR
400 million, while the lowest was during the global
financial crisis in 2009 and 2010 – EUR 216 and
236 million, respectively. As regards agricultural
employment, the number of employed persons in the
analysed period decreased from 138 thousand in 2005
to 76 thousand In 2016, or by 45%. Nevertheless, the
number of employees in agriculture still makes up a
significant share in the total number of employees in

Latvia – almost 9%, which results in a considerably
lower labour productivity level than in the national
economy as a whole (authors' calculations based
on LR Zemkopības ministrija, 2008; 2011; 2014;
2017). At a relatively steady volume of value added
in recent years and a fast decrease in the number of
persons employed in agriculture, the productivity
level measured as value added per person employed
gradually increased from EUR 2029 in 2005 to
EUR 4382 in 2016 (2.2-fold increase), yet it still
considerably falls behind the EU-28 average, which
indicates opportunities for growth in the future.

For the needs of the simulation, value added at
producer prices (support payments excluded) was
used to compute the volume of value added per
AWU in agriculture. The projection was made based
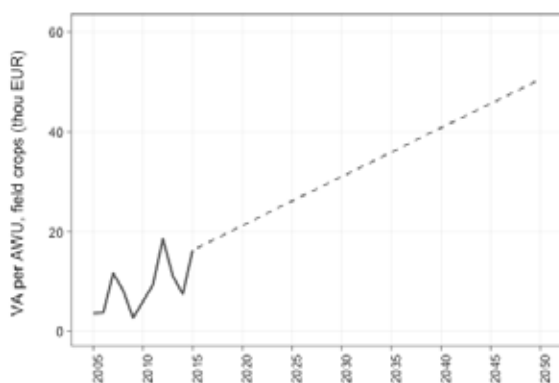
Source: authors' calculations based on Datu bāze par …, Zinātniskā pētījuma Lauksaimniecības …, 2017.

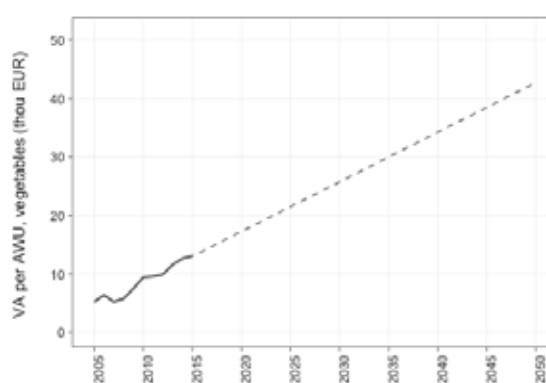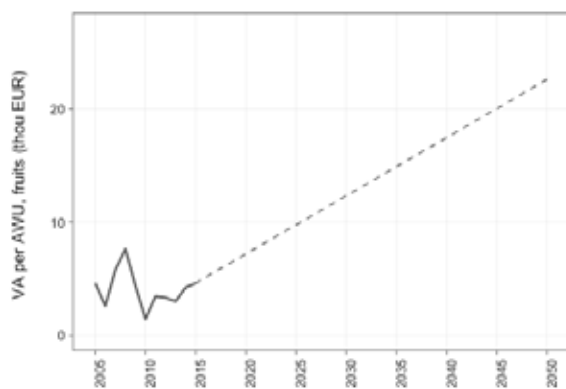| Figure 2. Value added per AWU on specialised field crop farms in the period 2005 – 2015 and a projection of it in Latvia in the period 2016 – 2050, EUR thou. | Figure 3. Value added per AWU on specialised vegetable farms in the period 2005 – 2015 and a projection of it in Latvia in the period 2016 – 2050, EUR thou. |

Source: authors' calculations based on Datu bāze par …, Zinātniskā pētījuma Lauksaimniecības …, 2017.

Figure 4. Value added per AWU on specialised permanent crop farms in the period 2005 – 2015 and a projection of it in Latvia in the period 2016 – 2050, EUR thou.
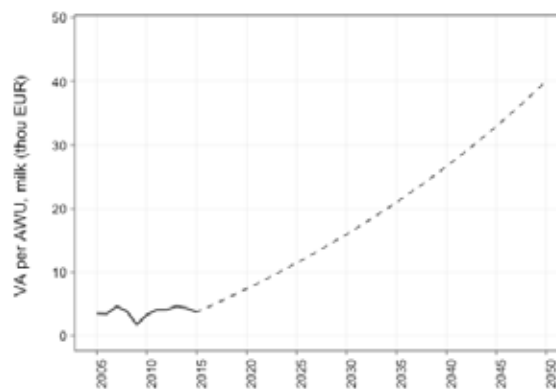
Figure 5. Value added per AWU on specialised dairy farms in the period 2005 – 2015 and a projection of it in Latvia in the period 2016 – 2050, EUR thou.

on the FADN data, analysing the farms by their specialisation type.

The productivity is projected to considerably increase on specialised *field crop farms* owing to the farm concentration and intensification of the agricultural production. The value added per person employed is projected to reach EUR 31 thousand in 2030 and EUR 50.5 thousand in 2050, which is 69% and 2.8 times more than in 2017 (i.e. EUR 18.3 thousand) (Figure 2).

For comparison, in 2015 the value added per person employed on specialised field crop farms in other countries was significantly higher: EUR 41.2 thousand in Germany and Sweden, also EUR 38.0 thousand in Ireland and even EUR 93.3 thousand in the Netherlands (Zinātniskā pētījuma Lauksaimniecības …, 2017). This means that a value added of EUR 50.5 thousand per person employed is an achievable target for field crop farms in Latvia.

Specialised *vegetable farms* demonstrated a steady increase in value added per person employed, and a similar increase is projected in the period up to 2050 (Figure 3). The current value added level in Latvia lags behind those in other EU Member States; for example, the value added per person employed in Germany was EUR 32.8 thousand, in the Netherlands – EUR 66.3 thousand (Zinātniskā pētījuma Lauksaimniecības …, 2017). According to the projections produced by the LASAM model, the value added per person employed on specialised vegetable farms is expected to increase from EUR 14.7 thousand in 2017 to EUR 42.7 thousand in 2050 (2.9-fold increase). A considerable increase in productivity is projected for 2030 too – up to EUR 25.7 thousand per person employed (+75% in comparison with 2017).

According to the projections, the value added per person employed on specialised *permanent crop*

farms also has an increasing tendency (Figure 4). In 2017, the value added per person employed on specialised fruit farms was only EUR 5.6 thousand; it will increase to EUR 12.3 thousand in 2030 and to EUR 22.6 thousand in 2050 (4-fold increase in comparison with 2017).

In 2015, for comparison, the value added per person employed on specialised permanent crop farms in Germany was EUR 30.3 thousand and in Denmark – EUR 66.1 thousand (Zinātniskā pētījuma Lauksaimniecības …, 2017).

According to the projections for dairy farming, an increase in productivity on specialised *dairy farms* is expected as well (Figure 5). However, unlike the trend in the value-added of the dairy sector, the value added per person employed is projected to increase after 2030, too, which will be promoted by production intensification. The projected increase in value added per person employed in the dairy farming is significant, as the current productivity level is low. In Latvia, it is projected to reach EUR 16 thousand in 2030 and EUR 40 thousand in 2050, which is 3 and 7.8 times higher than in 2017 (i.e. EUR 5.1 thousand).

For comparison, in 2015 the value added per person employed on specialised dairy farms in Germany was EUR 32.5 thousand, in Sweden – EUR 37.1 thousand, in Ireland – EUR 45.8 thousand, while in Denmark – even EUR 69.9 thousand (Zinātniskā pētījuma Lauksaimniecības …, 2017).

Large intensive farms dominate among specialised *granivore farms* in Latvia; for this reason, a persistent increase in productivity is projected for this industry (Figure 6). Compared with EUR 22.5 thousand in 2017, the value added per person employed is projected to increase to EUR 45.3 thousand in 2030 (2-fold increase) and to EUR 67.7 thousand by 2050 (3-fold increase).
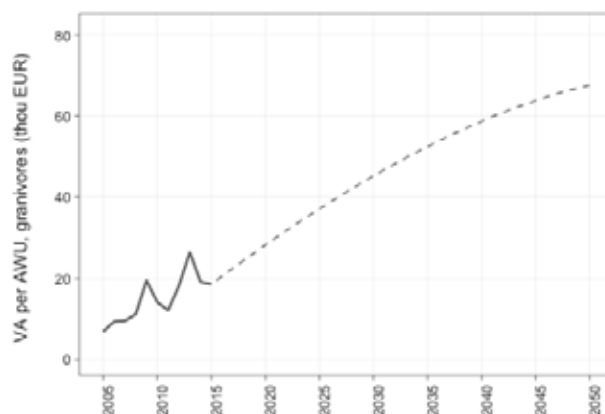
Figure 6. Value added per AWU on specialised granivore farms in the period 2005 – 2015 and a projection of it in Latvia in the period 2016 – 2050, EUR thou.

In other countries, the value added per person employed on the farms of this specialisation type is relatively high. In 2015, it was EUR 41.3 thousand in Germany, EUR 74.8 thousand in Sweden, and EUR 83.0 thousand in Denmark (Zinātniskā pētījuma Lauksaimniecības …, 2017).

The present and future increase trend of value added per person employed in Latvia is accompanied by decreasing agricultural employment. A similar situation is observed also in the EU as a whole where output growth has been achieved in a context of a shrinking workforce. Since 2005, the volume of agricultural output has increased by about 6%, but this number is quite volatile given the economic, agronomic and climatic uncertainties characterizing agriculture. Between 2005 and 2015, the total workforce in agriculture declined with about 25% to around 9.6 million full time equivalents, in line with the restructuring in the direction of fewer, but larger farms (European Commission, 2016).

Conclusions

1. A number of models are employed to make projections for agriculture. In 2016 in Latvia, the LASAM model was developed to generate projections for agricultural sector developments in Latvia until 2050. In 2017, LASAM was extended by a module for socio-economic assessment that allows projecting productivity for various specialisation types of agricultural holdings.

2. The value added of agriculture increased by 19% in Latvia in the period 2005 – 2016. In 2016, it was 17% lower than in 2015 – the highest level reached in the period of analysis, yet the share of agriculture in the value added of the national economy decreased. The number of persons employed in agriculture in the period of analysis persistently decreased – from 138 thousand in 2005 to 76 thousand in 2016 – or by 45%, yet it still makes up a significant share in the total number of employees in Latvia – almost 9%. This trend contributes to increases in productivity in agriculture.

3. A projection of productivity measured as value added per AWU for farms of various specialisation types in Latvia revealed that the productivity varies, and it is affected by the currently achieved productivity level and the factors affecting the industry, yet there are prospects for an increase in productivity for the farms of all types:
   - ✓ productivity of specialised field crop farms is projected to increase to EUR 31 thousand in 2030 and EUR 50.5 thousand in 2050;
   - ✓ productivity of specialised vegetable farms is projected to increase to EUR 25.7 thousand in 2030 and EUR 42.7 thousand in 2050;
   - ✓ productivity of specialised permanent crop farms is projected to increase to EUR 12.3 thousand in 2030 and EUR 22.6 thousand in 2050;
   - ✓ productivity of specialised dairy farms is projected to increase to EUR 16 thousand in 2030 and EUR 40 thousand in 2050;
   - ✓ productivity of specialised granivore farms is projected to increase to EUR 45.3 thousand in 2030 and EUR 67.7 thousand in 2050.

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ANALYSIS OF FARMING SYSTEM OUTPUTS AND METHODS OF THEIR EVALUATION

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Abstract
Farming outputs in agriculture depend on the nature of production, i.e. different farming systems generate different outputs. All these outputs are important for the society, and, therefore, require an integrated approach in view of the specific farming characteristics, where market and non-market outputs are taken into account. Therefore, the paper focuses on analysis of farming system outputs and methods of their evaluation. The objectives of this paper are to define the features of different farming systems and their outputs, then, to analyse the methods of evaluation of farming system outputs used in the studies. In order to achieve the research aim, analysis of economic scientific literature has been conducted; characteristics of farming systems and their outputs have been analysed; evaluation methods of the market and non-market farming system outputs, revealing their advantages and disadvantages, have been examined. Methods of systemic and logic analysis have been applied to analysis of the farming system outputs and their evaluation. The analysis has shown that intensive farming systems generate more market goods, while extensive farming systems – more public goods. Price-based methods are mostly used for the evaluation of market outputs of farming systems. Stated preferences methods are the most universal techniques used for the determination of the values from non-market farming system outputs. Hedonic pricing approaches are used for evaluation of specific agricultural public goods related to recreation or leisure and related to the particular groups of users.
Key words: agriculture, farming systems, market, non-market outputs, externalities, public goods.

Introduction

Agriculture is a specific activity, which, beyond the supply of food and fibre, shapes the landscape, provides natural resources, and preserves biodiversity. It also contributes to the viability of rural areas and their development, food security, and preserves the cultural heritage. Positive externalities of agriculture manifest themselves in the form of public goods, while intensive and environmentally unbalanced agricultural activity causes damage to the environment. These farming outputs depend on different technologies of production, i.e. different farming systems generate different outputs. However, all these non-market outputs from agriculture are not taken into account when assessing the value of farming system output. Usually, only farming outputs provided through market by separate farming systems are subject to evaluation on the basis of statistical data on micro or macro level, or certain non-market goods provided by the farming systems. There is lack of an integrated evaluation of farming system outputs in view of the specifics and intensity of farming.

Works by foreign researchers provide comprehensive analysis of the issues of non-market agricultural aspects, usually focusing on evaluation of the benefit or damage to society from agricultural activity. Some of them have been dedicated to identification of the benefit provided by certain farming systems (Arriaza *et al.*, 2008; Szabo, 2010; Jianjun *et al.*, 2013; Albert *et al.*, 2017), others – the value of damage (Pretty *et al.*, 2000; Kubíčková, 2004; Tegtmeier & Duffy, 2004; Wagner *et al.*, 2017). Market agricultural outputs are analysed on micro level on the basis of the Farm Accountancy Data Network data, and on macro level on the basis of data of the National Accounts. Although there is great interest among scientists in separate estimation of market and non-market outputs of farming system, external cost and benefit, and their integration into the assessment of efficiency of farming systems during the last decade, little effort has been made to evaluate the impact of farming systems on agricultural outputs comprehensively.

The objectives of this paper are to analyse the features of different farming systems and their outputs, then, to analyse the methods of farming system output evaluation used in recent studies. The paper is structured as follows: the first section of the results and discussion analyses the characteristics of farming systems and their outputs with the focus on intensive and extensive farming systems. The following section outlines the main valuation approaches appropriate for valuation of farming system outputs. Attention is paid to the analysis of the differences between valuation methods and specifics of their application. Conclusions are drawn in the last section of the paper.

Materials and Methods

In order to achieve the research aim, analysis of economic scientific literature has been conducted; characteristics of farming systems and their outputs have been examined; evaluation methods of the market and non-market farming system outputs have been analysed; the relevance of comprehensive analysis of different farming system outputs has been substantiated. The main focus has been put on the analysis of non-market outputs of the farming systems and methods of their evaluation. Methods

of systemic and logic analysis have been applied to analysis of farming system outputs and methods of their evaluation.

Results and Discussion

Characteristics of farming systems and their outputs

Farming systems are classified into intensive versus extensive farming systems according to the agro-technological approach. The intensive farming systems also are known as *high-input farming system* (Poux, 2008; Nemecek *et al.*, 2008; Zhukova *et al.*, 2017) or *conventional farming system* (Pacini *et al.*, 2003; Crittenden *et al.*, 2015). *Extensive farming systems* are designated as *low-input farming systems* (Poux, 2008; Nemecek *et al.*, 2008, *et al.*), or *low intensity farming systems* (Beaufoy *et al.*, 1994; Gómez Sal & González García, 2007). The intensive farming systems are mostly focused on achievement of the highest productivity, while the focus of extensive farming system is eco-friendly farming. Archambeaud (2008) defines intensive farming systems as systems where agricultural equipment plays a very important role in securing the productivity, there is high usage of fertilizers, pesticides or other protectors against weeds, diseases and pests. They are high productivity farming systems with negative impact on the environment and biodiversity. Traditionally, extensive farming systems are defined as systems where the amount of fertilizers, pesticides or other protectors is reduced. Therefore, such farming systems depend on the use of internal resources and are more sustainable

than the intensive farming systems (Fess *et al.*, 2011; Poux, 2008). Pointereau, Bochu, Doublet (2008) emphasize that these systems could cover different types of production as organic, integrated, high nature value, etc., where the main focus is on optimizing the internal farm resources and reducing the use of external resources. According to the definitions of intensive and extensive systems and following the review of studies, the advantages and disadvantages of these alternative farming systems have been identified and shown in Table 1.

In comparison to intensive farming systems, where non-farming input is mostly used, extensive farming systems mostly use the farm input, and, therefore, have low production outputs. However, from the environmental point of view, extensive farming systems create positive externalities, have the potential to reduce the pollution risk, improve the landscape or improve biodiversity. Extensive farming does not cause such environmental problems as soil or water pollution, and it does not require many inputs. However, the outputs are not very high in comparison to the intensive farming. There are also difficulties with extensive farming: first, there is a need for huge agricultural land areas that do not generate high outputs; second, there is a need for more manual work and taking care of crops and animals; and third, the agricultural products are more expensive. Therefore, it could be noted that intensive farming systems secure the society with private/marketable goods and are usually related to economic efficiency of production,

Table 1

The advantages and disadvantages of intensive and extensive farming activities

Intensive	Extensive
Advantages	
Rational land use	Preservation of natural landscape
Global food security	Preservation of wildlife habitats
Cheaper food products	Better quality and safer food products
Growing revenues for food export	More people involved in agricultural activities
Faster work using the modern equipment	Government supported activity
Doesn't need a lot of manual work	Lower additional cost (no need to buy mineral and other chemical fertilisers)
Disadvantages	
Technical equipment operation cost	More expensive food products
Additional cost of fertilisers, chemicals	More care for crops and animals grown
Capital replaces the labour, less people are involved in agricultural activities	More hand work needed
Need for specialists with higher qualification	Large agricultural land areas needed
Damage to environment, landscape, soil, water	Lower productivity

Source: created by authors according to Pacini *et al.* (2003); Scmid, Niggli, & Pfiffner, (2008); Poux, (2008); Nemecek *et al.* (2008), *et al.*
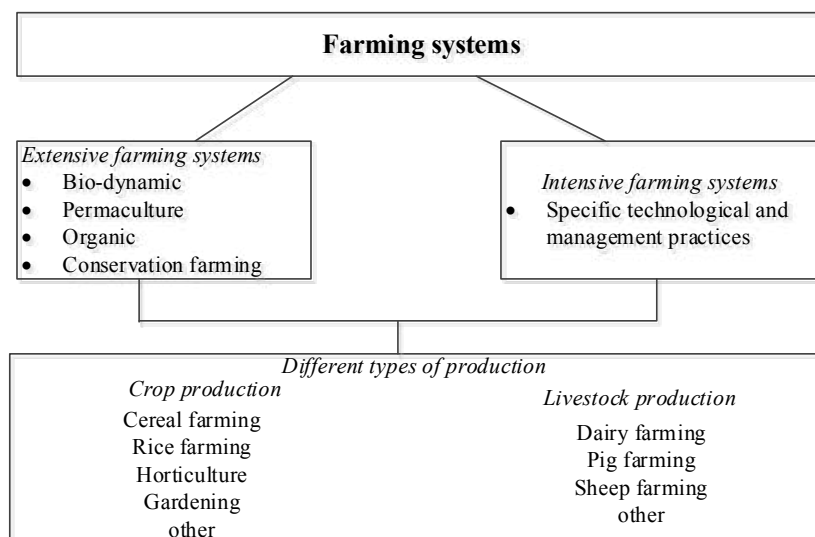
Figure 1. The typology of farming systems.

while extensive farming systems provide the society with more environmental and social public goods. The intensive and extensive farming systems may involve specific agricultural production activities such as dairy, cereal, sheep or other. All of these farming systems rely on plants which, in turn, depend on the soil (Podolinsky, 1985). Therefore, the outputs of the farming system are influenced by the type (intensive or extensive) of the farming system and the agricultural production activity chosen. Figure 1 illustrates the typology of farming systems.

There are four main types falling under the category of extensive farming systems: organic, bio-dynamic, conservation farming, and permaculture. Conventional farming is interpreted as intensive farming system, which has specific technological and management practices.

Therond et al. (2017) states that the biodynamics is an approach to farming, where farmers are seeking to create a diversified and balanced farm ecosystem. The main features of this ecosystem are the generation of health and fertility from within the farm itself as much as possible. Therefore, the fertilizers are prepared from manure and herbs, which help farmers to enhance the nutrition, quality, and flavour of the food being raised.

Permaculture is a system of cultivation intended to maintain permanent agriculture. It relies on renewable resources and a self-sustaining ecosystem. The focus of permaculture is placed on mindful and purposeful system design; its central premise is that when human beings can design systems that capitalize on the inherent abilities of the system components and the natural interactions between these subcomponents, the system will be more resilient, enduring and sustainable. In this sense, the philosophy behind permaculture is that by adhering to a set of design principles, man-created eco-systems or cultures will enjoy greater permanence (Jelinek, 2017).

As highlighted by (Rigby, Cáceres, 2001), the main goal of organic farming is the creation of sustainable production system, maximally using on-farm renewable resources, and invoking the management ecological and biological processes. This good farming practice provides appropriate levels of crop, livestock and human nutrition, protects from pests and diseases, and secures the appropriate return to the human and other resources. The last type of extensive farming systems is conservation farming. Rockstrom et al. (2009) defines it as a management system based on three principles that should be applied in unison in a mutually reinforcing manner: minimum physical soil disturbance, permanent soil covers with live or dead plant material (e.g., crop residues), and crop diversification, (e.g., crop rotations, cover crops or intercrops with legumes). Therefore, all types of extensive farming systems are fully focused on environmentally-friendly management practices, seeking to preserve the nature and improve the better provision of ecosystem services.

Farming systems could differ not only from the point of view of intensity, but also from the production specifics or type of production, as crop production (which could be cereals, rape, or other) or livestock production (such as sheep, pig or other). The outputs of these specific farming systems give different positive economic outputs as food products and different external outputs or externalities. For better understanding, they have been analysed and presented in Table 2.

The analysis of different agricultural production specifics has shown that intensive farming systems make negative impact on environment. It could damage different ecosystem services, such as water

Table 2

The outputs of different farming systems

Agricultural production	Market outputs (products)	Non-market outputs (externalities)
Crops	Wheat, rape, barley, rye, cotton	- An aesthetic values of the landscape (a beautiful monotonic landscape, mosaic landscape with some variety, with a lot of variety) - Nitrogen run off damages - Phosphorus run off damages - Pesticide run off to the underground water
Rice	Paddy rice	- Emissions of CH4, N2O, NH3 to the air - Nitrate and phosphorus run off to the water - Eutrophication due to the N and P fertilizer use
Dairy farming	Milk	- Ammonia emissions to the air - Contamination with nitrates - Greenhouse emissions - Nitrogen run off
Pig farming	Pigs	- Nitrate run off - Nitrogen emissions to the air - Phosphorus surplus
Extensive livestock breeding	Meat	Beautiful views due to the beautiful breeding animals
Orchards Gardens	Fruits	Beautiful agricultural landscape

Source: created by authors according to Reinhard *et al.* (2000), Kiatpathomchai, (2008); Asmild, Hougaard (2006); Arriaza *et al.* (2008); Battini *et al.* (2016), Lungarska & Jayet (2018) *et al.*

quality, soil quality, air quality, biodiversity, etc. It depends on the agricultural production activities, for example, crop production mostly damages soil, surface and underground water, while pig production affects the quality of soils and water. As stated by Wagner *et al.* (2017), all these farming systems have adverse impact on the human health, and environment; and the biggest part of it usually originates mainly from livestock husbandry. The extensive farming systems make positive impact on ecosystem services, including cultural services, such as aesthetic, spiritual, educational and recreational ones. Therefore, it should be noted that when calculating the value of farming system outputs, not only market output, but also positive and negative externalities should be taken into account.

Valuation of farming system outputs

The concept of Total Economic Value (TEV) defines the broadest scope of different market and non-market farming system output valuation exercises and is widely used in scientific research studies. According

Table 3

The concept of the total economic value of farming system (adapted from Pearce & Moran, 1994)

Total economic value =				
Use value (1,2,3) +			Non-use value (4,5)	
1	2	3	4	5
direct use value	*indirect use value*	*option use value*	*bequest value*	*existence value*
Consumable: agricultural products, fodder, fuels Non-consumable: recreation, agricultural landscape	Benefits of ecosystem functions: the protection of rivers, basins, soil, flood protection, landscape quality, water quality and cleaning, protection of local systems	The future benefits of current generation	Future generation benefit	Knowledge of the existence of disappearing species, conservation of biodiversity

Table 4

Relationship between valuation methods and value types of farming system outputs

Approach		Method	Value/farming system output
Direct market valuation approaches	Price based	Market prices,	Direct and indirect use (food, fuel, tourism, private landscapes)
	Cost-based	Avoided cost, Replacement cost, Restoration cost,	Direct and indirect use (flood control, groundwater recharge,)
	Production-based	Production function approach	Indirect use (How soil fertility improves crop yield)
Stated preference		Contingent Valuation, Choice experiments, Contingent ranking, Deliberative group valuation	Use and non-use (all non-market outputs provided by farming systems)
Revealed preference		Travel cost, Hedonic pricing	Direct and indirect use (agricultural landscape, water availability, flood protection)

to the TEV concept, the farming system outputs fall into two main categories of welfare gains or losses: use value and non-use value. The use value consists of direct use value, indirect use value, and option use value; the non-use value encompasses two categories - bequest value and existence value (Table 3).

The direct use value of farming system outputs consists of welfare gains or losses that could be received from direct consumption of a good (bad) or service (disservice), for example, from eating a fruit, enjoying the beautiful agricultural landscape or walking on green beautiful meadows. All outputs from agricultural production, as well as recreation services fall under the direct use value category. The indirect use value is received from the indirect use of ecosystem services, such as the use of air quality, flood protection, water quality and other benefits, which come from the ecosystem regulating services (Madureira *et al.*, 2013). The option value consists of the personal welfare gain or losses, which are associated with securing the option of possible uses of the goods or services in the future. Pearce & Moran (1994) emphasize that this type of value appears due to the doubts about unsecure use of goods in their future; so they are willing to pay for the opportunity to use these services (1 and 2 category) in the future. The non-use value category of TEV consists of all the welfare gains (or losses) that are not related either with the direct use (in the present or in the future) or the indirect use of goods or services. This value includes a set of non-use people's welfare gains (or losses) supposed by altruistic behaviour towards other people in the future (bequest value) or present (vicarious value), and sensible attitudes towards environment, or other species of flora and fauna (existence value) (Madureira *et al.*, 2013).

Within the TEV framework, if available, values are derived from information on individual behaviour

provided by market prices relating directly to the farming system output. In the absence of such information, price information must be obtained from parallel market transactions. They could be related to the goods to be valued. If both direct and indirect price information on farming non-market output are absent, hypothetical markets may be created in order to derive these values. These situations within the TEV framework fall into the three groups of the available techniques used to value farming outputs: (a) direct market valuation approaches, (b) revealed preference approaches and (c) stated preference approaches (Chee, 2004). Valuation methods and value types of farming system outputs are shown in Table 3.

Farming market outputs could be easily evaluated under the direct market valuation approaches as (a) market price-based approaches, (b) cost-based approaches, and (c) approaches based on production functions. The main advantage of using these approaches is that the data from existing markets is used, thereby reflecting actual preferences or costs to people. Moreover, such data – i.e. prices, quantities and costs are actual and are relatively easy to obtain (de Groot *et al.*, 2010). Vaznonis (2009) stresses that cost-based approaches usually are employed when analysing the quality of natural environment, by calculating the farmers' income loss or additional costs appeared, which are connected to environmentally-friendly farming.

In the absence of the markets, researchers are employing different non-market valuation approaches to analyse the outputs of the farming systems. Stated preference approaches are the adequate solution to collect the data on individual economic values on non-market goods or services from the farming systems. This approach implies application of survey-based methods, where the hypothetical market for goods and services is created (Bienabe & Hearne,

2006). Thereby, their implementation consists of the construction of a contingent market questionnaire, which is given to the potential beneficiaries or losers of the changes in the provision level of the non-market - good (bad) or service (disservice). As revealed by the studies (for example, Madureira *et al.*, 2013), the Contingent Valuation method and the Choice Experiments approach are the main techniques for the design and implementation of such contingent markets and the assessment of economic values. The revealed preference approaches include only the use values of the farming system, and can be applied only to the users of these goods' populations. Therefore, these aspects could have an additional limitation in application of this approach. For example, there are different groups of users for agricultural landscape and water availability, and quality. The first product could be important for incoming residents for recreation, while the second will be vitally important for local residents (the users of the watershed). In these cases, as stated by Madureira *et al.* (2013), the travel cost method could be used for measuring the value of agricultural landscape at different sites and Willingness to pay or Willingness to accept approach to measure the compensation for drinking water quality and availability at different watersheds.

In addition, farming outputs provided through market by separate farming systems could be easily evaluated on the basis of statistical data at micro or macro level by invoking direct market valuation approaches as price based approaches. For evaluation of non-market outputs, different non-market evaluation approaches could be used. The selection of appropriate method is substantiated by evaluation goals.

Conclusions

Agricultural production activities have positive or negative impact on the environment such as soil, quality of air and water, landscape and biodiversity. It depends on the intensity of agricultural activities and the agricultural production specialisation. Intensive farming systems secure the society with private/ marketable goods and are usually related to negative externalities, while extensive farming systems offer the society more environmental and social public goods. The measurement of farming system outputs uses market prices and is limited, because positive and negative externalities are created along with the commodity goods and services in the agricultural activities. Therefore, the integrated/comprehensive approach, covering market and non-market outputs of farming system is needed.

The concept of the total economic value could be applied for the analysis of farming system outputs, where all of them fall under two main categories, such as use and non-use values, and manifest themselves as gain or losses for individuals. Within the TEV framework, if available, values are derived, from information on individual behaviour provided by market prices relating directly to the farming system output. In the absence of market prices, Cost-based, Production-based, stated preference and revealed preference approaches are used. Stated preference approaches are the most versatile methods, as they cover valuation of all non-market outputs from the farming system. The revealed preference approaches are quite limited methods, as they are suitable only for evaluation of agricultural public goods related to recreation, or leisure, and are associated with the users related to the product under evaluation process.

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ASSESSMENT OF FARM EFFICIENCY AND PRODUCTIVITY: A DATA ANALYSIS ENVELOPMENT APPROACH

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Abstract
The objective of this article is to assess farm efficiency and productivity change in specialised large farms located in the region of Mazowsze and Podlasie during the years 2014 − 2016. For this, we used the non-parametric Data Envelopment Analysis (DEA) method and Malmquist index. Calculations were performed for three types of large farms classified as: field crop, pig and dairy. The study shows that mean technical efficiency of large field crop, pig and dairy farms amounted to 80, 75 and 70%, respectively. Technical inefficiency of field crop farms come mainly from scale efficiency, while of pig and dairy farms equally from pure technical and scale efficiency. It shows that inefficient management practices had an impact on farm performance. Therefore, in order to increase competitiveness of farms, an improvement of management practices is required. In the studied period the share of farms operating under increasing return was as follows: 67, 72, and 81%, respectively for field crops, pig and dairy farms. The improvement of efficiency of those farms could be achieved by increasing their size. The results indicate that 8% of field crops, 12% of dairy and 16% of large pig farms were operating under decreasing scale efficiency, which means that those farms were operating above the optimal scale. The increase in their efficiency could be achieved through size reduction. In dairy farms the average annual productivity growth of 2% was recorded. In pig farms the productivity reduction of 5.4% was observed. It was the result of a decrease in technological efficiency.
Key words: technical efficiency, scale efficiency, farm size, pig farms, Data Envelopment Analysis, Malmaquist indices.

Introduction

Efficiency and productivity assessment for different sectors is very important in practice because it allows to control production. Therefore, it has become a key research field (Toma *et al.*, 2017). There are two main approaches to measure productive efficiency i.e. parametric and non-parametric (Malana & Malano, 2006). The estimation of parametric production function is based on stochastic frontier analysis (SFA), whereas the non-parametric on linear programming. Data Envelopment Analysis (DEA) estimates the efficiency using a non-parametric technique (Charnes, Cooper, & Rhodes, 1978). The main advantage of DEA method is the requirement of only a limited number of a priori assumptions regarding the functional relationship between inputs and outputs overcoming some disadvantages of the parametric approach (Gadanakis *et al.*, 2015). Therefore, DEA methods have been commonly applied to agricultural sector (Atici & Podinovski, 2015; Cucchiela *et al.*, 2018; Fogarasi & Latruffe, 2009; Latruffe & Desjuex, 2016; Malana & Malano, 2006; Odeck, 2009; Parlinska & Bezet, 2010; Syp *et al.*, 2015; Toma *et al.*, 2015; Toma *et al.*, 2017; Vasiliev *et al.*, 2008).

The aim of the present study was assessment of efficiency and productivity changes of large farms with different specializations in the region of Mazowsze and Podlasie in the years 2014 – 2016. To achieve this, we applied DEA models to the obtained efficiency scores and Malmquist indices to assess the productivity growth. Some analyses were performed to calculate the efficiency and productivity of Polish farms using simple standard efficiency indicators. However, to our knowledge, there are not existing studies in Poland analysing efficiency and productivity of the farms in the region of Mazowsze and Podlasie according to their economic size and specialization using DEA method. Thus, this paper makes an important contribution in this area. The article is structured as follows: the next section presents the materials and methods in detail; the third section presents efficiency results and discussion: and section 4 offers some concluding remarks.

Materials and Methods

Study area

To perform analysis based on Farm Accountancy Data Network (FADN), the region of Mazowsze and Podlasie has been selected which is assigned the number 795 (Commission Regulation 2009). The region includes four voivodships, namely: mazowieckie, podlaskie, lubelskie and łódzkie. This area has been chosen to study because: a) the utilized agricultural area (UAA) of this region accounts for about 37.2% of the country's UAA, b) 29% of the Polish population lives on this territory, c) 30% of Polish population is employed in agricultural sector, d) 32% of crops of basic cereals come from this region, e) 48% of cattle and 26% of pig stocks are located there (CSO, 2017). In 2016, in the region of Mazowsze and Podlasie the number of applicants who submitted applications for payments amounted to 43% of all applying, and the declared area in hectares was 36% of country UAA. Moreover, payments under the single area payment and greening were 37% of national expenditures in the frame of Common Agricultural Policy (CAP).

Descriptive statistics of the FADN data set applied in DEA: 2014 – 2016

No	General information	Type of farms		
		Field crops	Dairy	Pigs
1	Number of farms	30	86	69
2	Total output (PLN)	861 227	784 318	796 285
3	UAA (ha)	161.3	72.4	44.0
4	Labour input (h)	10 285	6 090	4 981
5	Intermediate consumptions (PLN)	466 664	433 474	590 798
6	Total assets (PLN)	5 704 918	3 563 151	2 234 212

Notes: PLN – Polish currency. UAA – utilised agricultural area. H – labour input in working hours.
Source: authors' calculations based on the FADN data.

DEA model specification

The DEA methods were used to assess farm efficiency and productivity changes in the region of Mazowsze and Podlasie. DEA constructs the best practice frontier in the given set of data so the best performing farms form the envelope (i.e. the frontier). Next, it calculates the farm efficiency scores in respect to this frontier (Charnes, Cooper, & Rhodes, 1978). The concept of efficiency relates to the distance of the farm from the production frontier: a small distance indicates high efficiency, whereas a large distance presents low efficiency. Efficiency (total, pure and scale) indicators range from 0 to 1. The fully efficient farm received score 1 (i.e. on the frontier) and a larger score presents a higher efficiency. The score lower than 1 points out to what level the inputs could be reduced and still produce the same quantity of output. A farm technical efficiency (TE) score was calculated under the assumption of constant returns to scale (CRS). The TE was divided into two scores: pure technical efficiency (PTE) and scale efficiency (SE). PTE was estimated under variable returns to scale (VRS) and referred to management practices. SE, at the same time, was the ratio between TE and PTE and presented the potential scale economies accessible to the farm.

The DEA has two alternative orientations: input and output (Charnes, Cooper, & Rhodes, 1978). The input-oriented model estimates the proportional reduction of applied inputs while output remains unchanged. The concept of output-oriented model is to using the existing technology to produce the highest level of outputs from a given combination of inputs (Toma *et al.*, 2017). Some researchers stated that input-orientated model is more appropriate for agriculture because it depends on limited inputs (Malana & Malano, 2006; Toma *et al.*, 2015) and in the production process farmers have more control over input rather than output (Syp *et al.*, 2015). Others pointed out that it is easier for farmers to adjust their final outputs than the volume of inputs and,

therefore, selected output-oriented model (Fogarasi & Latruffe, 2009). However, Coelli *et al.* (2005) noticed that outcomes from both models are comparable, therefore, the choice of orientation is not crucial. Additionally, DEA enables to estimate under which returns to scale each farm operates: constant (CRS), decreasing (DRS) or increasing (IRS) ones. Our analysis proceeded in the following order: first the efficiency scores were calculated by using technical, pure technical and scale efficiency. The second step included the estimation of farms' scale of operations. The third – the use of Malmquist productivity indices to calculate of productivity changes. The Malmquist total productivity index (TFP) was divided into the technological change index (TC), which assessed the shift of the frontier over time, and TE change index, which measured variation in TE efficiency (Färe *et al.*, 1992). Next, TE change index was spread out into change of PTE and SE. Scores equal to 1 presented no change, higher than 1 – development, while lower than 1 – regress. The average change indices were expressed as geometrical means.

Data sets and variables

The study employed data from the Polish Farm Accountancy Data Network (FADN) for the period of 2014 – 2016. The database provides information on the physical and economic performance of farms in Poland. The research covered only those farms that were in the FADN system throughout the whole period taken into account. The analysis was performed for three types of farms based on their production specialisation: field crop farms (TF1), dairy farms (TF 5) and pig farms (TF 71). The criterion for classification of the agricultural holdings is that at least 66% of standard output (SO) from specific production of type farm must contribute to the total output of the farm. Then, from the group of farms selected for further analysis only large farms were chosen – with SO values more than 100 and less than 500 EUR K.

The analysed sample consisted of 185 farms, 30 of which were field crops, 86 dairy and 69 pig farms. The dependent variable in the input-oriented DEA models was total output (SE131) expressed in PLN (Polish currency). As inputs we selected and applied: labour (SE011) defined in work hours, total UAA (SE025) in hectares, total assets (SE436) total intermediate consumption (SE275). Values of total assets and intermediate consumption were presented in zloty.

Table 1 presents some descriptive statistics of the variable applied to the DEA model. During the studied period, on average, field crop farms had the highest UAA, labour input, total assets and output compared to livestock farms. The pig farms used the least labour, had the lowest total assets, and the highest intermediate consumption of all three specializations. The dairy farm values of total output and intermediate consumption were the lowest in comparison with the data of other farm types.

The DEAP software was used to calculate the efficiency and productivity change indices of selected farms.

Results and Discussion

The first step of our analysis involved calculation of the technical efficiency in order to provide information for potential improvements. The summary results of the DEA efficiency scores are presented in Tables 2 – 4. Because the maximum score of TE was 1, only minimum values are presented.

In the analysed period, the field crop farms were more technically efficient than dairy and pig farms. In 2014 – 2016 the field crop farms had a mean technical efficiency of 0.799, meaning they could reduce their inputs by 20% and still produce the same level of outputs.

In pig and dairy farms the reduction mean potential for input savings amounted to 25 and 30%, respectively. For individual years, we recorded the variations in average scores. In 2015, the highest scores were recorded for field crop and pig farms. It was mostly due to good climatic conditions for cereal cultivation which is mainly grown in these types of farms. However, the drought in the second part of 2015 caused very bad conditions for regrowth of vegetation on pastures, and resulted in lower technical efficiency scores of dairy farms. In the period of 2014 – 2016, the average coefficients of variation in all farm groups were on the same level, i.e. 0.21, which indicates the comparable distribution of technical efficiency scores through the samples. Similar rankings to technical efficiency averages were noted for PTE and SE indicators. However, only in the crop field farms the value of PTE increased year after year, which indicates that the management has been constantly improved.

Table 5 presents the share of farms operating under CRS, IRS and DRS. Our results show that the filed crop farms are more scale efficient than livestock farms (26 v. 7 v. 12). In the studied period all types of farms were mostly operating under IRS indicating that

Table 2

Descriptive results of field crop farms' efficiency estimates

Efficiency scores	Mean	Standard deviation	Minimum	Coefficient of variation
Technical efficiency				
2014	0.800	0.156	0.435	0.195
2015	0.819	0.179	0.501	0.219
2016	0.779	0.187	0.388	0.240
2014 – 2016	0.799	0.175	0.388	0.219
Pure technical efficiency				
2014	0.882	0.115	0.624	0.130
2015	0.908	0.122	0.615	0.134
2016	0.911	0.117	0.570	0.128
2014 – 2016	0.901	0.118	0.570	0.132
Scale efficiency				
2014	0.904	0.110	0.612	0.121
2015	0.895	0.120	0.653	0.134
2016	0.850	0.150	0.502	0.176
2014 – 2016	0.883	0.130	0.502	0.147

Source: authors' calculations based on the FADN data.

Table 3

Descriptive results of dairy farms' efficiency estimates

Efficiency scores	Mean	Standard deviation	Minimum	Coefficient of variation
Technical efficiency				
2014	0.719	0.156	0.310	0.218
2015	0.654	0.147	0.338	0.225
2016	0.718	0.167	0.276	0.232
2014 – 2016	0.699	0.135	0.276	0.193
Pure technical efficiency				
2014	0.875	0.119	0.616	0.136
2015	0.806	0.130	0.516	0.162
2016	0.822	0.125	0.402	0.152
2014 – 2016	0.836	0.128	0.402	0.153
Scale efficiency				
2014	0.825	0.147	0.310	0.178
2015	0.813	0.132	0.474	0.162
2016	0.868	0.121	0.510	0.139
2014 – 2016	0.836	0.135	0.474	0.162

Source: authors' calculations based on the FADN data.

they were too small. Thus, the important conclusion of these outcomes is that these farms can achieve efficiency growth by increasing in size. The results also indicate that the shares of farms operating under DRS were as follows: 8, 12 and 16%, respectively, for field crop, dairy and pig farms. This implies that these farms were too large and could gain efficiency by size reduction.

Table 4

Descriptive results of pig farms' efficiency estimates

Efficiency scores	Mean	Standard deviation	Minimum	Coefficient of variation
Technical efficiency				
2014	0.789	0.140	0.541	0.178
2015	0.750	0.144	0.449	0.193
2016	0.703	0.169	0.399	0.240
2014 – 2016	0.747	0.156	0.399	0.209
Pure technical efficiency				
2014	0.879	0.118	0.571	0.134
2015	0.863	0.121	0.604	0.141
2016	0.845	0.135	0.527	0.160
2014 – 2016	0.862	0.126	0.527	0.146
Scale efficiency				
2014	0.898	0.103	0.580	0.115
2015	0.872	0.120	0.449	0.138
2016	0.832	0.142	0.544	0.170
2014 – 2016	0.867	0.126	0.449	0.145

Source: authors' calculations based on the FADN data.

Tables 6-8 present the average TFP change indices as well as the average changes in TFP components for all types of the studied farms.

The average TFP changes were as follows: 0.948, 0.998 and 1.020, respectively, for pig, crop field and dairy farms. The figures indicate that productivity in pig farms decreased by 5.2% for the yearly scores between the first year and the next, whereas in the field crop farms only by 0.2%. The small increase of TFP was recorded for dairy farms and equalled by 0.2% each year. The decrease of TFP indices in pig and field crop farms was mainly due to the technological deterioration because the values of TE change indexes were above one. The further breakdown of TE change index shows that the main source of efficiency increased in pig farms was growth of SE by 4.3% and TC by 2.2%. In the field crop farms TE changes were only due to the growth of SE (+3.6%) which offset the decline of PTE indices. In the dairy farms the rise of TE change index resulted from the technical improvement (+3.3%) because the SE index dropped (-2.7%). This implies that farmers ameliorate their farming practices by reducing the input used and scale efficiency.

The input and output data applied in our study are consistent with the data applied by Dakpo *et al*. (2017), Fogarsi and Latruffe (2009), Ghali *et al*. (2016), Latruffe and Desjeux (2016), and Vasiliev *et al*. (2008). Latruffe and Desjeux (2016) calculated efficiency and productivity indices for different farm types in France for the period of 1990 – 2006. As the UAA averages of field crop and dairy farms in France are similar to the area of large field crop and dairy Polish farms in the region of Mazowsze and Podlasie, we could compare our results. Field crop farms in France obtain lower mean scores of TC (0.499 v. 0.799) and PTE (0.531 v. 0.901). The high differences between those scores resulted from a greater diversification in the selected French sample. The output of Polish farms was twice higher than that of French farms. However, the average SE score of French farms was 4.5% higher than the one recorded in our analysis. This confirms a better use of the inputs in the French field crop farms. The difference between efficiency indicators of dairy farms was much lower i.e. TC (0.669 v. 0.699), PTE (0.696 v. 0.836) and SE (0.952 v. 0.836). This data proves that the management of French dairy farms has better adjusted inputs to scale production. There were very small differences between changes of TFP, TE and TC of field crop and dairy farms in the studied countries. However, in French farms all scores had values slightly below 1, whereas in Poland above 1. The presented data show that the improvement of Polish farms' performance is still continuing when in French farms deterioration has started. Based on similar data inputs, Dakpo *et al*. (2017) assessed productivity changes and its components for several farm types in French agriculture in 2002 – 2014. The

Table 5

The proportion of farms according to scale – Constants, Increasing and Decreasing – as an average 2014 – 2016

No	Share of farms operating under:	Type of farms		
		Field crops	Dairy	Pigs
1	Constant (%)	26	7	12
2	Increasing (%)	67	81	72
3	Decreasing (%)	8	12	16

Source: authors' calculations based on the FADN data.

Table 6

Productivity change indices of field crop farms during 2014 – 2016

No	Average productivity change indices	Mean	Minimum	Maximum	Standard deviation
1	TE change index	1.020	0.804	1.418	0.116
2	PTE change index	0.984	0.832	1.113	0.056
3	SE chanage index	1.036	0.862	1.382	0.093
4	Technological change index	0.978	0.837	1.081	0.055
5	Malmquist productivity change index	0.998	0.738	1.313	0.125

The averages of productivity change indices are the geometrical means.
Source: authors' calculations based on the FADN data.

Table 7

Productivity change indices of dairy farms during 2014 – 2016

No	Average productivity change indices	Mean	Minimum	Maximum	Standard deviation
1	TE change index	1.005	0.660	1.809	0.146
2	PTE change index	1.033	0.785	1.526	0.094
3	SE chanage index	0.973	0.578	1.186	0.084
4	Technological change index	1.016	0.912	1.118	0.050
5	Malmquist productivity change index	1.020	0.604	1.762	0.133

The averages of productivity change indices are the geometrical means.
Source: authors' calculations based on the FADN data.

Table 8

Productivity change indices of pig farms during 2014 – 2016

No	Average productivity change indices	Mean	Minimum	Maximum	Standard deviation
1	TE change index	1.066	0.842	1.290	0.0974
2	PTE change index	1.022	0.874	1.212	0.072
3	SE chanage index	1.043	0.674	1.546	0.075
4	Technological change index	0.890	0.369	1.116	0.091
5	Malmquist productivity change index	0.948	0.723	1.173	0.087

The averages of productivity change indices are the geometrical means.
Source: authors' calculations based on the FADN data.

results of this study for field crop, dairy and pig farms were compared with our findings because the average of farms' UAA were alike. The values for French field crop farms were higher than our scores of 16.3%, 16.7%, 3.6% and 5.1%, respectively for TFP, TE, TC and PTE changes. Whereas, smaller differences were recorded for dairy farms. In those farms, the values of PTE, TC and SE were higher, respectively, by 2.1, 5, and 2.9%. The TFP and TE got lower values of 2.9 and 2.7%, respectively. The scores for pig farms differ more than in already presented farms. The higher changes were recorded for PTE (+13.4%) and TE (+17.4), lower for TC (-1.7%), PTE (-1.8%) and SE (-3.1%). In both countries the increase of SE in dairy farms was recorded. However, the greater growth of SE changes in French dairy farms indicated that French farmers limited input in greater extent. The drop of SE in the field crop and pig farms showed that farmers in the region of Mazowsze and Podlasie had to adopt the input saving technique better. The value of SE changes from Latruffe and Desjeux (2016), and Dakpo *et al*. (2017) studies show that even they analysed data from different years the SE changes in France were higher than in Poland.

So, this confirms that French farms better control and limit the inputs. Ghali *et al*. (2016) measured TE and PTE of French field crop and dairy farms based on data from 2010. The average UAA of filed crop farms was 148 ha, whereas of dairy farms – 96 ha, i.e. 33 % larger than Polish dairy farms. So the data from this study could be comparable with our outcomes. The average TE of Polish crop field and dairy farms were higher respectively by 14.9 and 4%. The average PTE score of field crop farms was higher by 9.1%, whereas in dairy farms lower by 0.4%. Despite the fact that both PTE scores were high and there was little difference between them, there is a place for improvement of management practices. In Vasilev *et al*. (2008) studies the efficiency scores were calculated for Estonian grain farms in which UAA were above 180 ha. Therefore, all the results of this study could be referred to our analysis performed for the large filed crop farms. The TE of those farms ranged from 0.70 to 0.78. Where as in the region of Mazowsze and Podlasie it varied from 0.78 to 0.82. The difference between PTE amounted to 5%. There was no difference between SE in that group of farms. Results of our analysis show that a higher percentage of farms working under IRS and CRS was recorded in the region of Mazowsze and Podlasie than in Estonia. Fogarsi and Latruffe (2009) compared the technical efficiency in dairy farming of France and Hungary in 2001 – 2006. Our studies cover a later period but results could be compared. The average TE efficiency

for the whole period of Polish dairy farms (0.699) was lower than for France (0.723) and Hungary (0.791). Similar differences were in SE scores. There was no difference between PTE values of Hungary and Polish farms. The mainly difference in TE comes from SE.

Conclusions

1. The results of this study contribute to the literature on efficiency and productivity measurement in the agricultural sector by applying the DEA method to calculate efficiency and Malmquist index to estimate the productivity changes.
2. This study was the first to provide efficiency and productivity estimates for large field crop, dairy and pig farms based on FADN data in the region of Mazowsze and Podlasie during the years 2014 – 2016. All calculated indices for this region are consistent with the results obtained in the previous studies.
3. The mean potential for input savings has been approximately 20% for large field crop farms, 25% for pig and 30% for dairy farms in the region of Mazowsze and Podlasie. Inefficiency of field crop farms comes mainly from scale efficiency, and of pig and dairy farms equally from pure technical and scale efficiency.
4. The high percentage of studied farms operated under increasing returns to scale. The growth of their efficiency could be realized by an increase of farm size.
5. In the studied period, only in dairy farms the average productivity growth of 2% per year was recorded. This increase was due to both technical and technological efficiency improvements. In pig farms the productivity reduction of 5.4% was observed. It was the result of a decrease in technological efficiency. There was no change in the productivity of field crop farms.

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ECONOMIC COMPONENT OF ANC PAYMENTS. EXAMPLE OF THE FARMS IN POLAND

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Abstract
Conducting agricultural activity in areas facing natural constraints (ANC) affects farms' production and economic results. ANC payments were introduced to compensate farmers for higher costs and lost income. The aim of the study is to compare the production and economic results of farms receiving ANC support with other farms. It was hypothesized that ANC farms achieve lower production and economic results than other units. The analysis is based on Polish FADN data concerning 2015. The sample included 12,105 farms, of which 4,652 (38.43%) received ANC subsidies. To describe the characteristics of the surveyed farms, positional measures were used due to strong asymmetry. The Mann-Whitney U test was used to assess the significance of differences in distributions. The results indicate the existence of significant differences in the production potential, production and economic efficiency of farms receiving ANC payments and ones without them. Agricultural farms receiving ANC payments are characterized by a significantly smaller area of agricultural land, a lower share of arable land in the UAA and a smaller share of leased land. They also have lower production volume, lower land and labour productivity. They achieve relatively lower incomes. Nevertheless, the payments to a small extent reduce these differences. On this basis, it can be concluded that ANC payments in Poland do not provide full compensation for differences in the production and economic results of a farm with worse agri-environmental conditions. Therefore, the impact of the CAP on the economic results of farms located in ANC is relatively small.
Key words: CAP instruments, LFA/ANC payments, production and economic results of agricultural holdings.

Introduction

Conducting agricultural activity in areas facing natural constraints (ANCs)[1] affects the production and economic results achieved by farms. This can even lead to reduction of agricultural activity (Vittis, Gadanakis, & Mortimer, 2017) and ANCs impede farm economic growth (Giannakis & Bruggeman, 2015). Therefore, ANC payments were introduced to compensate farmers for additional costs and lost income in order to keep agricultural activity and thus viable rural communities in such areas. Subsidies for farms operating in areas with specific limitations to efficient agricultural production are one of the longest, still operating instruments of the EU common agricultural policy (CAP). It was introduced in 1985[2]. Currently the ANCs occupy over 50% of the EU UAA (Pažek *et al.*, 2018). The objective of this support is to contribute to the maintaining of the countryside as well as to the maintaining and promoting sustainable farming systems by encouraging continued use of agricultural land (Regulation (EU) No 1305/2013).

There is vast literature on the production and economic indicators of farms operating in areas facing natural or other constraints. It shows significant differences in the production between ANC and non-

ANC farms (Střeleček *et al.*, 2008). Yet, there are also examples of farms operating in ANCs that achieve farm net value added per one annual working unit very good in comparison with other regions. This is the case of Czech farms with an extensive cattle breeding (Doucha, Štolbová, & Lekešová, 2012). The impact of ANC payments on the economic performance of farms is mixed. The study concerning the payments in the period 2004–2012 based on comparison of selected economic indicators showed that positive impact of these subsidies was observed only in mountainous areas (Lososová, Svoboda, & Zdeněk, 2016). The differences are stated also between countries. Štolbová *et al.* (2007) revealed that a significant impact of ANC subsidies was observed in the case of Czech farms, but not in the Polish ones.

The studies show contradictory results to the question of the impact of the ANC payments on maintaining agricultural activity. Positive impact was observed in the case of mountain farms in Austria, where the subsidies also contributed to offsetting higher production costs (Hovorka, 2006). A study of Latvian farms showed a positive impact (Veveris, Lakovskis, & Benga, 2014). The same applied to the study concerning Czech and Slovakian farms (Štolbová & Molčanová, 2009), while the study concerning Poland

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[1] Throughout the paper the current name of these areas is used in accordance with the Regulation (EU) No 1305/2013. Yet, it must be mentioned that before the programming period 2014-2020 the name of less favoured areas (LFAs) was used.

[2] LFAs were established in the European Union under the Directive 75/268/EEC on mountain and hill farming, and farming in certain less-favoured areas. The support measure was introduced by the regulation 797/85.

Table 1

Current rates of payments for the Polish ANCs

Type of ANC	Rate (PLN ha^{-1} year^{-1})	Approximate rate in EUR
Mountainous areas	450	107
Lowland zone I	179	43
Lowland zone II	264	63
Specific	264	63

Source: Ministerstwo Rolnictwa i Rozwoju Wsi (2018).

showed that this impact was insignificant (Giesecke, Horridge, & Zawalińska, 2010).

The problem of economic results of farms operating in ANCs is also of vital importance in the debate on the fine-tuning of delimitation of these areas called for by the last CAP reform. For example, the research on ANC farms in Greece showed that the farms in other than mountainous ANCs achieve higher gross revenues as a result of production of higher valued crops which leads to a conclusion that farms in mountainous ANCs need more support (Oxouzi *et al.*, 2012). The current trend promoted by the European Commission is to focus on the environmental aspects of the agricultural land. According to some studies, this would be a good opportunity to take into account such constraints as a high risk of droughts (Štolbová, 2011).

ANC payments can be received in Poland by farmers whose farms are located in four types of ANCs. Distinguished are the following types of ANCs: mountainous areas, lowland zone I, lowland zone II and areas with specific handicaps. The vast majority of the Polish ANCs are lowland areas, which account for 92.6% of ANCs in Poland, while the mountainous areas account for only 2.1% of the ANCs (Namiotko, Góral, & Soliwoda, 2017). The rates of payments depend on the type of ANC (Table 1). The ANC payments are subject to degressivity at farm level, depending on the total area of agricultural land covered by these subsidies:

- ANC area of up to 25 ha – 100% of payment;
- ANC area of 25.01 to 50 ha – 50% of payment;
- ANC area of 50.01 to 75 ha – 25% of payment.

The aim of the study is to present the conditions and compare the production and economic results of farms receiving ANC support with farms without such support. It has been hypothesized that farms, despite receiving ANC support, achieve lower production and economic results than other units.

The results of our research are part of the debate on the future of the CAP and its instruments. The possible diminution of the CAP's budget in the next programming period calls for increasing the efficiency and effectiveness in the use of the funds available. Therefore, the impact of specific policy instruments and their combination can serve as an important argument in the discussion on reshaping CAP's instruments.

Materials and Methods

The analysis was carried out on the basis of accountancy data obtained in 2015 from agricultural enterprises enrolled in the Polish FADN. Among 12,105 individual farms surveyed, 4,652 (38.43%) received payments for managing farms in areas with natural constraints. The largest percentage of farms that received ANC payments were farms located in lowland areas: I (68.76%) and II (25.76%). Farms with specific difficulties constituted 3.55%, while those in the mountain zone were 1.83%. In 2015, the surveyed farms received more than PLN 21.57 million in ANC payments. The analysis takes into account the production and economic results of farms operating in areas facing natural constraints (ANC) and not facing natural limitations (N_ANC). The study includes: a) production potential of farms, which has been characterized by variables such as: agricultural area, share of leased land in UAA, structure of arable lands, livestock density (LU ha^{-1}); b) production effects, productivity of factors of production and economic efficiency, characterized by: total production value, land productivity (PLN '000 ha^{-1}), gross value added, farm income, net value added per full-time person (PLN '000 AWU^{-1}), income from a family farm per a full-time employee and labour efficiency. Due to the existence of a strong asymmetry in the distributions of variables selected for the analysis, position measurements were used for their description (i.e. median, min, max, range, lower quartile and upper quartile). To verify the research hypothesis adopted for the purposes of the paper and the lack of conformity of distributions of the examined features with the normal distribution, the non-parametric Mann-Whitney U test was used. This test verifies the hypothesis of significant differences between distributions of traits in two independent populations (Moczko, 2014; Mann & Whitney, 1947).

Results and Discussion

The production potential of farms receiving ANC payments and without ANC payments was clearly different. Farms receiving payments for areas with natural constraints were characterized by a smaller size of agricultural land compared to farms with better quality environmental conditions. However, these differences were not significant. In the group of ANC farms, half of them operated on an area equal or smaller than 22.7 ha, while farmers with farms outside ANC had an area equal to or smaller than 25.1 ha (Table 2). The value of the asymmetry coefficient in both groups of farms indicates the presence of right-sided asymmetry, which means that the units with above average values predominate. Agricultural farms receiving ANC subsidies showed a much lower share of the lease in the land use structure. In the agricultural structure of the production space, arable land predominated in both groups of analysed farms. The value of the asymmetry coefficient indicates that both the first and the second group of farms are dominated by units with below-average values. It should be noted that farms with potentially better farming conditions were characterized by a relatively higher share of arable land in total area compared to ANC farms. This can affect the way of conducting agricultural activity and the type of farming, and thus also the effectiveness and competitiveness of farms. At the same time,

farms with ANC payments were characterized by a much larger share of permanent grasslands. Farms in which meadows and pastures have a high share in the structure of agricultural land are characterized by the combination of various types of plant and animal production. According to FADN data, in 2015 over one third of the farms receiving ANC payments in Poland conducted mixed production, thus, striving to take full advantage of the natural production potential of soils (Jha, Tripathi, & Mohanty, 2009), but also to maintain greater stability and financial security (Kurdyś-Kujawska, 2016). Moreover, according to Barszczewski (2015), farming on permanent grassland is generally carried out extensively. The share of grassland in the production structure of farms is related to the stocking of animals. Hence, in farms operating on areas with natural constraints there is a higher density of animals than in other farms. Meadows and pastures are used to produce high-nutritional forage at lower production costs. The stocking of animals in the ANC located holdings ensures an adequate inflow of organic matter from natural fertilizers to arable lands and enables the balancing of nutrients in the soil. Therefore, farmers from these farms are not forced to apply other practices (i.e. incorporation of straw or of secondary crops or purchase of natural fertilizers) (Wróbel & Barszczewski, 2016). To a large extent this influences the fertilizer costs per 1 ha of UAA,

Table 2

Production potential of farms operating in ANC and outside of ANC

Specification	Median	Min	Max	Lower quartile	Upper quartile	Range	Skewness
UAA (ha)							
N_ANC	25.1	0	665	14.74	44.3	665	4.8
ANC	22.7	1	703	13.8	39.4	25.6	5.7
Share of leased land in UAA (%)							
N_ANC	16.8	0	100	0	40.0	100	0.8
ANC	12.4	0	100	0	38.7	100	0.9
Share of arable land in UAA (%)							
N_ANC	94.1	0	100	75.1	100	100	-1.7
ANC	81.8	0	100	62.5	96.83	100	-1.1
Share of permanent grassland in UAA (%)							
N_ANC	3.6	0	100	0	18.2	100	1.9
ANC	15.5	0	100	1.3	33.8	100	1.1
Animals per ha (LU ha^{-1})							
N_ANC	0.17	0	1135	0	1.99	1135	82.54
ANC	1.06	0	49.2	0	1.99	49.2	8.7
Soil valuation index							
N_ANC	0.9	0.05	1.9	0.6	1.1	1.8	-0.1
ANC	0.6	0.05	1.7	0.4	0.8	1.6	0.3

Table 3

Production and economic efficiency of farms operating in ANC and outside of ANC

Specification	Median	Min	Max	Lower quartile	Upper quartile	Range	Skewness
Total output (PLN '000)							
N_ANC	155,990	-11,333	11,441.360	78,868	292,985	11,452.692	12.0
ANC	116,073	1,806	8,002.207	57,335	234,704	8,000.400	7.8
Land productivity (PLN '000ł ha⁻¹)							
N_ANC	5,509	0,027	9,666.378	3,929	8,522	9,666.351	46.1
ANC	4,852	0,187	1,978.235	3,184	7,543	1,978.048	26.9
Gross value added (PLN '000)							
N_ANC	78,798	-158,359	8,863.501	38,380	151,837	9,021.860	15.2
ANC	67,316	-55,598	1,812.419	33,488	132,751	1,868.017	4.3
Farm income (PLN '000)							
N_ANC	52,636	-526,930	5,609.913	21,611	107,466	6,136.843	12.1
ANC	43,587	-213,691	1,457.884	20,44	65,851	1,452.921	6.1
ANC *	47,600	-205,088	1,547.558	20,315	96,766	1,752.646	4.4
Farm value added per agricultural work unit (PLN '000 AWU⁻¹)							
N_ANC	32,384	-123,759	586,534	14,201	61,794	710,292	3.0
ANC	25,858	-100,791	780,889	11,507	51,424	881,680	3.5
Family farm income expressed per family labour unit (PLN '000 FWU⁻¹)							
N_ANC	30,272	-335,624	2,804.957	12,249	62,369	3,140.581	10.7
ANC	24,518	-244,962	1,245.789	10,016	51,921	1,270.285	51.7
Labour productivity (PLN '000 AWU⁻¹)							
N_ANC	95,303	-11,333	10,496.370	52,315	171,401	10,507.703	14.5
ANC	70,631	1,604	13,167.383	36,951	135,667	13,165.778	22.2

* farm income with ANC payments. The average value of subsidies paid per one farm amounted to PLN 4,638. The value of funds received was strongly diversified. The minimum and maximum values were respectively at PLN 145 and PLN 57,752. The exchange rate is: 1 EUR = 4.2 PLN

The obtained results of the Mann-Whitney U test allow to conclude that there are reasons to state the occurrence of differences in distribution of characteristics regarding production and economic results between farms receiving ANC payments and without them (p=0.0001).

which are significantly lower in farms receiving ANC payments (median PLN 468.55 ha⁻¹) than in farms without these subsidies (median PLN 659.20 ha⁻¹). The production capacity of farms is also conditioned by the level of quality of the soils. According to the results of the conducted research, ANC operating farms were characterized by significantly worse soils than farms without ANC payments. This is confirmed by the value of soil valuation index.

As shown by the results of the conducted research, a much higher value of agricultural production is visible in farms located in areas with potentially better environmental conditions than in the case of farms receiving ANC payments. The median value shows that in half of the ANC farms the value of production was equal to or lower than PLN 116,000, while in holdings other than ANC it was less than or equal to PLN 155,000 (Table 3). Taking into account the indicator

of land productivity, also in this case higher values of the indicator were characteristic of farms conducting agricultural activity under better environmental conditions. The value of the asymmetry coefficient in both groups of farms indicates the existence of a strong right-sided asymmetry, which means that the units with above-average features value are the majority. In addition to land productivity, one of the important measures of synthetic farm productivity is the labour productivity indicator. Labour productivity measured by net value added per full-time employee, family farm income and the value of agricultural production per one full-time employee on a farm shows a high level of differentiation between farms receiving ANC payments and without them. It should be noted, however, that considering the amount of ANC payments received by agricultural holdings to a small extent reduces the differences between

the amount of incomes of agricultural holdings conducting agricultural activity in areas with natural constraints and other farms. An important category, which reflects not only the increase in the value of goods produced by an agricultural holding, but also the impact of agricultural policy on the economic situation of a farm due to subsidies and taxes, is gross value added (Goraj & Mańko, 2009). The research proved that farms receiving ANC payments achieved a significantly lower volume of agricultural production than the other ones.

Compared to farms with better environmental conditions, farms operating in areas with natural constraints are characterized by significantly lower land productivity and labour productivity. The size of the gross value added by agricultural holdings receiving ANC subsidies indicates that these farms do not equal the other farms in terms of volume of agricultural production. They achieve relatively lower family farm incomes and ANC subsidies received by them reduce these differences only to a small degree. The research results provide the basis for a positive verification of the hypothesis.

Conclusions

1. There are significant differences in the production potential as well as production and economic efficiency between farms conducting agricultural activity in areas with natural constraints and farms with potentially better environmental conditions.

2. Agricultural holdings receiving ANC subsidies in Poland are characterized by a significantly smaller area of arable land, a lower share of arable land in the UAA and a smaller share of leased land.

3. On the basis of the conducted research, it can be concluded that ANC subsidies granted in Poland according to the current criteria do not ensure full compensation of differences in the production and economic results of farms with worse agri-environmental conditions. Therefore, the impact of the common agricultural policy on the production and economic results of farms operating in ANC is relatively insignificant.

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INNOVATING APART OR TOGETHER: LITHUANIAN FARMERS AND RURAL COMMUNITIES

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Abstract
The changing economic and social situation in the regions leads to the changing understanding of the potential which exists in the countryside. This research is based on the idea that farmers operate in close neighbourhood with the local communities and therefore they may hold a potential to start innovation processes in rural regions as agents of change. This may happen individually or together with the local community. Farmers are active in acquiring new knowledge and experience through collaboration with advanced innovation centres in research laboratories and universities, and sharing with the local community, thus making these innovations open. The success of innovators comes in line with the collaboration and therefore the defined three key factors of 'innovating together' in this research are: first, the shift from technical to organizational innovations; second, the shift from sectorial to territorial rural development strategies; third, the size of farms and rural enterprises due to the limited number of employees. Theoretical findings are followed by empirical investigations from representative data collected in Lithuanian farms in 2017, supported with relevant statistical analysis. Research results show that the potential for 'innovating together' in Lithuanian farms is rather weak when taking into account all three factors. However, there are reasons behind this which give insights for future developments in the field.
Key words: innovation, collaboration, farmer, local community, rural development.

Introduction

The current economic and social situation in rural regions is guiding the rural population towards the creation of new perceptions of farming and rural life that are totally different from the perceptions in the era of industrialization of agriculture. In such conditions the success is most often defined by the ability to innovate (Chrisman *et al.*, 2015; Dunne *et al.*, 2016; Kusano, Wright, & Conger, 2016). Farmers that focus on innovation as a core value are finding success in business (Madureira *et al.*, 2015; Reimers-Hild & Dye, 2015a; Reimers-Hild & Dye, 2015b; Neumeier, 2017; etc.). Innovative rural communities are creating better quality of life (Pittaway *et al.*, 2004; Vaccaro *et al.*, 2012; Esparcia, 2014; Lambrecht *et al.*, 2015; Salemink, Strijker, & Bosworth, 2017). However, a lot of innovative initiatives fail and there are numbers of reasons behind that (von den Eichen, Freiling, & Matzler, 2015).

The extensive review and systematization of scientific literature focusing on the innovative activities in the context of rural development shows that the success of innovators comes in line with collaboration. Therefore, authors proposed the existence of three key factors that call for innovating together, namely:

1. the shift from technical to organizational innovations;
2. the shift from sectorial to territorial rural development strategies;
3. the size of farms and rural enterprises due to the limited number of employees.

Recent findings demonstrate that technical innovations have been dominant since the middle of the last century. Griffin (2013) states that 'many of the most important innovations over the last 50 years have been technical' (p. 206). Most of them have been created by scientists and have provided technological solutions for a process or product which are new on a national or global level. The role of farmers used to be understood as implementers of the technical innovation only, since the initiators and designers of innovations used to be outsiders.

During the last decades, the shift from technical to organizational innovations has become evident (Griffin, 2013; Chrisman *et al.*, 2015; Kusano, 2016). Its main ideas take into account changes in the managerial and marketing processes in farming, as well. Dynamic business environment and the variety of roles to be fulfilled by modern multifunctional farm require focusing on organizational innovations (Vaccaro *et al.*, 2012; Creaney, McKee, & Prager, 2014; Salemink, Strijker, & Bosworth, 2017). Some scientific discussions have raised the issue of servitization of rural economy, which demands a lot of organizational innovations to be implemented (Jean, 2014; Salemink, Strijker, & Bosworth, 2017; Vidickienė, 2017).

The shift from sectorial to territorial rural development strategies has resulted in a stronger focus on endogenous factors of development (Creaney, McKee, & Prager, 2014; Zago *et al.*, 2015). However, the current challenges faced by agriculture and farming cover only a small part of the rural development issues. Rural communities encounter the need to solve a range of new social problems (Esparcia, 2014; Jean, 2014; Madureira *et al.*, 2015; Salemink, Strijker, & Bosworth, 2017). Imitation of urban models as the *apotheosis* of qualitative life does not work in the 21st century. The goal of modern innovators is to

use local cultures and know-how as key assets for rural development in a different way compared to the development of urban settlements.

The size of a farm and rural enterprise due to the number of employees in most cases is defined as a limiting factor to innovation (Creaney, McKee, & Prager, 2014; Esparcia, 2014; von den Eichen, Freiling, & Matzler, 2015; Dunne *et al.*, 2016). This restricts the potential of local inhabitants to search for and collect innovation-related information, their possibility to exchange knowledge with colleagues, discuss new important trends and to collaborate in cooperative innovation projects (Vacaro *et al.*, 2012; Lambrecht *et al.*, 2015).

Networking is perceived as an important strategic tool in attaining innovation. It is beneficial to capture ideas, reduce distance with policy makers, prevent them from insulation, know the right people and places to obtain information (Lambrecht *et al.*, 2015; Madureira *et al.*, 2015). Networks give access to complementary resources, skills, capabilities, and knowledge that are not internally available (Pittaway *et al.*, 2004; Vacaro *et al.*, 2012). Knowledge networking and multi-actor knowledge networks that facilitate knowledge exchanges, joint learning and the generation of new, more integrated solutions, are crucial if the agriculture is to become sustainable and resilient (Šūmane *et al.*, 2017). In order to achieve innovation, a wide range of network partners can be used, such as colleagues, input industries, traders, researchers, extensionists, government officials, civil society organizations, etc. (Pittaway *et al.*, 2004; Vacaro *et al.*, 2012; Lambrecht *et al.*, 2015; Madureira *et al.*, 2015; Šūmane *et al.*, 2017). It is also argued that the spread of innovation may also be done through farmer networking – whether or not facilitated by formal agricultural knowledge institutions, through collaboration between farmers and researchers as knowledge co-generators, and through multi-actor knowledge networks that bring together participants from various fields. It is suggested by Šūmane *et al.* (2017) that the dynamic contexts, complexity and the local specificity of the current challenges facing agriculture, and the many roles it is being asked to fulfill, require more inclusive, flexible modes of governing the generation, integration and sharing of knowledge. All stakeholders, including farmers, need to be recognised as equal co-authors of knowledge generation, and all kinds of knowledge, both formal and informal, need to be brought together in innovation processes.

The so-called 'openness' of innovation conditionally determines the willingness of innovating together. It overwhelms the spread of the affected area thus giving evidence on both internal and external effects of innovation for local community

implementation, especially with regard to distanced social systems in regions with the help of networks. This sometimes also refers to 'responsible innovation', as it is intended to make a positive change for society in the region. Therefore, it becomes evident how important is innovating together - spreading the externally acquired knowledge to local community members when raising its potential to innovate (Duh & Kos, 2016; Specht, Zoll, & Siebert, 2016). Local farmers may become a networked driving force for burning and sharing innovations with local community, thus making a tremendous contribution to the development of rural regions and local communities itself.

Therefore, we argue that a better integration of various forms of knowledge could be acquired by networking for innovation, and the potential held by a local farmer might be used for sharing knowledge with the local community to open and accelerate the innovation process. However, it depends on the farmers' state of cooperation with universities and research laboratories when acquiring the brand-new knowledge in the field of farming as a potential to innovate, as well as their willingness to share it with the local community and thus open the innovation process.

The aim of this study is to define the state of innovativeness of Lithuanian farmers in relation to their potential, willingness and conditions to share innovations with local community.

Materials and Methods
Research approach and methods

Positivist methodology approach has been taken as a basis to organize the research. Scientific literature review, systematization and theoretical modelling methods were used to compose a suitable conceptual framework to measure farmer's innovativeness in the community. Selection of an appropriate conception, which might best serve when taking into account the agrarian discourse-relevant innovation for society in the region dimension, was made using focused review of scientific literature regarding various approaches towards innovations in general and innovations for regional context. Reduction of context-specific material according to the research objective helped distinguish the topical issues in the 'innovating together' dimension of this research.

To ensure the reliability of primary theoretical findings, two-stage exert evaluation was performed. Voluntary team of six international experts in the field, selected using non-probability criterion sampling procedure, helped prove the most suitable approach, dimension and themes for innovating together in agrarian discourse. During the first stage experts rated different approaches towards innovation from most to least suitable to apply in the agrarian

discourse for defining intents for innovating together. During the second stage rating of separate dimensions from different approaches was done. The calculated Kendall's coefficient of concordance W was close to 1, thus demonstrating the assessed sufficient agreement among experts. Aggregated expert evaluation results approved the eligibility of primary theoretical findings: the three distinguished themes/key factors of innovating together are suitable to apply for valuing farmers as innovator's intent to innovate together with the local community.

Further analysis helped localize the object-specific category of innovating together with the society in the region. Theoretical modelling encompassed context-specific adaptation of selected innovative activity routes that are helpful to describe farmer's intent to innovate together with the local community.

Theoretical findings suggested empowering quantitative empirical study to be performed in finding actual evidence for solutions of defined scientific problem. The primary semi-structured interview questionnaire encompassed the two major options for measuring 'innovating together' using the five-point Likert scale. Farmer's intent to innovate together with the local community was defined from the two basic perspectives. First, farmer's activeness in acquiring the necessary potential to innovate and being part of the knowledge sharing network – wider than a region – was defined by option gaining brand-new knowledge from "collaboration with various research laboratories and universities". Second option for innovating together was defined as the farmer's openness when sharing the acquired knowledge and gained experience with the local community.

Pilot face-to-face interviews with 100 Lithuanian farmers were done by a team of scientists. Primary results revealed making insignificant corrections in the formulation of farmer's activities due to the better expressed essence and understanding of the activity.

After implemented corrections, original representative empirical data were collected by experienced research subcontractor. The population of Lithuanian farmers equals to $N=138,9$ thousand (Agriculture and food sector in Lithuania, 2016). The calculated representative population under statistical conditions of 3% error ($\varepsilon=0.05$) and 95% ($p=0.5$) confidence level is $n=1059$ (Schwarze, 1993). Respondents were selected using systemic sampling of research subcontractors' database. Data were collected using telephone interviews of Lithuanian farmers in January-February 2017. Potential respondents were called 3211 times, 1491 times without response, 612 farmers rejected the suggestion to take part in the interview. Finally, 1108 interviews were acknowledged suitable for further investigations, which satisfied the defined statistical conditions.

The obtained data was processed with descriptive statistical analysis. The percentage distribution of respondents' answers was calculated, comparing data between the groups by using χ^2 test (significance level $p<0.05$). The sample size of the study allows ensuring that the statistical error of the results does not exceed 3.1%. Statistical analysis of data was performed using the SPSS 22.0 program. A two-stage variable χ^2 independence test was performed to determine whether the respondent's characteristics (sex, age, etc.) affect the distribution of answers to questions. Only those answers were used as evidence, in which the test showed that the distribution of answers depended on the respondents' characteristics.

General sample characteristics

The interviewed Lithuanian farmers represent all the municipalities of the country, different natural areas reflect various farming conditions and the corresponding characteristics of farmers and farms: the gender, age, education of the farmer; the size of farm, duration of farming activity, and type of farming (Agriculture and food sector in Lithuania, 2015).

The study involved 57.7% men and 42.3% women. The majority of surveyed farmers (38.3%) were respondents aged from 55 to 64; the second age group (27.6%) were farmers aged between 45 and 54, respondents of 65 years and older composed 23.9%. The smallest group of respondents was represented by the youngest farmers: 1.1 percent is up to 35 years old and 9.1% aged between 35 and 44. The majority of respondents (34.5%) had acquired professional education; farmers with acquired upper and secondary education composed respectively 23.7% and 21.4%. The smallest group of respondents according to their education consisted of respondents with lower secondary (4.6%) and primary education (1.6%). The majority (88.4%) of the surveyed farmers acquired education before 1990 (or in the Soviet period), 10 percent – before the Lithuania's accession to the EU (i.e. in the period of 1990 – 2004) and 1.6% in 2005 or later, i.e. after Lithuania's accession to the EU.

Less than half of the surveyed farmers (40.2%) have a farm of economic size (turnover in euros per month) up to EUR 4,000 and, according to this criterion, falls into the smallest group of farms. 22.3% of respondents' farms has the turnover from EUR 4,001 to 8,000; 16.3% – from EUR 8,001 to 15,000; 8.8% – from EUR 15,001 to 25,000; 6.3% – from EUR 25,001 to 50,000. The smallest group of respondents consists of the farms with the largest turnover. The turnover of the surveyed companies ranges as follows: 3.4%– from EUR 50,001 to 100,000, 1.9% – from EUR 100,001 to 250,000 and 0.8% – more than EUR 250,001. The majority of respondents (44.8%) are farmers whose farm size is up to 20 ha; 32.1% – from 20.1 to 50 ha;

13.7% – from 50.1 to 100 ha. The smallest part of the respondents are farmers with farms of 100.1 to 500 ha (9.2%) and more than 500.1 ha (0.2%).

According to the criterion of the duration of the activity, almost half of the surveyed farmers (46.6%) started their farming activities 21 years ago or even earlier, a similar proportion of respondents (43.1%) – from 11 to 20 years ago, and the youngest farms with experience of 10 and less years of farming composed 10.3%. More than half of the respondents (54.1%) have mixed (both crop and livestock) farms, 21.5% are crop farmers, and livestock farmers compose 13.3%. By summarizing the general characteristics of survey respondents, it can be stated that the survey data is representative.

Results and Discussion

The evidence obtained through interviewing farmers helps prove the theoretically composed framework of innovating together. First of all, the collected structured data help define the state of technical (production facilities) and organizational (farm organizational processes) innovations in Lithuanian farms and the intensity of farmer's attention with regard to these innovations. Secondly, the measured intent to acquire new knowledge and experience through collaboration with research laboratories and universities, and willingness to share this knowledge and experience with the local community help define the shift from sectorial to territorial strategies in the name of local community involvement in the innovation process. The third analysed defining factor was the size of farms and operating units to demonstrate the potential to innovate. Altogether, these factors help identify whether Lithuanian farmers hold conditions and potential, as well as willingness to innovate together with the local communities.

The state of technical and organizational innovations

The interviewed farmers were asked, how often they upgrade the existing production facilities and how often they purchase modern production facilities in their farms, ranging from less than once a year, once a year or more often than once a year.

Research results demonstrate (Figure 1) that Lithuanian farmers are equally passive innovators.

The upgrade of the existing production facilities took the dominant position, represented by 76.1% of respondents, who said they do it is less than once a year. Organizational processes are also very rarely upgraded – 85.2% of the interviewed farmers said they do this less than once a year. The question concerning the purchasing of modern production facilities was mentioned as performed rarer than once a year by 90.2% of the respondents. Installing innovative organizational processes less than once a year is done by 84.3% of Lithuanian farmers. Going deeper into the detailed descriptive analysis of the research results, it becomes evident that among those farmers who responded that they perform the listed innovative activities 1 time per year and more than 1 time per year, are experienced farmers who hold the farm for 11 and more years. Due to the three distinguished types of farming, research results show that innovations are more acceptable to be installed and applied in mixed farms (56.8%), than in crop farming (25.5%) and the last position is taken by livestock farms (17.7%). It was an unexpected finding that the bigger the farm is due to its annual turnover, the less active it is in
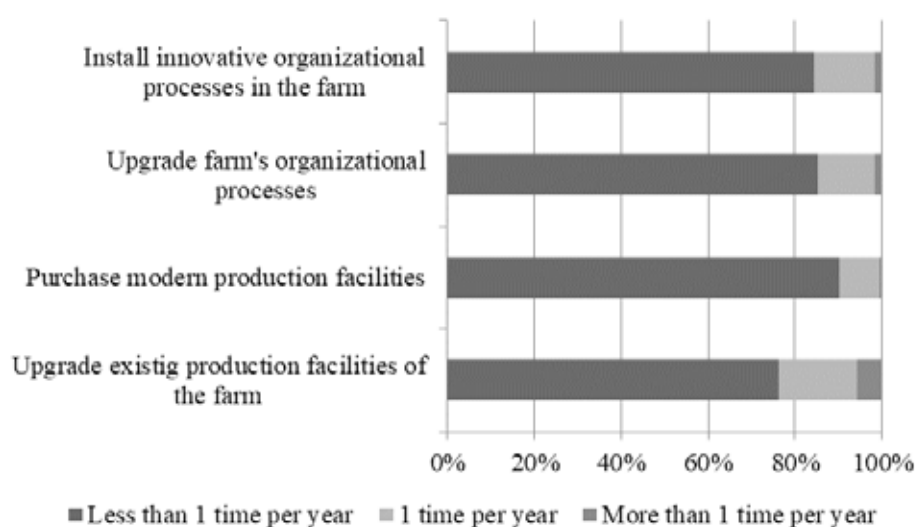
Source: authors' calculations.

Figure 1. The intensity of upgrading and installing facilities and organizational processes as innovations in the Lithuanian farms.

Table 1

Frequency of farmers' intent to acquire new knowledge for innovation and share it with local community

	Collaboration with various research laboratories and universities, valid percent	Sharing the acquired knowledge and experience with the local community, valid percent
Never	65.3	36.7
Very rare	9.4	9.0
Rare	13.6	18.3
Often	8.3	26.3
Constantly	3.4	9.7
Total	*100*	*100*

Source: authors' calculations.

upgrading its equipment and processes. The same situation was seen with purchasing new equipment and installing innovative organizational processes. It became evident from this point of view that most active innovators both from technical to organizational innovations are farms with the turnover of up to EUR 50,000. Research results reveal that most active innovators are aged between 45 and 65.

The potential to shift from sectorial to territorial rural development strategies

The potential to shift from sectorial to territorial rural development strategies is defined using the two core parameters for 'innovating together': first, collaboration with various research laboratories and universities; and second, sharing knowledge and experience with the local community. Aggregated research results are presented in Table 1.

Research findings demonstrate that in total only 11.7% of farmers constantly (3.4%) and often

(8.3%) collaborate with the research laboratories and universities as the potential sources for new knowledge and skill acquisition and take part in networking for innovation. The rest of the farmers demonstrate passive attitude towards innovation process. In contrast to that, sharing gained experience and knowledge with the local community was a more favourable option. Over one third of Lithuanian farmers constantly or often share their knowledge and experience with the local community and this shows a greater potential for spreading innovation. On the other hand, the knowledge and experience, which has a positive tendency to be shared with the local community, seems to be based on individual achievements and development rather than gathered through collaboration with advanced research institutions and excellence centres. Most disappointing results arrive from those who never collaborate (65.3% !) and never share (36.7%) any knowledge and experience. It means that a huge number of farmers have no intention to innovate both
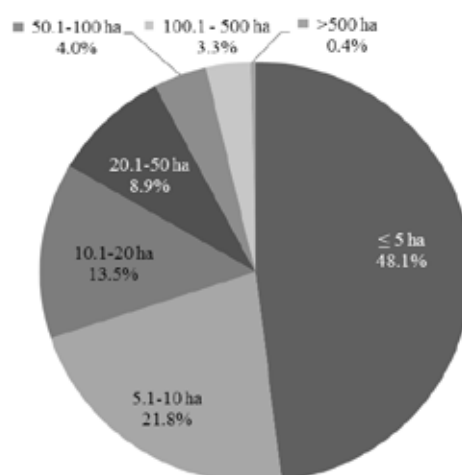
Source: Agriculture and Food Sector in Lithuania 2016.

Figure 2. Structure of farms by declared agricultural area in Lithuania in 2016, in percent.

apart or together. However, the intention to innovate apart is less distinct than the intention to innovate together.

Structure of farm size and rural enterprises in Lithuania

The above implemented theoretical analysis revealed that the structure of farm size is interrelated to the number of employees and, accordingly, to the potential to innovate. Therefore, analysis of the structure of farm size and rural enterprises might add to the analysis of 'innovating together' and help disclose the potential to innovate, arriving from the inside of a farm.

Small farms dominate in Lithuania. Most of Lithuanian farms and rural enterprises have a small number of employees. Analysis of structure of farms by the declared agricultural area in Lithuania in 2016 demonstrates this tendency. In 2016, according to the area declared by all agricultural entities, the average farm size in Lithuania was 21.2 ha. In 2016, the share of farms with the farm size less than 5 ha, was 48.1% (see Figure 2). A large share of 21.8% also belong to the farms with the farm size between 5 and 10 ha. Thus in Lithuania in 2016 almost 70 percent of all farms were small farms with the farm size less than 10 ha.

This situation explains why the cooperation and networking is so important for small farms in Lithuania. Farmers of such farms should focus on the implementation of the collaboration strategy, use various two-sided networks and their platforms to start close cooperation between farmers and users of their products – their customers.

Conclusions

Current economic and social situation of rural regions encourages rural population to create new perceptions in farming and rural life based on new success factors and ability to innovate. The shift from technical to organizational innovations dealing with changes of managerial and marketing processes in farming have occurred. Farmers and rural communities that focus on innovation as a core value usually result in successful business or community activities. Networking is perceived as an important strategic tool in attaining innovation.

The potential of 'innovating together' calls for collective actions via networking, which might help accelerate the access and acquisition to brand new knowledge as well as spreading these ideas for community in the region, which in total would lead to opening the innovation. 'Innovating together' might come into action in case of existence of the three main factors: first, the shift from technical to organizational innovations; second, the shift from sectorial to territorial rural development strategies; and third, the size of farms and rural enterprises due to the limited number of employees.

Empirical investigations suggest several important insights. First, the state of technical (production facilities) and organizational (farm organizational processes) innovations in Lithuanian farms demonstrate low farmer's attention as well as inputs with regard to these innovations. Second, the measured intention to acquire new knowledge and experience through collaboration with research laboratories and universities and willingness to share this knowledge and experience with the local community defined the non-existence of the shift from sectorial to territorial strategies in the name of local community involvement in innovation process. And third, the domination of small farms in Lithuania leads to the usage of cooperation and networking as tools for successful way of their activity. Farmers of small farms should focus on the implementation of the collaboration strategy, on using various two-sided networks and their platforms to start close cooperation between farmers and users of their products. Altogether, these factors help identify weak potential of Lithuanian farmers as well as willingness to innovate together with local communities.

Acknowledgements

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SMART SPECIALISATION DEVELOPMENT IN LATVIA

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Abstract
Based on data on the number of newly established enterprises and the total number of enterprises, the authors analysed whether and what changes occurred in the industries of the national economy that have high transfer potential in relation to smart specialisation implementation in the country, broken down by region, thereby identifying the RIS3 specialisation field on which the focus has to be placed and to which attention has to be drawn.
The aim of the research is to identify the entrepreneurship development in RIS3 specialisation fields broken down by region and economic development according to the RIS3 specialisation fields.
The research has found that the number of enterprises in the industries having high transfer potential in relation to RIS3 as a percentage of the total number of enterprises was slightly above 50%; the regional breakdown of the enterprises revealed that two thirds were located in the regions of Riga and Pieriga, and that ICT was the most significant RIS3 specialisation.
In the post-crisis period, the number of newly established enterprises increased at the highest rate in 2011, exceeding the rate of the previous year more than two-fold, whereas in the next two years the rate decreased below the 2009 level.
Key words: smart specialisation strategy, regional development, NACE code.

Introduction

The national strategy for smart specialisation has an ex ante conditionality for the European Union (EU) Structural Funds use from 2014 to 2020. The strategy envisages detecting smart specialisation priorities with the greatest potential to increase the competitiveness of national economies and mobilising resources for implementing the priorities (Boekholt *et al.*, 2015).

Smart specialisation strategy (RIS3) represents an explicit and place-based approach, while emphasizing prioritization and selectivity through non-neutral, vertical policies, and thereby acknowledging the large variations in regional policy challenges as regards promoting innovation, competitiveness and growth (Grillitsch & Asheim, 2018). Therefore, each region or country sets the fields and priorities for RIS3 that are most relevant to their development.

The Smart Specialisation Strategy of Latvia (RIS3) sets five RIS3 specialisation fields: (1) knowledge-based bio-economy, (2) biomedicine, medical technologies, biopharmacy and biotechnologies, (3) advanced materials, technologies and engineering systems, (4) smart energy and (5) information and communication technologies (ICT) (Gemma, Vītoliņa, 2017). The authors analysed changes in the number of enterprises operating in the industries of the national economy with high transfer potential, particularly for RIS3 specialisation fields, over a five-year period. Latvia has defined the RIS3 specialisation fields as the driver for new economic policies in relation to smart specialisation.

The authors acquired data for the period 2009 – 2014, then the data were processed and examined, splitting them into two data groups. The first data group represented a control period from 2009 to 2013. The research analysed the proportion of newly established enterprises in the RIS3 specialisation fields defined (the research examined and analysed the choice of RIS3 specialisation fields by comparing expert opinions and real trends in the industries). The second data group represented the year 2014 as a control period. The research examined the total number of enterprises in the RIS3 specialisation fields in Latvia by NACE code – the kinds of economic activity.

As this is the first step of the research, the current task is to clarify the boundary line when the RIS3 was adopted. Further analysis will be continued for the recent years.

The aim of the research is to identify entrepreneurship development in RIS3 specialisation fields broken down by region and economic development according to the RIS3 specialisation fields. To achieve the aim, the following specific research tasks were set: 1) to identify the number of newly established enterprises in 2009 – 2013 in industries with high transfer potential according to the RIS3 specialisation fields by region in Latvia; 2) to assess changes in the number of newly established enterprises in the regions; 3) to identify the number of enterprises by region in the RIS3 specialisation fields based on the data on the number of enterprises for 2014.

The research methods used were: monographic, comparison, abstract analysis and logical construction, synthesis and analysis, induction and deduction, the graphical method and statistical analysis.

Materials and Methods

To discuss the RIS3 specialisation fields proposed by the experts, 14 public discussions, in which more

Table 1

Consistency of the RIS3 specialisations with industries having high transfer potential

Industry	Knowledge-based bio-economy	Biomedicine, medical technologies, biopharmacy and biotechnology	Advanced materials, technologies and engineering systems	Smart energy	ICT
Agriculture, forestry	01; 02; 03	01; 02; 03			
Other manufacturing	05; 06; 07; 08; 09; 35; 36; 37; 38; 39			05; 06; 07; 08; 09; 35; 36; 37; 38; 39	
Food industry	10; 11	10; 11			
Light industry	13; 14; 15				
Wood processing	16; 31		16; 31		
Manufacture of non-metal minerals	23		23	23	
Metalworking			24; 25	24; 25	
Manufacture of electrical and optical equipment	26; 27	26; 27	26; 27		26; 27
Manufacture of machinery and equipment	28		28	28	
Manufacture of vehicles	29; 30		29; 30	29; 30	
Other commercial services					58-82; 90-96
Public services		84-88			84-88

Source: authors' calculations based on Viedās specializācijas stratēģijas…, 2017.

than 500 representatives from scientific institutions, education institutions and producer associations took part, were held in 2014. The discussions concluded that the industries of the national economy of Latvia were relatively highly specialised; for this reason, overall, it was not a problem of the national economy of Latvia (Informatīvais ziņojums…, 2017).

The research period was the period of 2009 – 2019 to see whether the opinions of the discussions and experts were in line with the defined specialisation fields for the period concerned. The data were acquired from the Lursoft database. The data on newly established enterprises pertain to the enterprises that have been registered, have operated for 12 – 18 months and have submitted an annual report on their performance. The data selected allowed to identify the main change in the growth of industries in municipalities and cities.

The research selected data only on the industries with high transfer potential that were broken down by RIS3 specialisation field (Table 1). In order to analyse the data by region, the data were selected for six statistical regions. The statistical regions are

enshrined in national legal acts and agreed with the EU statistical bureau Eurostat. Six statistical regions are established in Latvia: Riga, Pieriga, Vidzeme, Kurzeme, Zemgale and Latgale (Par statistiskajiem reģioniem, 2018). Across the regions of Latvia there can be still observed considerable socioeconomic disparities with the monocentric capital city-oriented development, distribution of people and economic activities (Jermolajeva et al., 2017).

The kinds of economic activity registered by enterprises are specified by NACE codes. NACE is an abbreviation in French "Nomenclature statistique des activités économiques dans la Communauté européenne" or the standard classification of productive economic activities in the European Union. Every NACE code corresponds to some kind of business an enterprise is engaged in (What is a…, n.y.).

Actually any industry can potentially use some RIS3 specialisation field; for this reason, the authors focused only on the industries that have high transfer potential. Table 1 shows the RIS3 specialisation fields

that could relate to the industries with high transfer potential (coloured), as well as corresponding NACE codes, i.e. indicating which kinds of economic activity were selected.

Results and Discussion

First of all, insight into the situation in the regions – a breakdown of enterprises by statistical region – was obtained, analysing the number of operating enterprises in the industries with high transfer potential by statistical region (Figure 1). The analysis clearly reveals that the monocentric pattern of development is explicitly characteristic of Latvia, as two thirds of enterprises have registered their economic activity in the capital city or in the vicinity of it (statistical regions of Riga and Pieriga). Monocentric development in particular is referred to as one of the problems of the innovation system of Latvia; it creates an unfavourable environment for entrepreneurship in the regions and contributes to depopulation and inefficient use of resources of a region. As the researchers Kreslins and Stefenberga admit, trends in regional development still are fairly monocentric, and according to RIS3 strategy there should be the development of economics and entrepreneurship in all regions, and best practices should be introduced outside the borders of a region (Kreslins & Stefenberga, 2016). With monocentric development continuing in Latvia, the competitiveness of the country is going to decrease, as the cost of labour and infrastructure in the monocentre is going to rise, while opportunities for growth in the regions will not be used (Informatīvais ziņojums…, 2013).

Among the other four regions, the highest performance was reported in Kurzeme region where

9% of the total operating enterprises engaged in the industries with high transfer potential in relation to RIS3 were registered. Two seaports of national significance are located in this region. The poor performance of Zemgale and Vidzeme might be explained by the fact that the regions have only one city of national significance (Jelgava in Zemgale and Valmiera in Vidzeme). The number of registered enterprises in Latgale is higher by one percentage point, as this region has two cities of national significance – Rezekne and Daugavpils, the latter of which is the second largest city in Latvia.

The analysis of the number of enterprises in the industries with high transfer potential broken down by RIS3 specialisation field (Figure 2) reveals that more than half of them were engaged in ICT, which encompasses such industries as manufacture of electrical and optical equipment, information and communication services, financial and insurance activities, real estate activities, professional, scientific and technical services, education, health, art, entertainment and recreation. The calculations were done taking into account the enterprises that had operated for more than a year as of 2014 and had submitted annual reports, in which they declared their kind of economic activity. This RIS3 specialisation field encompasses a lot of industries with high transfer potential (37 NACE codes); consequently, the number of enterprises in this field is large. The next largest RIS3 specialisation field, in terms of number of enterprises with high transfer potential, is the knowledge intensive bioeconomy, while smart energy accounts for only 4% of the total enterprises.

As shown in Figure 2, nationally more focus should be placed on the fields of smart energy and
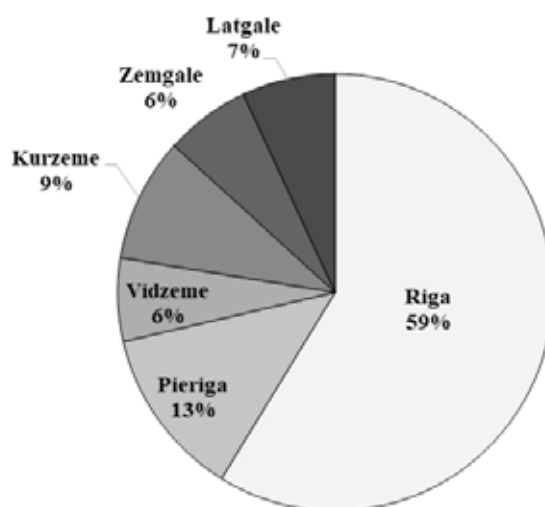
Source: authors' calculations based on Lursoft data.

Figure 1. Percentage breakdown of enterprises of industries with high transfer potential
by statistical region in 2014.
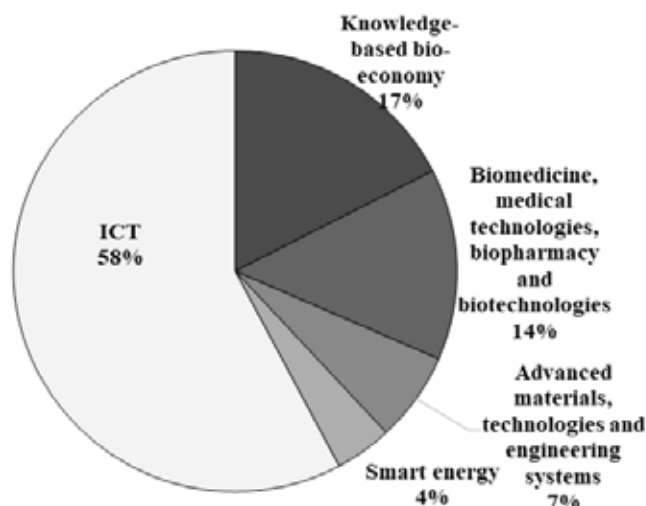
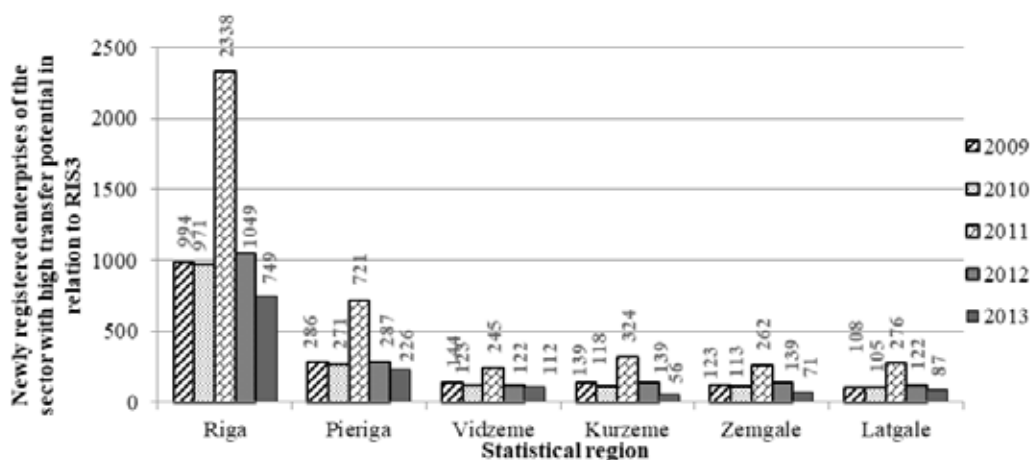Source: authors' calculations based on Lursoft data.

Figure 2. Percentage breakdown of enterprises registered in 2014 by sector with
high transfer potential in relation to RIS3.

advanced materials, technologies and engineering systems in order to increase their proportions.

The number of newly established enterprises also indicates the economic development in the country. An analysis of the number of newly established enterprises in the period 2009 – 2013 reveals interesting dynamics. The data on the number of newly established enterprises operating in the industries having high transfer potential in at least one RIS3 specialisation field were selected for the analysis. The economic situation of this period could be characterised as a post-crisis time, although the number of newly established enterprises in the industries with high transfer potential pertaining to RIS3 was slightly larger compared with 2010. A considerable increase in the number of newly established enterprises occurred

in 2011, which indicated a decline in the economic crisis. The largest number of enterprises in Riga in 2011 was reported in the field "real estate activities" (NACE code 68) – 469 newly established enterprises were registered in that year. In 2012, the number of newly established enterprises decreased by half, while in 2013 their number continued decreasing and was even below the 2009 level, thereby stabilising the situation in the real estate market that stagnated during the crisis.

The numbers of newly established enterprises registered in Riga and Pieriga were significantly larger, while in the other four regions the numbers of such enterprises were approximately the same in every year analysed. The above data were compared with the total number of newly established enterprises

Source: authors' calculations based on Lursoft data.

Figure 3. Number of newly registered enterprises of the sector with high transfer potential in
relation to RIS3 in the statistical regions in the period 2009 – 2013.
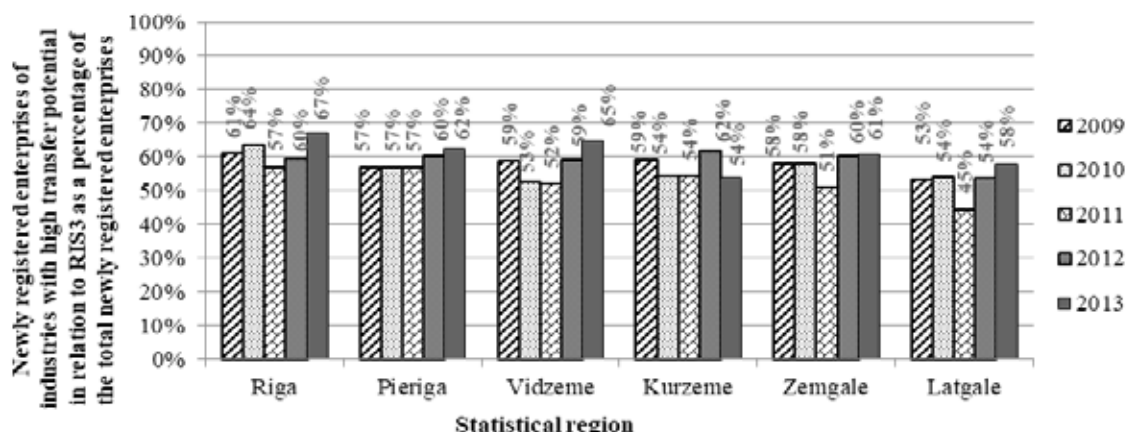
Source: authors' calculations based on Lursoft data.

Figure 4. Number of newly registered enterprises of industries with high transfer potential in relation to RIS3 as a percentage of the total newly registered enterprises in the statistical regions in the period 2009 – 2013.

in the entire economy (Figure 4), which revealed that the number of newly established enterprises in the industries with high transfer potential in relation to RIS3 expressed as a percentage of the total was, on average, slightly above 50%. It is worth mentioning that the significant increase in the number of enterprises in 2011 was reported particularly in the industries having no potential relation to RIS3, as the proportion of RIS3 fields in this year was even lower than in the other years analysed. In 2013 in all the regions, except Kurzeme, the proportion of RIS3 fields was the highest, which indicated progress in smart specialisation in the economy of Latvia.

Researcher Rivza with colleagues, using the same Lursoft data in the same period about Zemgale region entrepreneurship, discovered that the pace of economic growth differs among the municipalities. Comparing two indicators – increase in the total number of enterprises and the number of knowledge-based enterprises for the period 2009 – 2013 in five municipalities of Zemgale region, the total number of enterprises from 2009 to 2013 rose faster than that of knowledge-based enterprises, and the proportion of knowledge-based enterprises decreased from 8.2 to 6.4%. In other 15 municipalities an increase in the number of knowledge-based enterprises from 2009 to 2013 considerably exceeded an increase in the total number of enterprises, and their proportion rose from 12.1 to 15.0%. Increase differs significantly in each municipality, even in two municipalities of the Zemgale region the proportion of this kind of enterprises was greater than 20% of the total enterprises. It shows that the smart economic growth is also determined by municipal government performance, the activity of various public institutions and residents' readiness to work under the guidance of the institutions and organizations (Rivza *et al.*, 2016).

The regional distribution of the industries with high transfer potential in relation to RIS3 in all the regions was similar, only in Latgale the proportion was slightly lower. In general, Latgale region is recognized as economically least developed region in Latvia (Jermolejeva *et al.*, 2017).

The Figure 4 shows that in 2013, comparing with the data of 2009, the number of newly registered enterprises of industries with high transfer potential in relation to RIS3 as a percentage of the total newly registered enterprises decrease in all statistical regions of Latvia. This negative dynamics is also directly related to the RIS3 macroeconomic indicator "the proportion of innovative enterprises", where the share of innovative enterprises has sharply dropped, even below the base value of 2012. And it is quite clear that the target value of 2020 cannot be achieved (Šmīdlere, 2017).

Speaking about further development in Riga and Pieriga regions, the basis for regional economic development forms the attraction of new technologies, the promotion of innovation and improvement of the regional resource base. The development of these factors can be achieved with the structural reform planning (Rivza *et al.*, 2017).

Conclusions

1. A monocentric trend in the regional distribution of the industries with high transfer potential in relation to RIS3 was observed, as almost two thirds of enterprises have registered their economic activity in Riga and its vicinity. Among the other regions, the best performer was Kurzeme region where 9% of the total enterprises in the industries with high transfer potential in relation to RIS3 were registered.

2. Among the RIS3 specialisation fields, ICT accounted for the highest proportion – more than

half - which also encompassed the largest number of industries, while smart energy made up only 4%, which requires seeking solutions to foster the development of this field.

3. In the post-crisis period, the number of newly established enterprises in 2011 was two times larger than in 2010, while in 2009, 2010, 2012 and 2013 the numbers were almost equal. One can conclude that no considerable economic growth was observed in the analysis period.

4. The number of newly established enterprises in the industries having high transfer potential in relation to RIS3, expressed as a percentage

of the total newly established enterprises in the entire economy, reveals that in the period 2009-2013 in all the regions, except Kurzeme, the highest percentage of industries related to RIS3 was observed particularly in the last year, which indicated progress in smart specialisation in the economy of Latvia.

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PROSPECT POSSIBILITIES OF REMOTE WORK FOR INVOLVEMENT OF LATVIAN DIASPORA'S IN ECONOMY AND BUSINESSES OF LATVIA

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Abstract
During the last decade a huge number of Latvian citizens have left the country and live abroad, which complicates to a certain extent the chance of easily returning and settling down in Latvia. At the same time, the Latvian entrepreneurs are ultimately demonstrating their desperate need for all kind of workers. Especially it could be seen in sectors like medicine, retail, heavy and light industry. Rapidly growing Diaspora allows to acknowledge that there is a big potential of labour force flowing away from the country, sometimes staying without any work positions for quite a long time. The aim of this article is to find evidence that Latvian Diaspora could be involved in the Latvian economy and business by using a new attitude and approach, which should be supported by teleworking. During research the main methods used were content analysis of strategic and planning documents as well as analysis of the best practices in the world and Latvia, with the aim of establishing a model of remote work development and finding out proposals for a better participation of employees, employers and territory representatives – local governments and state institutions. This article is a part of and supported by the State Research Project EKOSOC-LV, part 5.2.2. The authors express their gratitude to the Institute of Social, Economic and Humanities research of Vidzeme University of Applied Sciences.
Key words: Latvian diaspora, flexable working, remote work, entrepreneurship, national economy.

Introduction

One of the main reasons for establishing European Union (EU) was free mobility of labour.

The labour movement from Latvia started as simple curiosity after joining the EU to examine and try out living and working conditions abroad.

During the last decade many people from Latvia have moved to other EU countries or to other parts of the world trying to find economic benefits and more comfortable living conditions. Although there are many other reasons for migration, in this article authors will be looking only at the economic or well-being reasons.

The global circulation of high-skill and low-skill labour from poor economies to rich ones and back is opening new possibilities for economic development. The changes are most noticeable in the behaviour of the most skilled workers (Kuznetsov, 2006).

There are predictions by media experts that in the long term – by 2030 – there could be 120 thousand vacancies, which will demand imported labour. Normal target would be to try to fill these vacancies with people from Latvia, but not emigrants from other countries.

However, previous research has proved that emigration in the long run will threaten the development prospects of Latvian economy, sustainability of social and demographic systems (Buholcs, Goldmanis, & Hazans, 2016).

It is possible to compensate this negative effect partially by involving Latvian Diaspora in the development of Latvian economy – promoting and supporting the return of emigrants and using their knowledge obtained to start the entrepreneurship, boost economy, culture, education and other important fields (Buholcs, Goldmanis, & Hazans, 2016).

The aim of this article is to find out if the Latvian Diaspora can be involved in the Latvian economy and business by applying new attitude and approach which is supported by remote working.

During research the main methods used were (1) content analysis of strategic and planning documents to identify the support activities for remigration or involvement, (2) elaboration of the remote work development model and (3) analysis of the best practices in the world and Latvia to find out proposals for better participation of employees, employers and territory representatives – local governments and state institutions.

Materials and Methods

Diaspora representatives are those people who are promoting Latvia in the world, excellent researchers, entrepreneurs and also ordinary people. They and their children are investors in the long-term development of Latvia (Kļava, Līcīte, & Motivāne, 2009).

The Ministry of Foreign Affairs acknowledges that there are more than 400 000 Latvian Diaspora representatives living, studying and working outside Latvia in different home countries. Latvian Diaspora includes nationals who have left the territory of Latvia during several emigration waves since the end of the 19th century, including the latest emigrants who still keep in touch with Latvia. The Ministry of Foreign Affairs also realizes that the biggest Latvian communities are in the UK, the USA, Canada, Ireland, Sweden, Australia, Russia, Brazil, Germany, Belgium, Israel, Norway, Spain and other countries in the world.

Latvian Diaspora is large and includes a great potential for cooperation and representation, as well as the development of Latvian society and state interests.

Diaspora members who want to remain associates and develop cooperation with the country of origin are of value to the entire Latvian society. Their knowledge, capabilities and network of contacts abroad and in Latvia can make a significant contribution to the Latvian transnational community. The Diaspora is a resource, and by strengthening the cooperation mechanisms with the Diaspora it is possible to promote the development of Latvia internally and externally (Ministry of External Affairs, 2015).

In literature the most commonly used term is "Latvian emigrants". The second most often used term for the target group is "diaspora". The Webster Dictionary defines diaspora as "a group of people living outside the area where they lived for a long time or where their ancestors lived" (Buholcs, Goldmanis, & Hazans, 2016).

In Latvia, with "diaspora", we often refer to the Latvian exile community that emerged in the Western countries after the Second World War. According to the classification of Arjun Appadurai, this community was considered a "diaspora of terror", as it arose in dramatic and precarious conditions. (Appadurai, 1996).

However, after the demise of the USSR, Latvian society encountered other migratory tendencies, in which political motives were replaced by economic ones. With the restoration of Latvia's independence, the exile "terror victims' Diaspora" lost its legitimate basis, but the young emigrants became familiar with the form of solidarity, which Appadurai calls "Diaspora of hope" (Diaspora of hope), a Diaspora that consists of people who seek work and better socio-economic conditions. As a result, relations between residents of Latvia living abroad and their country of origin have changed or broken up. It is even harder to find a term describing people who have returned to Latvia. Instead, it would be more appropriate to use the word "remigrants" and "immigration" (Buholcs, Goldmanis, & Hazans, 2016).

Innovative returns are returning emigrants who are ready to use the accumulated assets and knowledge to start a new business or implement other new ideas (Cerase, 1974).

Of course the management of every country who values its own labour force should put effort into innovative returns, where remigrants are ready to use the accumulated assets and knowledge to start new businesses or implement some other new ideas.

Worldwide research on diaspora politics over the period of 1990 – 2010 was based on three types of approaches for each year: (1) the use of diaspora resources; (2) value approach, perceiving members of the diaspora as the value of a national state; (3) management approach, in line with global standards. These approaches are complementary and allow broad cooperation with the Diaspora. (Ministry of External Affairs, 2015).

In today's fast-changing environment, with the advent of technology and science, new needs, desires and opportunities arise. Various technological solutions, forms of work, and an unlimited range of resources are available for business development and employee efficiency improvement. Internet accessibility and ICT innovations make it possible to work from anywhere, at any time. As a result, new forms of work are emerging, such as remote work that allows you to work from home or other out-of-office locations and remotely attract professional staff from other cities and countries.

The term "**remote work**" [in Latvian: telework, teleworking, e-work, mobile work, intellectual work, wise work, etc. In English: 'telework', 'telecommuting', 'smart work', 'remote work', 'distributed work'] is defined differently, but the meaning remains unchanged. The most important things that coincide in all definitions are: work using information technology and work outside the

Table 1

Remote work definitions overview

Information origin	Definition
European Commision	**Remote work** – the form of organization and / or performance of a work, whereby an employee can carry out work that could also be carried out at the employer's premises regularly out of these premises through the use of information technology (European social partners, 2006)
Latvian Sustainable development strategy 2030	**Remote work** – the employment relationship in which the employee performs his duties without being physically present at the workplace, but using information and communication technologies
Academic terms databases	**Telework, fareway work** – Replacing regular work with work at home or at another remote institution, transmitting data and documents to the central authority by electronic means
Legal Acts of Latvia	**Teleprocesses** – remote actions, processes or procedures that are not taking place directly from participants in the process (telework, telemedicine, telemedicine)

Source: created by authors'.

employer's premises. The definition of the European Commission further emphasizes that the distance work is carried out on the basis of an employment contract / relationship, which is not mentioned in Latvian terms. Latvian legislation does not contain any specific requirements for the employer and organization of a remote job that could explain this fact (Table 1).

There is more and more talk about remote job opportunities in Latvia, but so far this is an incompletely used model of work. Research done in Latvia confirms that most employees would like to work remotely, but knowledge of this type of work and the offer from companies are very small.

In Vidzeme region there is a low population density and that poses a threat to already lowering economic activity. So the question is: how to attract new, talented employees and future professionals. On the one hand, Vidzeme region has the highest proportion of creative class outside Riga region and a high proportion of people with higher education in development centers, which would ensure a widespread employment of the population. On the other hand, the region lacks jobs in the knowledge economy and professional staff. The problem has been identified in the analysis of Vidzeme Planning Region during the last years. This suggests that most young professionals go to work and live outside Vidzeme region and leave their family and home behind. Remote work is one of the ways of attracting highly qualified specialists and marketing to the region.

The topicality and importance of the issue is determined by the decline in population and the lack of professional labor force, which necessitates the search for new solutions for the development of the region and the preservation of rural population. Latvia is a polycentric country with one big city – Riga, – which causes people to leave the countryside and regions.

With the development of modern technologies and Internet access, there are great opportunities for people to work remotely – from home or remote work centers in sparsely populated areas. This will improve the level of employee satisfaction, save time on and off work, and bring a number of economic and social benefits to the company and territory. As a result, regional disparities are reduced and the share of the service sector in the national economy is increasing.

Remote work became popular in the 1970s, when the oil crisis in the world raised concerns about petrol consumption; a long road to work that caused congestions in major metropolitan areas was measured. Remote working opportunities have contributed to the technological advancement; employers have sought to reduce property costs and wanted to reduce workload. (Reilly, Sirgy, & Gorman, 2012).

On 16 June 2002, the European Commission drafted a framework agreement on remote work and

defined it as "a form of organizing and / or enforcement of a job, which an employee could perform at the employer's premises or on a regular basis outside the premises using information technology" (European social partners, 2006).

Regular remote work reduces carbon emissions and has a positive environmental impact. Remote work is seen as a new form of work organization that provides flexibility and security, increases the quality of work, and increases the opportunities for people with special needs to enter the labor market. One of the prerequisites of the European Commission is that remote work is a voluntary choice both by the employer and the employee. Work remotely can be done periodically or independently outside the employer's premises, for example, in a person's home, remote work center or other remote institutions. An essential prerequisite is that the time spent working remotely is to be recorded (European social partners, 2006).

The EU Framework Agreement does not apply to self-employed teleworkers and to occasional teleworkers, for example, if an employee is hired and then "takes work home", but remote work is not included in the employment contract (Akule, 2010).

There are three main types of remote work: working from home, mobile work and remote work in centers (European social partners, 2006).

The experience of European countries shows that nowadays more distant work centers, telecentres or SMART work centers are being built in order to improve economic activity in the more distant regions.

If it was possible to work remotely, 63% of public administration employees (poll, n=1244) and 81% of the population of Latvia (poll, n=1335) would use it (Project "Smart Work Centers in Non-Metropolitan Areas", 2013).

For example, the Estonian vision for development of 2030 states that "the work will be mainly carried out from home, while office space will be used to communicate with colleagues when discussing work problems and for information exchange" (Estonian Environmental Strategy, 2030).

Figure 1 shows possible professions which can be suitable for remote work.

There are several good practise examples in the world and in Latvia observed during the research.

- http://www.africandiasporanetwork.org/ Founded in 2001, this network focuses on developing knowledge and entrepreneurial connections between the local South African firms and well-connected individuals in the United Kingdom (Kuznetsov, 2006).
- The Indian high-tech diaspora in Silicon Valley and other technology centres in
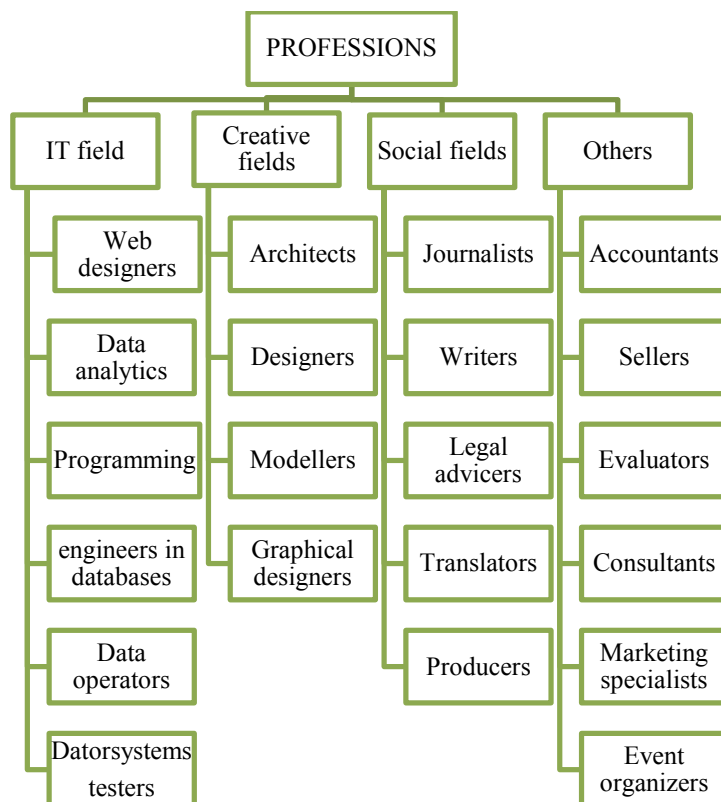
Source: created by authors'.

Figure 1. Potential professions in whichremote work can be applied.

the United States have become organized, forming a transnational community that brings experience, connections, capital, and deals to India (Kuznetsov, 2006).

- The World Latvian Economic and Innovation Forum, organized by PBLA since July 2013, which brought together more than 350 entrepreneurs, researchers, financiers and other professionals from 21 countries, organized by the LTRK and the MFA, was of particular importance in the "Global Latvian" activities program. It helped to stimulate the cooperation of Latvian entrepreneurs and professionals by encouraging engagement and investment in the Latvian economy. In order to achieve good results, such activities should be carried out methodically and regularly, choosing the areas of the relevant cooperation. (Ministry of External Affairs, 2015).

Expatriates do not need to be investors or make financial contributions to make an impact on their home countries. They can serve also as "bridges" by providing access to markets, sources of investment, and expertise. Influential members of diaspora can shape public debate, articulate reform plans, and help implement reforms and new projects. Policy expertise

and managerial and marketing knowledge are the most significant resources of Diaspora network (Kuznetsov, 2006).

Here it should be noted that during a recent survey the Ministry of Education and Science has discovered that currently about 40% of foreign students in Latvia own some land or housing, about 4% own a company or its parts in Latvia, the same proportion have maintained employment relationships in Latvia, and another 10% have taken out a mortgage. Similarly, bachelor students abroad often express their intention to establish a company in Latvia in the future, to create or help to establish business cooperation with Latvian partners. In general, about one third of Latvian nationals studying abroad want to enter the Latvian economy by acquiring real estate or engaging in entrepreneurship.

One of the goals of the Remediation Support Action Plan is to promote the creation of jobs, thus encourging the returning immigrants who are jobseekers. According to the data collected by the researcher Mikhail Hazan, only 20% of those who have left are planning to return to Latvia, taking into account that the longer the time spent in absentia, the less the desire to return.

The "Global Latvian" unified communication platform can offer tools for using existing databases
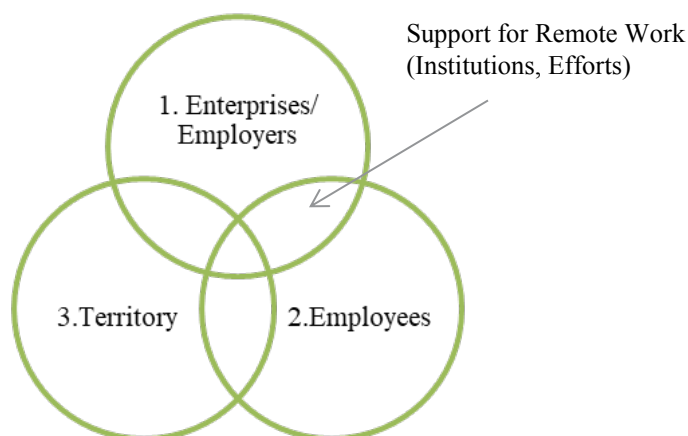
Source: created by authors'.

Figure 2. Model of remote work development and support.

and communicating returning experiences to the community (Ministry of External Affairs, 2015).

All target groups, namely, companies, employees and territory (Figure 2) can participate in the implementation and development of remote work. In order for this cooperation to be effective, there are proposals elaborated to promote remote work deployment and development.

1. PROPOSALS FOR ENTERPRISES TO PROMOTE DEPLOYMENT AND DEVELOPMENT:
   - Companies that successfully use remote job opportunities or want to start it can be merged into a Remote Work Association.
   - Businesses must be aware of all the challenges, benefits and related information of remote work.
   - The company must not only provide adequate material resources (transport and communication infrastructure, business support and training), but also social capital, business culture and an appropriate environment that allows adaptation to and benefit from change.
   - Entrepreneurs need to be prepared to cooperate with education and research institutions in order to gain higher added value (especially in rural areas).
   - Networking and collective learning that fosters innovation and competitiveness of enterprises, not only at the regional, but also national and international levels, should be encouraged. For example, by organizing business forums, engaging in associations, etc.
   - Promote the development of ICT in enterprises.
   - Support changes in the organization of work, for example, by allowing employees to work flexibly.

   - Provide informational support to employees about remote work opportunities.

2. PROPOSALS FOR POTENTIALLY EMPLOYED EMPLOYEES:
   - Employees must be aware of all the challenges, benefits and related information of remote work.
   - Keep up with and learn about the latest developments in the ICT industry, such as lifelong learning programs, universities or courses.
   - The ability for people with disabilities to work well and integrate in society.
   - Active use of e-services.
   - Support mobility activities and take advantage of remote job opportunities
   - Engage in communities and organizations through network access.
   - Take the opportunity to work in an international company and stay in Latvia.
   - Build mutual trust with the job manager.
   - Try some type of remote job.

3. PROPOSALS FOR THE TERRITORY (FOR THE VIDZEME AREA) TO PROMOTE OUTDOOR WORK:
   - Improve the image and prestige of the site in order to attract professional workforce, distance workers and businesses.
   - Improve the quality of living.
   - Municipalities have a more favorable attitude towards the population.
   - Provide leisure opportunities for the public.
   - Develop the school, kindergarten and internet infrastructure.
   - Facilitate access to real estate.
   - Ensure convenient traffic.

- Develop a place for marketing and branding (service sector, enhancement of visual attractiveness, promotion of activities, openness to competent young people).
- Provide jobs in the regions of the knowledge economy.
- Support the creation of remote work centers.
- Facilitate informing students about ICT opportunities in the field of education and develop measures to ensure that practical skills are acquired in the latest technologies.
- Stimulate the development of business types whose products have a high added value.
- Provide an active platform for communication and innovation.
- Invest in the area.
- Facilitate co-operation in establishing a remote cluster or association.
- Provide informational support.

4. PROPOSALS FOR DEVELOPED LABOR SUPPORT INSTITUTIONS (FOR REMOTE WORK PROVIDERS' ASSOCIATION):
- Provide informational support and promote remote job opportunities.
- Support the creation of remote work centers.
- Implement a unified model of remote work in Latvia.
- Promote good examples in Latvia and abroad.
- Facilitate the provision of information to students about ICT opportunities, develop measures to ensure the acquisition of practical skills in the latest technologies (ICT career days, Olympiads in Informatics, summer camps, interest groups in social networks).
- To promote citizens' e-skills and Internet access.
- Harmonize labor legislation with the peculiarities of remote work.
- Ensure the social guarantees of the remote employee and the protection of health and safety of work (including working in foreign companies).
- Promote financial support at an early stage in the implementation of the distance work.
- Facilitate tax reductions for employers employing remote workers.
- Promote the integration of distance work into sectoral policies.
- Use the possibilities of EU funds.
- Develop website and other informative materials.

The successful development and distribution of remote work requires the harmonization of labor legislation with the features of remote work. It is important to provide socially guaranteed workers and workers with a high level of protection, occupational safety and health protection (including working in foreign companies). To achieve this, there is a need for a policy of integrating the remote work system into national politics, followed by the attraction and exploitation of the EU background.

Conclusions
1. During last decade many people from Latvia have moved to other EU countries or to other parts of the world trying to find economic benefits and more comfortable living conditions. By the end of 2030 there will be 120 thousand vacancies, which may lead to labour import.
2. There are at least two ways of eliminating imported labour – the return of emigrants or involvement of Diaspora's representatives in the remote work in Latvia.
3. The Ministry of Foreign Affairs acknowledges that there are more than 400 000 Latvian Diaspora representatives living, studying and working outside Latvia in different home countries.
4. Diaspora members who want to remain associates and develop cooperation with the country of origin are of value to the entire Latvian society. Their knowledge, skills and network of contacts abroad and in Latvia can make a significant contribution to the Latvian transnational community.
5. With the development of modern technologies and Internet access, there are great opportunities for people to work remotely – from home or remote work centers in sparsely populated areas. Remote work is seen as a new form of work organization that provides flexibility and security, increases the quality of work, and increases the opportunities for people with special needs to enter the labor market. There are three main types of remote work: working from home, mobile work and remote work centers.
6. If it was possible to work remotely, 63% of public administration employees and 81% of the population of Latvia would use it.
7. In general, about one third of Latvian nationals studying abroad want to enter the Latvian economy by acquiring real estate or engaging in entrepreneurship.
8. The "Global Latvian" unified communication platform can offer tools for using existing databases and communicating the experience of returning to the community.
9. All target groups, namely, companies, employees and territory, can participate in the implementation and development of remote work. In order for this cooperation to be effective, there are proposals elaborated to promote remote work deployment and development.

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THEORETICAL MODELS OF SOCIAL ENTERPRISES IN LATVIA

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Abstract
Social entrepreneurship plays an increasingly important role in tackling socio-economic problems. It has gained recognition in Latvia among politicians, academicians and social entrepreneurs; consequently, the number of social enterprises increased in the country, yet there is a lack of research studies on social enterprise models and their classification. Accordingly, the research aim is to examine the theoretical models of social enterprises in Latvia. In the scientific literature, there is no strict classification of social enterprises, but based on different criteria, it is possible to distinguish several types or models. In Latvia, there are relatively few social enterprises; for this reason, it is quite difficult to categorise them. However, social enterprises are divided by sector, field of activity, target group, scale of activity and other criteria. The research stresses the following key social entrepreneurship models: the Self-initiative Model, the Government Participation Model, the Municipal Participation Model and the Company-initiated Development Model. These models are based on two key criteria – support intensity and taking the initiative in establishing and developing a social enterprise.
Key words: social entrepreneurship, social enterprises, social enterprise models, classification of social enterprises.

Introduction

Over the last years, the activities in the field of social entrepreneurship take place in scientific research, government policies, education, and the commercial sector (Mair, Robinson, & Hockerts, 2006; Nicholls, 2006; Perrini, 2006). It is an important tool to tackle social challenges and to respond to them when the market and the public sector do not. Social entrepreneurs create innovative initiatives and solutions to unsolved social problems, as a result they create benefit to different individuals and groups (Sekliuckiene & Kisielius, 2015; Dees, 2007). Besides, social entrepreneurship is important in developing social innovations that are focused on meeting social needs of the society (Dobele, Grinberga-Zalite, & Kelle, 2015).

Social entrepreneurship gains an increasing recognition in Latvia too, which is indicated by the fact that the Social Enterprise Law came into force on 1 April 2018. Social enterprises also have an opportunity to acquire grants under the Ministry of Welfare and ALTUM support programme in the range from EUR 5 000 to 20 000 for the establishment or development of a social enterprise, which is the first significant instrument of this kind aimed at promoting social enterprises in Latvia.

Given the urgency and the increasing role of social entrepreneurship, it has been researched by several scientists in Latvia as well. The first extensive research about foreign experiences with social entrepreneurship and its basic principles were studied in 'Latvia towards Social Entrepreneurship' (2012). Later the topicality of social entrepreneurship in the economic situation of Latvia was highlighted by I. Kalve (2012), V. Bikse, B. Rivza and I. Riemere (2014), J. Dehtjare and V. Riashchenko (2015), L. Dobele (2011, 2012a, 2012b, 2016a, 2016b), R. Lukjanska, M. Leszczyna-Rzucidlo

and J. Kuznecova (2017), L. Paula and A. Grinfelde (2017). Social entrepreneurship in Latvia is analysed also within the context of municipalities – the role of local government in social entrepreneurship and support mechanisms which the local government can provide to social enterprises (Pūķis, 2012; Lukjanska, Kuznecova, & Cirule, 2017; Lis *et al.*, 2017). However, in various information sources in Latvia, the phrases "social enterprise" or "social entrepreneurship" appear mainly as descriptions of social enterprises and situation in social entrepreneurship of Latvia. Even though an extensive study by the European Commission on the social entrepreneurship ecosystem was carried out in 2015 (A map of social..., 2014), there is still a lack of scientific findings about social enterprise models and their classification.

The research aim is to examine the theoretical models of social enterprises in Latvia. To achieve the aim, the following specific research tasks were set: 1) to examine the kinds of social enterprises and the classification thereof; 2) to identify the theoretical models of social enterprises in Latvia.

Materials and Methods

The paper is built on the analysis and synthesis of scientific literature which allow to describe the models and classification of social enterprises. According to that, several research methods were applied: monographic, descriptive, analysis and synthesis, induction and deduction.

To identify the theoretical models of social enterprises in Latvia, expert interviews with the following social entrepreneurship representatives were carried out in Latvia:
1. Madara Ūlande – the director of Social Entrepreneurship Association of Latvia, which is a member organization for organizations,

enterprises and individuals who want to promote social entrepreneurship in Latvia;

2. Vita Brakovska – the head of non-governmental organization 'ZINIS', innovation expert; conducts and organizes workshops about creativity, social entrepreneurship for different stakeholders;

3. Dace Indrika – a member of the Social Business Ambassador Network in Latvia.

4. Andris Bērziņš – the head of Samaritan Association of Latvia that provides various social, medical and educational services with the mission to improve the life quality for different risk groups in Latvia. One of social enterprises that participated in co-funding of Social Entrepreneurship Association of Latvia.

The selected experts represent diverse stakeholder groups in order to get comprehensive insight into the models of social enterprises in Latvia.

Results and Discussion

Theoretical framework of social enterprise models. A number of authors have sought to classify social enterprises, distinguishing the theoretical models of the enterprises (Alter, 2007; Grassl, 2012; Gawell, 2014; Wiguna, Ananda, & Susilo, 2015). However, there is no strict classification of social enterprises, but based on their activities it is possible to separate several types or models.

D. Crossan *et al.* (2003) describe the types of social enterprises based on their legal form, working field and the sector they are operating in. As a result, they distinguish several social enterprise hybrid models.

A.B. Wiguna, C.F. Ananda and Susilo (2015) mention two types of social enterprises. They describe the model of social entrepreneurship which is a model of value creation process that focuses on the economic aspect (individual needs) at the beginning and after that on social aspect. This model mainly encourages economic independence that allows to transfer the economic surplus to society. Model of socio-entrepreneurship, on the other hand, is a model of value creation process during which the focus is on the social aspect (collective needs). This model mainly encourages collective initiation of value creation, therefore it not only makes an economic independence but also a growth cluster in society at the same time.

K. Alter (2007) elaborated typology that explores how institutions have combined a mix of social values and goals with commercial business practices, and how they have come up with ownership models, income and capitalization strategies, as well as unique management and service systems designed to maximize social value. K. Alter classified social enterprises based on their mission orientation (mission-centric, mission-related and unrelated to mission), business / program

integration (embedded social enterprises, integrated social enterprises, external social enterprises). In accordance with the social enterprise's financial and social objectives, mission, marketplace dynamics, client needs or capabilities, and legal environment the researcher has designed operational models of social enterprises. There are 10 fundamental models of social enterprises (Entrepreneur Support Model, Market Intermediary Model, Employment Model, Fee-for-Service Model, Low-Income Client as Market Model, Cooperative Model, Market Linkage Model, Service Subsidization Model, Organizational Support Model), two Combining Models (Complex Model, Mixed Model) and two Enhancing Models (Franchise Model, Private-Nonprofit Partnership Model) (Alter, 2007).

M. Gawell (2014) distinguishes four kinds of social enterprises:

1. social entrepreneurship as business with a social purpose,

2. social entrepreneurship and social enterprises based on non-profit principles,

3. social-economy-based entrepreneurship and work-integrating social enterprises,

4. social entrepreneurship as societal entrepreneurship.

One of the latest classifications is made by EMES Network. According to it four social enterprise organizational models are identified on the basis of three dimensions: the nature of the social mission, the type of economic model, and the governance structure.

1. Entrepreneurial non-profit organizations: developing any type of (related or unrelated) earned-income business in support of their social mission.

2. Social cooperatives: the social cooperative model aims to implement forms of democratic governance, i.e. equal voting power in the general assembly and limitation of capital shares' remuneration. However, it goes beyond most conventional cooperatives in that the social cooperative combines the pursuit of its members' interests with the pursuit of the interests of the whole community or of a specific target group.

3. Social businesses: considering social enterprise as a mission-driven business is the dominant view among business schools, consultancy firms, various foundations, which foster more broadly business methods as an efficient path to address social problems. For them, social enterprises are companies developing business activities for a primary social purpose or mission.

4. Public-sector social enterprises: social enterprises can emerge as 'public-sector spin-offs'. In the framework of community development policies targeting deprived urban areas, for instance, local

public bodies may take the lead in setting up community enterprises seeking local development (Nyssens, s.a.).

These four models are characterized by specific trajectories driven by two distinct groups of institutional transformations (Defourny & Nyssens, 2016). The first group corresponds to shifts from capital and mutual interest towards the general interest and results in organisations such as social cooperatives and social businesses. The second relates to marketization and it is observable in non-profit and public organisations. These two groups of institutional transformations leave long-lasting marks on social enterprise governance. Given the particular path dependency of social cooperatives and social businesses, a key governance challenge in the pursuit of the general interest is to avoid the profit motive dominating the social mission. Secondly, among public and non-profit organisations, there is a movement towards marketization as a result of dramatic changes in the funding of goods and services of general interest. If social cooperatives and social businesses are used to operating in the market, public organisations and non-profit organisations were hitherto traditionally relying on non-market income; they were fully subsidized by public authorities or mixing public financing and philanthropic resources. Overall, SEs can be seen as hybrid organisations shaped by institutional trajectories. Their double bottom line combines market and non-market resources; general interest and, in some cases, mutual or financial interests; and economic activity and social or societal goals.

Social enterprise models in Latvia. Social enterprises could be classified by taking into account different criteria: economic performance, social impact, field of activity, target groups, scale of activity etc. However, it has to be taken into account that there are relatively few social enterprises in Latvia; for this reason, it is quite difficult to categorise them.

Sectors. The social enterprises operate in various sectors including, but not limited to social services, production of goods, health services (including prevention), charity shops, environmental protection, cultural diversity & heritage, education, work integration, consulting, information, and communications (Lis *et al.,* 2017).

Field of activity. There is a strong trend to integrate socially sensitive groups of people in creating design objects. This might be due to the influence of one of the very first 'modern' social enterprises in Latvia, MAMMU, that worked with designers to create a prototype for scarves and afterwards young mothers from different regions participated in the production of this product (Lis *et al.,* 2017). The development of design products could be explained by the fact that the Latvian market is small, and entrepreneurs seek to develop high value-added design products rather than focus on the market of consumer products. Social enterprises such as 'Blind Art', 'Ceribu sparni', 'DP Production' and many others also provide good examples of design products. Even though they are able to provide good quality products, many of these enterprises struggle with marketing, sales and access to global markets (Lis *et al.,* 2017).

Target groups. A lot of social enterprises are so called work integration social enterprises because they work with socially sensitive groups of people: single mothers, disabled people (mental disabilities; physical disabilities; visually impaired people), elderly people, refugees, children and youth, parents and teachers, former inmates and their families. Also, there are social enterprises that are active in sustainable development, e.g. recycling old materials into clothes or art objects. But, often the two target activities – work integration and sustainable development – go together hand in hand (A map of social…, 2014).

Economic performance. There are no statistics available on the aggregate annual turnover of social enterprises, but it is likely not significant. The turnover of individual enterprises varies widely from a couple of thousand annually to a couple of million, depending on the size and the scope of the enterprise. It should be stressed that most social enterprises are relatively new, having been established only within the last 3 to 7 years, and usually do not employ more than five people (Lis *et al.,* 2017).

Scale of activity. After examining various social enterprises in Latvia, one can conclude that their scale of operation is mainly local – within a region, a city, a municipality. Fewer enterprises operate at the national level and almost not a single one operates at the global level. In Latvia, it is important to promote social entrepreneurship in the context of global export ambitions, so that the social enterprises are competitive in the global market.

Social entrepreneurship expert V. Brakovska distinguishes three main types of social enterprises:
1. 'Profit generator' – economic activity makes no social impact, yet profits are allocated for this purpose.
2. 'Trade-off' – economic activity makes a social impact and a trade-off is made between the profit margin and the social impact.
3. 'Joint pace' – economic activity makes a social impact and generates profits.

If classifying social enterprises broadly, she distinguishes seven models of social enterprises in Latvia based on K. Alter's typology of social enterprises:
1. Employment and skills training. These enterprises employ socially excluded groups. The examples of such enterprises in Latvia are 'BlindArt' (employs

the blind and persons with sight impairment) and
'Humusa komanda' (employs refugees).
2. Fee for service. Special shops (products are
donated or bought at lower prices) have been
established for the risk groups. An example in
Latvia is the enterprise HOPP that produces three-
wheeled bicycles for seniors and persons with
mobility impairment.
3. Market intermediary. A social enterprise is an
intermediary that promotes the social risk group
in the market, and profits are allocated for the
expansion of the enterprise. An example in Latvia
is the enterprise 'Lude' that produces cloth rugs
from textile residue and seniors are engaged in this
activity.
4. Market connector. A social enterprise helps the risk
group to establish trade relations in new markets.
An example in Latvia is the enterprise 'Projektu
banka'. The concept of direct marketing also fits
the principles of this model – organic produce is
promoted in new markets.
5. Cooperative. The risk group is members of a
cooperative who promote their products through
the cooperative. An example in Latvia is the
Latvian association of disabled women 'Aspazija'.
Support instruments and initiative. Social
enterprise models can be designed also based on such
factors as taking the initiative (or the cooperation
partner) and the intensity of support instruments:
1. the Self-initiative Model;
2. the Government Participation Model;
3. the Municipal Participation Model;
4. The Company-initiated Development Model.
A schematic depiction is shown in Figure 1.
To examine the models in detail, their nature and
risks are specified.
Self-initiative Model. The foundation of a social
enterprise is an individual-initiated activity, which
does not involve significant support from a local
or national government-owned or a conventional
enterprise. The social entrepreneurs are involved in
social enterprises because of their social mission and
good will. In this model, social entrepreneurs identify
themselves as social entrepreneurs, but do not apply
to the status of a social enterprise, thus not receiving
potential benefits.
The greatest risk in this model is the financial
sustainability of social enterprises. Also, it is hard to
ensure initial capital and profitable operation during
the first three years of their existence.
Government Participation Model. This model
involves various support instruments focused on social
enterprises, of which the most important one is the
grant support programme for social entrepreneurship
provided by the Ministry of Welfare and ALTUM.
At the beginning of 2018, there was only one social
enterprise in Latvia that had received a grant for its
expansion – 'BlindArt'. The size of the grant was EUR
20 thousand, which would be used by the enterprise to
integrate individuals with sight impairment into the
labour market.
The biggest risk of this model is that a social
enterprise can become dependent on grant funding
and, after the grant is spent, cannot continue operating
on its own.
Municipal Participation Model. Local governments
can solve socio-economic problems in various ways.
One of the opportunities is collaboration with social
enterprises. The Social Enterprise Law provides an
opportunity for local governments to engage in the
activities of social enterprises in two ways – as co-
owners and as cooperation partners/supporters.
1. Local government as a co-owner of a social
enterprise. The status of social enterprise may
be acquired by a limited liability company, in
which one or several public persons do not have
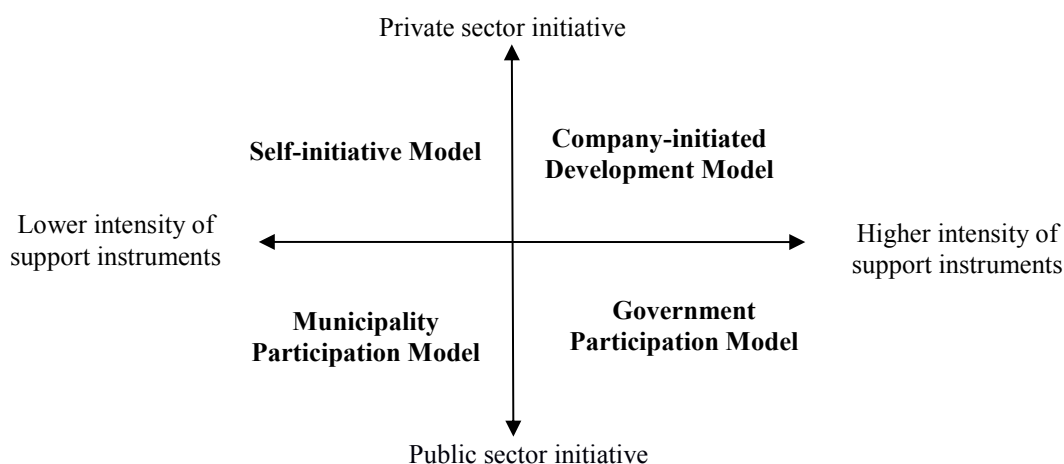
Source: author's construction.

Figure 1. Social enterprise models in Latvia based on support instruments & initiative.

a majority of votes if the goal set in the statute of the social enterprise is the employment of target audiences. However, this provision of the Social Enterprise Law will not be in force after 1 April 2021. This means that although a local government may establish social enterprises, it may be only a co-owner having no majority of votes, and only for labour integration social enterprises; besides, the local government has to 'exit' the social enterprise before 1 April 2021.

2. Local government as a cooperation partner/ supporter. Local governments, after the Social Enterprise Law becomes effective, may support social enterprises in various ways, including granting tax relief, free use of property, introducing other support instruments (e.g. special grant programmes). The Law does not oblige them to do it, yet it allows to do it, which is important in the case of local governments, so that they can legally establish their local social entrepreneurship support schemes.

In Latvia, successful patterns of cooperation between social enterprises and local governments can be mainly seen in the field of social services. One of the positive examples is observed in Sigulda where the local government cooperates with the social enterprise 'Ceribu sparni', as well as the Latvian Samaritan Association provides quality social services for municipalities. However, in general, cooperation depends on the duration of the partnership, the professional competence of local government officials and their general interest in the services or products provided by the social enterprise.

A significant problem is the fact that local governments do not see or do not estimate the real social effects resulting from the operation of a social enterprise; for this reason, the local authority might not wish to support it. Besides, it is often observed that a local government expects the social services to be provided by social enterprises free of charge or at a significant discount.

Company-initiated Development Model. The foundation of a social enterprise is initiated by companies or banks or they are trustful and stable cooperation partners for the social enterprise. The potential collaboration forms are described below.

1. Cooperation pattern of a conventional and a social enterprise may involve the delegation of certain functions of a conventional enterprise to a social enterprise. As a result of cooperation the products are sold to a conventional enterprise, thus reducing the risk of sales. This cooperation model is present in the operation of such social enterprise as HOPP that produces tricycles and aid transport for people with disabilities. The enterprise operates as a daughter enterprise under

the 'wing' of a larger conventional enterprise. Similar experience has also been built up by the Web platform mammamuntetiem.lv connecting new families, and educating and informing about the most important topics regarding children health, safety and family life. Mammamuntetiem offers its services to large enterprises that have recognised them to be family experts in Latvia, thereby calling for the implementation of various social projects for family support in Latvia.

2. Bank loans and social investment to social enterprises. A practice of granting loans at a low interest rate or interest-free loans, which provides a social enterprise with current assets, has not yet emerged in Latvia. Nevertheless, such a practice could contribute to the development of social enterprises in the future, especially after 2022 when the grant support programme is over.

In this model, a social enterprise enjoys greater stability and security owing to a sales partner. However, one of the risks in this model is that banks might grant no loan to a social enterprise because they do not see it as a self-sustaining business model. Besides, investors very often think that social enterprises are less profitable comparing with conventional enterprises. These perceptions may be explained by the fact that investors have lack of knowledge about the social effect of social enterprises. Conventional enterprises, however, might perceive the cooperation pattern as a way of getting rid of unprofitable kinds of business, thereby contributing to their own benefit.

Conclusions

1. In the scientific literature, there is no strict classification of social enterprises, but based on different criteria it is possible to separate several types or models according to their legal form, working field, sector they are operating, the nature of the social mission, the type of economic model, and the governance structure.

2. In Latvia, there are relatively few social enterprises; for this reason, it is quite difficult to categorise them. However, social enterprises can be classified by sector, field of activity, target groups, scale of activity and other criteria.

3. The research distinguishes the following key social entrepreneurship models: the Self-initiative Model, the Government Participation Model, the Municipal Participation Model and the Company-initiated Development Model. Social enterprise models are designed based on two factors affecting the development of social enterprises – taking the initiative (or the cooperation partner) and the intensity of support instruments.

4. The Self-initiative Model represents an individual-initiated activity, which does not involve significant

support from a local or national government-owned or a conventional enterprise. The other social enterprise models identified are based on support instruments from local governments and state-owned or conventional enterprises, thereby ensuring the sustainability and viability of social enterprises.

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OPPORTUNITIES FOR LATVIAN EXPORT OF MEDICAL SERVICES

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Abstract
Historical and current development tendencies of medical tourism in Latvia, economic and geographical accessibility of Latvia for medical tourists, the high acknowledgement by the European Parliament Committee on Transport and Tourism on the potential of Latvia of becoming one of the largest medical tourism destination points, allow us to evaluate the potential for medical tourism among the priority countries for Latvia. Unfortunately, the lack of further analysis of potential limits the development of medical tourism strategy and monitoring. The research goal: determination of export potential of medical tourism services in the priority countries for Latvia. The research showed that there is a potential in every of the given countries: in Norway – rehabilitation and insert of acrylic implants; in Sweden – endovenous laser surgery and eyelid surgery; in Finland – rehabilitation and breast enlargement; in Ireland – rehabilitation and eyelid surgery; in Great Britain – rehabilitation and eyelid surgery. Results of the SWOT analysis indicated that in order to reach the export goals the existing drawbacks to the provision of medical tourism services in Latvia have to be averted while amplifying the use of the comparative advantages of Latvia.
Key words: medical tourism, medical tourism services, export.

Introduction

According to the document produced by the Ministry of Economics of Latvia ´Guidelines of Latvian Tourism Development for 2014 – 2020', Latvia has chosen the medical tourism (MT) as one of its sustainable tourism development priorities. It is believed that the MT includes health improvement procedures (Carrera & Lunt, 2010; LR MK, 2014) and travelling with an aim of improving one's health (Bookman & Bookman, 2007). However, from economic perspective, MT can be viewed as a more beneficial service because of the price advantages (Edelheith, 2008). The research for TRAN Committee – 'Health tourism in the EU: a general investigation', carried out by the European Parliament Committee on Transport and Tourism in 2017 indicated that Latvia can become one of the largest international medical tourism destinations. This export niche is not only indicated by the historical tendencies of the Latvia medical tourism, but also by the fact that Latvia is accessible to medical tourists both geographically and economically, as well as because of the number of available specialists and the high quality of provided services(Mainil *et al.*, 2017). Until now the export capabilities of the MT in the priority countries of Latvia (further – priority countries), such as, Great Britain (GB), Irland (IE), Finland (FI), Norway (NO) and Sweden (SE) have not been analyzed, thus limiting the development of tourism development strategy and monitoring (TAVA, 2010).

The research aim: Evaluation of medical tourism export capabilities in the priority countries of Latvia.

The research tasks: 1) to study theoretical aspects of medical tourism; 2) determine and analyze the historical and current development tendencies of medical tourism in Latvia; 3) carry out the analysis of medical tourism market in the priority countries for Latvia: Great Britain, Irland, Finland, Norway and Sweden; 3) carry out SWOT analysis of themedical tourism in Latvia.

The object of the research is the export of medical tourism services of Latvia.

Materials and Methods

The main research methods applied: monographic, descriptive, logical, comparative analysis, analysis and synthesis, induction and deduction. Analysis of literature, e.g. legal regulations, research papers, academic papers, other scientific literature, and internet resources, etc., was conducted to prepare this scientific paper. The SWOT analysis was carried out in order to determine the conditions for successful reaching of the export capabilities of Latvia medical tourism services (MTS).

Theoretical aspects of medical tourism

In different literature sources the offered explanation of the MT includes both similarities as well as differences. Similarities include the movement of people in between geographical locations in order to receive medical services (Lunt *et al.*, 2016; Majeed *et al.*, 2017; Medical Tourism Association, 2017). Authors underline that the medical services may be available in the country of residence, though undermined by the wait in long queues and by high service price (Li & Cui, 2014). The differences in the explanation of the term are: economic acitivity, which defines the joint medical and tourism industries as set

on the goal of receiving and offering medical services, or as ensuring of continuous growth of the multi-billion dollar industry which makes countries compete in the area of medical standards and offered service quality, while maintaining the lowest possible price for the offered medical services (Bookman, 2015; Sandberg, 2017).

The term of the subject of the medical tourism – 'medical tourist' (Mt) is likewise debatable and can be explained – as a person which is travelling to different region or country with a goal of receiving more accessible, higher quality and cheaper services. Often people choose to visit foreign countries in order to receive medical services which are not available in their country of residence, for instance, euthanasia (i.e. assisted suicide) (Cohen, 2015).

In the context of Europe, the protection of Mt rights under the Directive 2011/24/EU allows for receiving safe, democratic medical services. Meanwhile, the research carried out by the European Public Health Alliance (EPHA) indicates the lack of accessibility, for instance, due to difference in the level of salary among the EU memberstates, (Legido-Quigley *et al.*, 2011; European Public Health Aliance, 2015). Authors conclude that the MTS can be defined as services with the aim of improving health, and that despite the numerous existing obstacles it is still a very profitable industry.

Retrospective in the medical tourism history

For the comprehensibility of the medical tourism history, the authors divided the observed time line in the following stages: (1) time before Christ (BC) (2) medieval time; (3) renaissance and post-renaissance period (4) the 20th century, and (5) the 21st century. In 4000 BC Ancient Shumeri created the first known health recreation complex with hot baths and temples (Benzier, 2013).The Bronze Age evidence shows that travelling with the aim of health improvement was taking place in the current day territories of Germany, France and Switzerland (Health Tourism, 2017). The roots of MT can be traced to the ancient Greek pilgrims who travelled to the Mediterranian region in the Epidauria Saronikas bay (the small Mediterranean town of Epidauria in the Saronic Gulf). It is believed that the Asclepia Temples was the first registered travel destination of such kind (Balaban & Marano, 2010). After the collapse of the Roman Empire, in the medieval time, the region of Asia became the leading attraction point for medical tourism. The meaning of temples was decreasing while their place was taken by the first hospitals in which travelers were offered medical treatment. However, the renaissance (the 14th – 17th centuries) is believed to be the development period of MT and during that time the term ´spa´ appeared and was used describing the facilities

which were more widely available (the 16th century) throughout the Europe (Li & Ciu, 2016).

MT is one of the phenomena of the 21st century that has attracted both the attention of state and private sector. As a result of globalization, MT has vast opportunities to seek cheaper, more accessible and higher quality services with a possibly shorter waiting period (Carrera & Bridges, 2006; Bakuczb, 2017).

The authors conclude that the history of MT show that people have gone travelling with the aim of health improvement, because the desired medical service has not been available in the country of residence.

The current global state of medical tourism

Already in 2010 Balaban and Marano predicted a sharp yearly rise of MT globally from 600,000 to 750,000 (Balaban & Marano, 2010). However, the reality of the MT field exceeded hopes, with trends in 2017 showing that around 3 – 4% of world citizens will use international health care and treatment in the next 10 years. Demographic change can be mentioned as the main reason, especially the ageing of many countries' citizens. Already in 2017 the market had reached 439 billion US dollars, but the predicted speed of increase is 25% larger than in 2016. The medical travel market might increase up to 3 trillion US dollars by 2025 (Healthcare Markets, n.d.).

The top fields of the world's MTS are: 1) cosmetic surgery; (2) dentistry (general, restorative, cosmetic); (3) cardiovascular diseases (angioplasty, CABG, transplants); (4) orthopedics (joint and spine; sports medicine); (5) cancer (often high-acuity or last resort); (6) reproductive (fertility, IVF, women's health); (7) weight loss (LAP-BAND, gastric bypass); (8) scans, tests, health screenings and second opinions (Healthy Travel Media, 2011).

Currently 28 countries in North America, South America, Europe and Asia are occupied with the international trade of the MTS available in their countries. 375 medical institutions in 47 countries have registered themselves as MTS providers. It is likely that the popularity of MT in the 21st century will continue to rise, as the demand for MTS in the Western countries exceeds the medical service offer (Li, & Ciu, 2014). Certainly, one of the MT trends today is the change in its structure, compared to what the world knew before. This trend is determined by market forces that take place outside the organized heath care system's regulations and control. It increases the impact of health care in developed and developing countries around the globe (Horowitz, Rosensweig, & Jones, 2007). The fact that this sphere is not regulated allows entrepreneurs giving services or the service intermediaries to satisfy all clients' wishes, if it is in their interests. However, the lack of regulation creates not only opportunities to be attractive in the eyes

of potential clients, but also threaten the quality of services. This trend is stressed by David A. Reisman (2010), expressing the risk of MTS being perceived as usual trade services and that choices may be taken merely driven by the price factor, not monitoring other quality factors. All parties involved in the health care have an undeniable need to become familiar with the MT and understand the economic, social, political, and medical forces that form this phenomenon (Horowitz, Rosensweig, & Jones, 2007).

Research methodology

Creation of a world level health treatment destination for MTS export purposes is a difficult task. The analysis of scientific research of variety of authors showed that its creation depends on the following factors: (1) political oversight and social stability; (2) investments of the private and public funds in the health infrastructure; (3) tourism infrastructure (4) international flow of patients; (5) compliance with the international accreditation, which ensures oversight of quality and results; (6) price, i.e. possible savings for alternative purchase of medical procedures; (7) long-lasting outstanding clinical reputation; (8) health sector innovation and achievement history; (9) the successful implementation of good practice and modern medical technologies; (10) availability of internationally educated medical personnel. One of the main criteria for comparative analysis of countries is based on the service availability – how long the potential client has to wait in order to receive MTS, available bed places per 1000 inhabitants, insurance, travel and time costs. In order to compare the price categories in the most objective way , the authors compared the average prices (from lowest to highest) of the private clinics (in Latvia and other countries), including each economic branch (MTS criteria group), and for at least 3 services. In dentistry the following services were analyzed: (1) visits; (2) tooth hygiene; (3) tooth removal; (4) tooth fillings; (5) dental crowns; (6) acrylic implants. In plastic surgery: (1) upper eye-lid plastic; (2) breast enlargement; (3) stomach lipo-suction. Flebology prices were compared for the following services: (1) foam sclerotherapy (for one leg); (2) biological methods with biologic glue (venaseal, for one leg); (3) endovenous laser surgery (EVLT) (for one leg). Cancer diagnostics: (1) melanoma diagnostics; (2) breast cancer diagnostics; (4) prostate cancer diagnostics. Rehabilitation prices: (1) health massage (10x); (2) balneotherapy (1 x); and (3) a ten day course - medical rehabilitation (in summer). Prices were recalculated to Euro from the local currencies, based on the Bank of Latvia currency trade rate for November 29, 2017.

Price and offer analysis included the following criteria: (1) service costs in the country of origin;

(2) service costs in Latvia; (3) residence costs in a hotel in Latvia; (4) transport costs from the country of residence to Latvia; (5) average time in queue and the time spent while traveling to Latvia. Taking into account the above mentioned, the comparison was carried out based on an original method created by the authors of this research, for possible savings for the patient if one would choose MTS in Latvia based on the following equation:

$$A_j = \frac{\sum_{i=1}^{n} W_i}{n} + \frac{\sum_{i=1}^{m} H_i}{m} + \frac{\sum_{i=1}^{k} R_i}{k}, \qquad (1)$$

where A_j – priority country full costs in Latvia were determined as MTS criteria group in Latvia; W_i – i cost of service; H_i – costs of hotel, R_i – travel costs from country of origin to Latvia; n, m, k – complementary number of criteria.

$$B_j = \frac{\sum_{i=1}^{n} W_i}{n} + \frac{\sum_{i=1}^{m} H_i}{m}, \qquad (2)$$

where B_j – the full costs are based on the full costs of MTS criteria group in priority country; W_i – i price of service; H_i – costs of hotels; n, m – number of complementary criteria.

$$S_j = \frac{A_j}{B_j} * 100 - 100 (\%), \qquad (3)$$

where S_j – savings of the patient (%) when choosing MTS in Latvia; A_j – priority country full costs in Latvia were determined as MTS criteria group in Latvia; B_j – the full costs are based on the full costs of MTS criteria group in priority country.

By determining the MTS export possibilities the authors analyzed those MTS with whom Latvia has comparative (price, availability, historical experience) advantages in comparison with other countries.

Medical tourism services in Latvia: history and current situation

The use of health improvement resources in Latvia can be dated back to the second half of the 18th century, when the nobles of the Dutchy of Courland for health improvement reasons used spring waters and sludge (Kemeri National Park Foundation, 2018). In the towns of Latvia, Liepaja and Cēsis, as far back as in the 19th century the Tsars of Russia and other nobles visited the sites for health improvement reasons, used swimming resorts and health improving creeks (Liepaja region tourism information bureau, 2015). The owner of Baldone, baron fon Korf received

from the Russian Tsar Catherina II a decree allowing him to create a sulfurwater treatment facility, and already in 1796 the resort was established, but in 1838 the Kemeru resort was opened (Kleinbergs, 1928; Grants *et al.*, 2014). In the end of the 19th century and beginning of the 20th century many travelers arrived from other parts of Russia, as well as other countries. Until 1914 in Kemeru resort the number of treated persons reached as many as 8300 per year (Bērziņš, 1978). The number of visitors attending sulfur bath resort in Kemeri during a single week in the summer of 1928 reached 2410. Visitors from Lithuania, Finland, Sweden, Poland etc., represented different social levels – from janitors to factory workers that were treated for neurological, digestive, gynecological diseases, as well as received the weight loss treatment. Heart, asthmatic diseases were treated in a specialized Birinu sanatorium established in 1925, while tuberculosis and other respiratory problems were treated in Tervete sanatorium. The availability of awide variety of treatment and tourism infrastructure, good bus and train connections, possibility to rent a car, take part in excursions and listen to symphonic music should be noted (Lībietis, 1928; 1938). During the German occupation in the WW II the treatment facilities and technical means of Kemeru resort were dismantled and taken away while the buildings were left intact. From 1945 a slow renewal of the resort took place. In the Soviet Union the Kemeri resort was a well-known and popular resort. Altogether six stand-alone facilities were built in the resort. In 1967 a new facility was built in Jaunkemeri, which was included in the Kemeri resort system. In 1971 Kemeri was given the state-level resort status of the whole Soviet Union which allowed toreceive additional financial aid from Moscow, as well as an increase of the overall number of employed personnel and construction of further extensions. Unfortunately, nowadays in Kemeri resort there is no functional facility. In Jaunkemeri only the rehabilitation resort "Jaunkemeri" and the resort "Jantarnij bereg", owned by the Chancellery of President of Russian Federation, are in operation. This centre of rehabilitation continues the use of Kemeri biologically active resources – sulphur water, bromium mineralwater and natural peat sludge (Grants *et al.*, 2014).

The authors concluded that historically Latvia has been a health tourism destination due to the fact that during the hay days of the resorts the visitors were sent to these facilities on basis of the doctor's prescription, and were treated to full-fledged health treatment procedures. However, nowadays it is important not to mix health tourism with MT, although in Latvian a stand-alone definition for the term is not available and other instances describe MT as a part of health tourism. Thus, the beginning of MT can be traced back to the post-renewal of independence in 1990ies, when in statistics those visitors which were visiting the country with the clear purpose of health improvement through purchase of MTS, were placed into this segment. However, such segmentation and the lack of statistical observations seriously influenced the development of the present day MT in Latvia.

After the economic crisis of 2009, a more active approach to tourist attraction was started, which resulted in the creation of the private clinic alliance 'Baltic Care.´ Its purpose was to attract foreign clients by combining the best known private clinics of Latvia and specialists in one place. The alliance includes 16 clinics which ensure such services as plastic surgery, vein treatment, dermatology, treatment of infertility, dentistry, traumatology, diagnostics, oncology and other services (Baltic Care, 2017).

Based on the data of the *Health Inspectorate* of *Latvia,* in 2017 there were 44 health facilities registered as MTS providers. The largest part of them were located in Riga, Jurmala and Sigulda, respectively 62%, 14% and 5%, but in Ludza, Priekule, Adazi county, Liepaja, Daugavpils, Krimulda, Balvi and Rezekne – 2% (LR VMVI, 2017).

'Baltic Care' ensures the following MTS (respective number of facilities): (1) flebology – 7; (2) proctology – 4; (3) ceratoplastics – 2; (4) treatment of fertility services – 2; (5) atmology – 2; (6) eyelid plastics – 10; (7) oncology diagnostics – 6; (8) cyberknife services – 1; (9) dentistry – 12; (10) melanoma treatment – 3; (11) prostate cancer treatment – 4; (12) plastic surgery – 9; (13) rehabilitation services – 10; (14) gastric bypass services are offered by two institutions (Baltic Care, 2017).

Results and Discussion

The health insurance system (Table 1) ensures that all inhabitants frompriority countries should have state paid health insurance, however, lately inhabitants have been purchasing additional private insurance. Currently as many as 6% of inhabitants have additional health insurance. The insurance does not cover dentistry services for the grown-ups, cosmetic, vision procedures and diagnosis. Patients have to co-finance almost every service up to 14% and every treatment has the highest price margin (The Commonwealth Fund, 2017). If the insurance does not cover services or covers them partly then the Mt, according to Milsteine & Smith (2006), chooses a service in a different country.

The availability of beds in priority countries for Latvia, according to the 2015 data, show some of the worst results in Europe (Table 1), Sweden being in the worst situation (OECD, 2017). Patients have to wait in queues also for paid services, according to the data for the year 2016. Euro Health Consumer index is a

Table 1

Priority countries: Summary of Insurance Types, Free beds per 1000 inhabitants and Maximum waiting time

Criteria	LV	GB	IE	FI	NO	SE
Insurance Type	private	state/ private	state/ private	state/ private	state/ private	state/ private
Free beds per 1000 inhabitants	5.7	2.6	3.0	4.4	3.8	2.4
Maximum waiting time	not specified	4 months	9 months	6 months	Individuāli	3 months

topical problem in these countries (Health consumer Powerhouse, 2016). Long queues for services have stimulated the creation and purchase of private health insurance, which financially is not available to every citizen. Therefore, many citizens are investigating health service opportunities outside of their own country borders in order to receive the needed medical services, as it has been underlined by Michael, et al. (2007).

When calculating the possible savings (in percentage) Sj, if Mt has chosen MTS in Latvia (Fig.1), it was determined that the Norwegian patients hold the highest export potential. The only service which is not financially feasible in Latvia for them is the melanoma diagnostics, which is muchcheaper in Norway, in comparison. Financially the most economical is to carry out rehabilitation course, which in total allows to save € 1303,87. In the meantime, for Mts from Sweden it is far more economical to carry out cosmetic procedures – endovenous laser surgery procedure, which in total allows to save € 1504,69, while just the eyelid surgery holds € 896,26 savings. In the meantime, for patients from Finland the only service which is not feasible to be carried out in Latvia is the melanoma diagnostics, but breast enlargement procedures in Latvia in comparison are 72% cheaper. The potential patients from Ireland would not choose Latvia to perform acrylic implant injection procedures, as well as melanoma diagnostics, because

in Ireland the overall costs are lower than those in Latvia, combined with the transport and living costs. Financially the most profitable for them is to carry out rehabilitation course which allows for a € 3337,40 savings, as well as eyelid surgery procedures, which allow to save € 2677,40. Misunderstanding the fact that geographically the distance from Ireland and Great Britain to Latvia is similar, the Mt from Great Britain would get the largest savings from purchasing services in Latvia by choosing arehabilitation course totalling at € 4967,00, or eyelid surgery – € 2203,16 in savings.

When summarizing the information about the price and full service comparison (Fig. 1), it can be concluded that Latvia has MTS export potential in the following countries and MTS: (1) Norway – rehabilitation and acrylic implants; (2) Sweden – endovenous laser surgery and eyelid surgery; (3) Finland – rehabilitation and breast cosmetic surgery; (4) Ireland – rehabilitation and eyelid surgery and (5) Great Britain – rehabilitation and eyelid surgery.

In order to successfully fulfill MTS export possibilities, the authors carried out MT SWOT analysis of Latvia. The strong traits included: (1) the number of available medical institutions and the quality personnel; (2) diagnostics of such medical sub-categories as plastic surgery, rehabilitation, oncology, flebology, high level professional output; (3) competitive price levels in MTS in comparison
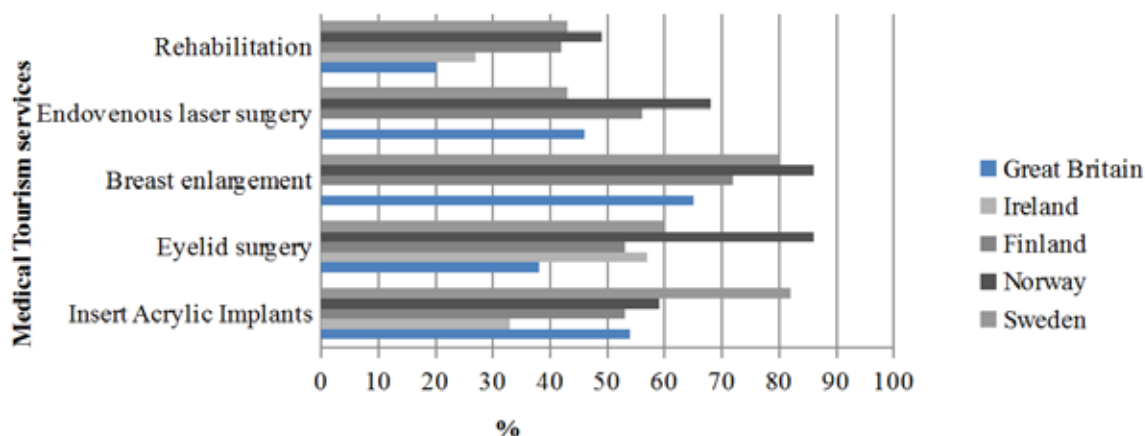

Figure 1. Percentage of possible gains from choosing medical tourism services in Latvia.

with priority countries; (4) non-limited access to paid services offered by private clinics. The weak points included: (1) lack of legal regulation; (2) lack of communication with foreign Mts about the licences of private clinics and other quality aspects; (3) lack of information about the possibilities to cover MTS costs in other countries. Some of the threats for MTS included: (1) language barrier; (2) with the increase and spread of MT the market developments increase competition with the service providers from the third countries; (3) the damage created to the MT industry by cheaper and less qualified service providers; (4) changes of law, larger financing for medical capacity in the priority countries; (5) the overall knowledge of all aspects connected to MT; (6) an increase of price, the reduction of competitiveness. As a result of the MT SWOT, the authors identified multiple possibilities: (1) medical associations should create the trustworthy service provider lists; (2) increase and development of MT market in the EU; (3) creation of a common connected MT legal regulation; (4) cooperation possibilities with the tour operators; (5) the geographical advantage of Latvia and use of possibilities by participation in the EU; (6) leading of competitive MTS in export markets; (7) carrying out monitoring of tendencies in the target markets, in order to adapt and support MTS export capabilities.

Conclusions

1. Since the second half of the 18th century Latvia has been a destination of health tourists owing to its provided health effects from usingspring waters and sludge. The development of resorts attracted Mts looking for neurological, digestive, gynecological, heart, tuberculosis and respiratory system disease treatment as well as for weight management – it was a historical basis on which the present day MT of Latvia was built.

2. The beginnings of the MT in Latvia can be traced back to the 1990ies when in statistics a segmentation of foreign tourists arriving with the aim of receiving health improvement services was carried out. Nonetheless, the segmentation of statistics and the lack of thrustworthy statistics has influenced the present MT development, especially because Latvia has to develop the MT service export possibilities.

3. Latvia should use the MT service export possibilities in the priority countries by offering certain services to specific countries: to Norway – rehabilitation and insertion of acrylic implants; to Sweden – endovenous laser surgery and eyelid surgery; to Finland – rehabilitation and breast enlargement; to Ireland – rehabilitation and eyelid surgery and Great Britain – rehabilitation and eyelid surgery.

4. In order to successfully fulfill the practical MT export possibilities, the MT of Latvia has to avert the problems in the legal regulation eliminate drawbacks in communication with the foreign medical tourists about the licences of the private clinics; to ensure the availability of information about the possibilities to receive MT services; as well as to use the existing advantages of the medical tourism of Latvia.

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THE MODEL OF AUTOMATION AND EXTENSION OF TOURISM ECONOMIC IMPACT ASSESSMENT IN SPECIFIC REGIONS

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Abstract
Tourism is measured by the statistics of visitor movements, expenditure and estimates of the number of visitor facilities. In the world there are many current tools, methodologies and innovative technologies used to measure the economic impact of tourism. Tourism statistics have been on the frontline of Big Data-related innovations of statistical sources and methods. Data from mobile phones (as part of Big Data set) are increasingly used as new indices for social science research. Therefore, this paper looks for an answer to the question – what is the specifics of a theoretical model for automation tourism economic impact assessment in specific regions via the use of ICT and mobile positioning data (MPD)? Using qualitative research methods authors propose theoretical model based on two interlinked parts. First of which – 'Data storage' – can be built upon the most popular BD platform 'Apache Hadoop Ecosystem', where the data precision of the online surveys can be increased by implementing mobile positioning solutions. Meanwhile the other part – 'Data analysis' – can be based on the locally created assessment methodology, which has been derived from the Finnish standardized economic impact estimation approach. The research results show the findings and propose a theoretical model. Its strength and novelty lies in the ability to use traditional tourism statistics, the economic impact analysis and passive mobile positioning data for spatial characteristics of tourism flow. Its construction is a distinctive combination of typically used technological approaches.
Key words: tourism economic impact, automation, mobile positioning data.

Introduction

Tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment. It is measured by the statistics of visitor movements and expenditure (demand) and estimates of the number of visitor facilities (supply). International tourist arrivals in the world grew by a remarkable 7% in 2017 to reach a total of 1,322 million. This is well above the sustained and consistent trend of 4% or higher growth since 2010 and represents the strongest results in seven years. Based on current trends, economic prospects and the outlook by the United Nations agency World Tourism Organization (UNWTO) and the UNWTO Panel of Experts, UNWTO projects international tourist arrivals worldwide to grow at a rate of 4% – 5% in 2018. This is above the 3.8% average increase projected for the period 2010 – 2020 by UNWTO in its Tourism Towards 2030 long-term forecast (Risi, 2018). Whereas, according to the Central Statistical Bureau of Latvia, the latest statistics show that in 2016 the travellers' balance (exports / imports) remained positive, activity in local recreational trips also increased by 2.1% (CSBL, 2017). Several impacts of tourism can be seen across various sectors, in addition, it is evaluated not only within administrative areas, but also in specific regions such as the National Parks (NPs) (Berzina, 2012). Estimated 311 million people visited NPs in the United States of America (USA) in 2017, visitors spending an added value of approximately 2,15 billion dollars in 2016 (Statista Ltd., 2018). However, according to Eagles (2013), there are significant research gaps that urgently need additional work including the economic impact of park tourism (Eagles, 2013). It is also relevant in Latvia, as the only broader study evaluating the economic significance of tourism in NP regions of Latvia was implemented in 2012, estimating that in 2010 the economic significance of tourism in NP regions of Latvia was more than EUR 71.3 million (Berzina, 2012). In order to ensure EI (economic impact) monitoring at a regional level, in some parts of the world, for example in the USA and Finland, the calculation process is fully or partially automated. There are very many current tools, insights, methodologies and innovative technologies used to measure the impacts of tourism across several sectors and development outcomes (Otarra, 2014). However, the rapid development of information and communication technology (ICT) is changing the research methods or approaches (Raun, Ahas, & Tiru, 2016). Tourism statistics have been on the frontline of Big Data-related innovations of statistical sources and methods (EUROSTAT, 2017). *Big Data* (BD) is high-volume, high-velocity and/or high variety information assets that demand cost effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation (Gartner Inc., 2018). According to the European Union (EU) Agency for Network and Information Security (ENISA), this definition points out the three most outlined dimensions of BD (also known as the 3Vs3) – volume, velocity and variety (ENISA, 2015). Besides these three 'core' Vs of BD, which reflect a more ICT oriented perspective, other key Vs have entered the debate in recent years – veracity, validity, volatility and value (EUROSTAT, 2017). The sources of BD are mobile network operator (MNO) data, smart mobile devices, cameras,

Internet of things (IoT) devices, traffic counters and sensors, bank/credit card transitions, web portals and websites, including social media and networks, databases, servers and others. BD when captured, formatted, manipulated, stored and then analysed, can help to gain useful insight to increase revenues, get or retain customers and improve operation, find new correlations of development trends. The world's technological per-capita capacity to store information has roughly doubled every 40 months since the 1980s, as of 2012 every day 2.5 exabytes (2.5×1018) of data are generated (Hilbert & Lopez, 2011; IBM, 2012). It is expected that the number of interconnected devices will reach 50 billion by 2020 (Mashal *et al.*, 2015). By 2025, the IDC Corporate (from the USA) predicts there will be 163 zettabytes of data (Reinsel, Gantz, & Rydning, 2017).

Many sources of BD, including mobile positioning data (MPD), are some of the most promising ICT data sources for measuring the mobility of people. Perhaps, the MNO data is the most commonly used BD source for measuring tourism flows. The growing penetration of mobile phone use and falling roaming rates in certain parts of the world (in particular the EU) make the analysis of the whereabouts of mobile phone use a highly relevant source for analysing the presence and movements of tourists (EUROSTAT, 2017). Some researchers consider the results show that MPD has advantages: (1) data can be collected for larger spatial units and in less visited areas, (2) spatial and temporal precision is higher than for regular tourism statistics. Random IDs allow to study tourists' movements (typical routes of certain nationalities) (Ahas *et al.*, 2008). Mobile phone data have many unique features and advantages which attract scholars from various fields to apply them to travel behaviour research, and a certain amount of progress has been made to date. However, this is only the beginning, and mobile phone data still have great potential that needs to be exploited for new spatio-temporal tools for improving tourism development planning. Data from mobile phones are increasingly used as an innovative tool in geography and social sciences research (Steenbruggen, Tranos, & Nijkamp, 2015; Wang, He, & Leung, 2017). It gives an opportunity to put forward the *research question* – what is the specifics of a theoretical model for automation tourism economic impact assessment in specific regions via the use of ICT and mobile positioning data (MPD)? In that context authors define the main *research tasks* – (1) to carry out research of the scientific and practical application practice in the world, (2) to evaluate and apply specific technologic combination approach which would be appropriate for the situation in Latvia, as well as to achieve the *aim of the research* – the development of a theoretical model for automating economic impact assessments

of tourism in specific regions. At the same time it is also the *novelty of the study*.

Materials and Methods

The study is a qualitative research, therefore it is based on scientific literature and practical findings. The study uses the monographic, comparison, abstract-logical methods; synthesis and analysis as methods are also used. The conclusions of professional organizations, researchers and practical research results relating to the experience of the estimation of tourism economic impact assessment, its automation and extension of European, Asian, American countries (especially the USA, Finland, Estonia) have been studied, selected and used. The methodologies, indicators, data types and sources, technical solutions for automated calculations, potential, problems and limitations have been studied.

There are several economic analysis methods in NP tourism. For instance, based on Burchell and Listokin (1978), Walsh (1986), Warnell (1986), Johnson and Thomas (1992), Williams (1994), Frechtling (1994), *et al.*, theories, which help to estimate extended impact: economic impact (EI), fiscal impact, financial, demand, cost benefit (C/B) analysis, feasibility study, environmental impact and tourism income multiplier assessment (Berzina, 2012). Only a few of them – I/O, C/B, EI analysis and multiplier assessment – are included in the automated or partially automated technical solutions.

In 1976 in the United States Forest Service a linear programming model was created – Impact Analysis for Planning (IMPLAN). IMPLAN estimated the cross-sectoral economic effects of resource outputs on local communities. Now it is developed into the software of an economic impact assessment modelling system, mainly for evaluating development scenarios. This software and exclusively provided several accompanying databases allow building just Leontief's input-output (I/O) models of regional economies. I/O is commonly used to estimate the impact of an economy and to analyse resulting effects that rely on regional economic base data, and an analyst's collected information on a specific economic change of a particular region. Economic consequences can be estimated in the form of jobs, revenues, profits, earnings and/or taxes (IMPLAN, 2018). Model can be used only in administratively defined territories within the region.

The 'Money Generation Model' (MGM) was developed in 1995 and updated in 2000. It is an economic assessment tool available to NP managers in the USA to help gauge the economic impact of NP visitor spending on local economies. The MGM2 estimates direct, indirect, and induced economic effects of visitor spending, and multipliers. Inputs can

come from a variety of sources – typically provided by the NPs Public Use Statistics Office, and from NPs Visitor Services Project survey data. If data are not available, generic estimates are provided. EI calculated by the MGM2 are reported in four key areas: sales, jobs, personal income, and value added. The MGM2 model is an Excel based tool (Fish, 2015).

Based on MGM2 model, a method has been developed for standardized EI estimation done by the Finnish Forest Research Institute and Metsähallitus Natural Heritage Services. It is based on the standardized visitor monitoring and provides comparable results between the NPs and other nature recreation areas, and over time. It also enables annual follow-up of the impacts in a cost-effective way. The methodology of tourism impact analysis include the I/O (as IMPLAN) and tourism satellite accounts (TSA) – widely used in the state-level examinations. Finnish standardized EI estimation is done by an Excel-based application 'Paavo'– built on Excel sheets, and it applies Excel functions, macros and SQL queries. The number of visits as well as all the data from visitor surveys is enquired half-automatically from the visitor information database system 'ASTA'. The park classification and multipliers are built in the Excel (Huhtala, Kajala, & Vatanen, 2010). The weakness of the model is its half-automation; the reliability of the method is highly dependent on the success of visitor counting and visitor surveys because the errors in visitor monitoring will be repeated when the total effects are calculated; it can be used just in NPs or other administratively defined territories within the region; access to TSA is needed.

Due to the lack of dynamics of output data, many of EI assessing methods still cannot be used in specific regions of Latvia, except the EI analysis. By combining several techniques used by MGM2 and Finnish standardized economic impact estimation, a methodology for assessing the economic significance of tourism in NP regions was developed, scientifically approved and approbated in Latvia in 2012 (Berzina, 2012). The tourism EI indicators used in the methodology also correspond to the indicators included in the European Tourism Indicator System (ETIS) developed later by the European Commission (EC) in 2016 (EC, 2016). EI analysis estimates the economic significance by calculations of direct, caused, indirect, total economic impacts, and regional economic significance by administrative territories included in the region (Berzina, 2012). The calculation process was not automated; MS Excel and IBM SPSS programs were used for summarizing and analysing the data from surveys. The model has a significant positive aspect – it can be applied even if the research area is not limited to an administrative territory. However, like in Finland, the main drawback is the

dependence of the data obtained from surveys on the accuracy of counting. This means additional solutions should be found in order to provide this.

According to de Jonge, Pelt and Roos (2012), there is an additional indicator of economic activity in a region – mobile phone calls, because these data might lead to an indicator that shows that economic activity is changing (Arhipova *et al.*, 2017). The latest research on MPD was carried out in Latvia in 2017. Its methodology corresponds to the field of economics, however, it uses tourism-relevant indicators – mobile call activity, call date, time to test MPD suitability for a theoretical model of updatable Latvian regional business index (Arhipova *et al.*, 2017). One of the conclusions of this study is worth taking into account - the use of MPD allows for a more precise volume determination of the entire assembly of the research and the spatial manifestation of the human flow (directions, intensity).

MPD characterizes the location and movement of a mobile device and it can be divided into two main methods for obtaining the MPD: (1) active positioning and (2) passive positioning. For the active positioning, a specific targeted request can be made to locate the mobile, while for the passive positioning – historical data can be collected and no active requests should be sent. Active and passive data can be monitored both in real-time and historically, although in the active positioning location requests have to be made regularly over a period of time to get the historical data. The active mobile positioning also refers to the ability of installed application to use the location of the mobile device. Mobile applications mostly use three types of location methods – Global Positioning System (GPS)/Assisted Global Positioning System (A-GPS), Wireless networks (WiFi) and network antenna-base location databases. The advantage of the active positioning data is that the geographic information is generally very precise and accurate. The active positioning can be used by researchers for replacing or supplementing travel diaries in spatial behavioural analyses and for generating mobility statistics. The main weakness of this data source is the need to recruit the respondents resulting in a rather small sample size (Ahas, 2014; Tiru, 2014).

Extensive research of active MPD capture and analysis has been carried out by Tasmanian Sensing Tourist Travel (TSTT) project team in Tasmania, and another research was carried out in the port of Palermo, Italy (De Cantis *et al.*, 2016; Hardy *et al.*, 2017). Both tracking applications were implemented in traditional surveys to obtain information about tourists in specific locations. Both studies pointed out that application-based GPS tracking has a huge potential because it gives rich dataset emerged as a result of combining surveys with the precision of the

GPS capabilities of the device. Despite the significant potential of GPS technologies, there are also limits like an investigated group size, battery life of the device and spatial accuracy in a range of situations. To solve the GPS data accuracy, the data were overlaid with different location-based spatial layers (city map, road, NP boundary, etc.) (De Cantis *et al.*, 2016).

Passive MPD are automatically stored in the memory files of mobile operators for call activities or movements of handsets in the network and can also be stored in the memory files of applications in the mobile devices (Ahas *et al.*, 2008; Tiru, 2014). The most common source of data in the case of the passive positioning is Call Detail Record (CDR) and Data Detail Record (DDR), which are automatically saved by using the telephone. CDRs can be stored in binary, Extensible Markup Language (XML) or in plain text format (CSV). DDR and CDR data contains – phone ID, the country of registration of the phone, time of event, location coordinates of event. Application based passive MPD is MNO independent and is stored either in the mobile device or in application provider's central databases (Tiru, 2014). Compared to the active positioning data, the spatial accuracy of passive MPD is much lower and the spatial interval is usually irregular and with longer 'time gaps' (Ahas, Raun, & Tiru, 2014). The MNO antennae are distributed unequally throughout the country and also with different network coverage, therefore there is an unequal spatial accuracy – dense regions such as urban areas and roads with heavy traffic have much higher antennae density than rural areas (Kuusik *et al.*, 2011). The main advantage of the passive positioning method is the cost-effectiveness of obtaining huge amounts of data involving all phone users (Tiru, 2014). The passive mobile positioning enables to observe and measure the duration, timing, density, seasonality and dynamics of visits. Moreover, it also allows distinguishing repeat visitors. The repeat visitors could be segmented by their countries of origin, frequency of visitation, seasonality, etc. For the repeat visit determination, 7 days as the preliminary proxy for a single visit can be used. In addition, the local destinations and events most loved by the repeat visitors and their movement trajectories also could be identified (Kuusik *et al.*, 2011). The weaknesses of data are related to problems of accessing data, as operators do not wish to share data and because of the privacy and surveillance concerns. Another problem is also that the data is another quantitative dataset with limited features (Ahas *et al.*, 2008).

Privacy issues are the most critical aspect of using MPD, because mobile phones become very intimate objects for users (Kuusik *et al.*, 2011). There are several EU laws like General Data Protection Regulation 2016/679 (GDPR), which will be enforced after 25 May 2018 (its successor 95/46/EC), Electronic Privacy Directive 2002/58/EC and other regulations, for example, Directive 223/2009/EC, which determines statistical confidentiality (EP, EC, 2018). Therefore MPD anonymization is very important. The anonymization refers to the process of modifying personal data in such a way that individuals cannot be re-identified and no information about them can be learned. A perfect anonymization is difficult to achieve in practice without compromising the utility of the dataset and with BD this problem increases due to the amount and variety of data. On the one hand, low level of the anonymization (e.g. mere de-identification by just suppressing direct identifiers) is usually not enough to ensure non-identifiability. On the other hand, too strong anonymization may prevent linking data on the same individual (or on similar individuals) that come from different sources and, thus, thwart many of the potential benefits of BD (ENISA, 2015).

According to De Montjove *et al.* (2013) just 4 spatio-temporal points are enough to uniquely identify 95% of the individuals. The analyzed dataset contained 1.5 million phone users with hourly specified individual geographical locations and with a spatial resolution equal to that given by the carrier's antennas. The authors concluded that the spatial aggregation is achieved by increasing the size of the regions in which the user is known to be during his interactions with the service (De Montjoye *et al.*, 2013). A significant work of passive MPD analysis and usage was done by Estonians – 'Positium LBS' in cooperation with the University of Tartu. 'Positium LBS' has developed a special software 'Positium Data Mediator' for MNO system. It collects data about call activities (including SMS, MMS, GPRS incoming and outgoing) of selected roaming service users from the billing memory. After that the data collection is processed and anonymized – replacing the direct identifiers with pseudonymous. The pseudonymous data (pseudonymous ID, time of the call activity, cell ID with the geographical coordinates of the antenna, nationality – the country of origin (contract) of the telephone) are obtained from the operators' systems and transferred to the servers of 'Positium Data Mediator'. The visitor flows in the network cells are interpolated geographically for sampling purposes using accommodation statistics, border crossing data and a questionnaire survey. After sampling procedures, the data processing is completed in 'Positium Data Mediator' and the data are ready for analysis (Kuusik *et al.*, 2011).

For determining the usual environment with MPD, Estonian researchers compared 3 different methods. Density-based spatial clustering of applications with a noise method is a rather universal approach to measure people's usual environment and it is most commonly

used to determine anchor points from GPS data, but also works well over a longer time period (such as one month) for mobile CDR data. However, this method is rather weak in describing functionality of movements and using in the areas with a mixed land use. Second is an anchor point method whose algorithm is based on the identification of places regularly visited in particular day/night times (Novak *et al.*, 2013; Ahas, Raun, & Tiru, 2014). An observation period of at least one month is required to determine the most likely locations for home, work, education, summer home and transportation channels by considering the locations and times of phone usage, visitation frequency, regularity, and variety. In addition to meaningful locations, 'less meaningful' regular visitation areas or secondary anchor points are also determined. The third method is based on borders of administrative units. Researchers compared the distribution of CDR points on a level of a) local community (1 – 5 km); b) municipality (5 – 30 km), c) county (30 – 80 km). This method has less accuracy and has problems with measuring cross-border activities and selecting an appropriate spatial resolution. The positive side of this method is the compatibility with administrative unit based official statistics (Ahas, Raun, & Tiru, 2014). In preparation for a new GDPR (will be enforced in May, 2018), 'Postium LBS' has added one more layer for 'Positium Data Mediator' called 'Sharemind' – secure computing platform developed by 'Cybernetica AS'(Tiru & Bogdanov, 2017). Source data owners encrypt each record on premises with the 'Sharemind' importer and upload to the 'Sharemind' Application Server cluster (Cybernetica AS, 2009). The 'Sharemind' hosts cannot decrypt the data and therefore need to use module called 'Rmind' for the purpose of analysis. At this moment 'Sharemind' is free for developers and privacy researchers.

Results and Discussion

Taking into account that administratively defined territorial units differ from specific regions, as their regionality is more manifested within the boundaries of influences or interests (and thus also within the limits of available official statistics), the authors cannot adapt the IMPLAN technological solution to the tourism EI assessments by developing it up to the process modelling level (Eagles, 2013; IMPLAN, 2018). However, the experience that would be transferable is the possibility of IMPLAN integrated inter-industry economic assessments. Also The MGM2 model is applied within the boundaries of administratively defined territories that constitute the NPs or their regions. As the range of data necessary for calculating multipliers is still not comprehensive in Latvia, but MGM2 requires it, the authors cannot include this approach in the model at present (Berzina, 2012). However, we should take into consideration that data becoming a commodity the situation in the availability of statistics in the world is changing, and the multiplier measurements do not lose their significance. Yet, implementing the goal of the study, the authors can integrate the assessment methodology developed in Latvia derived from the Finnish standardized EI estimation approach in the automated model of the tourism EI assessment (Huhtala, Kajala, & Vatanen, 2010; Berzina, 2012). By the automation of data acquisition, accumulation, summarizing and analysis, on-line surveys can be developed with a direct and immediate connection to the data bank – database system, addressing the dependency of the data obtained from surveys on counting accuracy. This can be increased by the use of MPD (Arhipova *et al.*, 2017). The main strengths of MPD is the spatial accuracy and timeline, which allows a more precise identification of the number of trips taken, number of nights spent, including non-registered accommodation, the duration of the visit, frequency of visits, number of unique visitors, and visited places in the country or region compared to the traditional surveys - based on travellers' honesty and memory. It has also been pointed out that MPD can be used as a supplement for tourism statistics and not as a replacement source of data due to the lack of information about the purpose of a trip and type of accommodation (Ahas, Raun, & Tiru, 2014). Comparing the active positioning with the passive positioning data collection method, there are several differences. The application based active position uses GPS location services, which are independent on a mobile network operator and the data is stored in the mobile device, therefore this method can be used in small sample groups. The main advantages of the passive positioning dataset are costs and speed when obtaining a huge amount of data. The spatial accuracy of passive MPD is lower than in active, but in both cases, as research has showed, there is a need to use overlaying layers not only to correct spatial accuracy, but also to tie with administrative borders. Given that the active positioning dataset is relatively small and, in the specific case, would be equivalent to surveys, MNO provided passive MPD is in use. This has been taken into account in the development of the theoretical model for automating the tourism EI assessment in specific regions of Latvia, and for supplementing these assessments with the spatial dimension of the tourism flow (Figure 1).

The model has been developed based on the assumption that MNO provided sample set of data is at least on one calendar month, it is anonymized and geographically aggregated. Based on the findings of 'Positium LBS', MPD processing is planned to include data cleansing – cleaning from unnecessary
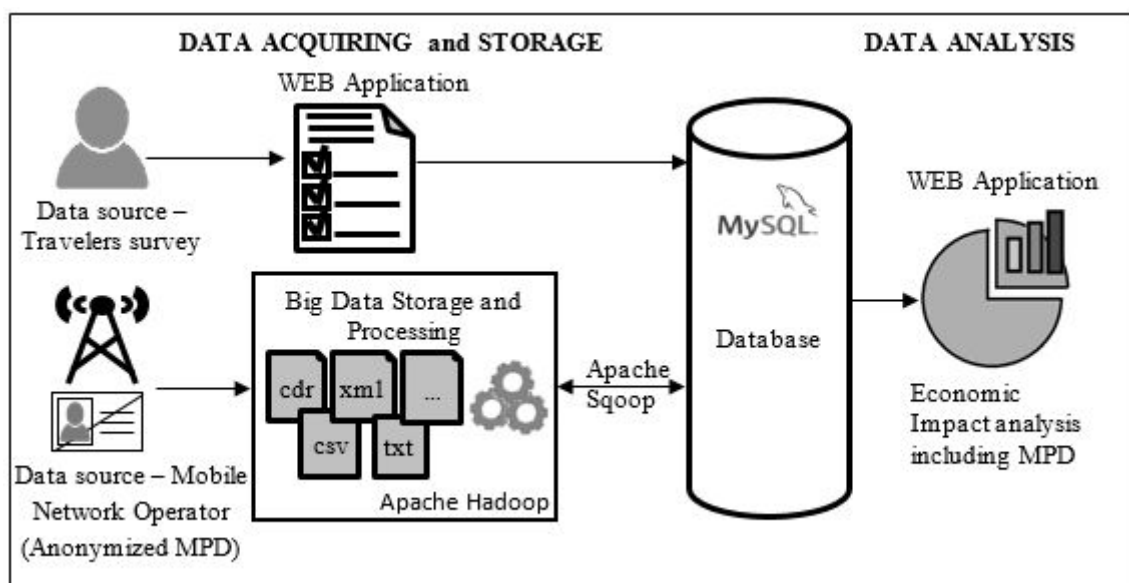
Figure 1. The theoretical model for automating tourism economic impact assessment, and for supplementing it with the spatial dimension (created by the authors).

information, foreign long term visits, cross-border noise, corrupted data, etc., spatial aggregation – spatial interpolated with administrative units – cities and parishes, spatio-temporal statistics – to identify tourist activities and visitor segmentation (Tiru & Bogdanov, 2017). For data storage and processing, the most popular BD platform 'Apache Hadoop Ecosystem' can be used (Apache Software Foundation, 2018). The reason of that decision points to: (1) 'Apache Hadoop' is an open-source software framework that allows for the distributed processing of large datasets across clusters of computers using simple programming models, (2) it is designed to work with any data types – structured, unstructured, semi-structured, which makes it very flexible, (3) in this platform it is possible to use one of the most popular free programming languages and environments called R, which is widely used for statistical analyses and visualizations, (4) the 'Apache Hadoop' software platform is also available as a service from the public cloud providers such as Google Cloud Platform, Amazon Web Services (AWS), Microsoft Azure, Cloudera and others, (5) in the future it will be possible to move to one of the public cloud platforms for more computing resources.

Conclusions

1. The assessment of tourism EI in the USA and Finland is based on the use of fully or partially automated technical solutions, but an essential precondition for their use is that the territory to be assessed must have administrative boundaries.
2. MPD as a part of the BD set has a high potential for the tourism EI assessment. It is also used increasingly in the world to supplement other

tourism economic assessments, including the spatial dimension. However, this use is aimed at wider administrative territories than a specific region with peculiar economic impact zones.
3. The methodology for the tourism EI assessment in the NP regions developed in Latvia in 2012 can theoretically be automated. Theoretical model has two interlinked parts. First of them – 'Data storage' - can be built upon the most popular BD platform 'Apache Hadoop Ecosystem', where the data precision of the online surveys can be increased by implementing mobile positioning solutions. Meanwhile the other part – 'Data analysis' – can be based on the locally created assessment methodology. The most important novelty would be that a similar combination of methodological and technological solutions could be used in the regions that are not administratively defined, and such combination has not been developed and tested until now.
4. Using MPD, EU directives and regulations that limit the processing and use of data must be strictly observed. This is a significant challenge for the authors in further scientific-practical research on the particular topic.

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SUPPORT TO THE LATVIAN FISHERY SECTOR THROUGH THE EU FINANCIAL INSTRUMENTS

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Abstract
Latvia, just like many other EU member states, receives multiannual financial support through the EU financial instruments for implementation of the common policies by the EU. The support is aimed at the priorities set at the level of the EU and is adapted to the peculiarities of each member state's sphere. The aim of the study is to evaluate the importance of the support, provided by the EU financial instruments, for the development of Latvian fishery sector. The analysis was made on the basis of the available data and their quality. As a result of the study, the author found out that in the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020, for the development of fishery sector in Latvia the support of several EU financial instruments was available. Development of fishery sector is significantly impacted by the availability of the financial support through the EU financial instruments and use thereof. Considering the dependence of the fishery sector on the sustainability principles coordinated at the level of EU, corresponding fishery possibilities, and considering the increase of global competitiveness in the world's markets, the strengthening of fishery's competitiveness plays a significant role in the facilitation of the Latvian economy.
Key words: Common Fisheries Policy, EU financial instruments, financial support, fishery sector.

Introduction

The length of the Latvian border is 1836 km, 27% or 494 km of which is the length of seacoast, constituting 0.7% of the total EU shoreline of 66000 km (European Commission, 2014). The territorial waters of the Baltic Sea up to 12 nautical miles from the coastline, as well as economic zone and 28 thousand km^2 area of continental shelf are in the jurisdiction of the country (Agriculture Ministry, 2014).

Latvia has the possibility of fishing in the Baltic Sea and the Gulf of Riga, based on the long-term study of environment and fish resources at the national and international level. According to the international contracts concluded by Latvia, there are possibilities of fishing also in the economic zones of other countries and regions encompassed by international conventions (Finance Ministry, 2003). High-seas fisheries take place in the areas confirmed by the Northwest Atlantic Fisheries Organization (NAFO), Northeast Atlantic Fisheries Commission (NEAFC) and Fishery Committee for the Eastern Central Atlantic (NEAFC) (European Commission, 2014).

Fishery sector is closely related to the rational and sustainable use of country's economic zone and territorial waters as well as living natural resources in the internal bodies of surface water and preservation of biological diversity (Finance Ministry, 2003). The Baltic Sea is one of the youngest seas in the world and it is one of the biggest brackish water areas, which is also recognized to be one of the dirtiest seas in the world (World Wide Fund for Nature, 2005). Since the Baltic Sea has a unique ecosystem, determined by its particular geographical and hydromorphological conditions (European Commission, 2014), it requires sustainable and rational management in order to have a favourable influence on the development of fishery sector.

To implement the Common Fisheries Policy (CFP), Latvia just like other EU member states receives multiannual financial support through the EU financial instruments. The support is aimed at the priorities set at the level of the EU and is adapted to the peculiarities of each member state's sphere. The aim of the support, provided by these EU financial instruments, is to facilitate competitive, sustainable, in terms of environment, economically viable and socially responsible, fishing (European Parliament and Council, 2014). Provision and allocation of purposeful support is important for the advancement of fishery sector's development (European Parliament and Council, 2013). Since the support provided by the EU financial instruments is available to the participants of the fishery sector also for the development of other spheres, which influences their common economic activity and development, it is important to gather the information also about the importance of these financial instruments.

The aim of the research was to evaluate the importance of the support provided by the EU financial instruments in the development of the Latvian fishery sector. To reach the aim, the following work tasks were set: 1) to analyze the support provided to the participants of the Latvian fishery sector by the EU financial instruments and the use thereof in the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020; 2) to evaluate the development of the Latvian fishery sector.

Novelty of the research – the first research broadly reflecting and analyzing the support, provided to the Latvian fishery sector by the EU financial instruments, in connection with its general development within the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020. The obtained results provide an opportunity to the institutions involved in formation

and implementation of fisheries policy, entrepreneurs and researchers to better understand the scope of the support provided by the EU financial instruments and its importance in the development of the Latvian fishery sector.

The author has reflected the results of the research in the article; however, more detailed and wider analysis of the results is available in the research called 'FAP Investments in Fishery to Achieve Goals of CFP' ('ZRP ieguldījumi zvejniecībā KZP mērķu sasniegšanai') funded by the Ministry of Agriculture of the Republic of Latvia.

Materials and Methods

To obtain information about the support provided by the EU financial instruments to the Latvian fishery sector in the planning periods of 2004 – 2006, 2007 2013 and 2014 2020, first of all the author identified the participants of the fishery sector pursuant to the data in the Central Statistical Bureau (CSB) (Central Statistical Bureau, 2018), Latvian Fisheries Integrated Control and Information System (LFICIS) (Agriculture Ministry, 2018) and Information System of the Rural Support Service (Rural Support Service, 2017).

According to the compiled list, the author requested information from the Ministry of Finance (MF), Ministry of Environmental Protection and Regional Development (MEPRD), Development Financial Institution "Altum" (ALTUM) and "Environmental Investment Fund" Ltd. (LEIF) about the following EU financial instruments: European Regional Development Fund (ERDF), European Social Fund (ESF), Cohesion Fund (CF), Latvian-Swiss Cooperation Program (LSCP), European Economic Area Financial Mechanism (EEA FM), Norwegian Financial Mechanism (NFM), Norwegian Government Bilateral Financial Instrument (NBFI), European Agricultural Guidance and Guarantee Fund (EAGGF), European Agricultural Fund for Rural Development (EAFRD), Latvian Guarantee

Agency (LGA) financial instruments, Climate Change Financial Instrument (CCFI), European Territorial Cooperation Programmes (ETC), Emissions Quota Auctioning Instrument (EQAI), and others. The RSS provided the author with the information about the Financial Instrument for Fisheries Guidance (FIFG), European Fisheries Fund (EFF) and European Maritime and Fisheries Fund (EMFF).

The analysis includes the total funding (public (EU financial instruments and state) funding and private co-funding) in the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020 (from May 2004 until August 2017). The author analyzed information about 1299 projects with the status "confirmed", "supervision started" and "closed". Availability and quality of data determined the period from 2005 – 2016 for evaluation of the general situation in the Latvian fishery sector.

The qualitative and quantitative research methods were used in the study, including the general scientific research methods, statistical research methods, mathematical methods and sociological research methods. The author mostly applied the methods of analysis and synthesis in elaboration of conclusions. Microsoft Excel, Microsoft PowerPoint and IrfanView program were used in processing and the analysis of the study results.

Results and Discussion
EU financial instruments support

In 2004 – 2006, 2007 – 2013 and 2014 – 2020 planning periods, the fishery sector received the support in amount of EUR 161.35 million from the several EU financial instruments: EAGGF, ERDF, FIFG, EFF and EMFF, including state and private co-funding (Figure 1).

From the total provided support, 86% was the public funding, but the other 14% – private co-funding. The greatest support was provided through the EFF with government co-funding – 51%, and
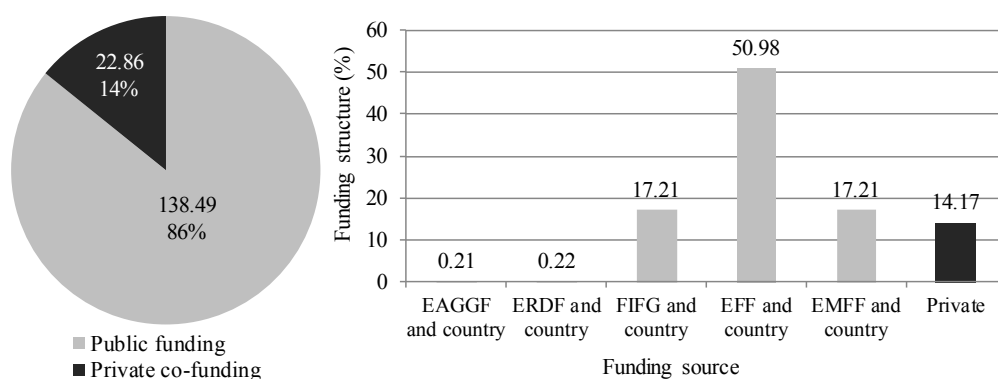

Figure 1. Structure of the total funding (A) and source of funding (B) to the participants of the fishery sector in the planning period of 2004 – 2006, 2007 – 2013 and 2014 – 2020 (EUR million, %) (author's calculations based on data from Finance Ministry, 2017; Rural Support Service, 2017).
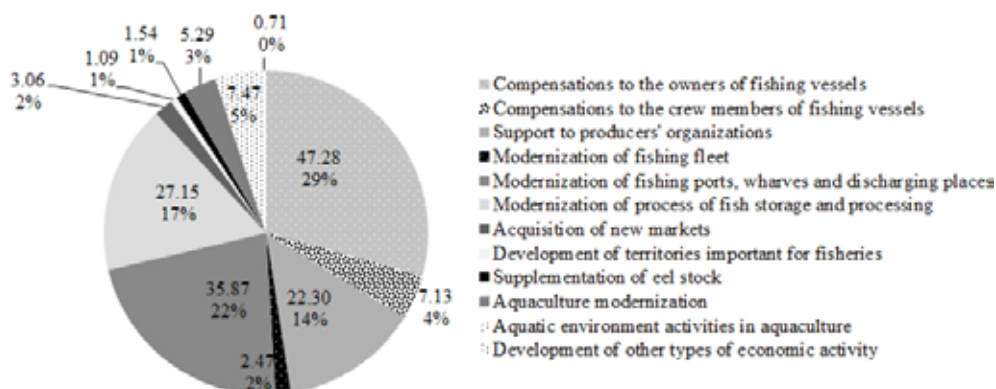
Figure 2. Total funding to the participants of fishery sector divided according to the types of investment in the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020 (EUR million, %) (author's calculations based on data from Finance Ministry, 2017; Rural Support Service, 2017).

the smallest: from the EAGGF with government co-funding – 0.21%.

52% of the total funding of EUR 161.35 million was channelled to 160 or 75% fishery companies, 28% of co-funding – to 14 associations, 16% of funding – to 10 various institutions (municipalities, port administrations, BIOR). Only 5% of the total funding was channelled to 552 or 50% of individual persons – in this case crew members of fishing vessels who lost their jobs as a result of decommissioning of fishing vessels.

As separate fishery companies are employed not only in fishing, but also fish processing, tourism, aquaculture and other types of economic activity, support of the EU funds was used also for the development of these fields (Figure 2).

The biggest funding (EUR 54.42 million or 34%) was directed to the measures for structural adjustment of fishing fleet to the available fish resources. As a result of the support provided by the FIFG, EFF and ENFF, 242 fishing ships and boats were decommissioned, including scrapping or giving to non-profit purposes (79 fishing vessels in the framework of Fisheries Operational Programme (FOP) 2004 – 2006, 158 fishing vessels – FOP 2007 – 2013 and 5 fishing vessels – FOP 2014 – 2020). As a result, the owners of the decommissioned fishing ships and boats received compensations in the amount of EUR 47.28 million, and the crew members of 552 fishing vessels who lost their jobs – in the amount of EUR 7.13 million.

Relatively big financing was channelled to modernization of fishing ports, wharves and discharging places – correspondingly EUR 35.87 million or 22% of the total funding. As a result of the support, wharves were restored, breakwaters were reconstructed, several unloading places and places for storing fishing equipment were modernized. Moreover, there were purchased inventory for fishing vessels and fishing equipment, different transfer

facilities, ice machines and supply systems. Also different freezers and stands, sorting yards for fishing products and refrigerators were built, as well as other kind of equipment and machinery bought.

Funding of EUR 27.15 million or 17% was channelled to modernize the process of fish storing and processing. Within the framework of this funding, several activities took place: modernization of production units and processing workshops, purchase and installation of technological equipment and facilities, establishment of different chambers (quick freezer for fresh fish, fish curing establishment etc.) as well as modernization of the process of processing (introduction of new tin lids) and improvement of the territory.

The development of fishery producers' organizations also received important support. Funding in the amount of EUR 22.30 million or 14% was channelled to modernization of fishing ports and discharge places, the use of added value, product quality and bycatch, restoration of production, processing and marketing equipment and infrastructure. Furthermore, the funding was channelled to support storage, trade events (acquisition of certificates, participation in international exhibitions) and to cover the expenses related to the development and implementation of Production and trade plans (Table 1).

Funding in the amount of EUR 12.76 million or 8% was channelled to the development of aquaculture. Funding of EUR 5.29 million was directed to modernization of aquaculture processes (purchase of various equipment, formation of plants for fish farming and incubation, renovation of ponds, purchase of tractors, etc.), and EUR 7.47 million – to aquatic environment activities.

Acquisition of new markets and modernization of fishing fleet received funding in the amount of EUR 3.06 million and EUR 2.47 million, respectively, or 2%. Funding of EUR 1.54 million or 1% was

Table 1

Total funding channelled to producers' organizations in the planning periods of 2004 – 2006, 2007 – 2013 and 2014 – 2020 (EUR million,) (author's calculations based on data from Finance Ministry, 2017; Rural Support Service, 2017)

Type of investment	Total funding				
	Public			Private	TOTAL
	FIFG and country	EFF and country	EMFF and country		
Fishing ports and discharging places	-	5.31	3.47	1.86	10.64
Added value, quality of products and use of bycatch	-	-	5.29	1.76	7.05
Investments into production, processing or marketing equipment and infrastructure	-	3.10	-	0.38	3.47
Storage support	-	-	0.87	-	0.87
Trade events	-	-	0.10	0.03	0.14
Production and trade plans	-	-	0.08	0.03	0.11
Compensations of administrative expenses	0.02	-	-	-	0.02
Total:	0.02	8.41	9.82	4.06	22.30

allocated to the activities regarding eel stocking. Within the framework of the activities of FOP 2007 – 2013 "Renewal and development of villages where fishing activities take place", "Development of small-scale infrastructure and services related to fisheries and tourism", "Restructuring, reorientation of economic activities and diversification of activities" and the activity of Fisheries Operational Programme 2014 – 2020 "Implementation of community-led local development strategy", EUR 1.09 million or 1% of funding was directed to the development of the territories significant for fisheries.

Conversely, the least funding (EUR 0.71 million or 0.44%) was channelled to the development of other economic activities, for example, agriculture, forestry, tourism, pig breeding, aviculture and electricity generation where the support was absorbed via EAGGF and ERDF.

CFP aims to ensure environmentally sustainable fish farms in the long-term performance as well as their management in accordance with the objective to ensure benefits in economic, social and employment sector, thus enhancing availability of food (European Parliament and Council, 2013). General objective

Table 2

Activities determined within the framework of the support of the FIFG, EFF and EMFF for the development of Latvian fishery sector (author's calculations based on data from Finance Ministry, 2003; Agriculture Ministry, 2007; 2014)

of CFP is to ensure that fishing and aquaculture activities help with providing long-term sustainable environmental conditions necessary for economic and social development. Moreover, the directed policy should contribute to facilitating productivity, ensure sufficiently high standard of living to those who are employed in the fisheries sector and stable markets, as well as it should ensure availability of the resources and that products are available to consumers at reasonable prices (European Parliament and Council, 2014) (Table 2).

The policy of Latvian fisheries sector is a planned guiding by the framework established by CFP and the opportunities for facilitating sector's development, which thus requires highlighting of the main priorities at national level. The implementation of several activities was determined in order to facilitate the development of Latvian fishery sector via FIFG, EFF and EMFF.

On the basis of the analysis, it may be concluded that the participants of the fishery sector invested EUR 90.84 million or 56% of the funding in the development of their main activity, whereas EUR 16.10 million or 10% – in the facilitation of other spheres (development of territories significant for fisheries, eel stocking, development of aquaculture, etc.). Remaining funding in the amount of EUR 54.42 million or 34% was paid in the form of compensations for cessation of fishing activities. Contribution provided by the EU financial instruments reflects also in other indicators characterizing the development of the fisheries sector.

Overall situation in the Latvian fishery sector

In 2016, 205 companies were operating in the Latvian fishery sector; 679 fishing vessels with a total engine power of 47.12 thousand kW and total gross tonnage of 28.52 thousand GT were at their disposal. Fishing fleet was composed of 12 vessels plying the high seas, 57 vessels fishing in the Baltic Sea and the Gulf of Riga beyond the coastline and 610 coastal fishing boats (Table 3).

Within the framework of FIFG, EFF and EMFF support, the activity for balancing of fishing vessel capacity with the available fish resources was implemented through the Fisheries Operational Programme. As a result, not only the number of fishing vessels (-27%), their power (-27%) and tonnage (-26%), but also the number of the persons employed in the companies (-37%) decreased in the period from 2005 to 2016. The activity for balancing of fishing vessel capacity has enhanced the increase of the catch per fishing vessel and work productivity (respectively, by 4% and 180%), which, in turn, has positively influenced the wages.

Although the amount of wages in the Latvian fisheries sector has multiplied by 3 since 2005 (to EUR 516 in 2016), it is still not competitive either in the local or the EU-28 labour market (the average net wage in Latvia in 2016 was EUR 631; the available data show that the average gross wage in EU-28 in 2013 was EUR 2242) (Central Statistical Bureau, 2018; Eurostat. Database, 2018). The employed labour may choose a job in another sector or abroad which is equivalent in terms of working conditions but offers

Table 3

Development of Latvian fishery sector from 2005 to 2016 (number, EUR, kW, GT, tons, %) (author's calculations based on data from Agriculture Ministry, 2018; Central Statistical Bureau, 2018)

Indicator	2005	2016	Changes (%)
Number of companies	189	205	⬆ 8
Number of fishing vessels	928	679	⇧ -27
Power of fishing vessels (thousand kW)	64.67	47.14	⇧ -27
Tonnage of fishing vessels (GT)	38.59	28.52	⇧ -26
Number of employees	1 357	849	⬇ -37
Average net wages (EUR)	157	516	⬆ 230
Work productivity (thousand EUR per	828.13	2 517.07	⬆ 204
Catch per fishing vessel (tons)	161.93	168.86	⇧ 4
Catch (thousand tons)	150.27	144.66	⬇ -24
Catch value (million EUR)	27.79	48.68	⬆ 75
Balance of external trade (million EUR):	1.84	14.90	⬆ 711
import (milj. EUR)	1.12	1.05	⬆ -6
export (milj. EUR)	2.96	15.96	⬆ 439

Note. ⬆ arrows indicate positive changes, ⬇ arrows – negative changes, however, ⇧ arrows show the changes of direct effects of FIFG, EFF and EMFF support.

more competitive wages, thus raising additional risks in ensuring sector's competitiveness and its further development.

Provision of Common Fisheries Policy that at least 50% of the public funding (compensation) received within the framework of the activity of Fisheries Operational Programme must be invested in commercial activity, shall be evaluated positively (Ministers cabinet, 2008; 2015). Taking into account the support to this activity provided by FIFG, EFF and EMFF, approximately EUR 23.64 million were invested in the development of Latvian economy.

In 2016, the total catch constituted 114.66 thousand tons with a value of EUR 14.68 million. In state's territorial waters fishermen mainly caught sprat, herring and cod, but in the high seas – mainly horse-mackerel, pilchard, sardinella and mackerel. The catch was discharged in the territories of Latvian ports and outside them, as well as in the ports of other states.

Fishing opportunities of Latvia and fishing quotas in the Baltic Sea and the Gulf of Riga are based on the long-term research of environment and of fish resources at national and international level. Catch volumes of commercially significant and internationally controllable species depend on the quotas annually allocated to Latvia, which, in turn, depend on the state of the fish stocks. Environmental pollution, unfavourable spawning conditions, as well as intensive fishing and other factors have a negative influence upon the state of the fish stocks. As a result, in the Baltic Sea fishing quotas and the available fish raw materials decrease every year, and it has a negative influence not only on the activity of the fishing companies, but also on the fish processing companies. Due to stock fluctuations and changes in fishing opportunities allocated annually at the EU level, fishery companies have difficulties to plan their future activities.

Fishing quotas of Latvia have not been fully utilised thus far, and the main reasons are: restrictions on fishing-tackle usage regarding certain fish species, changeable hydro-meteorological conditions, and seasonal weather conditions which burden fishing or make it impossible (Latvian State Institute of Agrarian Economics, 2013).

Although the total catch has decreased since 2005 (-24%), the catch value has increased significantly (+75%). It indicates that the support provided by the EU financial instruments to modernization of fishing ports, wharves and discharging places and support to producers' organisations has improved the quality of fishing products and increased their added value, thus leaving a positive influence also on the balance of external trade. Fishing companies have managed to

multiply export value by 5 (from EUR 2.96 million in 2005 to EUR 15.96 million in 2016), not increasing import at the same time.

Considering that fishery sector depends on fishing opportunities coordinated at the EU level and consistent with principles of sustainability, experts do not forecast growth of demand for vocational education in this sector in future (Latvian State Institute of Agrarian Economics, 2014). However, the potential of Latvian scientific institutions is sufficient to meet the needs of fishery sector in the innovation sphere. Currently several scientific institutions in Latvia are interested in collaboration in the sphere of innovations, enhancing their competence, if necessary (Latvian State Institute of Agrarian Economics, 2016).

Competitiveness and efficiency are identified as a driving force for sustainable development of fisheries. Taking into account that fishery sector depends on fishing opportunities coordinated at the EU level and consistent with the principles of sustainability, as well as intensified competition in global markets, strengthening of fishery competitiveness plays an important role.

Conclusions

In the planning periods of 2004-2006, 2007-2013 and 2014-2020, financial support of several EU financial instruments was available to the participants of the fishery sector. In this period the support was provided by EAGGF, ERDF, FIFG, EFF and EMFF in the amount of EUR 161.35 million, including the state and private co-funding. 75% of fishery companies and 50% of the employed in the companies, as well as different associations and institutions related to fishery sector received the support. Funding of EUR 90.84 million was channelled to the development of fishery sector and EUR 16.10 million - to the development of other fields. The remaining funding in the amount of EUR 54.42 million was received in the form of compensations for cessation of fishing activities.

From 2005 to 2016 in the fishery sector of Latvia the catch per fishing vessel and work productivity have increased, which, in turn, has positively influenced the wages. The funding invested into the fishery development provided the companies with an opportunity to improve the quality of fishing products, not increasing import at the same time, and exporting the product with a higher added value than it was done initially. The directed EU policy and the support provided within its framework by the EU financial instruments have facilitated the development of the fishery sector in Latvia.

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FISH PROCESSING BY-PRODUCTS EXPLOITATION AND INNOVATIVE FISH-BASED FOOD PRODUCTION

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Abstract
In the fish processing sector, the further exploitation of by-products and wastes left after industrial production promotes sustainability of raw materials, access to added value and increased profitability, as well as contributes to environmental protection by reducing the volume of dumped products. Besides obvious value-added features, it also addresses the clear market demand dictated by prospects of the population growth. Given the limitations for further expansion of the husbandry sector, fish-based items available for human consumption represent a major avenue for coping with the pressing demands of increased population and enable the development of innovative food items of high nutritional importance. Current research is focused on the analysis of fish processing by-product utilization possibilities available up to date and introduces empirical findings of innovative food product development made on the basis of by-products left after traditional canned "Sprats in oil" production. In Latvia, "Sprats in oil" production is an integral part of fish processing sector and the rural economy overall. The production accounts for at least 30% of raw material left as by-products (smoked heads and, in some cases, tails) after such technological stage as smoked sprats processing into cans. Efforts were made to prepare value-added and attractive to customer food product made out of this fish-processing by-products, which are typically processed to a fishmeal or just dumped as waste. The study demonstrates a strong potential for its utilization to a range of fish pâté with various flavours and of high nutritious value.
Key words: fish processing by-products, fish-based pâté, smoked sprats, innovative food products, food economy.

Introduction

The problem of the integrated and rational use of raw materials continues to remain highly relevant for the seafood processing industry all over the world. The search for new technical and organizational solutions aims to make it possible to effectively utilize the proceedings that are of little use and reduced commercial value.

Demand for innovative fish and fish-based items follows an upward trend in fish processing, generating a significant amount of by-products and wastes as well as large volumes of low-value fish by-catch that are not efficiently exploited to maximize their economic potential. In 2012, over 21 million tons of fish were lost or served to non-food purposes (FAO, 2014) because of an array of undesirable characteristics, e.g. extreme heterogeneity, small size, flavour, bony structure, unacceptable appearance, substantial fat content, threat of toxic substances. As a result only 50 – 60% of catch is used for human consumption and 25% directly discarded as waste (Rustad, 2003). Research indicate that up to 50 – 80% of raw fish material can be dumped as solid waste after processing, i.e. traditional round filleting (Wasswa, Tang, & Gu, 2007). Shahidi & Botta (2012) mention such major fish processing by-products and discards as edible tongue, cheeks, stomach and liver, proteins from residual fish, fish skin, chitinous materials, cartenoid pigments, flavourants, gut enzymes, and anti-freeze proteins from blood of cold-temperature fish that can be considered for further processing. In Latvia, traditionally, low-value fish and fish-processing by-products are exported as a raw material with little added value, processed into fishmeal, or considered for a uniform production (i.e. smoked sprats), thus, determining significant loss in terms of economic gains for the whole industry (Mulye *et al.*, 2014). The exploitation of these types of fish and fish processing by-products to develop innovative products has a vast potential to add value, minimize wastage, and promote their efficient utilization.

Fish processing by-products can be transformed into various types of items such as food, pharmaceutical and biotechnology products with good market value. The consumer market has become used to the regular supply of innovative, new products, which forces producing companies to engineer new product lines and use updated processing technologies. In food sector, the contemporary research in this area is directed primary at developing new approaches for various types of fish-based minced meat and obtaining a wide range of products made on their basis, such as culinary and sausage products, delicacy product analogues, preserves and canned goods (Sharma & Basu, 2003; Devi, Aparna, & Kalpana, 2013).

The main difference between minced meat products and products based on the whole fish or its specific part (i.e. fillet) is the extent to which the raw materials are used. Overall, in the classic fish industry, only 30 – 40% of the fish are processed into high quality produce (fish steaks, medallions or fillets) and 60 – 70% are the fish processing low-quality and low economic potential by-products that virtually are not in demand in the food market. Moreover, the utilization of such surpluses in production is usually problematic

and creates large financial and environmental costs. Nevertheless, fish processors are focused on extracting the most value out of primary products, with little interest in by-products resulting in missed economic opportunities because of insufficient investment in technologies that allow for the utilization of such material.

The aim of the study is to explore the exploitation options of the fish processing by-products and develop a new consumption-ready product with satisfactory organoleptic qualities ready for production and diversification. The research also aimed to indicate and address the technological challenges of sprat processing by-product exploitation as a raw material. As a result of the project, fish-based pâté parte (spreadable product) has been developed out of sprat processing by-products, while fish-based terrine (typically served in slices) is in its developmental phase. A number of variations (additives, flavours, colours) have been developed from each basic product to expand the range.

Materials and Methods

Our research focuses on Baltic sprats (*Sprattus sprattus balticus)*, a small herring-like, marine fish found in the Baltic Sea waters and very traditional for the Latvian rural economy. The fish processing waste, i.e. the heads and, in some cases, tails, of smoked sprats (from in-house laboratory, *Piejūra* Ltd., Nīca, Latvia) were used to develop the pâté. The research was implemented in a period of seven months and took place from September, 2017 till March, 2018. The current research has resulted in further series of researches on the product line diversification.

The latest data from 2015, available at the Food and Agriculture Organization of the United Nations Global Capture Production database, show that marine capture production for *Sprattus sprattus* has significantly increased by 36.9% from 2014 to 2015 and reached 677,029 in 2015 (FAO, 2017). Despite being an integral part of Latvian and regional fish sector, Baltic sprats are considered an *industrial* species since the largest part of the caught gets processed into commodities not intended for human consumption, specifically, fishmeal (Miles & Chapman, 2015). Industrial species are characterized as marine wild-caught, small, bony, and oily fish not suitable or with limited suitability for human consumption (Rustad, 2003). In Latvia, approximately, only 25% of sprats caught are processed into items for human consumption, mainly into canned sprats, usually smoked, ("Sprats in oil"). Besides, canned sprat production is very resource consuming and does not provide significant profits. Moreover, while being a traditional product in the region, the market for "Sprats in oil" is quite limited. Despite the wide export geography, the product is consumed mainly by the local population and proportionally small Eastern European expat communities abroad.

The implemented project explored the possibilities for the technology development aimed at ready-to-eat product elaboration from sprat processing by-products remaining after smoked fillets are processed further to traditional "Sprats in oil". The literature review of fish processing by-products, as well as analysis of technological potential of the pâté production out of the sprat processing by-products, explore the possibilities of innovative fish-based product exploitation in the food sector.

Results and Discussion

Fish processing by-products and their economic potential

At present, there is an established shortage of high-quality animal protein in the world (Pimentel & Pimentel, 2003). The main source of such protein - livestock and husbandry - in the developed countries is approaching the saturation limits and it is difficult to predict multiple increase in productivity, despite the pressing demands of rapid urbanization and overall population growth. At the same time, industrial fishing and fish farming have great development prospects. For example, a lot of research demonstrates that sprats are a valuable source of protein, minerals, lipids, and vitamins, at the same time containing only a small amount of carbohydrates. Nonetheless, it should be acknowledged that the range of fish products is quite limited and the industry is facing the need to develop and bring to the market new products from fish, expanding the variety from the currently prevalent fresh, frozen and canned fish offerings. On the other hand, the fish product processing produces a large amount of by-products and waste with a high content of nutrients, which are denied for human consumption, for example, ridges with meat cuts and fish heads.

Overall, there can be distinguished four main roads for fish processing by-products and waste utilization according to the potential added-value volume and profitability: fertilizers, feed production for aquaculture, livestock and domestic animals, food production intended for human consumption, and advanced solutions for biotechnological, pharmaceutical and similar sectors.

- Fish-based fertilizers have been used in agriculture for centuries. The approach may not even require any processing when i.e. spoiled fish is dumped on the fields to increase land fertility. The production of fertilizer from dead fish was industrialized as early as at the beginning of the 20th century, however, the profitability of this approach is quite low. Approximately 10% of fish processing by-products and waste is used as organic fertilizer for agricultural needs.
- The next segment is fishmeal production for aquaculture and domestic mammal animals,

mainly in the form of fish flour. Worldwide, up to 30% of total fish and shellfish catch is processed into fishmeal and oil (Bimbo & Crowther, 1992). Meals & Chapman (2015) indicate that approximately 90% of fishmeal is utilized in fish and animal diets, including pets, providing about 14% of the world's need for animal protein (Venugopal, Shahidi, & Lee, 1995). In Latvia, 75% of sprats catch is utilized to satisfy the fishmeal production, a commodity of significantly lower profitability than food production intended for human consumption or advanced technological solutions (Jackson, Kerr, & Cowley, 1984).

- Fish-based products meant for human consumption compose the two areas of fish processing providing a significantly better profitability – food production and advanced solutions such as bioactive components for pharmaceutical and biotechnology sectors, including beauty industry. For instance, in comparison to mammal collagen, fish-based collagen has been much less studied despite the fact that about 30% of fish processing wastes are skin and bone with high collagen content (Wasswa, Tang, & Gu, 2007). Nonetheless, whilst being the sector with the highest potential profitability, the high-end solution sector is the most progressive and, thus, requires significant and consistent investment as well as scientific capacity. Innovative solutions for fish processing by-product exploitation for the food sector, although, also require significant innovation and knowledge intake, are yet more available for scaling and introduction to fish processing sector of our region.

Rustad (2003) indicates that the market interest is an essential factor promoting investment and innovation fuelling improved utilization of fish processing by-products. The market potential of innovative fish-based human consumption products, including those based on *industrial* species, is clearly rooted in the growing population. For instance, Parfitt, Barthel, & Macnaughton (2010) note that by 2050 there must be found "prospects for feeding a population of nine billion". Moreover, United Nations estimations (2008) indicate that by 2050 70% of the population will live in urban environments, thus, indicating steep shrink of the agricultural sector. At the same time, research demonstrates that currently, up to 50% of food does not reach the consumer (Lundqvist, de Fraiture, & Molden, 2008; Parfitt, Barthel, & Macnaughton, 2010). Most of the waste appears within the post-harvest phase, whereas process losses can be eliminated by introducing more advanced production methods and technologies.

These tendencies, along with the changing consumer behaviour and increased pace of the daily

life, have been already indicating large market potential for ready-made consumption products. Moreover, the demand for fish-based ready-made consumption products is expected to grow. As demonstrated by Parfitt, Barthel & Macnaughton (2010), the increasing demand for fish-based products is strongly associated with Bennet's law, indicating the decline in consumption of starchy food staples and dietary transition towards dairy, meat, fish, and fruits and vegetables as income increases. This will further increase the added value, which is demand driven and exists if the consumer wants the product and is willing to make the purchase (Salin, Atkins, & Salame, 2003). In addition, it should be noted that there is a strong market demand to make sure food items are still affordable for lower income groups (Parfitt, Barthel, & Macnaughton, 2010).

Thus, sprat processing by-product further exploitation in human consumption ready food item production can be considered as the best solution providing the highest potential added-value volume and profitability, whilst requiring comparatively moderate investment. At the same time, it addresses both the immediate need for additional food sources and increased consumer interest towards fish products, as well as the demand for products in a low-cost segment. It clearly offers the producers an additional income source, whilst reducing costs for processing waste disposal. Nonetheless, in such a production a number of technical challenges should be considered along with producing a sprat processing by-product-based food item with satisfactory organoleptic features, so final customers would be interested in buying it.

Innovative pâté *made of smoked sprats processing by-products ready for human consumption*

Following the changing consumption behaviours, in the food industry the number of ready-to-eat foods, which do not require culinary processing and include heterogeneous components, is increasing. Examples of such products already available on the market are drinks from whey and juices, cheeses with slices of ham, hams and sausages with pieces of cheese and so on. However, in the fishing industry, the trend is not so pronounced, the number of ready-to-eat foods is small, and the situation has been changing significantly slower.

According to Gildberg (1993), by-products are all the raw materials, edible or inedible, left during the production of the main product. Traditionally marine by-products that can be considered for food production are bones, skin, viscera, and cut-offs left after fillet cut. In the production of the classic fish product canned "Sprats in oil", the by-products are fish heads and, often, tails left after fish decapitating

from strings used for smoking. Such by-products are usually utilized or, at best, processed for fish meal, while the content of proteins and lipids allows them to be considered as raw materials for food. Indeed, our research demonstrated that these products can be used as a source for added-value human consumption item production. The production process of "Sprats in oil", requires sprat smoking after the fish is sorted, washed, and then threaded on rods through the gills. After smoking, the fish is decapitated by cutting it off the rods (the fillet is separated from the head that remains on the rods). Fillets are further used for canning, while smoked heads usually do not find use. Nonetheless, heads of sprats constitute 13 – 17% of the mass of fish and contain up to 55% of valuable food raw materials - proteins and lipids.

There is a number of difficulties in the further processing of smoked head of sprats, which prevents their consumption in food:

- The small size of heads, which does not allow to separate edible parts from inedible;
- A large number of solid parts (bones of the skull, gills, jaws), which cannot be chewed;
- Strong smell of smoking and a large concentration of smoking substances, exceeding concentration acceptable in food products;
- A large amount of connective tissue and an unsatisfactory amino acid score.

The research indicated the utility of the following technological operations aimed at addressing the difficulties, thus, allowing to consider the smoked heads of sprats as the food raw material:

- Thorough grinding with an aim of achieving the homogeneity of the structure. Fine grinding of fish raw materials is the main technological problem. In industrial production, well-configured high-speed cutters are to be used to finely cut fish waste, or the pâté made in a low parameter cutter is to be regarded as a semi-finished product and should be passed through the emulsifying process. In many cases, a simple cutter used in conjunction with the emulsifying is much better than an expensive high-speed cutter.
- Enrichment with a high-value protein (animal, vegetable or milk) to improve the amino acid scores.
- Use of fillers to reduce the concentration of smoking substances to those permitted for use in the food industry.
- Treatment with special substances to soften the bone tissue (if necessary). When choosing the amount of vinegar required for the decalcification of bone tissue, it should be taken into account that, on the one hand, a large amount of vinegar protects the product from spoiling and considerably softens bone tissue of the cut fish heads; on the

other hand, continuous storage of the pâté in cans allows reducing the amount of vinegar, making the product flavour less spicy and acid as well as reduces the possibility that the pâté will lose its colour as a result of long-time storage.

- Use of texturates, thickeners, spices and flavours to ensure required organoleptic parameters. The TARI blend of food flavourings may be replaced by considerably cheaper mono-ingredient blends.
- The choice of the mode of sterilisation considerably depends on the autoclave equipment and working conditions at each specific enterprise as well as on a number of other factors. This question is to be considered individually together with the enterprise technologists taking into account the ingredients and microbiological analysis of the pâté.

The analysis of processing peculiarities of by-products left after "Sprats in oil" production, led us to the conclusion that pâté is the most promising product that can be made out of smoked sprats by-products. Pâté is a finely grinded product containing a significant amount of fillers, emulsifiers and flavouring agents. In addition, pâté has been regarded as a cheap product, therefore, using low cost fish raw material such as sprats and its processing by-products have been found suitable. One of the main issues still to be resolved is identifying additives that provide for extending the shelf life, as well as ensuring the specified structure and colour without changing and maintaining certain quality indicators. At present, the biggest challenge is to achieve the lighter colours and diminish the number of E-substances in the composition.

It should be noted that given the target niche of the product using expensive ingredients should be overall avoided. Nonetheless, it should not compromise the organoleptic features of the product in order to maintain the demand. Since smoked heads have a distinct flavour and smoke aroma, the solution is to use ingredients having a distinct and spicy flavour (onion, garlic, black pepper, etc.) rather than mild spices. In order to lower the concentration of the substances generated in the process of smoking, fillers (cream of wheat, starch, soy, fibres) should be used. It is recommended adding phosphate blends to the pâté together with salt during the first stage of production to increase the water-binding capacity of fish raw materials and moisture retention. In order to get the pâté texture intended, water binders or fillers may be used. The research allowed to produce pâté with acceptable organoleptic qualities. The pâté developed during the research was scored between "average" to "good" during the evaluation process for all the attributes: colour, aroma, texture, taste, aftertaste, and appearance (*N*=58).

On the basis of the neutrally flavoured pâté, it is possible to produce a wide range of products with

more complicated flavours. The variety of the product has been expanded by adding flavours to obtain such pâté variations as:
- "Borodinsky" with cumin and cardamom;
- "Chilly" with red hot chili pepper flakes and grains (this pâté is coloured using the liquid paprika extract);
- "Mediterranean Herbs" – with dried rosemary and thyme;
- "Tomato" pâté containing 80% of pâté and 20% of tomato paste;
- "Classical" – it is the base pâté coloured using the "Caramel – burnt sugar" colouring.

Conclusions
- The growing population, rapid urbanisation and changing consumption behaviours create a strong market interest for innovative food products, including fish-based food products. Despite the constantly growing demand, only approximately a half of catch is used for human consumption, whilst, 25% is directly discarded as waste; up to 50 – 80% of raw fish material can be discarded as solid waste after processing.
- The sector with the highest potential profitability for utilisation of the fish processing by-products is food production intended for human consumption and advanced solutions for biotechnological, pharmaceutical and similar sectors. Due to associated extensive investment and scientific capacity limitations of the latter option, the food production is more promising for the fish processing industry of our region.
- The implemented project has successfully proved that fish processing by-product exploitation

as a raw material for fish-based innovative food products has a significant potential. The experimental research has proved the possibility to produce food items available for human consumption (pâté, terrine) out of heads of smoked sprats, the by-products left after traditional canned "Sprats in oil" production.
- There is a number of technological difficulties associated with the processing of smoked heads of sprats, which challenge their consideration as a raw material for food production intended for human consumption, – mainly heterogeneity of the pâté structure and strong smoked aroma of the raw product. The research indicated that there are several technological operations available to address the limitations. The implementation of the technological solutions led to obtaining products with satisfactory organoleptic features approved by the final customer.
- Producing neutrally flavoured pâté allows developing an expanded range of products with more complicated flavours that are attractive for customers, thus, increasing the profitability of fish-processing by-product exploitation.

Acknowledgements

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VERTICAL PRICE TRANSMISSION ALONG THE POTATO SUPPLY CHAIN IN LITHUANIA

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Abstract
Potato sector is one of the competitive areas of the European Union (EU) agriculture. Although Eurostat declared that in 2015 Lithuanian share in the EU-28 harvested production was modest and composed only 0.7%, according to Food and Agriculture Organization of the United Nations (FAOSTAT), this crop remained on the list of top 10 commodities by net production value in Lithuanian agriculture. However, over the past decades the Lithuanian potato sector survived undesired transformations. The aim of this paper is to analyse the changes of the main indicators, related to the potato sector, and vertical price transmission among the chain of potatoes in Lithuania. The conducted research indicates the most important development trends of the potato sector and applies econometric techniques to investigate if there is any long-run relationship between the farm and retail prices of potatoes for the period of 2010 to 2016. Although the statistics show the shrinking production and domestic consumption of potatoes in Lithuania, the analysis of the vertical price transmission does not provide evidence of market inefficiencies. The Johansen cointegration test confirms the existence of a long-run relationship between the farm and retail prices, while the Granger causality test shows that there is a bidirectional causality between the examined series. The M-TAR model does not provide evidence of the farm and retail price asymmetry in the long run.
Key words: agriculture, supply chain, cointegration, potato, price transmission.

Introduction

Over the past decades, global markets of agricultural commodities survived several crises, accompanied by significant food price shocks peaked in 2008 and 2010 – 2011 (Islam, 2011). Previous dynamic changes of prices often resulted in market inefficiencies and led to the undesired impact on the welfare of farmers and consumers, and determined the changes in the crop structure in the EU member states. The aforementioned situation encouraged scientists to focus on the research explaining vertical price transmission mechanisms of agricultural and food products.

During the previous decades research on price transmission of fruit and vegetable markets was fragmentary and often led to the contradictory findings, which were mostly based on the case studies of selected agricultural markets in different countries. One of the most cited contributions to this research area investigating price transmissions of seventeen fresh vegetables (including potatoes) belongs to Ward (1982). The findings confirmed the relevance of asymmetry for the USA markets of fresh vegetables and allowed to identify a wholesale market as an actor with the major pricing power, while changes of retail and shipping prices lagged. Ward (1982) made an assumption that perishability could be a major determinant of price asymmetry among the supply chain of fresh vegetables and initiated the scientific discourse on vertical price transmission based on different estimation techniques.

Important contributions to this discourse were made by the studies of selected agricultural commodities in the USA (Brooker *et al.*, 1997;

Girapunthong, VanSickle, & Renwick, 2003; Acharya, Kinnucan, & Caudill, 2011; Li & Sexon, 2013), Brazil (Aguiar & Santana, 2002), France (Hassan & Simoni, 2002), Hungary (Bakucs, Fertő, & Szabó, 2007), Greece (Rezitis & Pachis, 2013), Slovakia (Pokrivcak & Rajcaniova, 2014; Rajcaniova & Pokrivcak, 2013), Dutch (Assefa, Kuiper, & Meuwissen, 2014; Verreth *et al.*, 2015), the United Kingdom, Germany, Denmark, the Netherlands and Spain (London Economics, 2004), Turkey (Aysoy, Kirli, & Tumen, 2015), Malaysia (Zainalabidin & Iliyasu, 2017). An essential conclusion emerges from the aforementioned research with conflicting results – every study brings valuable knowledge about supply chain management and critical market efficiency factors in the particular country. Generalizations and applications of research results to other industries and time periods often fail to explain the situation in the supply chain of the particular agricultural commodity (Aguiar & Santana, 2002).

The paper contributes to this scientific discourse exploring vertical price transmission along the supply chain of potatoes. Despite the importance of this crop in the EU, only few researchers carried out a more comprehensive research on the situation of the vertical price transmission along the supply chain in Hungary (Bakucs, Fertő & Szabó, 2007), Slovakia (Rajcaniova & Pokrivcak, 2013; Pokrivcak & Rajcaniova, 2014), Dutch (Assefa, Kuiper, & Meuwissen, 2014; London Economics, 2004), the United Kingdom, Denmark, Germany and Spain (London Economics, 2004). Rajcaniova & Pokrivcak (2013), Pokrivcak & Rajcaniova (2014) found strong evidence of asymmetry in the vertical price transmission of

Slovakian potato chain. In both research cases consumer prices reacted to the decrease in producer prices more rapidly than to the growth of price and were determined at the producer level. Assefa, Kuiper & Meuwissen (2014) studied the Dutch ware potato sector and the linkage of retailer oligopsony power with asymmetric behaviour. They found that price decreases on farms were transmitted partially while the increases almost fully and concluded that farmers' oligopoly power did not improve price transmission and could worsen the market situation.

Bakucs, Fałkowski & Fertő (2007) investigated the transmission of producer and retail prices in Hungary and did not confirm findings about the price transmission asymmetry in the potato chain. The Hungarian potato sector was affected by seasonality and the price level determination came from the producer to retail. However, the long-run and short-run vertical price transmissions were symmetric. The results of the Hungarian case corresponded to the previous findings of London Economics (2004) final report for Department for Environment, Food and Rural Affairs (DEFRA) covering research of the potato sector in six EU member states and reporting about symmetric farm-retail price transmissions. Peculiarities of national potato markets were noticed: the United Kingdom, Denmark and Spain markets had a long-run symmetric transmission, Germany had a short-run, the Netherlands potato sector had a long-run symmetric transmission for the producer-retail direction and a short-run symmetric transmission for the retail-producer direction. The speed of price adjustments in the selected countries differed; however, the proportion of the adjustment was higher for the producer price changes than for the retail (except in the Denmark case).

The aim of this paper is to analyse the changes of the main indicators related to the potato sector and vertical price transmission among the chain of potatoes in Lithuania. Though some researchers reported on the structural transformations of the potato sector in Lithuania during the recent decades (Lukošiutė, 2009;

Melnikienė, 2017), the research on vertical price transmission of the EU countries omitted Lithuanian case as the reliable statistics was not available. The paper covers this gap and provides empirical evidence on the price transmission among the chain of potatoes, contributing to a better understanding of the potato sector development trends and market functioning issues. The conducted research provides a comprehensive view on the situation of vertical price transmission along the potato chain utilising different techniques to show multiple aspects of market inefficiency for the same period.

Materials and Methods

The paper covers two objectives, which are implemented applying different methodological approaches: 1) to analyse the main indicators of the potato sector's development, 2) to study vertical price transmission along the chain of potatoes in Lithuania.

The first objective – the analysis of the main indicators of the potato sector's development – employs methods of graphical and comparative data analysis. This task investigates changes for the period from 2010 to 2016 and relies on the secondary data from Statistics Lithuania. The results identify main development trends related to potato production, domestic consumption, and self-sufficiency.

The second objective – the study of vertical price transmission along the chain of potatoes in Lithuania – also covers the period from 2010 to 2016 and analyses the relationships between the average selling prices on commercial farms and the average retail prices for fresh potatoes of Lithuanian origin. The research of vertical price transmission of the potato sector relies on a weekly data collected by the state enterprise 'Agricultural Information and Rural Business Centre'. The price on farm is set as the average of minimum and maximum price; the retail price shows the average price in the main network supermarkets of 7 counties. Figure 1 illustrates changes of the aforementioned average farm and retail prices. The second objective employs different econometric techniques applied
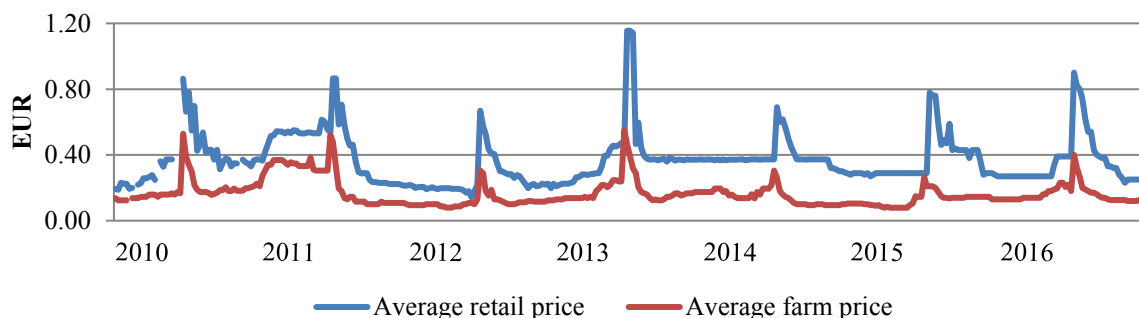
Source: SE 'Agricultural Information and Rural Business Centre' and authors' calculations.

Figure 1. Average potato prices: farm and retail levels.

for the analysis of time series compiling a 4-stage methodological research framework in order to explain the relationships between the farm and retail prices of potatoes. The econometric tests were run employing Eviews software.

The methodological 4-stage research framework for the investigation of the vertical price transmission is based on the analysis of the aforementioned literature on research of vertical price transmission in fruit and vegetable markets. The structure of the framework is set as follows: 1) ADF test; 2) Johansen cointegration test; 3) Granger causality test; 4) M-TAR model.

Stage 1: the augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979). The non-stationary data can lead to a 'spurious regression' (Brooks, 2008). In this case, the empirical results of the research could be in accordance with the theory and the hypothesis, but the regression, indicating the relationship between prices, has no meaning. The series of the farm and retail prices are tested for the unit root employing the ADF test. If the null hypothesis (H_0) is not rejected, it is presumed that the analysed sample of price series contains a unit root. The alternative hypothesis is in favour of stationary price series without a unit root. The results of the ADF test make an impact on the selection of the further econometric analysis techniques. The proposed methodological research framework is applied only if the H_0 is rejected.

Stage 2: the Johansen cointegration test (Johansen, 1991; 1995). Cointegration analysis is an empirical technique used to establish the degree to which variables are related in the long run. The introduction of cointegration was due to the realisation that most of the financial data is non-stationary. Curtbertson (1996) implied that regression models from non-stationary time series variables cause spurious regressions. However, when cointegration deals with data with stochastic trends, the problem of spurious regression is avoided.

Johansen developed a methodology for the analysis of the cointegration between the selected variables and common trends in vector autoregression (VAR) models with Gaussian errors and seasonal dummies (Johansen, 1991). This test is used to identify the existence of the long-run relationship between the farm and retail prices. It allows testing more than one cointegration relationships and includes two types of tests: trace and eigenvalue. The Johansen trace test examines the H_0 that the number of linear combinations r is equal to a given value, while the alternative hypothesis is in favour that the number of linear combinations r is greater than a given value. The rejection of the H_0 means that there is a long-run relationship between the farm and retail prices. Maximum eigenvalue allows testing for the existence of more than one combination ($r + 1$) of the price

variables. The rejection of the H_0 allows stating that the certain number of possible linear combinations exists.

Stage 3: the Granger causality test (Granger, 1969). Granger causality tests for the short-run relationship between the farm and retail prices. This stage assists in defining empirically the direction of causality between the farm and retail prices, and exploring the feedback situation. The Granger causality test studies whether the farm price causes the retail price and how much of the current selected price variable could be explained by its values in the past and by values of the second price variable. Granger causality exists if one price helps to predict another or if the coefficients on the lagged second price variable are statistically significant. Test runs two-way causation investigating if the farm price causes the retail price, and vice versa. However, the Granger causality test does not assure that one price is causing another; the results only confirm that the price series of one variable helped to predict another.

Stage 4: the momentum threshold autoregressive (M-TAR) model (Enders & Granger, 1998; Enders & Silkos, 2001). The M-TAR model for unit roots extends standard cointegration analysis and allows investigating nonlinear adjustment mechanisms and identifying asymmetry. The asymmetry could demonstrate that time series is 'more 'momentum' in one direction than the other (Enders & Silkos, 2001), i. e. positive and negative price shocks in the long run are transmitted with different intensity. The two-step procedure is followed. The first step tests the H_0 that there is no cointegration between prices in the long-run relationship. The second step tests the H_0 that there is a symmetric adjustment mechanism between the farm and retail prices in the long-run equilibrium.

Results and Discussion
Main indicators of potato sector development in Lithuania

The potato sector, especially potatoes for human consumption, is one of the competitive areas of the EU agriculture. Though in 2015 Lithuanian share in the EU-28 harvested production was modest and composed only 0.7% (De Cicco & Jeanty, 2017), this crop remained on the list of top 10 commodities by net production value in Lithuanian agriculture (FAOSTAT.., 2017). In 2016 this specialization remained unpopular at agricultural companies and enterprises, and 97.3% of Lithuanian potatoes were harvested at farmer and family farms (Melnikienė, 2017).

The comparison of the most important indicators of potato sector identifies undesired development trends (Table 1). The harvested area fell by 39.6% from 2010 to 2016. During the same period, the harvest of potatoes decreased from 476.6 to 351.5 thousand

Table 1

Main indicators of the potato sector in Lithuania

	2010	2011	2012	2013	2014	2015	2016	2016 compared with 2010 (2010=100%)
Harvest, thou t	476.9	587.7	549.9	426.5	468.5	399.2	351.5	73.7
Average yield, 100 kg ha^{-1}	130.0	156.0	171.0	148.0	172.0	170.0	159.0	122.3
Harvested area, thou ha	36.6	37.7	32.2	28.7	27.3	23.5	22.1	60.4
Production per capita, kg	154.0	194.0	184.0	144.0	160.0	137.0	123.0	79.9
Consumption per capita, kg	94.0	99.0	95.0	93.0	96.0	94.0	94.0	100.0
Self-sufficiency, %	79.0	107.0	103.0	88.0	100.0	90.0	84.0	106.3
Domestic consumption, thou t	607.5	547.2	532.6	485.2	470.6	442.9	416.7	68.6

Source: Lietuvos…, 2015; Lietuvos…, 2017; authors' calculations.
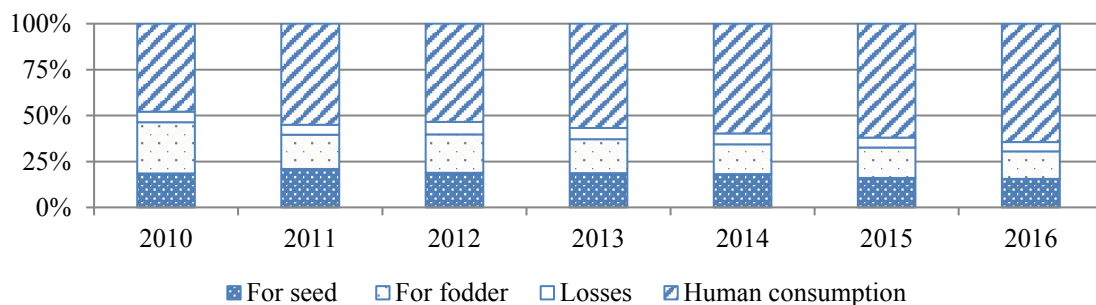
Source: Lietuvos…, 2015; Lietuvos…, 2017.

Figure 2. Structure of potato total domestic consumption.

tons. The average yield increased, but the results showed significant fluctuations and varied from 130.0 to 172.0 kg ha^{-1}. The indicator of potatoes per capita fell by 20.1%. However, consumption per capita remained almost stable since 2010 with a moderate increase from 2011 to 2014. Despite the decline in the production observed in 2010 – 2016, the indicator of self-sufficiency improved. The annual indicator of self-sufficiency demonstrated significant fluctuations: in 2011, 2012 and 2014 the figure exceeded 100.0%, but since 2015 the dependence on imported potatoes increased. Import of potatoes is mostly orientated for the periods of early harvests in countries with warmer weather.

Domestic consumption of potatoes fell by 31.4% from 2010 to 2016. The annual decrease of this indicator was accompanied by the transformation of domestic consumption structure (Figure 2). Over the analysed period, the domestic consumption of potatoes for agricultural purpose fell (seed had a drop of 15.7%, fodder – 46.2%), but the share of human consumption in the structure increased by 34.4%.

The consumption of processed potatoes is increasing, while the consumption of fresh potatoes demonstrates a decrease trend. Melnikienė (2017) argues that the indicator of human consumption

for Lithuania is higher than the EU average and the further decrease of the consumption is possible in the immediate future. The unfavourable demand trends affect the supply of potatoes and the structure of agricultural crops gradually transforms.

The vertical price transmission among the potato chain

The shrinking of the potato sector in Lithuania could be influenced by the inefficiency of vertical supply chain. The paper investigates the relationships between the farm and retail prices applying the 4-stage research framework for the identification of different chain inefficiency aspects.

The first step of the empirical analysis is the ADF test, which examines the stationarity of the farm and retail price series. Table 2 presents the results of the ADF test on the examined series and the results show that for both prices the *t*-statistic is greater than the critical value at 5% level of significance when prices are expressed in levels. This is also supported by the *p*-value of probability which is less than 0.05. Thus, the series of the farm and retail prices does not have a unit root, the H_0 is rejected and the examined series can be characterized as stationary and integrated of order zero.

Results of the ADF unit root test for the farm and retail prices

Variables	t-statistic	p-value	Critical value (5%)
Farm price (0*)	-3.51	0.01	-2.86
Retail price (0)	-4.42	0.00	-2.86

Note: * Parentheses in the ADF test indicate the lag length based on Schwarz information criterion.

The Johansen cointegration test results for the farm and retail prices

Hypothesized No. of CE(s)	Unrestricted cointegration rank test (Trace)			Unrestricted cointegration rank test (Maximum Eigenvalue)			Prob.**
	Eigenvalue	Trace statistic	Critical Value (5%)	Eigenvalue	Max-Eigen statistic	Critical Value (5%)	
r=0*	0.12	43.20*	12.32	0.12	42.62*	11.22	0.00
r=1	0.00	0.58	4.13	0.00	0.58	4.13	0.51

Note: * indicate rejection of the H_0 at the 5% level of significance. **MacKinnon-Haug-Michelis (1999) p-values.

The second step is the Johansen cointegration test. This approach uses the maximum likelihood estimation in a VAR model. There are two statistics reported using this test: the trace and maximum eigenvalue. We found evidence from the ADF test that all the series are integrated of order zero. The results of the Johansen approach indicate that there is one cointegration vector between the tested price series (Table 3). The p-value 0.00 is lower than 0.05. The comparison of trace statistic and maximum eigenvalue

statistic to critical values allows rejecting H_0 ($r = 0$) at the 5% significance level. The Johansen cointegration test demonstrates a long-run relationship between the farm and retail prices of the potato chain.

The Granger causality test is the third step in order to ensure that residuals are uncorrelated. The second step shows that there is one cointegration vector for the examined price series, so the Granger causality test can be defined as a joint test (F-tests) for the significance of the lagged value of the assumed exogenous variable

The Granger causality test results for the farm and retail prices

H_0	F-statistic	Prob.
Retail price does not Granger cause farm price	6.74*	0.00
Farm price does not Granger cause retail price	35.19*	0.00

Note: * indicate rejection of the H_0 at the 5% level of significance.

The threshold autoregressive model for farm and retail prices

Variable	Coefficient	Std. Error
Above Threshold ($\rho1$)	-0.19	0.04
Below Threshold ($\rho2$)	-0.05	0.04
Threshold Value	0.00	
F-equal ($\rho1=\rho2$)	5.25	(3.07)*
T-max value	-1.34	(-2.07)*
F-joint (Phi) ($\rho1=\rho2=0$)	9.24	(5.78)*

Note: * simulated critical values for 5% significance level.

and for the significance of the error correction term. The results are reported in Table 4. The *p*-values are lower than 0.05 and the comparison of *F*-statistic to critical values indicates that there is a bidirectional causality between the farm and retail prices, and both variables cause each other simultaneously.

The fourth step tests for the asymmetry between the farm and retail prices. Threshold autoregressive models are used to determine whether asymmetry is present within the chain. The results for the farm and retail price threshold autoregressive models can be found in Table 5. The results suggest that there is a cointegration but the hypothesis of asymmetry is rejected, thus, positive and negative shocks from the retail prices affect the farm prices with the same magnitude.

To test for asymmetry, we separate the residuals obtained from the long-run equation into positive and negative with a zero threshold. The positive residuals (above threshold) are named as ρ1 and the negative (below threshold) – ρ2. The ρ1=ρ2=0 represents the result for cointegration under asymmetry. In Table 5 it is named as *F*-joint (Phi) and amounts to 9.24. The H_0 means that there is no cointegration and the alternative hypothesis states that there is a cointegration. The comparison of *F*-joint (Phi) with the critical value *F*-stat (9.24>6.07), provided in Enders & Siklos (1998), allows to reject H_0. The alternative hypothesis means that there is a cointegration under asymmetry.

The ρ1=ρ2 represents the result for asymmetry. In the Table 5 it is named as *F*-equal. The H_0 presumes symmetry and the alternative hypothesis is in favour of asymmetry. The comparison of the *F*-equal with the critical value *F*-stat (5.25<6.07) does not allow to reject the H_0 and they witness in favour of symmetry.

The results of the Lithuanian case correspond to Bakucs, Fałkowski & Fertő (2007) findings for the Hungarian potato chain. The long run symmetric farm-retail transmission was also found in some countries included into London Economics (2004) final report for DEFRA. The Lithuanian case of the potato chain does not witness serious issues of market inefficiency as both farmers and retailers influence market prices.

Conclusions

Analysis of the main indicators for the period 2010 – 2016 shows the shrinking of the Lithuanian potato sector. The harvested area fell by 39.6%, the harvest reduced by 26.3% (though the average yield increased by 22.3%). The situation in the potato sector is determined by changes in the structure of domestic consumption, e. g. declining use of agricultural commodity for agricultural and human consumption.

The econometric analysis of vertical price transmission among the chain of potatoes does not indicate serious problems which could result in market inefficiencies. The Johansen cointegration test confirms that there is a long-run relationship between the farm and retail prices. The Granger causality test shows the evidence of two-way causality and confirms that in the short-run the changes of prices are influenced by both the producer and the retailer. The M-TAR modelling allows stating that in the long run increases and decreases of prices are transmitted with similar intensity and shocks are fully transmitted between the farmer and retailer.

The conducted research allows to make an assumption that the shrinking of potato sector could be better explained by changes in the consumption than by market inefficiency issues. Though the results of the empirical research do not show obvious evidence of market inefficiency, the conclusions can be influenced by research limitations determined by available statistics. The current research draws attention to the farm and retail prices, however, some researchers provide an evidence of market inefficiencies between different stakeholders along the chain, while the empirical research on the farm and retail prices does not show serious problems. The further research could investigate the price transmission situation within a chain with more stakeholders.

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EMPLACEMENT OF CREATIVE IT SPECIALISTS IN LATVIA

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Abstract
Current paper contains the research concerning the role and concentration of IT specialists in contemporary Latvia. It is based on theoretical findings about the location of creative class in certain areas that meet the requirements of technology, tolerance and talent. At the same time, the advantages of creative people staying in the area are undoubted. Creative class and, first of all, super-creative core of creative class bring economic and technological development into the area it is located at. The goal of the article is to examine areas of creative IT specialist concentration within Latvia.
The statistics and dynamics of IT position increase were examined and trends found. In order to define the role of IT specialists in Latvia, the allocations of IT specialists across the country were analysed. Herfindahl-Hirschman Index of Information and communication industry employee concentration was calculated. It was found that IT specialists in Latvia are extremely concentrated. Riga planning region accumulates 91.51% of all IT specialists in Latvia.
Key words: creative class, IT specialists, concentration, urbanization.

Introduction

Sustainable development demands equability of regions within the country in their access to resources, including information and communication technologies. These resources are provided by IT specialists living in the area. Along with access to information, IT specialists bring prosperity and development by giving economic benefits through business activity growth. As a part of creative class IT specialists develop the community making it a better place for living. Every country is interested in developing service sector and digital economy. Through IT technology companies, regions and countries become more productive in comparison with other economic subjects. This is why studying the emplacement of creative IT specialists in Latvian regions is extremely important.

Nowadays Information and communication technology sector takes the leading role all over the world. Post-industrial development is aimed at using IT specialists to provide Latvia with some competitive advantages in global economy. This is why the role of IT specialists in the structure of working force in Latvia has to be examined.

Materials and Methods

The research question of the article is finding out the areas of concentration of IT specialists in Latvia. According to the research question, the aim of the paper is to apply theoretical approach to the creative class concentration and analyse European and Latvian statistical data in order to evaluate the regions of allocation of IT specialists in Latvia. The research is based on secondary data drawn from previous research and statistical reports dated 2014 – 2016.

Objectives of the article are:
-    Estimate the significance and demography of IT business enterprises in EU through analysing the tendencies of development of IT enterprises;

-    Evaluate theoretical studies concerning creative class concentration in certain areas. Different researches dedicated to the emplacement of creative IT specialists prove the mutual influence of creative class emplacement and regional development;

-    Study the allocation of specialists in Information and communication sector in Latvia through the evaluation of contemporary statistic data;

-    Calculate concentration coefficient of IT specialists in Latvia. Herfindahl-Hirschman index is applied for this purpose.

In order to achieve these objectives, bibliographical sources are critically reviewed, statistical data is analysed and economic models are applied. Reviewing bibliographical sources through studying and comparing relevant theories let us build the basis for empiric research such as statistical data evaluation. Official statistical sources were studied and organized to provide the proof of theoretical conclusions. Herfindahl-Hirschman index, which is usually applied for estimation of market monopolization, was applied to estimate IT specialist concentration.

The Significance of IT Specialists in the European Union

The Information and communication technology (ICT) sector represents 4.8% of European economy. Investments in ICT account for 50% of productivity growth in the united Europe. ICT sector also generates 25% of the total business expenditure in Research and Development (ICT Research and Innovation, 2017). Statistical data show that both the number of active ICT enterprises and the number of IT specialists continually grow (Rosetti, 2017).

Obviously, the European leaders among ICT enterprises are United Kingdom, Germany and France. Latvia holds less than 1% of ICT enterprises of EU.
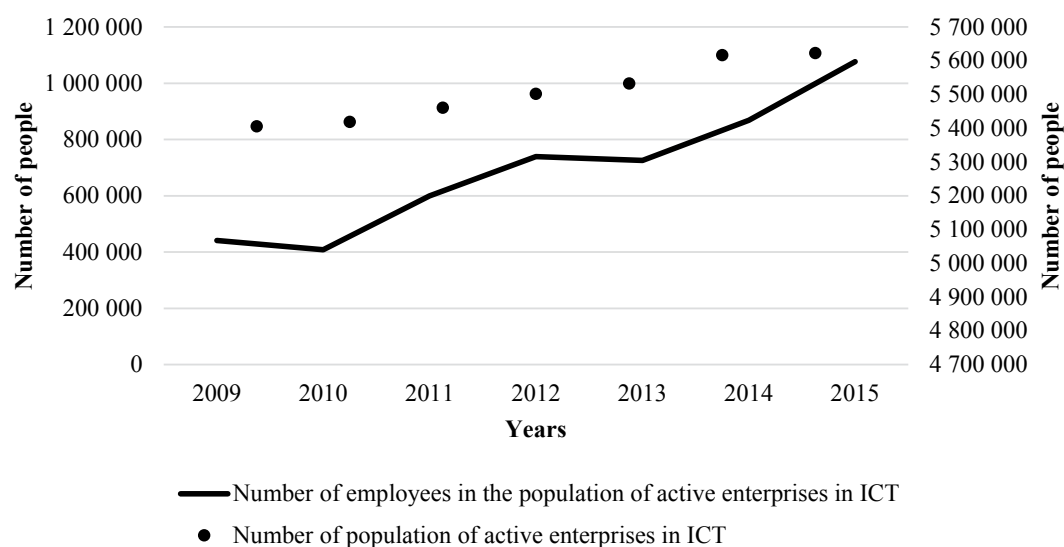
Source: Rosetti, F. (2017). The Business Demography of the ICT Sector in Europe.

Figure 1. Evolution of the number of active enterprises and employees in the Information and
communication technology sector – Total (ICT) in the EU from 2009 to 2015[1].

However, it is clear from the Figure 2 that the number of births of new enterprises exceeds the number of their deaths (Rosetti, 2017). This is a very positive trend reflecting the distribution of IT technologies in Latvia.

Most employees of ICT enterprises are located in UK, Germany, France, Italy and Spain. These are countries that are considered to be the most economically and technologically developed in the EU. It supports the idea of Rosenau about fragmentation when IT specialists double the movement of both integration and fragmentation (Rosenau, 2003). On the one hand, they concentrate in global IT centers that provide them with better working and living environment. But on the other hand, the diversity of such centers makes IT labor force spread out. It raises a question whether creative IT specialists are accumulated in these countries because they are thriving or prosperity of these countries is generated by creative IT specialists.

Theoretical Justifications of Creative Class Concentration in Certain Areas

IT specialists represent ambiguous layer of creative class. According to Florida's division, two cores of creative class are super-creative core and the creative professionals. Super-creative core is responsible for creating new products, knowledge and know-how, while creative professionals work in knowledge intensive industries (Florida, 2002). IT specialists can operate in both cores: creating new knowledge and developing new software products as a super-creative class, and maintaining information system as creative professionals.

According to the human capital theory, the cities and creative IT specialists form a vicious circle: regional growth is stimulated by highly educated creative people and creative people are attracted by opportunities of highly developed regions. According to Castel's Network Society theory, IT revolution created new conditions that set both constraints and possibilities for the new society (Castells, 2000). Creative Class Theory developed by Florida brakes this vicious circle. It states that it is creative educated people who choose territory and make it a center for innovations and economic growth. One proof of this theory is East Berlin. Recent statistical data show that 14.8 % of specialists employed in professional and related occupations (IT, engineering, art, education, legal and health) in the USA are foreign born (Foreign-born Workers: Labor Force Characteristics – 2016, 2017). After the fall of the Berlin wall creative talented people moved into the city and quickly turned it into one of the fast developing regions in the world. The chosen territory should meet 3 T's condition: technology, tolerance and talent (Florida, 2004). However, the human capital theory strikes back, arguing that Florida's "creative capital" is formed by highly educated individuals and there is no novelty in stating that educated people drive the region's economy development (Gleaser, 2005). Pratt argues that "creativity is a magic bullet that leads to competitiveness" (Pratt, 2009).

To determine the urbanistic context within which the growth of innovation and creativity take place, 'the creative city' concept appeared (Kong & O'Connor, 2009). In accordance with Lobo at al.

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[1] Updated data Retrieved July 17, 2018, from: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do.
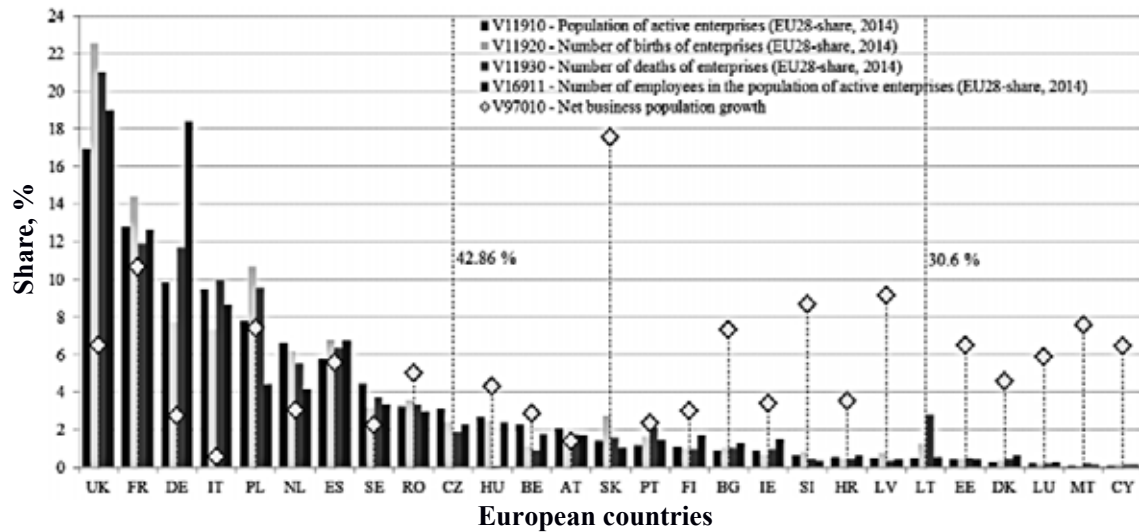
Source: Rosetti, F. (2017). The Business Demography of the ICT Sector in Europe.

Figure 2. Member States by their shares (%) of the EUactive ICT enterprises in 2014.

research findings, highly productive metropolitan areas tend to have higher levels of educated creative individuals (defined as creative professionals by Florida) but they do not necessarily have high levels of inventive labor (defined as super-creative class by Florida).

Lobo at al. also concluded that the growth of regional productivity is caused by super-creative class while creative professionals have negligible or negative effect (Lobo *et al.*, 2014). Hence, it is possible to deduce that creative professionals represent demand for development while super-creative class perform as a source of development. Mommaas mentions that professionals oriented towards economic success and technology prefer more homogeneous suburbs, while art- and culture-oriented professionals choose informality and diversity within the city (Mommaas, 2009).

In order to attract creative class, the areas compete with each other and build place- marketing strategies. By using marketing tools they try to satisfy the demand of creative specialists in urban goods and services (Braun, 2008). There are empiric researches proving an obvious correlation among the residence of creative class in the area and development of cultural services, diversity and economy in European context (Andersen *et al.*, 2008; Clifton, 2008).

Division of creative class as a solid group into subgroups with different preferences and priorities concerning emplacement is justified by Bjørn Asheim and Høgni Kalsø Hansen. Depending on affiliation of creative class to analytical, synthetic, and symbolic knowledge, sub-group location preferences differ (Asheim & Hansen, 2009). IT specialists belong to synthetic knowledge sub-group and have different preferences than artists from symbolic knowledge sub-

Table 1

Occupied posts by kind of economic activity on average per year

	2005		2010		2015		2016	
	Occupied posts	% of Total	Occupied posts	% of Total	Occupied posts	% of Total	Occupied posts	% of Total
Total	919 469	100.00	776 742	100.00	883 759	100.00	887 310	100.00
Information and communication	18 008	1.96	18 190	2.34	27 800	3.15	30 456	3.43
Programming and broadcasting activities	1 398	0.15	1 516	0.20	1 616	0.18	1 590	0.18
Computer programming, consultancy and related activities	3 654	0.40	5 498	0.71	11 924	1.35	13 432	1.51
Information service activities	909	0.10	1 857	0.24	5 687	0.64	6 848	0.77

Source: Author's calculations based on the data of Central Statistical Bureau of Latvia.

group or scientists in analytical knowledge sub-group. So, for IT specialists as part of synthetic knowledge sub-group, business climate is more important than people climate (Asheim & Hansen, 2009).

Wuwei tries to show the relations between creative class, creative district and creative cluster putting them all at the same level in process of creating creative community (Wuwei, 2011).

For most IT specialists living in the cities is not a matter of choice. IT companies tend to cluster (Florida, 2004). It is conditioned by necessity to mobilize IT resources rapidly and be able to catch the novelties as soon as they appear. However, Florida's theory has some limitations in case of EU. Compared to the USA, European countries face language and cultural differences that do not allow the creative class flow to be so unordered. Competition between the cities on the national level in Europe is less intense, social benefits and women's participation in labor market rate is higher (Asheim, 2009). This is why Florida's

Table 2

Occupied posts by region and kind of economic activity; average per year, 2016

	Riga region (Riga)		Pierīga region		Vidzeme region		Kurzeme region		Zemgale region		Latgale region		Latvia Total
	Occupied posts	% of Total Latvia	Occupied posts	% of Total Latvia	Occupied posts	% of Total Latvia	Occupied posts	% of Total Latvia	Occupied posts	% of Total Latvia	Occupied posts	% of Total Latvia	
Total	487 085	54.89	133 940	15.10	57 455	6.48	76 209	8.59	65 055	7.33	67 566	7.61	887 310
Information and communication	25 535	83.84	2 337	7.67	400	1.31	983	3.23	439	1.44	762	2.50	30 456
Programming and broadcasting activities	1 444	90.8	21	1.32	36	2.26	39	2.45	37	2.33	13	0.82	1 590
Computer programming, consultancy and related activities	11 075	82.45	1 477	11.0	141	1.05	309	2.30	170	1.27	261	1.94	13 432
Information service activities	6 000	87.6	410	6.0	70	1.02	242	3.53	51	0.74	75	1.10	6 848

Source: Author's calculations based on the data of Central Statistical Bureau of Latvia.

theory should not be taken as given in the European context.

Estimating creative class concentration in certain areas, R. Florida provides top five regions in the USA: Washington D.C., Boston, Austin, the Research Triangle and San Francisco (Florida, 2004). These areas are also characterized by highest Inequality Index that compares the wages of creative sector workers to those in the manufacturing sectors. Creative areas outside the United Stated include Toronto and Vancouver in Canada, Sydney and Melbourne in Australia, Dublin, London, Helsinki, Amsterdam, and Copenhagen in Europe. However, now the trend is switching to China, India and Russia. For example, a report on Shanghai's digital content industry shows that the industry employed almost 3 times more people in 2006 in comparison with 2002 (Wuwei, 2011).

Nowadays the EU government understands the necessity of using the potential of creative class for developing innovations. HORIZON 2020 Work Programme 2016 – 2017 highlights that one of the challenges of technological development in Europe is widening and accelerating the exchange of ideas, knowledge and skills between super-creative class and entrepreneurs (Horizon 2020).

Concentration of IT Specialists in Latvia

Post-industrial era demands IT specialists as one of core professionals providing technological development of the country. In 2017 Latvia was ranked 33rd in Global Innovation Index and further development is possible through enlarging and spreading creative IT specialists through the country (The Global Innovation Index, 2017). Statistical data

proves that the number of employed specialists in Information and communication sector increased by 69% in 2016 in comparison with 2005. The fastest growth occurred since 2010 and it is still continuing. Thus, the growth of the number of specialists in Information and communication sector in 2016 was 9.55% compared to 2015. Latvian statistical data perfectly matches previous European research by which "the rank-size distribution of the creative class indicates a greater proportionate growth than that of the general population's" (Lorenzen & Andersen, 2009). This research also indicates that it has greater diseconomies of small cities (Lorenzen & Andersen, 2009).

The most noticeable growth took place in computer programming, consultancy and related activities, as well as Information service activities. Programming and broadcasting activities did not experience dramatic changes.

Theoretical findings studied above showed that creative IT specialists need convenient environment and they tend to congregate in certain areas. The analysis of Latvian statistics proves this statement. Riga region accumulates only 54.89% of total posts. However 83.84% of all posts in Information and communication sector are concentrated in Riga region.

The allocation of IT specialists is shown in Figure 3. Riga planning region, which includes Pieriga region and Riga itself, contains 91.51% of total IT specialists of Latvia. The concentration of IT specialists in Kurzeme and Latgale regions exceeds 2%, while Vidzeme and Zemgale regions accumulate less than 2% of Latvia's IT Specialists. The concentration of
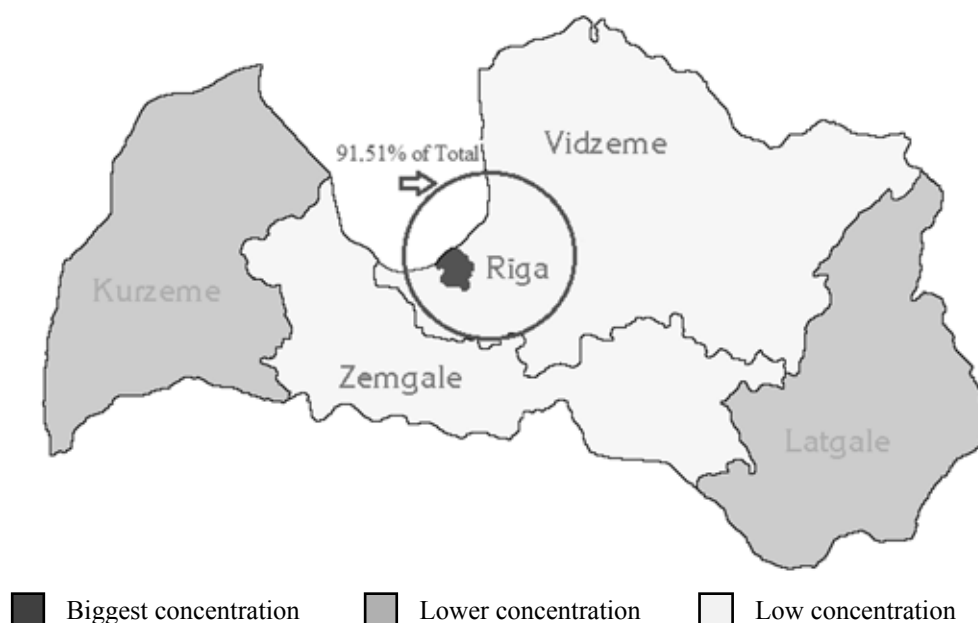

Figure 3. Concentration of specialists in Information and communication sector in Latvia.

creative IT specialists near Riga corresponds with the European creative cities concept, where cities are viewed as post- and para-national concept (Corijn, 2009).

In order to define the extent of concentration Herfindahl-Hirschman index may be applied.

$$HH = \sum_{i=1}^{N} s_i^2 \qquad (1)$$

For IT specialist concentration in Latvia:

$$HH = 0.8384^2 + 0.0767^2 + 0.0131^2 + 0.0323^2 + 0.0144^2 + 0.025^2 = 0.72$$

Herfindahl-Hirschman index above 0.25 indicated high concentration. Concentration of Latvian IT specialists is extremely high.

There are various explanations of the high concentration of creative IT specialists in large urban areas. The most common one: "creative begets more creative" (Lorenzen & Andersen, 2009). According to social network theory (Watts, Dodds, & Newman, 2002), the larger the city and larger the presence of creative class in the city, the more links they possess to attract more creative people. (Uzzi & Spiro, 2005). This raises a question: what should small cities do? Within European Union in terms of open borders even Riga with its over 640 thousand population can be considered relatively small. Lewis and Donald believe that small cities should rely on "livability" and "sustainability" in their attempts to attract creative IT specialists (Lewis & Donald, 2010). They should attract the creative class with the "quality of life" and "authenticity" (Rich, 2013). Hereby, developing regions of Latvia by attracting IT specialists seems possible.

Results and Discussion

Even though it was proved that in case of Latvia creative IT specialists concentrate near urban agglomerations, the compliance of these areas with 3 Ts (tolerance, talent and technology) was not studied and should be covered in further research.

Theoretical dilemma concerning precedence of creative class location or technological and economic development received no empiric findings. This correlation may beathe subject of a separate paper.

Another topic for futher studies is the relation of concentration of IT specialists and IT enterprises to the concentration of specialists and enterprises of any type in certain areas. It might be interesting to compare the share of IT specialists and enterprises among overall employees and enterprises in certain areas and to receive both relative and absolute indicators.

Conclusions

Theoretical and methodological analysis performed for this paper allowed to reach the following conclusions:

1) ICT sector is fast and permanently growing sector within European economy;

2) Latvia's ICT sector is developing as the number of births of new enterprises exceeds the number of their deaths;

3) Cities and creative IT specialists form a vicious circle: regional growth is stimulated by highly educated creative people and creative people are attracted by opportunities provided by highly developed regions. Opinions in support of both theories were provided;

4) The role of IT specialists in Latvia occupied posts was evaluated;

5) According to Herfindahl-Hirschman index, the IT professionals are extremely concentrated in Riga planning region.

The results of the research may be useful for regional authorities in their attempts to increase regional attractiveness by attracting IT specialists. In order to provide steady development, other regions in Latvia should create working places and attractive environment for creative IT specialists.

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ASSESSMENT OF LITHUANIAN RURAL HOMESTEADS' WEBSITES QUALITY

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Abstract
Considering tourism as a driving force in the growth of rural economy, the research in this industry is gaining its popularity. In the era of the Internet, no business is imaginable without having its own website. However, implementing a website does not already mean that customers will like and approve it. Website quality is a necessary task to maintain in line with its functioning. The aim of the research is to assess the quality of the Lithuanian rural tourism homestead websites. Only understanding the website-related factors that are important for consumers may lead to a proper management of a website and customer attraction as well. The research results show that the information on the websites has to be easy findable, clear, and consistent; photos that substantiate the information are necessary; the information and photos have to be managed properly; and the eWOM part has to be included on the website. Proper management of latter factors can enhance the possibility of maintaining a high quality website that encourages consumer intention to visit the homestead.
Key words: Lithuania, rural homesteads, rural tourism, website, website quality.

Introduction

The concept of 'rural tourism' has become all-inclusive over the time (Patil & Mulani, 2017); according to Ghadban *et al*. (2017) it encompasses many forms of tourism, such as nature-based tourism, community-based tourism, ecotourism, agro-tourism, and many more. Rural tourism is rapidly expanding all over the world (Hidalgo-Alcázar, Sicilia, & De Maya, 2015). For communities living in rural areas, tourism is an important tool of revenue generation (Ghadban *et al*., 2017): tourism may provide jobs as well as generate additional income through the number of other allied activities (Patil & Mulani, 2017); moreover, tourism development has a multiple social and cultural impact on the community (Csaholczi *et al*., 2017). Therefore, bearing in mind that the development of rural regions is one of the key targets for the regional politics (Didenko *et al*., 2017), and considering that the main socio-economic problems in rural areas include poorly developed social and hard infrastructure, high unemployment level, poorly developed services and low level of education of the local residents (Wojewódzka-Wiewiórska, 2017), it can be argued that the development of rural tourism becomes an essential activity requiring proper attention and management. Rural economies have been first and foremost about natural resource consumption and exploitation; whereas rural tourism development is a rather new phenomenon when compared to traditional rural economic activities (Gartner, 2005).

Kastenholz *et* al. (2018) emphasize that rural tourism is driven by the search for unique and memorable experiences in particular settings. The study provided by Hjalager, Kwiatkowski, & Larsen (2018) showed that rural tourism has its basis in a dichotomy between authenticity and modernization. Modernization, in terms of technological development and the expansion of the Internet, has a significant impact on the development in all economic sectors including travel and tourism industry. According to Boyne & Hall (2004), the Internet has developed rapidly and has become a potentially effective advertising and promotional tool; and for tourism purposes, the web is the most often used research tool by consumers seeking out information and images concerning potential destinations, activities and services. Moreover, according to Hidalgo-Alcázar, Sicilia, & De Maya (2015), the sector of rural tourism is one of the most active on the Internet. Melo, Hernández-Maestro, & Muñoz-Gallego (2017) emphasize that in the tourism industry, most customer feedback and searches for relevant information take place online; therefore, it is important to assess the impact of business online activities and customers' online comments on the choice of tourism object. To be more precise, tourists usually consult user-generated content on the Internet to plan a trip (Hidalgo-Alcázar, Sicilia, & De Maya, 2015). Therefore, it can be argued that user-generated content in terms of electronic-word-of-mouth (eWOM) has a significant impact on consumers' assessment of information provided by a legal entity (in our case, rural tourism homestead).

Maintaining a scientific discussion, **the object** of this research is Lithuanian rural tourism homestead website quality. Accordingly, **the aim** is to assess Lithuanian rural tourism homestead website quality. During the research, special emphasis is placed on the impact of eWOM. The **scientific problem** solved by the research is which factors affect consumer perception of rural homestead website quality? Vassiliadis, Fotiadis, & Piper (2013) argue that while it is relatively easy to define the quality of a product, the process of defining the quality of a service is a challenge. Primary attempts of assessment of website quality are related to the model provided by Barnes & Vidgen (2000) called WebQual. Many

attempts to verify, improve or adapt this model can be found in scientific literature (e.g., Ahmad & Khan, 2017; Loiacono, Watson, & Goodhue, 2002, 2007, etc.). Initially, four dimensions were established as the characteristics of website quality: ease of use, experience, information, and communication & integration. During its modifications, the model was extended to twelve (Loiacono, Watson, & Goodhue, 2002), or reduced back to four dimensions (Ahmad & Khan, 2017). Therefore, it can be stated that determinants of website quality are still underassessed.

Materials and Methods

Achieving to assess the quality of Lithuanian rural homestead websites, the following categories were indicated:

- Overall website quality (Likert scale): useful, reliable, positive, informative;
- Expectations for rural homestead based on the website (Likert scale): reception, atmosphere, nature, overall expectations;
- Looking for eWOM when choosing a rural homestead (Likert scale);
- Relying on eWOM when choosing a rural homestead (Dichotomous question – yes / no);
- Most affective eWOM when choosing a rural homestead (Dichotomous question – positive / negative);
- Importance of factors affecting the rural homestead choice (Likert scale): price, location, convenience, eWOM information, eWOM photos, information on the website, photos on the website.

All of these categories were included in the questionnaire for respondent evaluations with the scales specified. Moreover, question-filter was included in the questionnaire to eliminate the respondents that have never visited a rural homestead. In the end of the questionnaire, two demographic questions, namely, gender and age, were included.

The questionnaire research was conducted on the internet through a specialized survey websites. Totally 298 respondents filled the questionnaire, but 42 of them indicated that have never visited a rural homestead, thus were eliminated from the analysis. Hence, 256 questionnaires (74 per cent of respondents were women; all of the respondents were at the age of 20 – 35) were applied for the analysis of the research results.

Descriptive statistical analysis with IBM SPSS Statistics v.20 and XLSTAT 2014 software packages was done to obtain the results. The application of frequency analysis for respondent evaluations revealed the number of occurrences of each response chosen by the respondents. The two most frequent evaluations revealed the trend of respondents' attitude towards the measured objects.

Results and Discussion

The overall evaluation of rural homestead website quality contains the evaluation of website usefulness, reliability, the evaluation of whether the website seems to be positive and informative. As it can be seen, 82 per cent of respondents evaluated the rural homestead websites as useful (see Figure 1) – the evaluations of 4 and 5 in the 5-point scale. Only 3 per cent of respondents evaluated rural homestead websites as not useful (the evaluations of 1 and 2 in the 5-point scale). Hence, it could be stated that based on the respondents' evaluations rural homestead websites seem useful to them.

The frequency of the evaluation of rural homestead website reliability is visualized in Figure 2. As it can be seen, 71 per cent of respondents chose the evaluation of 4 or 5 in the 5-point scale, meaning that they evaluate rural homestead websites as reliable. Only 6 per cent of respondents believe that rural homestead websites are not reliable (the evaluations of 1 and 2 in the scale of 5).

The frequency of the evaluation of rural homestead websites as positive is visualized in Figure 3. As it can
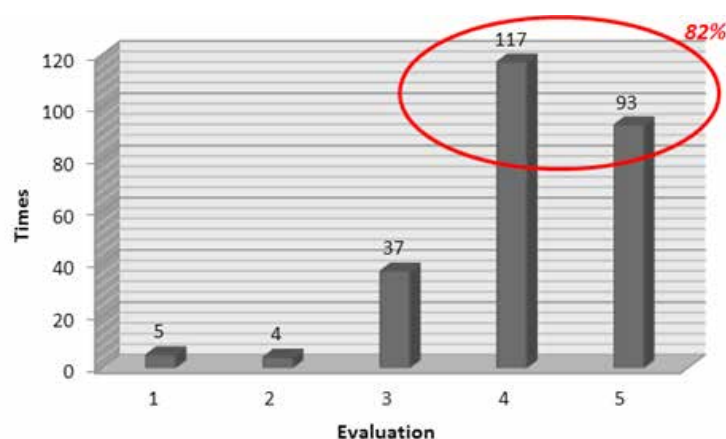

Figure 1. Frequency of the evaluation of website usefulness.
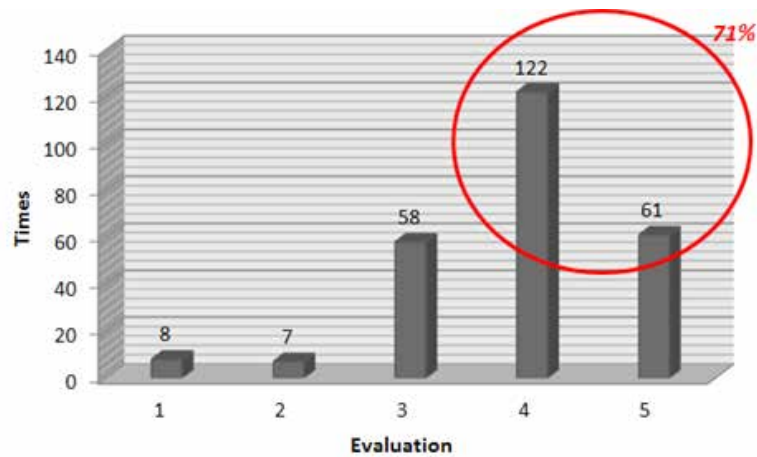
Figure 2. Frequency of the evaluation of website reliability.
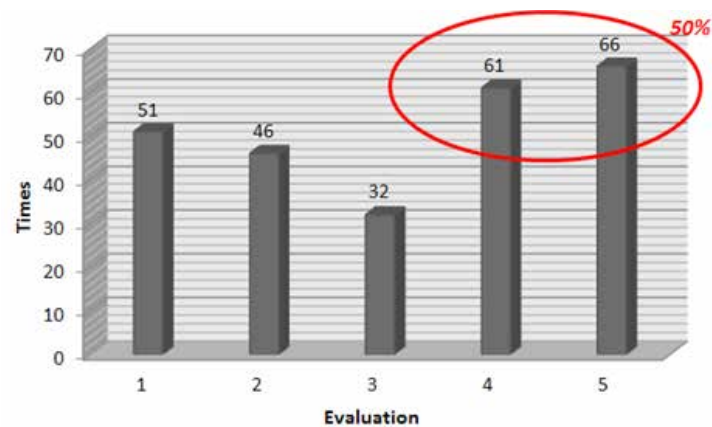

Figure 3. Frequency of the evaluation that website is positive.

be seen, 50 per cent of respondents chose the evaluation of 4 or 5, meaning that they evaluate rural homestead websites as positive. Nevertheless, 38 per cent of respondents evaluated rural homestead websites as negative (the evaluations of 1 and 2). Hence, unlike the evaluation of rural homestead website usefulness and reliability, the evaluation of rural homestead websites as positive has a greater dissemination. Therefore, it

could be stated that the positivism of rural homestead websites has management gaps.

The frequency of the evaluation of rural homestead websites as informative is visualized in Figure 4.

As it can be seen, most of the respondents (55 per cent) chose the evaluation of 1 or 5, meaning that they evaluate rural homestead websites as very informative or very uninformative. Totally, 44
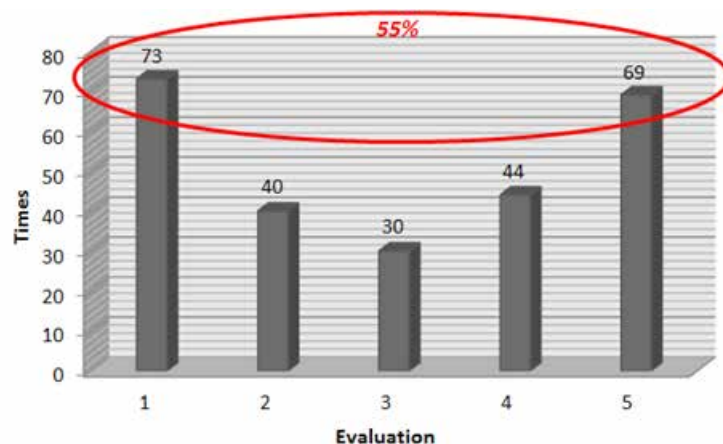
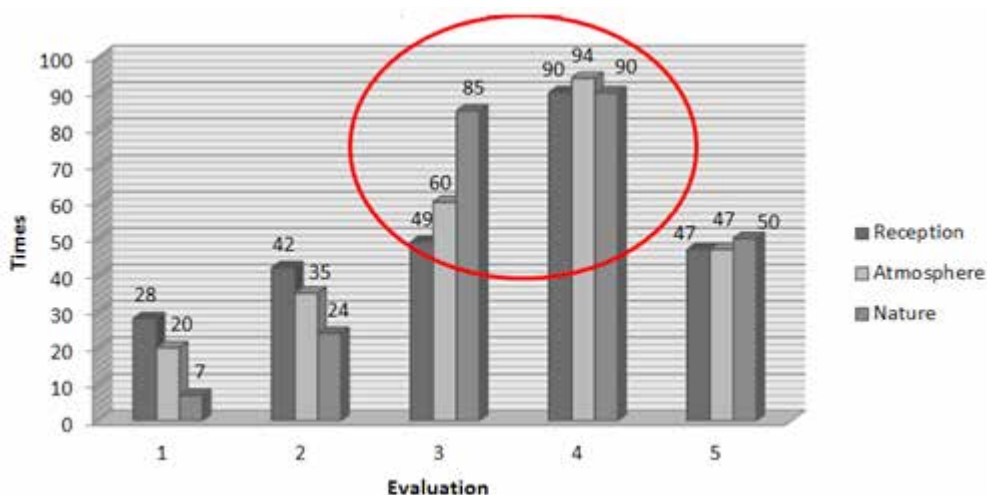Figure 4. Frequency of the evaluation that website is informative.

Figure 5. Frequency of the evaluation of the expectations for reception, atmosphere, and nature.

per cent of respondents chose the evaluation of 4 or 5, meaning that the websites are informative, and 44 per cent of respondents chose the evaluation of 1 or 2, meaning that the websites are not informative. Such dissemination of the results signifies that the amount of information on the rural homestead websites can be sufficient, but it has to be managed in another way. Hence, the assumption could be made that consumers do not find the information on the rural homestead websites easy or in the convenient place of the website.

The frequency of the evaluation of expectations for rural homestead reception, atmosphere, and nature after visiting their websites is provided in Figure 5. As it can be seen, respondents have average and above average expectations for reception (54 per cent), atmosphere (60 per cent), and nature (68 per cent) for rural homesteads after visiting their websites. The assumption could be made that rural homestead websites do not provoke high expectations with the information and visuals provided regarding reception, atmosphere, and nature. The question rises whether

this is done on purpose in order to raise satisfaction (if the reception, atmosphere, and nature exceed expectations, the level of satisfaction rises) or this is done not on purpose. In the first case, if this is done on purpose, there is a threat that low expectations may cause negative influence on the behaviour (customers will not come to the specific homestead due to the low expectations for the reception, atmosphere, and nature). In the second case, if this is done not on purpose, the information and visuals regarding reception, atmosphere, and nature on the websites must be managed properly in order to raise expectations.

Despite average expectations for rural homestead reception, atmosphere, and nature, overall expectations for rural homesteads after visiting their websites are high (see Figure 6). As it can be seen, 69 per cent of respondents evaluate their overall expectations with 4 or 5 in the scale of 5, meaning that they evaluate expectations for rural homesteads based on their websites as above average / high. Hence, based on the analysis of the research results, it could be stated that
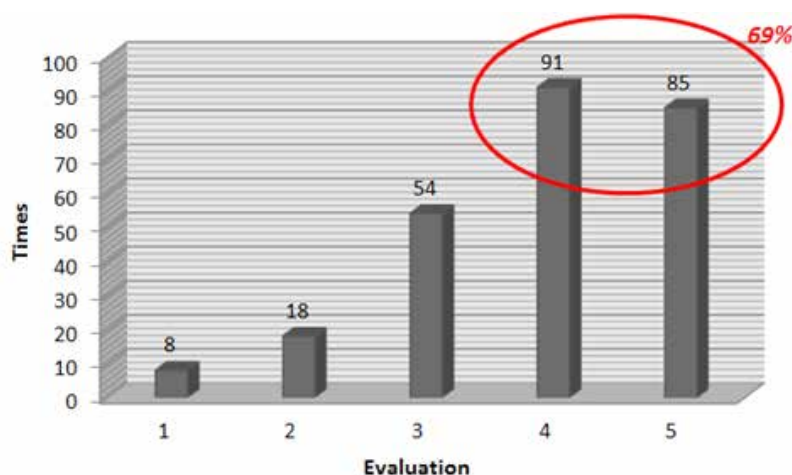

Figure 6. Frequency of the evaluation of the overall expectations.
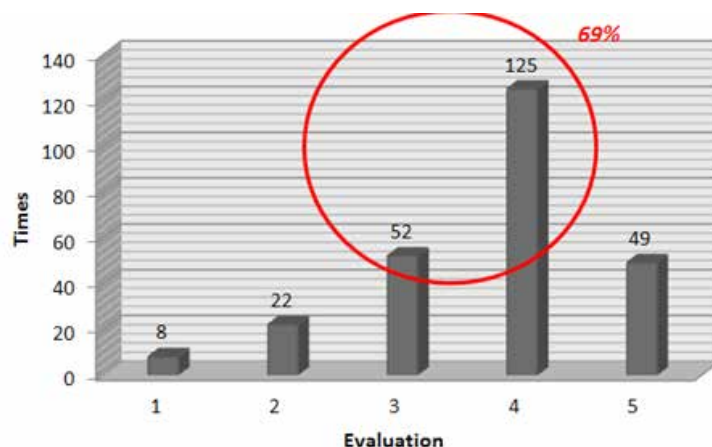
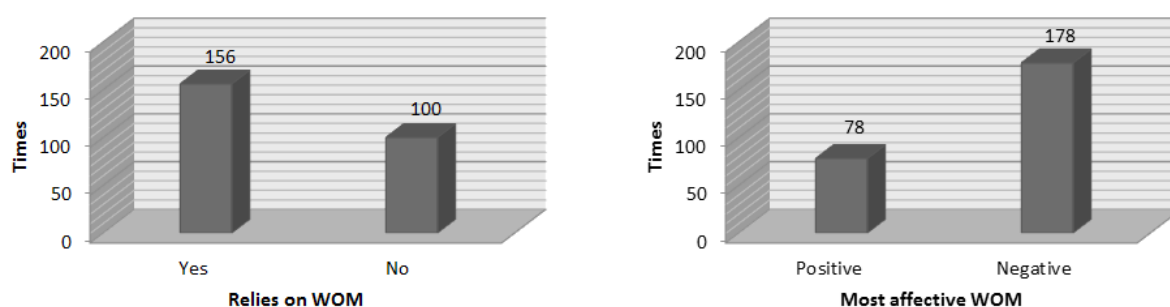Figure 7. Frequency of the evaluation of looking for eWOM.

Figure 8. Frequency of the evaluation of relying on eWOM and most affective eWOM.

rural homestead websites provoke high expectations except for reception, atmosphere, and nature.

The frequency of the evaluation of looking for eWOM on the Internet regarding rural homesteads is visualized in Figure 4. As it can be seen, the two most frequent evaluations are 3 and 4 (69 per cent of respondents); hence it could be stated that respondents are looking for eWOM regarding rural homesteads, but not always and / or not widely through the Internet.

The frequency of the evaluation of relying on eWOM and the most affective eWOM is provided in Figure 8 below. As it can be seen, 60 per cent of the respondents rely on eWOM when choosing a rural homestead. Moreover, for the 70 per cent of respondents negative eWOM are the most affective; hence, it could be stated that negative eWOM has higher impact on the choice of the rural homestead when compared to the positive eWOM. Based on the results, the assumption could be made that consumers are looking for negative eWOM regarding a specific rural homestead and if there is none, such rural homestead becomes the choice under consideration, but if negative eWOM are found, they rely on the eWOM and do not consider this rural homestead. To manage such situation, the recommendation is to contain the eWOM part on the rural homestead's website in order to reply to the negative eWOM and

lower the possibility that consumers will search for the negative eWOM widely through the Internet.

The frequency of the evaluation of the importance of price, location, and convenience provided on the website when choosing a rural homestead is shown in Figure 9. As it can be seen, all of these three factors are very important when choosing a rural homestead and should be provided on the rural homesteads' websites. Price is very important (evaluations of 4 and 5) for 79 per cent of respondents, location is very important (evaluations of 4 and 5) for 88 per cent of respondents, and convenience is very important (evaluations of 4 and 5) for 77 per cent of respondents. It could be stated that the absence of the description of these factors on the rural homestead's website can influence the decision not to consider such a homestead for the visit.

The frequency of the evaluation of the importance of eWOM information and photos compared to the information and photos provided on the website when choosing the rural homestead for the visit is provided in Figure 10. As it can be seen, eWOM information and photos, as well as information and photos provided on the rural homestead websites are very important (the most frequent evaluations are 4 and 5 in the 5-point scale). eWOM information is evaluated as important / very important by 83 per cent of the respondents;
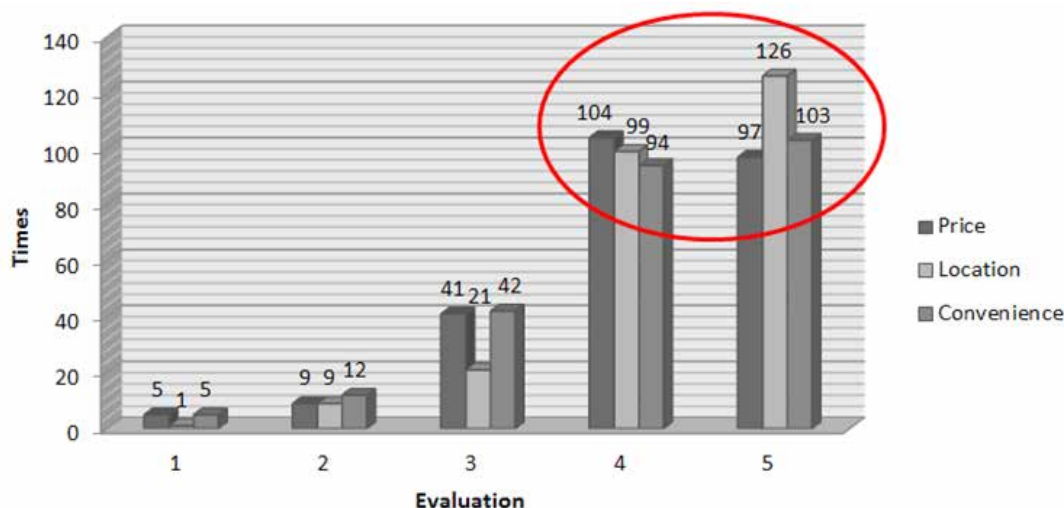
Figure 9. Frequency of the evaluation of the importance of price, location, and convenience.
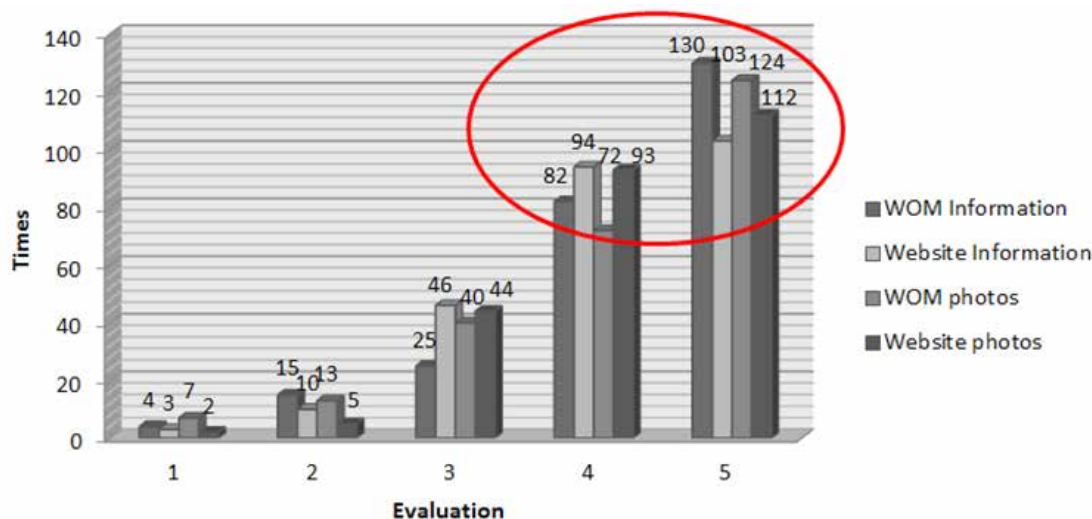

Figure 10. Frequency of the evaluation of the importance of eWOM information and photos compared to the information and photos provided on the website.

information provided on the rural homestead websites is evaluated as important / very important by 77 per cent of the respondents. eWOM photos are evaluated as important / very important by 77 per cent of the respondents; photos provided on the rural homestead websites are evaluated as important / very important by 80 per cent of the respondents. Consequently, most of the respondents evaluated eWOM information and photos provided on the rural homestead websites as very important. Hence, not only the information provided on the rural homestead websites, but photos as well have to be managed properly in order to maintain high website quality. Moreover, the results of the evaluation of the importance of eWOM information and photos support the recommendation to contain the eWOM part on the rural homestead websites.

The research results indicated the main problems related to the quality of Lithuanian rural homestead websites. Knowing the problems, the solutions for their management can be elaborated.

Conclusions

Based on the analysis of the research results, it could be stated that in order to achieve high Lithuanian rural homestead website quality, the management of the websites is necessary. Firstly, the information on the websites has to be easy to find, clear, and consistent. The information has to contain the aspects of price, location, and convenience of the homestead. Secondly, the information on the website has to be complemented by photos that substantiate the information. Thirdly, the information and photos regarding reception, atmosphere, and nature provided on the websites has to be managed properly in order to raise current expectations. Finally, the recommendation is to contain the eWOM part on the rural homestead websites in order to reply to

the negative eWOM and lower the possibility that consumers will search for the negative eWOM widely on the Internet. The management of these factors can enhance the possibility to maintain high quality website that influences consumers' intention to visit the homestead.

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PROTECTION OF TRADITIONAL HANDICRAFTS: THE LITHUANIAN CASE

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Abstract
The preservation and nurturance of national heritage products, which are inherent to particular localities, are very significant for the economic and social vitality, and sustainable development of a country. National handicrafts are a means of maintaining national identity, originality, and distinction in a constantly changing world. For a long time Lithuania was an agrarian country, so its cultural heritage and handicrafts are closely related to the rural environment, culture, traditions, and materials. Nowadays this heritage is a very important source of alternative employment opportunities. In 2007 Lithuania enacted the Law of National Heritage Products; in 2008 and 2011 Programmes for the Protection of National Heritage Products, their Market and Development of Handicrafts were approved. The goal was to provide governmental support to create favourable conditions for the creation, realisation and popularisation of national heritage products. The aim of this paper is to evaluate the situation with traditional handicraft protection in Lithuania within the Programme implementation framework and to submit proposals for better implementation. The analysis shows that not all Programme goals were achieved: those for which municipalities were responsible were implemented better than those implemented by governmental institutions. A presumption could be made that the top-down approach is only partially suitable for the Programme implementation. The partners from the 'bottom' (associations, local activity groups) should be involved in the implementation of the Programme to reach better results.
Key words: cultural heritage**,** national heritage protection, traditional handicrafts, Lithuania, new social movements.

Introduction

2018 was officially launched by the European Union as the European Year of Cultural Heritage. The aim is to raise awareness of Europe's cultural heritage, which has the power to bring communities together and to build a shared understanding of the uniqueness of the place we live in. Cultural heritage is the basis of every nation's identity, helping to keep the consciousness of the nation as distinctive amidst the community of nations. Preservation of national cultural heritage, formed interactively with landscape, traditions and knowledge, stimulates sustainable development (Kniūkšta, 2014). Some authors argue that culture is a crucial element in sustainable development, as it forms peoples' identities, cosmologies and epistemic frameworks, determining how the environment is viewed, understood and lived in, including social and economic systems. Culture shapes how humans act in the surrounding world (Nurse, 2006; Hawkes, 2001).

Cultural heritage is divided into the tangible and the intangible. According to the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage 'intangible cultural heritage means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and individuals recognise as part of their cultural heritage' (UNESCO, 2003). Cultural heritage encompasses traditions, performing arts, social practices, rituals, festivals, knowledge and practices concerning nature and the universe and national handicrafts. Manufacturing of traditional heritage products is especially important for rural dwellers as alternative economic activity when the importance of agriculture in the employment structure of rural population is declining.

The preservation of national handicrafts is the topic of this article. To protect traditional handicrafts means to implement measures which ensure the viability of heritage through ensuring continuous practice, maintenance of the process of heritage production, and transmission of knowledge and skills through education for future generations. Until 2007 the laws protecting national handicrafts were incorporated in common governmental programmes as cultural protection laws. Legal protection was episodic, directed towards implementation of projects, separate measures and initiatives, and the different institutions took part in protection processes: there was no integrated view.

In 2007 the Parliament of the Republic of Lithuania, prompted by non-governmental associations and organisations, announced the Law of National Heritage Products (the Law), which was a strong top-down attempt to preserve traditional handicrafts as one part of the cultural heritage. The Law ensured governmental protection, allowing protection and dissemination of accumulated experience of national handicrafts. The principles of governmental maintenance were created. The Law defined national heritage products as the traditional handicraft products of craftsmen. The Law determined the principles of handicraft product classification and certification process, and specified favourable conditions for traditional craftsmen to create, realise, and popularise products of national heritage (The Republic of Lithuania, 2007).

Certification ensured that products were made from traditional materials, by traditional methods, protecting

unique features, composition, and colour of wares. The system of certification enabled the systematisation of handicrafts and products of national heritage, marked with a specially-created logo. There are 72 certified, historically developed traditional handicrafts, and more than 2,700 certified national heritage products produced by around 600 certified craftsmen.

In 2008 the government of the Republic of Lithuania approved 'The Programme for Protection of National Heritage Products, their Market and Development of Handicrafts for 2008 – 2015' (the Programme), it was suspended in 2011 and a new, advanced Programme for 2012 – 2020 was approved. In this Programme a wide spectrum of governmental institutions were and are taking part: the Ministry of Agriculture of the Republic of Lithuania, Ministry of Culture, Ministry of Economy, Ministry of Environment, Lithuanian State Department of Tourism under the Ministry of Economy, and municipalities (self-government institutions). The meaning of traditional handicraft protection is multifunctional, which is why, for the preservation and adaptation to contemporary requirements, an integrated approach concerning implementation of protection measures was necessary. The multiplicity of selected cultural heritage protection measures was revealed in the Programme for Protection of National Heritage Products, their Market and Development of Handicrafts for 2012 – 2020 (further Programme). It was planned to operate in the economic dimension of sustainable development (job creation, income generation), the social dimension (development of a training system), and the environmental dimension (presentation, promotion and the use of cultural resources) (The Government of the Republic of Lithuania, 2011).

The situation and development possibilities of traditional handicrafts were analysed by V. Atkočiūnienė, A. Aleksandravičius and D. Albrektaitė *et al.*, (2008b), V. Rudzkienė and R. Skrodenytė (2012). E. Ribašauskienė and D. Šumylė (2016) investigated the activity of traditional handicraft centres, G. Parafinavičė and I. Krikštaponytė (2010) analysed the realities and prospects of traditional craftsmen education and skills training. A. Aleksandravičius *et al.* (2008, 2009, 2012) researched endogenous and exogenous factors influencing the development of handicrafts and the role of traditional handicrafts in rural sustainable development. J. Ramanauskienė and Z. Vagonis (2010) investigated the benefits of interaction between the rural tourism and handicrafts. B. Žuromskaitė (2010) aimed to discover the role of traditional handicrafts in promoting cultural tourism. No research was done to investigate the results of the Programme implementation.

The aim of this paper is to evaluate the situation with the traditional handicraft protection in Lithuania

within the Programme implementation framework and to submit proposals for better implementation. The tasks of the paper are: 1) to analyse the development of national heritage protection inspirations in Lithuania; 2) to examine the extent of craftsmen involvement in the Programme, identifying the main challenges.

Materials and Methods

Analysis of scientific literature, national documents, and discourse analysis were used to disclose the theme. To achieve the aim of the paper, the quantitative method of structured questionnaire was applied.

The intermediate results of Programme implementation were evaluated by comparing planned indicators with the achieved results.

Three information sources were used to gather information about the implementation of the Programme: governmental organisations, municipalities, and craftsmen. The data from governmental organisations and self-governmental institutions were chosen to supplement the answers of craftsmen and for better explanation.

To evaluate the intermediate results of the Programme implementation, the structured questionnaire was conducted in September–November of 2016 for two groups – certified craftsmen and municipal agents. 567 certified producers of national crafts were asked to fill in a questionnaire on an internet platform. 233 answers were received: according to statistics this ensures the representativeness of research with a confidence level of 95 per cent and a 5 per cent margin of error. The questionnaire was designed to investigate such themes as demographic characteristics of surveyed respondents, duration of activity and its aspects, and the use of government support measures. The research data were analysed using an Excel package. 53.6 per cent of respondents were dwellers of rural areas and small cities, and 46.4 per cent were town craftsmen. 61.8 per cent have been creating national heritage products for more than 10 years, 23.2 per cent for 6 – 10 years, and 13.7 per cent for 5 years and less. 65.2 per cent of respondents were women. The most frequent activities were knitting, weaving, pottery, carving, baking of bread, food preparation, and production of sweets. The majority of respondents were 40 – 59 years old, 18.0 per cent – 60 years and older, 15.9 per cent 29 – 39 years old and the smallest number – 2.6 per cent, were younger than 29.

The questionnaire was sent by an e-mail to all municipalities of Lithuania, 31 responses were received, and it composed 51.7 per cent of the general set. According to statistics with a confidence level of 95 per cent, the margin of error was 10 per cent. They were asked to indicate what measures they implement to improve the preservation of traditional craftsmen.

For the governmental organisations participating in the Programme implementation, official letters were sent asking them to contribute their input.

Results and Discussion
Tendencies of the cultural heritage protection
The preservation of cultural heritage has a long tradition in Lithuania. It was very important in the period when Lithuania was under the Soviet regime and started around the 1960s. The goals of the ethnocultural movement were to explore the country and regions, to preserve and clean monuments, to collect folklore and old songs, to organise ethnographic expeditions, folk groups and folk clubs, and to keep national traditions. Acting in secret, as the Soviet government inhibited such activity, a complex network of circles of friends, private and public spaces, hid under the legal shelter of official organisations. Conflict was directed towards the existing government, and activists sought to dissociate from the reality of Soviet society by establishing an alternative worldview, promoting alternative social norms of behaviour and community values (Ramonaitė & Kukulskytė, 2014). The members of movement were persecuted, punished and sanctioned, but an alternative community was formed and connected by a common identity. With the help of community members, meeting places and festivals were hidden, while a whole communication system existed. Because of the political situation, persecuted activists chose those forms of collaboration which reflected the networking principles of new social movements. According to scientific literature, this ethnocultural movement could be seen as a new social movement as it satisfies the main features and elements of new social movements scientists distinguish: conflictual interaction with opponents, networks of informal exchanges between individuals and/or organisations, and collective identity (Diani, 2002). The reason new social movements arise is the human will to resist the state and state interference in the lives of private people (Žukaitė, 2016). The nature of new social movements is cultural and oriented towards a struggle for quality of life. The goal is to reconstruct values, personal identities and cultural symbols, contributing to the emergence of alternative lifestyles (Tovey, 2002). In contrast, the so-called old social movements were directed towards reducing material inequalities, while new social movements are guided by non-material considerations, concerning the achievement of symbolic goals, and the defence of symbolic resources (Woods, 2003).

After Lithuania regained independence in 1990, joining the EU in 2004, political, economic, and social circumstances changed. While activities and networking of social movements transformed, the tendency to preserve national cultural heritage in grassroots ways still persists as an addition flow for governmental or top-down preservation of cultural heritage. In the face of globalisation, consuming mass culture products, Europeanisation, and the threat of convergence – the willingness to protect our nation's individuality and its identity intensified. Non-governmental associations, non-profit seeking organisations (Lithuanian Folk Artists' Association, Lithuanian Association of Ethnic Culture, and others) were established with the purpose of protecting ethnic culture and national heritage, and to unite national craftsmen. They sought common purposes: to protect national cultural heritage, handicrafts, identity, to keep traditions, improve the quality of life by suggesting better quality of handicraft products, which are not mass cultured ones. Those bottom-up initiators induced national government to pay more attention to national heritage and especially to protection of traditional heritage products, handicrafts and craftsmen. With pressure from them, the special Laws in 2007, 2008, and 2011 were accepted. The bottom-up approach in the preservation field was essential in the period of the Soviet Union and lasted as an important inspiration for cultural protection in later times.

Results of Programme implementation
For the evaluation of craftsmen involvement in the Programme, four indicators, corresponding to objectives of the Programme, were measured:
- the craftsmen's participation in government supported measures (implementation of the responsibility of government institutions);
- the creation of work places by craftsmen (implementation of the responsibility of government institutions);
- the improvement of craftsmen's qualifications (implementation of the responsibility of government institutions);
- the influence of government support on the improvement of national heritage product image (implementation of the responsibility of government institutions and municipalities).

One of the objectives of the Programme was 'To develop the state support which will promote the preservation, creation and realisation of national heritage products'. The data of the craftsmen survey showed that on average 30.5 per cent of respondents used state support under the 'Programme for the Protection of National Heritage Products, their Market and Crafts Development for 2012 – 2020' each year to develop their craft activity. 85.9 per cent of respondents used the support for participation in exhibitions, fairs and festivals, 74.6 per cent purchased equipment or adapted premises for the activity, 67.6 per cent used support funds for product certification, and 59.1 per

cent for the publishing and organisation of educational events. The Programme predicted that 60 per cent of craftsmen would participate and use the government support measures. Achievement of the planned goal required an ambitious annual increase of at least 10 percentage points of craftsmen participating in state support measures. The results of the survey also showed that the main reasons for not using the state support was lack of their own resources, and the lack of information about support measures. This could be explained by the Programme's implementation top-down principles when the highest-level institutions are responsible for the support supply. The top-down implementation principle of the Programme does not assure optimal collaboration between the support provider and recipient. Government institutions are too distant from the craftsmen and top-level information needs to be easily accessible by craftsmen. It is especially important bearing in mind that the majority of craftsmen live in rural areas and small towns, and are middle aged or older. No less important reasons for the non-use of governmental support are the complicated requirements and limited access for urban craftsmen, because a part of the measure is financed by the Rural Development Programme 2014 – 2020, the purpose of which is to support rural dwellers.

An objective to ensure the adoption of ethnic cultural values and the continuity of traditional handicrafts through the creation of new working places was stated in the Programme. The survey data disclosed that only 13.8 per cent of respondents, using governmental support, created workplaces for themselves or family members. Half of those who created workplaces created part-time workplaces for themselves, one third of craftsmen created a full-time workplace for themselves, one fifth created a part-time workplace for a family member. Only 5.2 per cent of respondents created a full-time workplace.

One fifth of respondents indicated that support had no effect on creation of workplaces, and none were created. Such survey results allow assuming that in 2020 the planned target will not be achieved. The Programme forecasts that 100 workplaces would be created in 2020 as a result of implementing support measures. According to the survey results, from 2012 to 2016 only one third of the planned number of workplaces were created during the period. Here it could be stated that top-down implementation of the desired goal to create workplaces did not give the predicted results, and the approach was not vindicated.

By implementing the third objective of the Programme 'To develop and coordinate the traditional craft training system', it was expected that in 2020 the share of traditional craftsmen whose qualification level in the handicraft sphere will be evaluated as increased, following the implementation of the Programme

measures, would reach 80.0 per cent. Governmental institutions are responsible for the implementation of this objective. Only 22.0 per cent of craftsmen pointed out that their level of qualification has risen due to the implementation of the Programme measures. This number discloses that a danger arises that the purpose of the criterion will not be achieved if no changes are made. The main causes of such a low result are the inadequate actions of the institutions involved in the implementation of the Programme by developing and coordinating the traditional craft education system. Methodologies necessary for qualification development were insufficiently developed, the network for the development of competences for national heritage product developers was not created, and the management, marketing, and entrepreneurship training was not organised. A large proportion of traditional craftsmen are middle-aged and elderly, and their entrepreneurship and ability to work under today's business conditions are scant. On the other hand, the production of national heritage products requires a lot of time and labour costs; it is not a very lucrative economic activity, so it is unattractive for young people. In traditional craft technology training the transmission system is sluggish, so some crafts are on the brink of extinction. The proposal would be to dispense the implementation functions to the more flexible, adoptable bottom-up approach, when the lower institutions often are more capable to organise actual training in their regions in response to the requirements of craftsmen.

The fourth objective of the Programme was to 'Form the attractive image of national heritage products in the country and abroad' and the Programme stipulates that by 2020, the average image of national heritage products will grow by 10 per cent a year among consumers. One of the most important measures of forming the image of national heritage products is certification of such products by the Ministry of Agriculture and the provision of a national heritage label. 88.0 per cent of craftsmen used a certification logo to mark their production: 60.5 per cent always, 27.5 per cent sometimes. The craftsmen survey results showed that 26.6 per cent of respondents believe that because of the use of the national heritage label for more than 20.0 per cent of consumers the image of craftsmen production has improved, correspondingly 24.8 per cent indicated that image has improved for 5 – 14.0 per cent of consumers and 24.0 per cent indicated that image of national heritage products has improved for 15 – 20 per cent of consumers. It should also be noted that municipalities contribute significantly to the image formation of the national heritage products. The survey of municipal administrators showed that, in most municipalities, the promotion of national heritage products and traditional services

was organised in the form of exhibitions, traditional festivals and fairs: 75.0 per cent of respondents participating in the municipalities' survey organised such events more than 8 times during the period of 2008 – 2016. 51.6 per cent of the representatives of the municipal administrations indicated that more than once a year they place information about national heritage on the web site of the municipality, 32.3 per cent – that seminars were organised at least once a year in the municipality's territory. About a half of municipalities provided craftsmen with franchise to trade, to obtain business licenses. This shows that the formation of national heritage product image is positive and that the analysed objective of the Programme's implementation for 2020 is being achieved.

The results disclosed that from the viewpoint of craftsmen not all indicators of the Programme will be achieved. One of the reasons is the top-down approach of the implementation principles. The Convention for the Safeguarding of the Intangible Cultural Heritage states that every state must take the necessary measures to preserve elements of cultural heritage and to involve as wide a range of participants in preservation as possible (UNESCO, 2003). Today's situation and the received evaluation show that the input to the Programme only of the governmental organisations is insufficient. It is necessary to include a wider spectrum of actors in the Programme implementation. Measures prepared and used in the top-down approach should be supplemented by bottom-up support, which must be included in the Programme. The results disclosed that the implementation level was higher of those objectives of the Programme where the top-down and bottom-up approach were combined, i.e. where protection measures included a wider range of supporting groups: government and municipal authorities. The bottom-up principle is characterised by cooperation, civic participation, local democracy. It manifests itself through direct representation, shown by the direct identification of needs and expectations, the involvement of local organisations in the formulation and implementation of policy decisions, and the achievement of policy goals and objectives through local agents (Atkočiūnienė, 2008).

Therefore, in the future, in order to ensure the most effective protection of cultural heritage and handicrafts and a more fluent implementation of the Programme, participation and cooperation must be assured, as well as synergy between different agents: local action groups, local communities, craft centres, associations, municipalities and governmental institutions. J. Blake (2009) emphasises the necessity to generate a state-community approach, or in other words bottom-up and top-down partnership, with the government role as supportive in the sense of finance and expertise. A new approach to the preservation of cultural heritage

should be discussed and the functions must be distributed among different levels of organisations.

In this paper, the formal legally-established protection of traditional handicrafts was analysed and this is the most frequent evaluation trend. Alongside the formal preservation of national heritage, which could be called the top-down approach, a bottom-up approach prevails, arising from grassroots activities. Historically bottom-up initiatives are inherent to Lithuania and have features of a new social movement. This approach could be explained by the fact that not all initiatives are formed from the top, but arise from the grassroots. The dimension of new social movements could be an additional feature explaining the results of the Programme. It could suggest one explanation why the formal support is so little used, as another dimension of cultural, handicraft protection exists. At least 8 associations, non-profit organisations operating for the protection of cultural heritage can be identified; they unite craftsmen and artists concerned about their activities and organise exhibitions, festivals, and fairs, develop publishing activity, and organise seminars and conferences. The phenomenon of a new social movement could be explained by the fact that formal side, the top-down approach to the preservation of national heritage does not affect all craftsmen: some act independently, not wanting to participate in formal structures, or participating only a little. A number of craftsmen are not certified, as it is their lifestyle choice to make some crafts in their leisure time – nor do they seek national support; they do not join formal networks or structures, but they participate in the preservation of cultural heritage in other different ways, through initiatives taken by associations. New social movements dissociate from institutional systems and are responses to life politicisation, when policy does not protect some interests. New social movements act like a protest against modernity (Gorlach, Lostak, & Mooney, 2008). The role of new social movements is shaping society. The intention to maintain cultural tradition reflects a collective (nationalist, folk) transformative identity construction within civil society that forms islands in the sea of public liberation. This dissociation from traditional channels could be the basis for growth of new social movements (Gorlach, Lostak, & Mooney, 2008). The role and purpose of the movements in protecting national heritage and traditional handicraft preservation should be examined in future, broader research.

Conclusions

The preservation of national cultural heritage has a long tradition in Lithuania. The grassroots movement of heritage protection during the Soviet period could be defined as one of the flows. Alongside governmental

protection the grassroots movement remains important following Lithuania's regaining independence. This ethnocultural movement acted according to the principles of new social movements and was the bottom-up initiative which prompted government to preserve traditional national handicrafts by law.

The analysis of the intermediate results of the Programme implementation showed a potential danger that not all objectives of the Programme will achieve planned results. It is especially important with regard to measures which were implemented by governmental institutions: that is the use of support measures, the creation of workplaces for craftsmen and the increase of craftsmen's qualification level. The improvement of the image of national heritage products produced by craftsmen will achieve planned goals because the objective of this Programme will be implemented by municipalities, which are in closer relationship with craftsmen than are governmental institutions.

The results of the craftsmen survey disclosed that the handicraft preservation implementation levels were higher where the approaches of top-down and bottom-up were combined, i.e. where protection measures included a wider range of supporting groups, for example, government and municipal authorities. Therefore, in order to ensure the most effective protection of cultural heritage and handicrafts, participation and cooperation, as well as synergy between participants like local action groups, local communities, craft centres, associations, government, and municipalities must be assured. The activity and influence of the movement towards cultural protection from the bottom-up level, which acts under the principles and ideology of new social movements, should be investigated more extensively.

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FACTORS AFFECTING THE COMPETITIVENESS OF A HIGHER EDUCATION INSTITUTION: SYSTEMATIC LITERATURE OVERVIEW

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Abstract
The aim of the study is using systematic literature analysis method – literature overview – identify the factors, which affect the competitiveness of a higher education institution in the conditions of globalization. Qualitative methods, as well as systematic literature analysis method – literature overview have been used in the study. More than 6000 scientific articles were considered to choose 20 full text articles for in-depth analysis. Main conclusions and results – the systematic literature analysis method – literature overview is a convenient tool for systematizing, selecting and collecting information about the research subject, using author's articles, which have already gathered key information from a number of researchers of a specific topic together; the competitiveness of higher education institution is influenced by the internal factors that are formed by the internal environment of the higher education institution and external factors that are formed by the external micro-environment and macro-environment influenced by the state policy; an analysis of the internal and external factors of an institution is important in order to create competitive advantages in a higher education institution.
Key words: higher education institution, competitiveness, competitiveness factors.

Introduction

The competitiveness of higher education institution is a widely researched topic and this is very important in strategic management of higher education institution, identifying competitive advantages and creating new ones. Furthermore, the role of competitiveness of higher education institution is increasing according to changes in higher education sector overall – world-class universities, the USA phenomenon, classification in research universities and universities of applied sciences, the increasing influence of stakeholders, etc. Competitiveness can be defined as the ability of an organization to create and maintain competitive advantages (Dimitrova & Dimitrova, 2017). One more significant aspect in creation and identification of competitive advantage is determination of factors affecting the competitiveness of a higher education institution. Factor analysis is required in order to determine the variety of factors and classification possibilities. Competitiveness of a higher education institution characterizes its ability to meet the needs of internal and external stakeholders on the basis of available competitive advantages which are formed under the influence of set of internal and external conditions – competitiveness factors (Ashmarina, Khasaev, & Plaksina, 2015).

The research question for this scientific research is – what factors influence competitiveness in a higher education institution? According to the study, the object of the study is the higher education institution and the subject of the research – factors influencing competitiveness. The aim of the study is using systematic literature analysis method – literature overview – identify the factors, which affect the competitiveness of a higher education institution in the conditions of globalization. The following tasks have been defined to reach the aim – to conduct literature analysis about factors, which affect competitiveness of higher education institution, using the systematic literature analysis method – overview; to collect and analyse the most relevant aspects about factors influencing competitiveness of higher education institution; determine the factors influencing competitiveness for a particular higher education institution; to summarize the results of the analysis and draw conclusions.

The most effective way to select and analyse high-quality and appropriate literature for the relevant research issue is the systematic literature analysis. It is possible to obtain the most relevant results of the research question during systematic analysis of the literature, as well as to select the appropriate literature, focusing directly on the research question.

As one of the tasks is to determine the factors influencing competitiveness for a particular higher education institution, Riga Technical University (RTU) is chosen for analysis. RTU is a modern internationally recognized university. It is the only polytechnic university in Latvia and the largest university in the country – it educates and trains almost 15 thousand students. RTU is constantly developing its infrastructure by constructing a campus on Ķīpsala Island. On completion, the campus will be the most advanced engineering study centre in the Baltic Region.

Materials and Methods

During the research, qualitative methods were used – monographic method, analysis and synthesis method, as well as systematic literature analysis method – literature overview.

Applying overview method, more than 6000 scientific articles were considered to choose 20 full-text articles for in-depth analysis using the method PRISMA Flow Diagram. Scientific articles were selected from databases EBSCO and Web of Science. For data synthesis a tabular method was used and information was displayed chronologically.

Results and Discussion

Systematic literature analysis method overview is based on a chronological, thematic, conceptual or other analysis of the literature review with an aim to summarize the most relevant and specific according to the research question. The process of writing a literature overview can be divided into five stages - the formulation of a research question, literature search, literature screening, synthesis and final analysis (Booth, Papaioannou, & Sutton, 2012).

The research question for this scientific research was formulated using a three question method – who (who is the research question about?), what (what must the researcher find out to answer the research question?) and how (how will the study impact on the 'who'?), is – what factors influence competitiveness in a higher education institution? (Booth, Papaioannou, & Sutton, 2012).

The next step is to search appropriate literature according to the research question. To select the most relevant literature, it is important to define the right key words. In this scientific article the following keywords were chosen – competitiveness, higher education institution, global competition, factors that affect competitiveness. Using defined key words, 5107 scientific articles were obtained in EBSCO database. During literature search process two key words were used on each search stage and the following results were obtained – competitiveness *and* higher education institution (3821 scientific articles); higher education institution *and* global competition (846 scientific articles); higher education institution *and* factors that affect competitiveness (440). Correspondingly, in the database of Web of Science, 1258,351 and 40 scientific articles were found.

The PRISMA flow diagram designed to help scientists /researchers improve the overview of systematic literature analysis, will be used to compile and select the most appropriate records (PRISMA Flow Diagram, 2018). The diagram is based on four steps – identification, screening, eligibility and inclusiveness. According to these steps, scientific articles will be selected and a selection of records will be conducted with the aim of reaching at least 20 sources corresponding to the research question - which factors influence competitiveness in higher education?

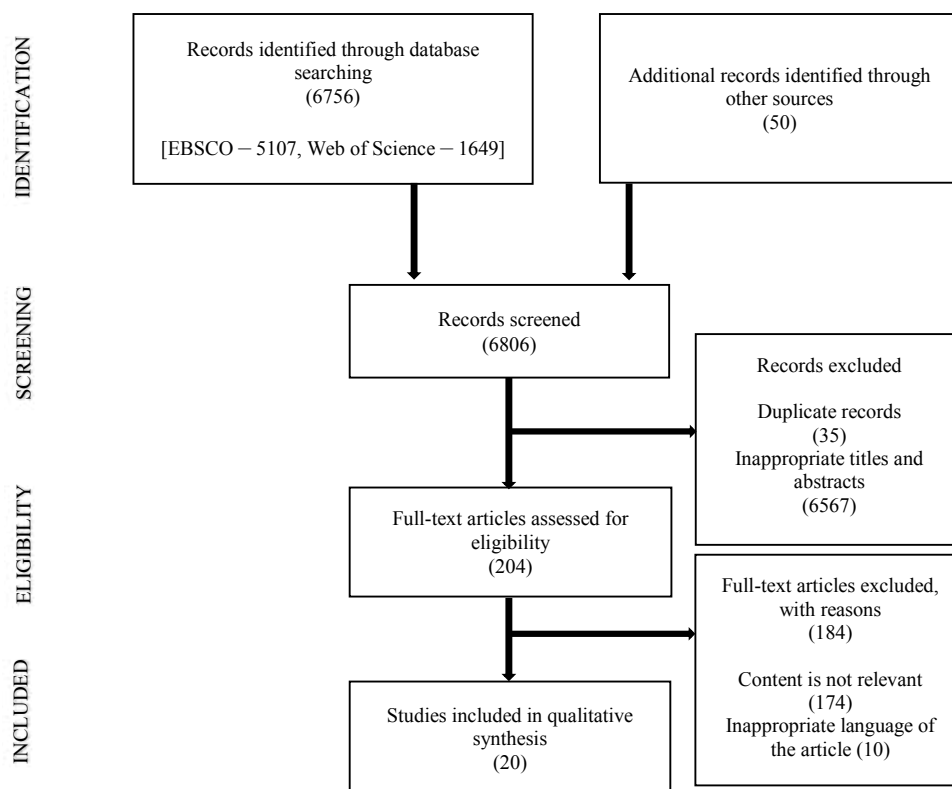Figure 1 shows a flow diagram.

Figure 1. PRISMA literature search flow diagram (designed by the authors according to (PRISMA Flow Diagram, 2018).

As a result, 20 entries were selected for inclusion in the literature overview. Scientific publications are mostly selected as well as some conference materials and paragraphs from books. The literature and source selection process is time-consuming, so defining and adjusting keywords in the selection process is important. Obtained results during literature search are summarized in Table 1.

According to applied systematic literature overview done in Table 1, in Table 2 is given an example of concrete University and factors affecting competitiveness of this higher education institution.

The core activities of RTU are teaching and learning, and continuous improvement in this field is also indicated in RTU Strategy. RTU provides prestigious, internationally recognised high-quality studies that educate and train internationally competitive specialists who promote growth of the national economy of Latvia and are able to participate in lifelong learning. RTU evaluates student satisfaction on the basis of regular student surveys and annual self-assessment reports of study programmes in order to address the identified weaknesses and continuously improve the study process. RTU graduates have a

Table 1

Factors affecting the competitiveness of a higher education institution: results of systematic literature analysis method overview

No.	Factors affecting the competitiveness of a higher education institution (HEI)		Relevance
	Group of factors	*Factors*	
1.	Internal factors of higher education institution competitiveness	Personnel, intellectual, material, financial, infrastructure resources	Theory of the resources and capabilities is relevant and useful in analysis of internal environment. Innovations, market segmentation, provided services, inimitability can be analyzed as internal capabilities. VRIO model is aimed to internal factors analysis – value, rareness, inimitability and organisation (Mainardes, Ferreira, & Tontini, 2011). Internal processes of HEI are classified in educational, research and administrative processes and internal factors – personnel, intellectual, material, financial, infrastructure (Ashmarina, Khasaev, & Plaksina, 2015). Resource-based strategic approach, which is based on identification of that kind of available resources and capabilities, which will be important in long-term and will ensure long-term competitiveness (Matkó & Szűcs, 2012).
2.	External factors of higher education institution competitiveness	Macro environment factors	Macro environment factors are caused by the policy of the state, these are social, scientific and technological, economic, political and legal. To define and analyse macro environment factors of competitiveness, different methods are applicable – - Porters' five forces model. First force is entry of competitors, second – bargaining power of buyers, third – bargaining power of suppliers, fourth - rivalry among the existing players, fifth – threat of substitutes. Sixth force - government's influence – is used in Porters' model modification and this sixth force is important in analyses of HEI (Mainardes, Ferreira, & Tontini, 2011). - PEST analysis – political factors (how government political decisions affect HEI), economical factors (how entrepreneurship is organized and affects development of HEI), social (cultural aspects, population, attitude to a career, level of education etc.) and technological factors (research and development, technological changes, innovations) (Matkó & Szűcs, 2012).
		Microenvironment factors	Different kind of relationship analysis – with society, with companies, with government, with potential students and power of students (Mainardes, Ferreira, & Tontini, 2011). The microenvironment factors are caused by the activity of the direct higher education institution environment – students, business community, society etc. (Ashmarina, Khasaev, & Plaksina, 2015).

3.	Other factors	Factors influencing the competitiveness of higher education institutions: the level of qualification of educational service providers; the image of a higher education institution; satisfaction of key players in education market services (Dimitrova & Dimitrova, 2017). International accreditation of study programmes; proportion of study courses in English of whole study programme study courses; the role of applied sciences universities in whole higher education system – competitiveness factors (Komárek *et al.*, 2017). Virtual academic mobility as a competitiveness factor – improves the competitiveness of University graduates (Absalyamova *et al.*, 2017). Competitiveness factors – quality of the input factors; financing; utilization of the financial resources; appropriate level and quality criteria of the education; internationality; technological development; international recognition (Labas, Darabos, & Nagy Tunde, 2016). Knowledge management as a competitiveness factor (Nguyen, Pattinson, & Scott, 2016). Striving for a world-level university – competitiveness factor (Chirikov, 2016). Globalization and valorisation - the drivers of competitiveness and the factors affecting it (Bagley & Portnoi, 2016). An intercultural environment as a factor in improving the competitiveness of higher education (Galkin *et al.*, 2015). Enterprise Resource Planning Systems as a factor affecting the competitiveness of a higher education institution (Soliman & Karia, 2015). Competitiveness of higher educational institutions depends on many factors – an educational activity; research work; international activity; financial and economic activity (Kobets & Masych, 2015).

Table 2

Factors affecting the competitiveness of a higher education institution: Riga Technical University

Types of competitiveness	Factors of competitiveness	Assessment indicators of competitiveness
Competitiveness of study process	Experienced teaching staff	1. The share of scientific and teaching employees having a Ph.D. and a Doctor of Science degree, in the total amount of scientific and teaching employees. 2. The share of full-time employees in the total amount of academic teaching staff. 3. Systematic upgrading of the academic staff competence. 4. University annually attracts highly qualified foreign guest lecturers from the European Union and beyond in order to strengthen the inclusion of international knowledge into University study process
	Study process - - developed study process - on traditional academic value-based study process - advanced teaching methods	1. University provides study programmes in 12 of 29 different study fields in Latvia. 2. Majority of the study programmes are in the STEM field. 3. The number of students studying at University is stable; however, the number of Latvian students drops every year. 4. Growing number of international students. 5. High percentage of alumni employment. 6. Improved and revised study programs. 7. The amount of additional education programs – life-long learning promotion.
	Innovation driven teaching process	1. Introduced new interdisciplinary study courses for innovative product development and entrepreneurship skills. 2. University's Design Factory provides students the opportunity to create and develop their projects using advanced prototyping devices and the latest technologies.

Competitiveness of study process	Renewed infrastructure (premises and equipment)	1. Infrastructure improvements to make the study environment more adapted to the needs of a student-centred learning approach. 2. Infrastructure improvements to ensure accessibility to the study facilities for students with disabilities, thus creating an inclusive study environment. 3. Reconstructed Scientific Library – common complex in the campus: new service and opportunities for users; available to students twenty-four hours a day, seven days a week, contributing to study accessibility. 4. Open-access laboratories available for students.
	Well-designed feedback system (for students and industry)	1. Student surveys and their feedback about the study process; regularly revised student survey questions. 2. Employer participation in the work of study field commissions. 3. Employer satisfaction with the competence of graduates.
Competitiveness of research process	Experienced, internationally recognized research staff	1. Increased selection requirements for professors to raise competitiveness amongst the potential candidates. 2. 3-year tenure track for professors. 3. Support system for young researchers. 4. Researchers attraction from abroad.
	Renewed infrastructure (premises and equipment)	1. Student campus is concentrated and suitable for the modern research process. 2. All faculties have included short-term, medium-term and long-term objectives and activities in their research programmes to provide better research environment and infrastructure.
	Well-structured research process	1. Research at University is organized in six inter-faculty research fields or research platforms: Energy & Environment; Information and Communication Technologies; Materials, Processes & Technologies; Transport; Urban Development; Safety & Security Technologies. 2. University funding is distributed among the structural units on the basis of research result quality and efficiency indices; the amount of the allocated funding depends on the quality of publications. 3. The Open Access Policy – to ensuring that all publications and research data by University researchers are open, will provide the opportunity to achieve better visibility of University researchers and develop networks.
	Study process integrated in research process	1. Student involvement in research activities and mobility programmes (vertical integration).
	Research staff renewal policy	1. The University Doctoral School is support mechanism for young researchers within the Doctoral Studies Department to improve research environment and quality of scientific work as well as to encourage interdisciplinary and inter-institutional cooperation among doctoral students. 2. University Research Excellency Grant for young scientists to ensure that outstanding and promising young researchers are able to start their researchers' career at University and develop their research in the direction of a high and internationally important perspective. 3. Post-docs are normally members of research project teams holding a position of researcher or senior researcher.
Competitiveness of valorisation process	Strong innovation and valorisation ecosystem	1. All faculties of the university take part in the valorisation process, which is coordinated by the following units: - *Department of Business Development and Investments*, which aims to establish and sustain long-term relationships with business and social partners, thus contributing to the increase in the number of contracts, as well as to attract investments to University, projects and to lease University real estate. - *Innovation and Technology Transfer Center*, which aims at promoting recognition of intellectual potential and innovation and technology transfer at University. - *Research Infrastructure and Technology Support Centre*, which provides access to University research infrastructure and resources (administrates UseScience *data base* and *High Performance Computing)*.

Competitiveness of valorisation process	Strong innovation and valorisation ecosystem	- Design Factory offers support to University researchers, students and staff in the fields of research, design, prototyping and education. - Business incubators: student business incubator in University branch, IdeaLab, and other. 2. The total amount of innovative products of the university.
	Experienced commercialization personnel to facilitated	1. University has structural units that give an opportunity to apply for business incubators – finances, human resources and other assistance are provided to students in order to successfully start their companies and create innovative products and services. 2. Involvement of students as well as academic and research staff in the process of new product development.
	Well-developed infrastructure (premises and equipment)	1. United study and research complex in Campus. 2. Efficient technology transfer and innovation development environment to promote creation of new technology businesses and products.
	Strong collaboration with industry	1. Well-developed collaborative networks fostering involvement in projects and contract work. 2. The amount of contracts/agreements to be made by R&D. 3. Research that is highly innovative and is investigating topics vital for the society and national economy. 4. Research programmes' activities provide commercial research services to companies and governmental bodies and targeted commercialization of new developments. 5. Growing income from contracts with entrepreneurs and institutions.

stable and recognised status in the labour market. The quality of education provided by the RTU is greatly respected by both Employers' Confederation of Latvia, which unites leading enterprises in the industry, and foreign companies – CERN, Daimler AG, ESA and other, who employ RTU Doctoral students, research staff and alumni. The quality of RTU studies has been approved by international students as well. Due to a wide range of study programs implemented in English, in the last three years the number of international students at RTU has tripled, amounting to 11% from the total number of students. RTU has foreign students from all over the world – a total of 70 countries.

RTU conducts internationally competitive research and cooperates with reputable international research institutions, such as the European Organization for Nuclear Research CERN, European Space Agency, Royal Institute of Technology, Sweden, Fraunhofer Institute, Germany, and other.

RTU is the leader in research and innovation in the Baltic States. University research is an integral part of the study process. RTU Research Programme is a constituent part of RTU Development Strategy. Research at RTU is organized on six research platforms based on active and continuous analysis of market needs and commercial potential. The objective of research platforms is to ensure multi-faculty and interdisciplinary research in the areas of great significance for the national economy and society.

Nowadays the role of a university is broader than before, since the outcomes expected from the society are not only linked to the academic and research capacity, but are also related to the third mission of higher education institution and its role in the society. RTU actively promotes technology transfer and innovation processes by supporting continuing education and is active in social engagement and interaction with the society.

RTU has declaimed valorisation – new product development and commercialization activities – as its third priority. Valorisation includes innovation, technology transfer and commercialization; therefore, special attention is paid to creation of new innovative technologies, their development and commercialization promoting establishment of new enterprises by students and members of academic personnel.

Conclusions

1. Systematic literature analysis method overview is a convenient tool for systematizing, selecting and compiling information about the research question using author's articles, which have already gathered key information from a number of researchers of a specific topic together.
2. In order to create competitive advantages for higher education institution, an analysis of the institution's internal and external factors is important.
3. The competitiveness of a higher education institution is influenced by internal factors, which are formed by the internal environment of a higher education institution - material, financial,

personnel, infrastructure and other internal resources, and external factors formed by the external micro-environment (students, society as a whole) and the macro environment influenced by national policies (social, political, economic, legal, scientific and technical factors).

4. Analysing the macroeconomic factors PEST analysis can be used, which divides the macro environment into the political, economic, social and technological category, as well as there is a possibility to increase the number of categories by adding an analysis of cultural, environmental and other factors. This analysis method is used for strategic planning.

5. The Porter five-force model, which analyses the power of buyers and suppliers, threat of competitors, potential competitors and substitutes can be used to analyse external macro-environment, thus identifying existing positions and creating competitive advantages.

6. The VRIO model (value, rarity, imitability, organization) that describes the institution's internal resources and abilities can be used in internal factor analysis. This analysis shows how the existence of resources, competences and individuality makes a difference to one organization on the other, thereby creating a competitive advantage.

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TOPICALITY OF CAREER GUIDANCE AT SCHOOLS FOR PROMOTING OF STUDENTS' PROFESSIONAL SELF-DETERMINATION

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Abstract
Professional self-determination is an important issue for anyone in the course of a lifetime. The dynamic nature of modern social and economic circumstances makes the issue even more topical. It determines the necessity to improve the career development support system currently existing in the field of education, where various specialists, by purposeful and systematic cooperation, help students in setting their career goals, understating the changeable working environment, seeing various alternatives and making deliberate career decisions. The career support is important as it helps learners choose a suitable professional sphere, profession and educational institution for continuation of their self-improvement upon acquiring of general secondary education. *The aim of the research* is to provide a scientific basis for topicality of career guidance implementation in school educational environment in order to promote the students' professional self-determination. In Latvia, a number of career development guidance systems, including counselling and student career support methods and forms are being created and approbated in the educational environment, focusing on the career support curriculum and principles, which would ensure a purposeful implementation of students' professional self-determination at schools.
Key words: career development, career guidance, pedagogical facilitation, psychological-pedagogical support, professional self-determination, educational environment.

Introduction

Nowadays, in our dynamic and rapidly changing world, a person must be a self-actualized and competitive personality capable of critical self-esteem and evaluation of personal abilities in order to find the optimal self-determination way for personal fulfilment. Learning to find the ways of making the most appropriate decisions, the learners must develop the ability to tolerate the uncertainty by creating the comprehension of changes taking place in the world, accepting these changes and understanding what to do in order to live in harmony with them rather than suffering from livelong discomfort and unawareness of what will happen with them, what should they do.

The sphere of education in general education schools is affected by social, economic and political changes taking place in the world. It is vital that youngsters understand their professional life path after the acquisition of general secondary education, while the teachers are to understand how they can help the upper school students in a purposeful, systematic, consistent way in line with the modern requirements. Therefore, any contemporary school must be aware of the possibilities to render support and assistance to young people in facilitation of their professional self-determination, as the practice shows that this process has mostly irregular nature, moreover, this process lacks the coordination with the professional plans of the students, the progress of their interests, educational institutions, programmes and the choice of profession.

To achieve the major changes both in the field of education and in the society, it is important to ensure the career support for the upper school students. Based on theoretical research, we can establish the theoretical insights related to the qualitative implementation of a career development support system in the sphere of education in terms of creation of professional self-determination among young people.

The aim of the research: to provide a scientific basis for the notion of career guidance and the topicality of its implementation in the educational environment for promoting the student professional self-determination.

Materials and Methods

This scientific article consists of the results of theoretical studies analysing the theoretical and practical insights of various scientists on career support in the sphere of education.

Research methods: study of theoretical literature; analysis and evaluation of scientific literature; reflection of personal pedagogical experience.

Within the context of career guidance, the theoretical basis for research of learners' professional self-determination is the following:

- *Western theories of career self-management* (Akkermans *et al*., 2013; Alhaddad, 2014; Hooley *et al*., 2013; King, 2001; King, 2004; Kossek *et al*., 1998; Kuijpers, Meijers, & Gundy, 2011; Lengelle *et al*., 2014; Mackay *et al*., 2015; Paradnike, Endruiulaitiene, & Bandzeviciene, 2016; Raabe, Frese, & Beehr, 2006; Sturges *et al*., 2005).
- *the theories of professional self-determination existing in Russian science* (Дереча, 2005; Климов, 2010; Кузнецов, 2015; Лесовик, 2006; Муратова, 2008; Предигер, 2013; Пушкина, 2012; Воронина, 2013).

The results of theoretical studies serve as philosophical and methodological framework for

creation of the career support system models, their empirical approbation and implementation in various general secondary education institutions in Latvia. The research is carried out within the project "Career support for young people at comprehensive and vocational education institutions (2016 – 2020)" being held under the EU financed Operational programme "Growth and Employment".

In this paper the authors offer a part of their theoretical research results.

Results and Discussion
Insights of the theoretic research related to pedagogical support in the process of professional self-determination of students

The upper school students of general secondary education institutions must understand that the support rendered to them in the course of making their professional choice will help them in taking important decisions. Purposefully organised pedagogical support in the educational environment can ensure a systematic and consistent assistance for pupils who need it in the course of their professional self-determination, helping to understand themselves, as well as to become aware of the needs of the society and the surrounding environment. The research examines a number of studies on pedagogical support, its planning and implementing, as well as the studies on pedagogical support systems, on the necessity of the support in the process of professional self-determination and pedagogical facilitation, as well as the research on changes necessary during the training and education process for implementation of a pedagogical support in schools.

The necessity for a timely, systematic and well-organised pedagogical support of students in the process of their professional self-determination

E. Voronina (Воронина, 2013) makes an important finding that the best results in the process of professional self-determination are ensured by a timely and methodologically correct pedagogical support. Considering the contemporary life and situation in education, the self-determination of a person is formed under contradictory circumstances, therefore, it is important to create a system which would promote the professional self-determination of pupils in terms of their individual traits, abilities, interests and regional demands. This process has the greatest importance at the age of 16 – 18, when a person is in search of his or her personal identity, trying to answer such questions as: Who I consider myself to be? What kind of person am I? How do I find my niche in life? E. Voronina offers the principles of the arrangement of a pedagogical support system, providing for a cycle of preventive and operative

studies focused on the introduction of the world of professions, understanding the personal treats of the pupils and the development of a realistic self-esteem, awareness of the demands existing in the modern job market and available education possibilities, the legislation in the field of technologies and professional activity, acquisition of skills in self-introduction and career planning.

I. Derecha (Дереча, 2005), providing a theoretical consideration of the necessity of the pedagogical support, emphasizes that the modern life requires that a pupil is able to make an immediate decision in case when a choice must be made. Therefore, the ability to make decisions in the changing social and economic environment helps pupils understand that the choice must be made among multiple options, which the youngsters must evaluate in terms of various situational aspects and choose the one that meets both their inward nature and the requirements of the surrounding environment.

Whereas, I. Lesovik (Лесовик, 2006) describes the system of pedagogical support, which is purposefully focused on the professional self-determination of an individual. The pedagogical support model elaborated is described as a system of psychological and pedagogical tools guiding the pupils in the process of their professional choice, developing their value system, abilities, self-awareness, enhancing their competitiveness and adaptation to rapidly changing job market conditions, as well as implementation of a professional career. This model provides for a beneficial cooperation among teachers, pupils and parents, which can be achieved by the purposefully selected means, diversified and variable forms of pedagogical support by ensuring a comprehensive approach to solving the pupils' professional self-determination issues.

At the same time, as it follows from E. Klimov (Климов, 2010), prior to the rendering support to young people in the process of their professional self-determination, it is important to understand the aim and the point of such support, to define the perspective of personal development depending on the choice of the profession and further professional education. The pedagogical support must be theoretically justified and systematically correctly planned. A. Muratova (Муратова, 2008) offers the stages of pedagogical support, such as: 1) the stage of screening – determination of a problem; 2) the stage of searching – looking for the problem causes together with a pupil; 3) the stage of coordination – planning of activities of a teacher and a pupil, defining the functions and the responsibility of each of them in solving the problems; 4) the stage of activity – the actions are taken by both the pupil and the teacher; 5) the stage of reflection – mutual discussion of the achievements and failures

on the previous activity stages, stating the ways and methods of problem solving or restating of problems for continuation of the activity.

The promoting role of a teacher in providing the career guidance to students

Validating the aspects of pupils' professional self-determination, many scientists and academic authors underline the importance of promoting or encouraging the function of a teacher as an essential activity principle in providing the career support, qualifying it as *pedagogical facilitation* (Кузнецов, 2015; Пушкина, 2012). The studies focus on two types of facilitation: *social facilitation* and *pedagogical facilitation.* With reference to the studies by O. Pushkina (Пушкина, 2012), the notion of *pedagogical facilitation* implies the purposeful process aimed at simplification of the educational process and enhancement of the efficiency of a teacher-pupil interaction contributing to professional self-determination and personal self-development, and promoting the self-organization and self-improvement skills.

To implement the process of education involving the personal development, the teacher can use various forms and methods in his or her work. M. Prediger (Предигер, 2013) states that it is important to develop a subjective and reflexive experience as pupils are not ready for serious self-development, their self-development motivation is low. Therefore, the motivation for a successful professional self-determination can be only ensured by a purposeful pedagogical cooperation, which provides the support or assistance and which must be implemented in the form of interaction between a pupil and a teacher in the process of education.

The experience in implementation of career support is different throughout the world. This is the reason for the differences in types of career support services and the specialists who render support to pupils during the process of professional self-determination in educational environment. In Latvia, it is a Career Counsellor and a Teacher-Career Counsellor. Pedagogic guidance as a process is a complex of purposeful consecutive and constant activities, it is a system of career development support, which helps pupils understand the life situation occurred and ensures their self-development based on reflection of this situation. It creates various conditions for a pupil to take the optimal decisions in various life situations when a choice must be made, as well as to accomplish themselves in any social and economic conditions.

The educators' knowledge of student self-determination (including career self-determination) influences the pedagogical support in the context of career guidance at school (Thoma *et al*., 2002).

Facilitating student self-determination can be difficult (Thoma, Rogan, & Baker, 2001; Thoma *et al*., 2002), therefore it is very important to include the career theories, educational content of student (including student with disabilities) career self-determination and career guidance in teacher education.

Theoretical justification of career guidance in studies by foreign scientists

The notion *career*, which is not so popular among Russian scientific researchers, is used within the context of professional self-determination. E. Klimov (Климов, 2010) characterized it as the achievement of the heights of mastery. However, at the same time, he notes that a professional life path is not striving for higher positions but moving up the scale of mastery and activity types, which is evaluated according to the efforts invested and the results achieved for the benefit of society.

Such terms as *career guidance* and *career support* are used in the studies carried out in Western Europe and other countries when speaking about the development of professional self-determination and career guidance skills.

Guidance is a multidimensional activity established in different contexts with varying meanings to different practitioners. In some literature, the terms educational, vocational, career guidance and career counselling are used interchangeably. The problem of definition is also compounded by the fact that different countries refer to persons performing guidance duties in different terms. Thus, we find reference to guidance counsellors (e.g. Flemish speaking Belgium, France, Greece, Iceland and Ireland), career education officers (Iceland), study counsellors (Finland), career path counsellors and school godmothers (Czech Republic), guidance teachers (Malta) and others (Sultana, 2004; cited from Debono *et al*., 2007).

The notion *career support* mostly implies a moral, mental support, while the notion *career guidance* is used to denote an advice, recommendation, the process of professional orientation, at the same also using such terms as *occupational guidance* and *vocational guidance* (Athanasou & Van Esbroeck, 2008). *Career guidance* within the context of Western Europe and the world is theoretically and practically based on many various aspects, starting with the globalization and the world's social context, various degrees of education, types of activity and changeable job market, and up to the context of ethical values, cognitive thinking and other aspects, revealing the broadness and versatility of the term. The notion of *career guidance*, the same way as the notion *career*, can be viewed as an interdisciplinary construct combining the insights in the field of psychology, pedagogy, sociology,

economics and other branches of science, as well as theoretical and empirical studies in the respective fields (Greenhaus & Callanan, 2006). The notion *career guidance* is often used as an alternative for *career education*. However, it must be noted that *career guidance* is a more systematic process ensuring self-appraisal of a person, providing information about the world of work in order to simplify the development of an individual career and to train the decision-making skills. *Career guidance* can be considered as one of *career education* components (Greenhaus & Callanan, 2006). In addition, the notion *career guidance* is often mixed with the notion *career counselling*, which is one of the ways for career support implementation during the process of career development (Spencer & JoAnn, 2002). In the study by I. Luobikiene (Luobikiene, 2015), the notion of *career guidance* is defined as an individual help in making a reasonable choice of appropriate education and occupation possibilities, receiving the career education, career information and career counselling services.

As of 2006, when the notions *career guidance, career guidance system, career development guidance, career development guidance system* started to be used in the Latvian educational environment instead of the term *professional orientation*, the following elements constitute the system of career development support: informing, career education and career counselling. (Hansen, 2006). The notion of career support is defined in numerous scientific researches carried out in Latvia (Jaunzeme, 2011; Pāvulēns, 2016; Pranča, 2014; Pudule, 2013) by reviewing the notion within the context of a general education school, vocational and higher education, as well as within the context of occupation, associating the understanding of the notion with the issues of career education, career guidance and choice of profession. I. Mikelsone (Miķelsone, 2008) defined the notion *career development guidance* as a complex of activities with the aim to teach a person how to make decisions when choosing education or profession throughout his or her life by means of self-cognition.

Changes in implementing the career guidance in the Latvian educational environment

In the educational sphere in Latvia at present there has been highlighted the issue on both the development of competency-based learning curriculum and the possibilities to ensure career development support at educational establishments, which would be centred on pupils and the facilitation of their self-determination under the changing conditions of educational environment and labour market.

At the moment, not every educational institution in Latvia has a purposefully elaborated system of pedagogical support which would help young people in the process of their professional self-determination. Nevertheless, rendering support to learners in the process of their professional self-determination has been always a topical issue on the national scale, at the local government level and also at the school level. Currently the scientific environment of Latvia is concerned with elaboration of support models, which would be the most appropriate for every certain situation and ensure the efficient support of youngsters in making their decisions allowing for self-fulfilment in their chosen career area.

The process of pedagogic cooperation in education environment contributes to professional self-determination of a pupil, which is a very important aspect within the context of globalisation and changeable job market, therefore the above mentioned theoretical insights must be used as a philosophical and methodological basis for creation, approbation and implementation of the career development guidance system models in various general secondary education institutions of Latvia participating in the EU financed Operational programme *"Growth and Employment"* (Operational Programme…, 2014), the project *"Career support for young people at comprehensive and vocational education institutions"*. Within this project, the availability of career support services for learners is planned to be increased in 308 general secondary education institutions and 20 vocational education institutions. It will be achieved by instituting a position of a Teacher-Career Counsellor or a Career Counsellor at every school involved in the project. Before the project was commenced in 2016, the career guidance for students was rendered by the respective supervising teachers, school administration and/or school psychologists within their competence. This project though implies a teamwork of various support specialists, including Career Counsellors and/or Teachers-Career Counsellors. It has been observed that a number of schools have tried to systemise the availability of career guidance within their educational institutions, and in certain cases, it was also achieved by cooperation with local authorities. However, no conceptual and systematic coherency can be observed among the educational institutions, local governments and state authorities. The situation might improve after some of the career guidance models start working within the project "Career Guidance in General and Vocational Education Institutions", which would ensure a consistent and systematic approach to the career guidance for any student attending general or vocational education school. Consequently, further studies of career guidance availability to students within the project implementation period are required to identify the career guidance models and define the efficiency of such models in various local government educational institution of Latvia. It would allow to

ensure the career guidance during the entire school period for learners of any age – from preschool age until acquiring secondary education. In order to ensure the local labour force in the educational and working environment, it is essential, when assessing the existing resources, their potential and weaknesses, as well as the developmental opportunities and challenges of sustainable society, to implement the conception of a local scale career support system, which would provide long-term return and, as a result of the implementation of which there would be facilitated the professional self-determination of young people.

The family is one of the main factors which influences the student career self-determination, therefore it is very necessary to cooperate with the members of student families (Epstein, 1992; Whiston & Keller, 2004). The authors' pedagogical experience testifies that Latvian schools have good practice in this field.

Conclusions

1. School years play an important role in the process of personal self-determination, when young people have to decide about their future professions and careers, by purposefully defining the stages of self-development.

2. To facilitate and promote the process of professional self-determination of youngsters, schools have to ensure the career support with the focus on rendering assistance, encouragment, promotion or facilitation, making young people feel secure about their future in the circumstances of unstable and changeable environment.

3. Special attention in the career support has to be paid to pedagogical and psychological support to ensure that a pupil can easier adapt to real social and economic environment, certain job market conditions, and be able to focus not only on the necessities in a certain situation but also to consider possible changes in the development of society and to adjust to the needs accordingly.

4. The studies by Russian scientists discuss such notions as *pedagogical support* and *psychologically pedagogical support*, including the term *facilitation*.

5. Scientific research carried out in Western Europe and other countries, when speaking about the professional self-determination in the educational environment, mentions the notion *career support*, which is theoretically and practically based on various aspects, revealing its broadness and versatility in terms of three functions: informing, career education and career counselling.

6. A number of notions exist in Latvian educational environment: *career guidance, career guidance system, career development guidance, career development guidance system.* These notions are closely interlinked and actually denote the same, i.e., the role and the function of teachers in the promotion and facilitation of the process of professional self-determination of pupils.

7. In Latvia, a number of career development guidance systems, including counselling and pupils' career support methods and forms are being created and approved in the educational environment, focusing on the career support curriculum and principles, which would ensure a purposeful implementation of pupils' professional self-determination at schools.

8. Upon starting the activity of Career Counsellors and Teachers-Career Counsellors in Latvian schools, various career guidance models, methods and forms are being created and tested in educational environment by focusing on the content and the principles of career guidance, which would systematically facilitate professional self-determination of students in schools and ensure the availability of career guidance for every learner during the entire school time.

9. It is also important to analyse various theoretical insights and, considering the results of approbation, to improve the career guidance system in Latvian schools and to understand the situation so that it is possible to provide recommendations aimed at ensuring more efficient career guidance in the educational environment.

10. These are the objectives of further practical researches which can be implemented considering the main theoretical insights analysed herein related to the career guidance during the process of professional self-determination of students, and combining both the theories of professional self-determination and pedagogical support existing in Russian science, and the Western theories of career self-management and career guidance theories.

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INNOVATIVE METHODS AND APPROACHES TOWARDS THE DEVELOPMENT OF THE STUDENTS' ENTREPRENEURIAL COMPETENCIES

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Abstract
In educational strategy papers, it is determined that entrepreneurial development should be implemented already in schools. Various methods and approaches can be used for the development. The majority of entrepreneurial competences are developed at the university – subjects devoted to the development of entrepreneurship are included in the study programs. Environment of the university is very friendly to this – not only because of activities devoted to entrepreneurship occurring in the academic environment, plenty seminars and trainings, but also because of the students' personal maturity and motivation. Scholars actively raise the following questions: how to develop entrepreneurial competences effectively? Which methods are the most applicable? What kind of innovative methods are the most necessary? 104 students, who tried simulation traineeship of entrepreneurial development, were questioned in order to analyze the impact of methods and the change in entrepreneurial competences. The research was carried out in the Faculty of Economics and Management of Aleksandras Stulginskis University. The participants of the research were involved in the business simulation, where they had an opportunity to estimate themselves and improve their backgrounds, abilities and skills. Methods promoting and developing creativity were applied in simulation business enterprises; however, not all methods had worked. The methods of graphic representation were used by the minority and they were not considered to be very effective. The aim of the research was to determine entrepreneurial competences and innovative educational methods theoretically and to test empirically the development of entrepreneurial competences via simulation method.
Key words: methods of innovative education, entrepreneurial competences.

Introduction

Many scholars search and analyze entrepreneurial competences and educational methods. However, this is still a relevant subject to scientific analysis due to the fast changing person whose competences are being developed. The main problem of all systems is that the person has to estimate his entrepreneurial competences on his own – there is no system, which would help to develop a portfolio of entrepreneurial competences.
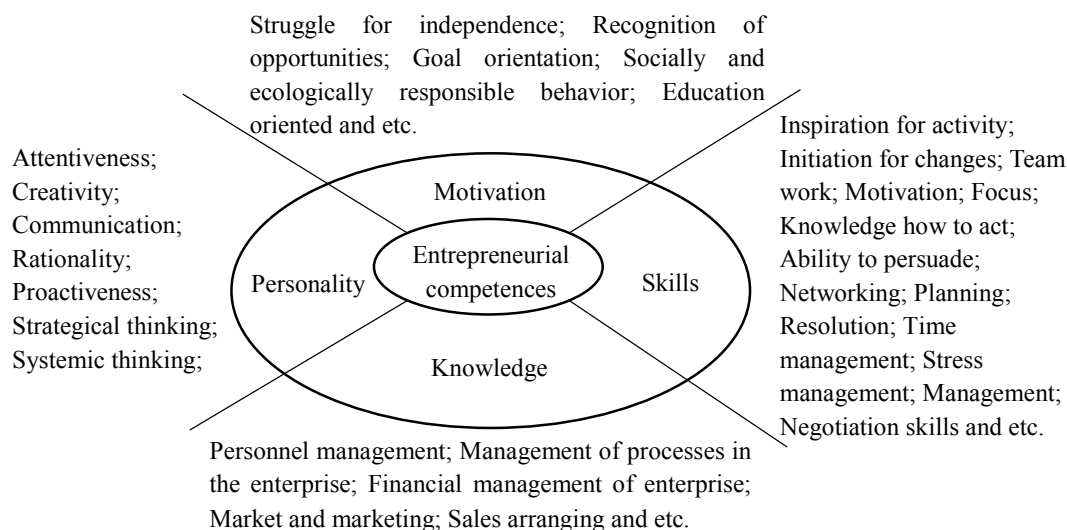
The aim of the research was to determine entrepreneurial competences and innovative educational methods theoretically and to test empirically the development of entrepreneurial competences via simulation method.

In some cases (Robles, Zárraga-Rodríguez, 2015), there is an aim to determine the essential entrepreneurial competences; however, the researchers follow the holistic approach – entrepreneurial competences are combined and integrated sets of person's knowledge, skills, views, personality and motivation (Driesen & Zwart, 1999; Kyndt, Baert, 2015; Lans, 2014; Schachter *et al.*, 2015), which create the potential for the entrepreneurship.

Scholars (Schachter *et al.*, 2015; Estrin *et al.*, 2014; Schelfhout *et al.*, 2016; Ismail *et al.*, 2015; Lans *et al.*, 2014; Donnellon *et al.*, 2014; Driessen & Zwart, 1999) present different and individual sets of characteristic features, which, in general, can be identified as entrepreneurial competences of entrepreneurial person (Figure 1). Entrepreneurial competences are very individual – if the person has

entrepreneurial competences, it does not mean that he will become a businessman. This is caused by many objective and subjective factors, external business environment conditions (Stamboul *et al.*, 2014). It is often an open question – whether entrepreneurial competences are inherited or gained? However, it is recognized (Garalis & Stazdienė, 2006) that the level of entrepreneurship and motivation will be higher in that case if entrepreneurial competences are developed. The scholars agree that experience influences person's entrepreneurship significantly; however, dynamic business environment causes the fact that gained knowledge and abilities have to be developed constantly. Development of entrepreneurial competences include knowledge transfer, development of skills and formation of personality. According to Henry (2005) *et al.*, it is very important to develop students' entrepreneurship in the environment close to real business.

Mueller & Anderson (2014) state that the problem of the development of entrepreneurial competences is the fact that entrepreneurial competences are integrated and complex objects; therefore, simple methods are not enough for the development of these competences. According to Jansen (2015), it is necessary to create the whole "ecosystem" of the development of entrepreneurship, which includes lectures, business orders, practices, meetings with successful businessmen, instruments for financial support, etc. The education of entrepreneurial competences is only a tool helping to prepare, improve skills and knowledge. Also, it is often highlighted that

Struggle for independence; Recognition of opportunities; Goal orientation; Socially and ecologically responsible behavior; Education oriented and etc.

Attentiveness; Creativity; Communication; Rationality; Proactiveness; Strategical thinking; Systemic thinking;

Inspiration for activity; Initiation for changes; Team work; Motivation; Focus; Knowledge how to act; Ability to persuade; Networking; Planning; Resolution; Time management; Stress management; Management; Negotiation skills and etc.

Personnel management; Management of processes in the enterprise; Financial management of enterprise; Market and marketing; Sales arranging and etc.

Motivation

Personality — Entrepreneurial competences — Skills

Knowledge

Source: developed by Schachter *et al.*, 2015; Estrin *et al.*, 2014.

Figure 1. Structure of entrepreneurial competences.

methods driving creativity are very necessary for the education of entrepreneurship.

Consequently, it can be stated that education of entrepreneurial competences is a dynamic process, where methods and other measures used for the education of entrepreneurial competences should be updated regularly. Methods can be divided into provided methods, for instance, methods driving creativity, resolution, and methods simulating real situations and this particular method is adapted in studies of management from medical studies. The majority of scholars has the opinion that students do better when active simulation methods are included in learning process. This is due to the fact that simulation method helps to try activities in safe environment and students are not to be afraid of results and mistakes (Hyun & Kim, 2015; Shin *et al.*, 2015). According to Walters *et al.*, (2017) a simulation method improves participants' knowledge, increases motivation and improves competences. Simulation is applied effectively in medicine and this adapted method can be used in management studies, when simulation business enterprises have been developed. Meanwhile simulation has been connected to the theory of experiential learning and the so-called game method is used to achieve the desired results (Guardia *et al.*, 2014).

In order to develop entrepreneurial competences, the following four dimensions should be developed: creative thinking, graphic thinking, provocation creative technique and resultative thinking. These dimensions can be improved while applying various methods, which in one or another way contribute to the development of each personal entrepreneurial competence. The educational simulation method of entrepreneurial competence has to be composed of

mentioned four dimensions:

Creative thinking (the following entrepreneurial competences are developed: attentiveness, creativity, communication, rationality, pro-activeness, strategical thinking, systemic thinking).

Applied method – Lotus flower. The most important thing in this method is to ensure that students would not lose the main idea – all other ideas should complement the idea which is in the center of lotus flower. At the very beginning the main idea, problem, question or situation is written in lotus center. In the second stage 8 petals are drawn and each petal is filled with solution related to the issue (Misiukonis *et al.*, 2015).

Applied method – SCAMMPERR. This is a method, which promotes the generation of new ideas within several elements. S – substitute (possible alternatives), C – combine (to blend, combine, mix, learn to use one instead of another), A – adapt (adaptation is more complicated process than general linking. In this case, we change the general functions of linked elements), M – magnify (to maximize, boost), M – modify (to modify, change), P – put (to find another way to use a product), E – eliminate (to remove, delete), R – rearrange (to change the order), R – reverse (to turn everything upside down). This method can be used all day in that case if students perform every action consistently while discussing and working out final solutions (Buzys, 2016).

Graphic thinking (the following entrepreneurial competences are developed: inspiration for activity, initiation for changes, teamwork, motivation, focus, knowledge how to act, ability to persuade, networking, planning, etc.)

Applied method – Visualization. This method is appropriate for discussion of results and expression

of opinion. Students can be asked to draw or work with a colleague. Also, they can be asked to search relevant examples of solutions on the Internet, group and schematize findings and provide suggestions. This method can encourage students to provide suggestions in a creative and non-standard manner. In addition, the program canva.com can be suggested to the students as a tool for visualization. This program is free and every user can use various designs, present collected information in an interesting way and learn new ways of creation on their own.

Provocation creative technique (the following entrepreneurial competences are developed: struggle for independence, recognition of opportunities, customer orientation, goal orientation, socially and ecologically responsible behavior, education oriented, etc.)

Applied method – World café. This method is useful when there is a need to share information, create informal dialogue and relation, provoke bigger discussion with large groups, solve complicated, difficult questions and find solutions, to promote person's responsibility for the results. Participants sit by the tables and discuss about suggested topic, identify the main ideas and share them with other participants sitting by other tables (Misiukonis *et al.*, 2015).

Resultative thinking (the following entrepreneurial competences are developed: personnel management; management of the processes in enterprise, financial management, market and marketing)

Applied method – Diary. This method is applied in all stages of the process. Participants in advance are asked to identify all their feelings, questions, contradictions, joys and failures. It is very important to start a diary from the first stage of the process in order to form a habit of filling the diary. The diary should be anonymous and not discussed publicly – it goes to enterprise as a written document and becomes an additional source of information about the improvement of the possible involvement process (Buzys, 2016).

A combination of selected entrepreneurial competences has to be applied to each dimension and the developed combination should be promoted during methods selected to each stage of thinking. Modern students change very rapidly; thus, it is important to search innovative educational systems constantly and to evaluate the achieved result, for example, personal portfolio of entrepreneurial competences.

Materials and Methods

While organizing and performing empirical research the systematical framework was followed – in order to solve problems, to learn about phenomenon, it is necessary to apply various quantitative and qualitative research methods (Žydžiūnatė, 2017;

Kardelis, 2016). In this case, qualitative research was compiled with quantitative research.

The aim of the empirical research was to determine the importance of innovative educational methods in the field of the development of students' entrepreneurial competences.

In order to perform empirical research, a method of case analysis was chosen. Simulation practice of education of entrepreneurship in the Faculty of Economics and Management in Aleksandras Stulginskis University was chosen as case for analysis. In order to collect necessary data, methods of document analysis and surveys were applied. Principles of simulation development of entrepreneurship were identified after the document analysis. In order to evaluate the importance of this practice in developing students' entrepreneurial competences, a survey was carried out. 104 students, who had this traineeship in the spring semester in 2017, were surveyed. Authors of the article performed a role of consultants during the traineeship. They took into consideration their insights and opinions while analyzing received results of survey.

A questionnaire was composed of several blocks of questions. Firstly, the aim of the first block was to collect data about respondents as well as their general characteristics. Due to the fact that the traineeship of simulation entrepreneurial development was aimed to improve students' knowledge gained while studying different subjects at the university, in the second block of questions students were asked to evaluate their gained knowledge of different study subjects (10 point scoring system). Also, respondents were asked to estimate the possibility to reach the full potential of their personalities during the traineeship. The other block of questions covered challenges, which prevented the reach of the full potential of students' entrepreneurial competences during the traineeship of simulation entrepreneurial development. During this traineeship various nontraditional methods were applied; thus, respondents were asked to estimate importance and efficiency of each method. The last block of questions asked respondents to estimate the change of knowledge, abilities and skills during the traineeship of simulation entrepreneurial development. In order to assess the change in the reach of full potential of personality, challenges, methods and measures, knowledge, abilities and skills, the scales were used, in which 6 – significant change/challenge, 1 – no change/challenge.

The general characteristic of respondents: during the spring semester of 2017, 124 students participated in traineeship of simulation entrepreneurial development. 104 students participated in the research. Students participating in traineeship studied in different study programmes: Logistics and Commerce

(3rd year), Administration of Rural Development (3rd year), Management of Rural Development (3rd year), Culture and Tourism Management (3rd year), Applied Economics and Business Analysis (3rd year), Accounting and Finance (4th year). According to sex, respondents distributed as follows: 46.2% – men, 53.8% – women. While defining the profile of respondents, it is important to highlight that 79.8% of respondents has an experience as employees, 19.2% of respondents has an experience in their own business and 30.8 percentage of respondents has intentions to develop their own business.

Results and Discussion

Presentation of the traineeship of simulation entrepreneurial development. Students of the Faculty of Economics and Management of Aleksandras Stulginskis University are participating in the traineeship of simulation entrepreneurial development. This is the obligatory subject for the final year students. The main principle of traineeship – students participate in an intensive one-month course where they establish simulation business enterprise, elect a manager. 4 simulation business enterprises are established while organizing traineeship. Elected managers form their teams, which are composed of students studying different subjects. In each business, an enterprise activity is carried out in four departments: Department of Marketing and Sales Management, Accountancy and Finance management, Production and Procurement Management, Personnel Management. The main purpose of this traineeship is to improve gained specialist knowledge, promote students' awareness regarding entrepreneurship, develop students' management, technical and personal skills, develop students' entrepreneurial competences. In order to achieve this aim, simulations occur – the enterprise is established and its produced goods or services have been sold. The course is intensive, employees of the enterprise attend the course daily as

they would go to work and perform all planned tasks, in order to achieve the main goal of enterprise – to generate profit. Various entrepreneurial competences – from general to specific – are developed. During the traineeship students often have to leave their comfort zone and achieve their goals and this is the time when great changes occur and students understand the main goals of the traineeship. University teachers, who are specialists of finances, management and marketing, work with students during the traineeship. During the traineeship teachers play a role of consultants. They answer students' questions regarding business activity, mentor the implementation of the tasks and give the final evaluation. The agenda of the traineeship of simulation entrepreneurial development is composed while trying to consolidate students' gained knowledge and to help learn or consolidate entrepreneurial competences.

Presentation of research results. Respondents were asked to evaluate their knowledge gained during studying different subjects and which were necessary while performing tasks given during traineeship. The research results suggest that respondents evaluated themselves averagely. The evaluation is between 6 and 8 (10 point scoring system): management – 7.8, human resource management – 7.7, accounting – 6.6, finance management – 6.8, marketing – 7.8, business information systems – 7.5. Such research results occurred because the respondents part of subjects studied in early years; moreover, students of different programme studies separate subjects not at the same level. Thus, during the traineeship students had to search additional information, pay a lot of attention to studies on their own, because they feel a lack of some knowledge, specifically, in the fields of accounting, finance management, management of business information systems.

Not only knowledge, experience and motivation are important in business – certain moral, psychological preparation and personal characteristics
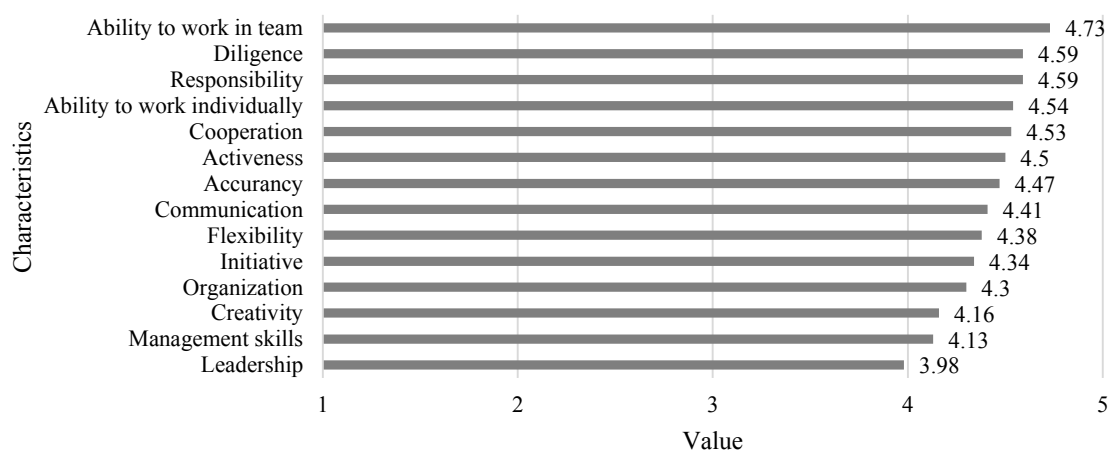

Figure 2. The growth of personal potential during traineeship of simulation entrepreneurial development.
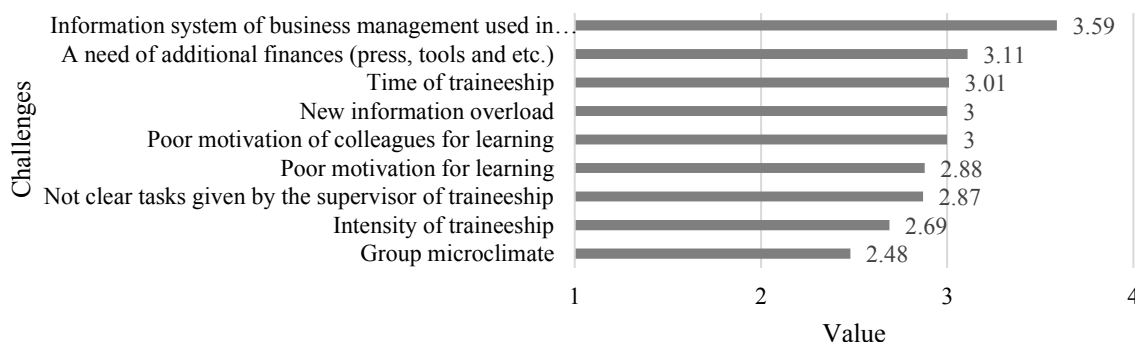
Figure 3. Challenges for the development of entrepreneurial competences during TDE.

play an important role as well. During traineeship of simulation entrepreneurial development every student has an opportunity to choose what kind of position – a manager or specialist they would like to have. 38.6% percentage of respondents took part as managers, 61.5% percentage of respondents became specialists. Students willing to become managers were the minority. On the other hand, not all students expressed a wish to be managers were appointed to these positions. These decisions were made by other students, because they knew each other better during study years.

During research respondents were asked to estimate the change in the reach of full potential of their personality (evaluation scoring scale: 6 – *full potential*, 1 – *no potential*).

According to the respondents, such a personal quality as ability to work in a team was displayed on a high level (4.73 – displayed). The majority of tasks were oriented towards teamwork. From the research results it can be concluded that students studying different subjects and having different experience are able to achieve coherently planned goals, search common solutions and solve problems and conflicts. Diligence (4.59 – displayed) and responsibility (4.59 – displayed) were valued a little lower. These personal qualities were developed via the intensity of the traineeship (the duration is one month, 4 hours every day). During the traineeship respondents have to behave responsibly, to perform their duties and

tasks, to come to work on time. Various disciplinaries (during the simulation traineeship students develop and implement the system of motivational measures by themselves) were applied to those, who were late to work and did not perform tasks in time. According to the respondents, these qualities developed during the traineeship.

Also, the amount of applied methods to the traineeship makes this traineeship of entrepreneurial development more intensive. Respondents were asked to evaluate the main challenges, which prevented the growth of personal qualities and acquisition and development of entrepreneurial competences. As the biggest challenge the respondents identified information system for business management (3.59 – displayed). During the studies only students of accounting and finances are familiar with IT programs for enterprise management. As a result, the usage of this program becomes an obstacle for students from other programs. Students spend a considerable amount of time while analyzing the main principles of this system while performing tasks. A need of additional finances, time of traineeship respondents identified as big challenges; however, these challenges were very important for the development of such entrepreneurial competences as time planning (a part of students worked as employees), stress management, creativity, rationality, ecological behavior (tried to work with limited resources), etc. In conclusion, it can be stated that teamwork and formed teams were able to create
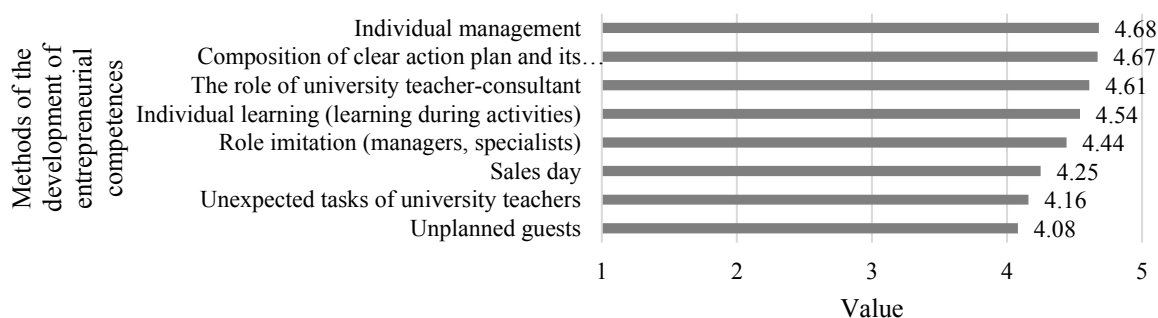

Figure 4. Methods of the development of entrepreneurial competences applied in traineeship.
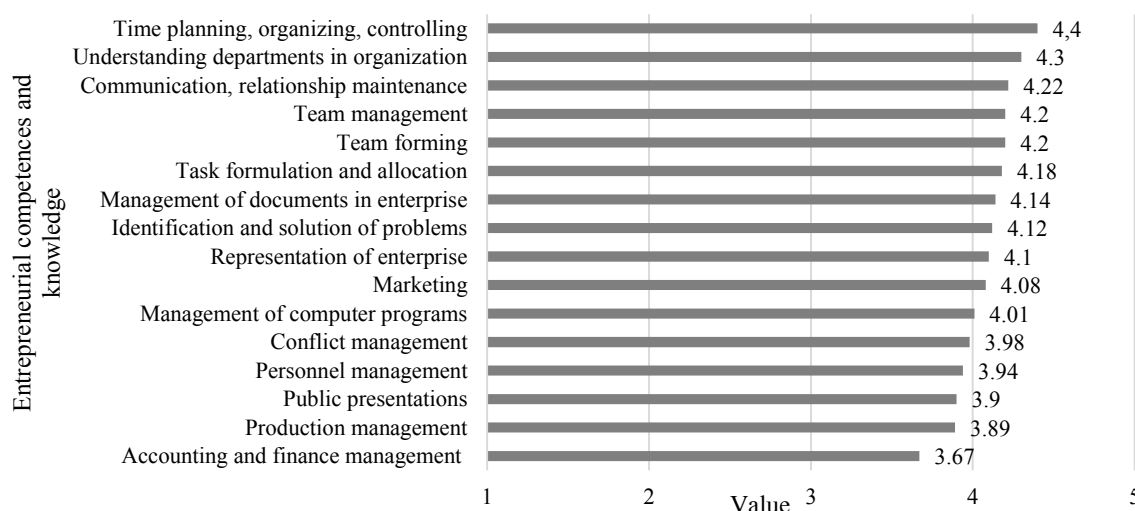
Figure 5. The change in the entrepreneurial competences and knowledge during traineeship.

a positive microclimate within the group and solve problems with competences and resources of the group.

Various innovative methods directed to the development of students' entrepreneurial competences were applied in traineeship of the entrepreneurial development. A lot of attention was paid to students' individualities during traineeship in enterprise management and decision making; therefore, individual management (4.68 – displayed) respondents identified as a very important method. During the practice a task was formulated that students' simulation business enterprise would operate according to their developed activity plan for the whole period. The research results show that respondents evaluate it as a very important method. During the traineeship of entrepreneurial development, university teachers do not play their traditional role. In this case, the university teacher plays a role of consultant – he provides recommendations, helps to formulate possible alternatives to the solution; however, all decisions are made by the students themselves. According to the research, this role of a teacher – consultant (4.61 – displayed) is quite an important educational method. During the research the following 8 methods from 17 were identified by the students as the most important and have the greatest impact.

Methods applied in traineeship of simulation entrepreneurial development and the structure of this traineeship allows to improvise, to display personal qualities in various innovative ways and to develop students' entrepreneurial competences. In the last block of questions students were asked to estimate the change in their entrepreneurial competences during the traineeship of simulation entrepreneurial development. According to the respondents, such competences as activity planning, organization and control more changed than remained unchanged

(4.4 – displayed). Also, the big part of respondents stated that their awareness regarding connections between the departments in organization was improved during this intensive traineeship (4.3 – displayed). Due to the fact that the main attention was paid to form a team having a common purpose, respondents stated that the competence of communication and relation maintenance has changed (4.22 – displayed). However, the smallest change occurred in the area of accounting and finance management (3.67 – displayed). Such research results were caused by the fact that quite a small part (15%) of students participating in the traineeship studied accounting and finances. Students of other programs have only basic knowledge regarding accounting and finance and their knowledge is not very deep in this area. Another reason – business management system was used during the traineeship, and this system was not clear to all students.

Research results cover acquisition of entrepreneurial competences during traineeship of entrepreneurial development in both ways: qualitative and quantitative. The general tendencies revealed that the model of traineeship of entrepreneurial development, which operates as a simulation enterprise, contributes to the development of students' entrepreneurial competences. A survey lets to identify a problematic area of this traineeship, possibly less effective methods for the development of entrepreneurial competences and search possibilities to improve this area.

After taking into consideration the carried out research, it can be stated that there is a need of a set of systematic and structural methods, which would develop entrepreneurial competences. In this area, it shall be recommended to complement methodology, specifying tasks and identifying portfolio of entrepreneurial competences as a purpose of every

student in the traineeship. The main improvements could be directed to the model of entrepreneurial competences development while using the creation of simulation via four dimensions: creative thinking, graphic thinking, provocation creative technique and resultative thinking.

Conclusions

In the development of students' entrepreneurship, it is important to promote their entrepreneurial motivation and development of their personal competences. Every student is an individual, who has different work experience, knowledge and motivation. This actualizes application of various methods promoting students' creativity in the process of the development of entrepreneurial competences.

The research results show that entrepreneurial competences developed during the traineeship of entrepreneurial competences; the development was positive, and applied methods were evaluated as quite effective. However, it can be stated that there is a need for a common system and the action plan of traineeship of entrepreneurial development, the precise introduction of each method and an application system. Several identified methods compose only one part of all possible innovative methods; however, they also have to be selected and applied in quite an accurate manner. However, while evaluating entrepreneurial competences, it becomes obvious that respondents tend to evaluate positively personal qualities and they understand and analyze their entrepreneurial competences.

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USE OF NOSQL TECHNOLOGY FOR ANALYSIS OF UNSTRUCTURED SPATIAL DATA

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Abstract
Every day millions of new data records with spatial component are produced in the world, which provide valuable information to make decisions and solve business-related issues. However, a large part of this data is hardly analyzed because of their different structures and schemas. The aim of the paper is to improve the integration, processing and analysis of unstructured spatial data.
During the research, the author analysed geospatial data types and sources, explored NoSQL solutions for geospatial data processing and chose the open-source tools which are the most appropriate for the stated goals, as well as analysed the coverage of forest areas with protected zones using MongoDB database capabilities and visualized results in a map, using QGIS software.
MongoDB is a useful tool for geospatial data analysis and has a large number of embedded topology analysis functions and has drivers for widespread programming languages like JavaScript, Python, PHP, Java, Scala, C#, C, C + +, etc. QGIS has extensions that allow to make connections to databases, including a connection with MongoDB. Using these features, the developers can develop geographic information systems to analyse geospatial data – structured, semi-structured and unstructured.
Generally MongoDB is used for real-time data analysis, however, complicated analysis of large data sets can take up to hours and even days, so it is still necessary to find the best solution to get results in an acceptable time for users. Using MongoDB together with Apache Hadoop - the framework to support big data applications - could be a possible solution for this problem.
Key words: NoSQL, MongoDB, geographic information system, spatial data, database.

Introduction

A lot of spatial data is produced in business sector and also in everyday life. Not in all situations this data has an easily processable structure for relational databases. In most cases this data is unstructured or semi-structured. NoSQL solutions may provide possibilities to process this data in a more effective way and provide business sector with valuable information, which can be used to make decisions and solve issues related to business.

The amount of geospatial data created, collected and used is increasing because of observations and measurements of geo-sensor networks, satellite imageries, point clouds of laser scanning and location-based social networks. It has become a serious challenge for data management and analysis systems. Traditionally, relational database management systems (RDBMS) are used to manage and analyze geospatial data, but there are some situations, when these systems may not provide required efficiency and effectiveness. The authors (Amirian, Winstanley, & Basiri, 2013) consider that NoSQL solutions can provide the efficiency necessary for applications using geospatial data.

RDBMS requires exact schema definition for input data into database. Database schema should be changed by modifying or adding fields to it every time when the business requirements for application are changing. It can be a lengthy process. NoSQL databases are free from this restriction because nearly all these databases are schema-less. Without predefined schema, NoSQL can be used for various

data types like structured data, semi-structured data and even unstructured data (Yue & Tan, 2017).

Several spatial extensions are included in multiple NoSQL databases, which enables NoSQL based systems to address the complexity of distributed data. This feature allows using NoSQL where traditional geographic information systems cannot offer highly distributed and scalable performance (de Souca Baptista *et al.*, 2014).

Latvia lacks a simple united system for everyday user where to combine, analyze, review and store various geographic data from different systems, for example, precise agricultural systems, Rural Support Service, State Forest Service and other geographic information systems (GIS) that are accessible to public. Currently in Latvia the user has an opportunity to retrieve GIS data, but has no chance to combine and search for interconnection of this data because national information systems and various other geographic information systems are not connected and most likely the user has no tools to analyze GIS data. For example, in the precision agriculture various machinery, tractors and devices equipped with sensors are used and every manufacturer has their own system for data processing, however, a simple GIS application, which would allow combining data from various systems, is missing. Problem is also that every data set can have a different structure. There is an online portal geolatvija. lv with some data from national institutions, however, there is no functionality implemented in the portal that would support users' own data uploads and analysis, including the execution of queries for the data.

The aim of the paper is to improve the integration, processing and analysis of unstructured spatial data. To achieve the aim, the following tasks were set:
- to analyze unstructured data types and typical sources;
- to explore NoSQL technologies and solutions for unstructured spatial data analysis;
- to analyze the coverage of the forest areas with protected areas using MongoDB database capabilities;
- to display the results of the analysis on the map using QGIS software.

Materials and Methods
Software

During the exploring of variety of NoSQL databases and their used technologies and solutions for spatial data analysis, MongoDB NoSQL database was chosen, which might be one of the best-known NoSQL databases in the market. MongoDB is free and open-source software, with the usual GNU (GNU General Public License is a free software license) and Apache-type licensing restrictions, which was designed more for analytics and complex data than it was for tables, ACID (Atomicity, Consistency, Isolation, Durability) compliance, and other standards and support requirements that come with ordinary relational databases. MongoDB is considered to be a document-oriented database which uses BSON (Binary-JSON) as a data description tool. BSON is an extension of JSON; it uses a length field to increase the efficiency of scanning (Pries & Dunnigan, 2015).

MongoDB database is called non-relational and schema-less, which makes working with data flexible because there is no predefined structure required in documents. MongoDB's data structure is not entirely lacking of schema, because it is still needed to define collections and indexes in database, but there is no need for predefined structure for documents added to database (Hows *et al.*, 2015).

For geospatial data analysis MongoDB Community Server 3.4.10 release (October 31, 2017) was used during this research. This version is compatible with Windows, Linux and MacOS operating systems. For data visualization on a map, QGIS Desktop 2.18.13 with GRASS 7.2.1 software was used. It was chosen because it is an open-source software and has plugins like Load MongoDB Layers, which links with MongoDB database and makes it possible to get spatial information directly from database into QGIS and then visualize it, as well as Save Data in MongoDB, what is usable for data saving back in MongoDB database after changes have been made to the spatial content. QGIS software allows to create, edit, visualize, analyze and publish geospatial information on Windows, Linux, Unix, Mac OSX and Android devices and supports numerous vector, raster, and database formats and functionalities (QGIS Development Team, 2018).

Data

For spatial data analysis with NoSQL, information about protected areas and forest areas in Latvia was used. The data of protected areas in Latvia is available online on https://www.daba.gov.lv/public/lat/iadt/ or https://data.gov.lv/dati/lv/dataset/ipasi-aizsargajamas-dabas-teritorijas-iadt government web sites. It is possible to download shapefile datasets from these sites. These datasets then should be converted in csv, tsv or GeoJSON file formats and geospatial data should be transformed in WGS84 coordinate reference system because MongoDB only supports WGS84 reference system for geospatial queries on GeoJSON objects. The data of protected areas was transformed in WGS84 coordinate reference system and converted to 17 csv files, which contain spatial information (polygons, points and lines) with ~ 120 thousands of protected area marks all over Latvia, and then imported into MongoDB database as GeoJSON objects. The information about forest areas of Latvia was provided by the State Forest Service of Latvia. The data was downloaded from the database into 1 csv file with ~2.5 million polygons of forest compartments of the whole Latvia in WGS84 reference system and imported into MongoDB database as GeoJSON objects.

Data analysis

For the unstructured spatial data analysis with available data, a NoSQL script was developed, which was searching and counting for every forest compartment its intersecting protected areas. In such a way, the forest compartments, where economic activity more likely will be restricted or limited, were found. Script were developed according to the scheme in Fig. 1. According to the scheme, it was determined that the number of processed compartments is 0 at the beginning and the first while loop is executed. This loop determines that operations will be continuously repeated in it while the processed compartment count will not be the same as the count of all compartments in the database. Then all unprocessed compartments are selected and in the next while loop operations are going through all these unprocessed compartments one by one. If there is any unprocessed compartment in this set, then its intersecting protected areas are searched. If any are found, the number of intersecting areas is saved in a separate field for compartment. Compartments with the highest number of protected areas are considered as the most restricted by the economic activity.
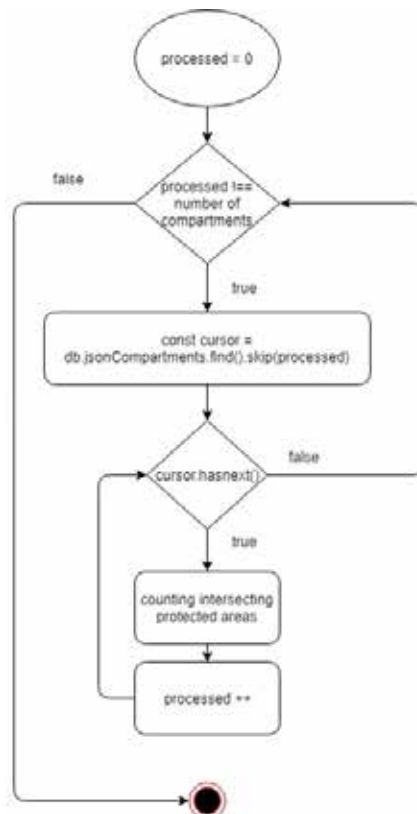
Figure 1. Search scheme for intersecting protected areas.

Results and Discussion

Data analysis results were imported into QGIS software using plugin – Load MongoDB Layers. Then the results were visualized using the map in Fig. 2. The darkest colors indicate places (forest lands) with the highest density of protected areas. The darker the green color is, the larger is the number of protected areas that intersect with this forest compartment, so it can be estimated that in these places the economic activity will be the most restricted. In turn, the lightest – yellow areas – characterize forest territories where the economic activity will not be restricted by the protected areas. White areas in the map are places where there are no forest lands – cities, agricultural land etc.

If the results of the analysis will be appended with features of roads and traffic information, thus lightening those forests which are easier to access, the map can be used to make a decision to purchase this forest land or not. If the land is hardly accessible and economic activity more likely will be restricted then probably the potential land buyer will decide not to buy this forest. In addition, if only 'Latvia's State Forests' (LVM) forests will be showed on the map together with traffic information, and national roads along with forest roads, this information can be used to create an application for people to make a decision, based on the frequency of visits to forest by other people as well as road accessibility, if it is worth to go to this forest to look for a Christmas tree in winter time or pick mushrooms or forest berries in summer.

MongoDB is commonly used for real-time data analysis. Complex analysis of large amount of perpetual data sets can take up to hours or even days. As the spatial data analysis with NoSQL took a long time (several days), the best solution to achieve results within a reasonable time still have to be found. A possible solution for this problem could be using MongoDB together with Hadoop - a software technology designed for storing and processing large volumes of data (as well as Big Data). Hadoop can be used as a data warehouse where larger data sets from MongoDB and other data sources can be uploaded. Then data analytics can use MapReduce or other programming models to create queries on these large data sets and return results back to MongoDB database. MongoDB together with Hadoop solutions for Big Data analysis are used by such well-known brands as Ebay and FourSquare (MongoDB, Inc., 2018).

According to the research and time used for analysis, it can be concluded that if the GIS application for data analysis from various data sources without predefined schema is created for small data sets and small areas (for example, within the borders of owners one or a couple of properties), then MongoDB will be
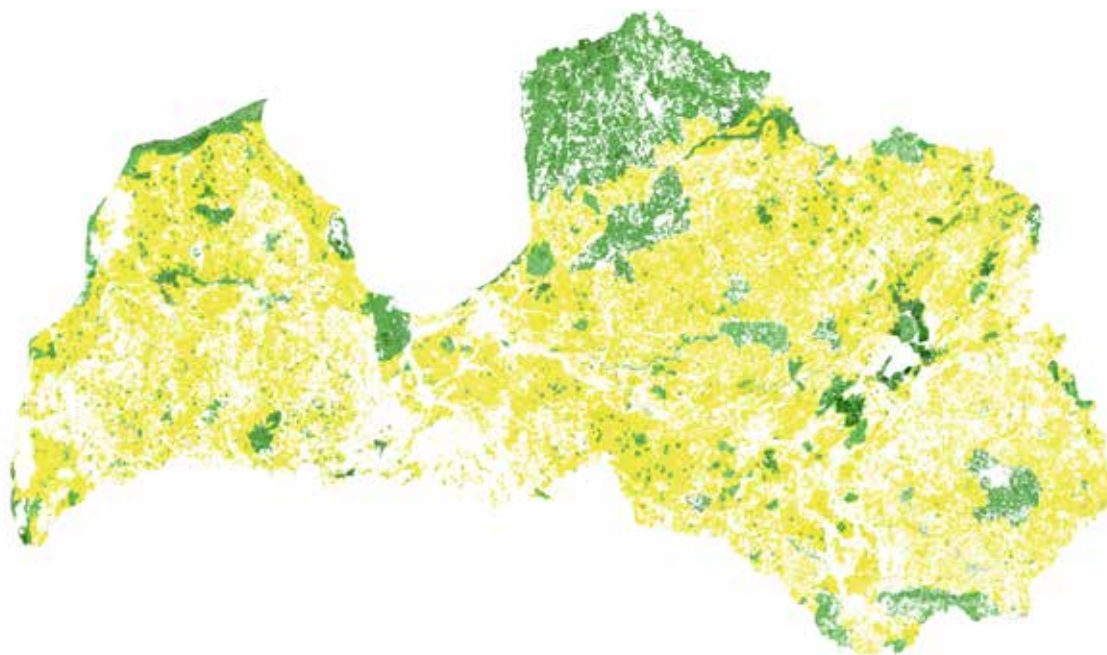
Figure 2. NoSQL data analysis of Latvia forest land intersections with the protected areas,
visualized on a map.

a good solution for data analysis tasks. But if the data sets are large and cover large areas (for example, large regions, states or countries), then using MongoDB by itself for analysis tasks is not the best solution.

Conclusions

1. NoSQL solutions is a suitable tool for storage and analysis of data sets from various data sources without predefined schema or united structure of data, since there is no need to predefine table, structure, data types and columns for data import into database.

2. MongoDB can be used as a GIS database because of its integrated spatial functionality with fairly large spatial data analysis capabilities, however, there is a restriction that data should be transformed in WGS84 coordinate reference system before importing into database, otherwise spatial indexing will not work.

3. Results of this study show that MongoDB can be used for spatial data analysis with NoSQL, but for large areas and data sets it took a long time to obtain results, so the best solution for analysis of large data sets still need to be found.

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CONTENT MARKETING DECISIONS FOR THE CUSTOMER VALUE CREATION IN SOCIAL NETWORKS: 'ILZENBERG MANOR' CASE

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Abstract
This article presents theoretical and practical aspects of content marketing decisions for the customer value creation in social networks by using the case of the organic farm 'Ilzenberg manor'. Focus of this paper is to determine which content marketing decisions create the biggest value for the customer in social networks.
The first part of the paper deals with theoretical insights into the content marketing decisions and their ability to create the customer value in social networks. Findings of theoretical analysis disclose that there are interfaces between content marketing, separate content marketing decisions and the customer value in the context of social networks. Respectively, it leads to an assumption that the usage of content marketing decisions can be valuable for the customer value creation in social networks.
The second part of the paper focuses on the case analysis of the organic farm 'Ilzenberg manor'. In order to determine which content marketing decisions create value for the customer in social networks, authors examine a correlation between separate content marketing decisions and consumer value indicators by using data from 'Ilzenberg manor' Facebook page.
The obtained results expose that not all content marketing decisions create value for the customer in social networks. Hence, it means that a selection of separate content marketing decisions in social networks can be made through the customer value perspective. The article ends with insights, conclusions, limitations and future research possibilities.
Key words: content marketing, value for the customer, social networks, customer engagement.

Introduction

In the context of high competition, many companies are trying to conquer the market clutter using various types of marketing strategies. Many authors (Laric & Lynagh, 2010; Kose & Sert, 2017; Kannan, 2017; *et al.*) have admitted that nowadays the situation in the market is characterized by aggressive competition, information overload and more educated consumers. As a result, the fight for the consumer is fierce and complicated. It is not a secret that the prevalence of widespread social networking and digitization has also contributed to these conditions (Diaconu, Oancea, & Brinzea, 2016; Kidane & Sharma, 2016; Kannan, 2017). Therefore, it is widely recognized that creating value for a consumer is one of the main tasks for a competitive company (Woodruff, 1997; Ivanauskienė *et al.*, 2012; McMurrian & Matulich, 2006; Kumar & Reinartz, 2016). Moreover, researchers (Ivanauskienė *et al.*, 2012; Baltes, 2015) point out that the value for a consumer is not limited to the direct benefits of the product. Accordingly, it is important to look for new decisions, which can help to create value for the customer.

One of the newest and, considering the current market situation and challenges for companies, the most promising marketing strategy is content marketing. Over the past decade several articles have been published related to the content marketing concept (Kucuk & Krishnamurthy, 2007; Steimle, 2014; Ahmad, Musa, & Harun, 2016; *et al.*), application (Holliman & Rowley, 2014; Baltes, 2015; Kose & Sert, 2017; *et al.*) and its effect (Singh, 2016; Kidane & Sharma, 2016; *et al.*). Nevertheless, despite the fact that the content marketing concept lays strong focus on value and value creation, there is lack of studies about the role of content marketing decisions in the customer value context. Discussions about the content marketing decisions for the customer value creation show the importance of knowing how they can be associated with, which content marketing decisions create value for the customer and how they can be used in different communication channels.

Considering all the discussed insights, **the object** of this research is content marketing decisions that serve the purpose of customer value creation **The scientific problem** analysed in the article is formulated by a question: how the content marketing decisions relate to the created customer value in social networks? **The purpose** of the research is to determine the strength of the relationship between the content marketing decisions and created customer value.

Materials and Methods

To achieve the purpose of the article, the analysis and synthesis of scientific literature in the fields of content marketing (Pulizzi, 2012; Holliman & Rowley, 2014; Kose & Sert, 2017; *et al.*), the customer value (Shanker, 2012; Ivanauskienė *et al.*, 2012; McMurrian & Matulich, 2006; Kumar & Reinartz, 2016; *et al.*) and social networks (Lipsman *et al.*, 2012; Ashley & Tuten, 2015; Jaakonmäki, Müller, & Brocke, 2017; *et al.*) are provided. In order to determine which content marketing decisions create value for the customer in social networks, the correlation analysis is conducted. The general scientific research methods

were applied as well – systematic analysis, evaluation, generalization, comparison and abstraction.

Theoretical substantiation

The dramatically changing virtual environment has formed a competitive business setting, which provides opportunities for conducting business communication online (Kidane & Sharma, 2016). Due to the developed and changing environment, organizations have understood the importance of marketing, because marketing is one of these fields that often employs technologies to improve activities and make everything better for more effective and efficient results (Khan & Siddiqui, 2013; Järvinen & Karjaluoto, 2015; Kose & Sert, 2017). Companies must adapt to the new realities and challenges in business environment in which they exist and adopt the newest marketing strategies as the means by which they can develop long lasting relationships with both customers and stakeholders (Laric & Lynagh, 2010; Archer-Brown, Piercy, & Joinson, 2013; Diaconu, Oancea, & Brinzea, 2016; Singh, 2016; Kannan, 2017; *et al.*). Moreover, the adoption of the newest marketing strategies can be understood much more broadly – not only as a survival tactic, but also as a way to win a customer.

One of the winning strategies offered by business and science (Pulizzi, 2012; Hanafizadeh & Yarmohammadi, 2015; Kose & Sert, 2017) is content marketing. Accordingly, there areplenty of marketing strategies that focus on content marketing to capture consumer's attention through unique, valuable, well produced and entertaining content, to make a more intense and significant impact than before (Aguilera-Moyano, Baños-González, & Ramírez-Perdiguero, 2015). It is worth mentioning that content-based orientation is not really a new strategy and it is actually as old as any other marketing paradigm, but content marketing, as a purified concept and separate type of marketing, is still in the development phase (Pulizzi, 2012; Azad, AliAkbar, & Zomorodian, 2016). Besides that, as Kose & Sert (2015) emphasize, content marketing today is one of the most remarkable approaches in the context of marketing processes of companies. The value of this kind of marketing has improved over time, due to the latest developments in computer and communication technologies.

In scientific literature we can detect several types of content marketing definitions: from one of the earliest definitions 'Content marketing attracts potential consumers and increases their engagement and empowerment through the creation, dissemination and sharing of free content, relevant, meaningful, valuable and able to inspire confidence in existing and potential customers' given by S. Kucuk & S. Krishnamurthy (2007), to one of the newest 'The

content marketing is sharing the valuable information regarding the products and brands to attract others to participate in purchasing activities that create the engagement relationship between consumers and the companies' given by Ahmad, Musa & Harun (2016). Obviously, those ten years of content marketing development did not dramatically affect the essence of its concept. According to J. Steimle (2014), the key factor in content marketing is value. He makes a short statement about this subject saying that 'You can tell if a piece of content is the sort that could be part of a content marketing campaign if people seek it out, if people want to consume it, rather than avoiding it' (Steimle, 2014). There is also an approach understanding content marketing as the means of value creation, putting a lot of weight on the conduit (Hanafizadeh & Yarmohammadi, 2015). Such a view considers content as the means of producing value for the target audience. Therefore, it is clear that the main goal of implementing content marketing is to distribute valuable and consistent content to the target audience in order to stipulate the profitable consumer action. In other words, content marketing concept is based on an assumption that when enterprises provide valuable information for the customer, they can expect useful customer response.

Considering the previously discussed content marketing concept, it can be seen that the idea of content marketing has interface with the idea of the customer perceived value. Content marketing not only directly and indirectly relates to consumer value attributes (Pulizzi, 2012, Steimle, 2014; Kose & Sert, 2015; Hanafizadeh & Yarmohammadi, 2015; Ahmad, Musa, & Harun, 2016; *et al.*), but also can be incorporated into the value for the customer creation process. Kumar & Reinartz (2016) highlight that one of the most important marketing tasks is to create and communicate value to the customers to provoke their satisfaction, loyalty, and profitability.

Previous studies in the customer value field (Woodruff, 1997; Shanker, 2012; Ivanauskienė *et al*., 2012; McMurrian & Matulich, 2006; Kumar & Reinartz, 2016; Jiao, Jo, & Sarigöllü, 2017; Fandrejewska, 2017; *et al*.) allow us to have some insight into what customer value is really about. It can be explained at different levels. At the lowest level, value for the customer can be viewed as an attribute of a product that customer perceives to receive value from (Woodruff, 1997; McMurrian & Matulich, 2006; Kumar & Reinartz, 2016). At a higher level, the customer value can be viewed as a social and emotional payoff and achievement of a goal or desire (Ivanauskienė *et al*., 2012; Fandrejewska, 2017). From content marketing perspective, Baltes (2015) refers to value for the customer as the creation of content that is interesting, draws customer's attention,

and later transforms into long lasting relationships. Hence, if a company is able to create content that the customers find useful and valuable, the company has managed to create value (Holliman & Rowley, 2014). For this reason, content development, which would be valuable for the target audience, should be a priority task in the marketing campaign planning process. However, in order to create value for the customer through content marketing, the issue of content distribution and particular decisions is also important. With more and more media platforms available, consumers have developed an insatiable demand for content. M. Diaconu, Oancea, & Brinzea (2016) argue that the complex networks of friends, family, and peers now influence customers' purchase decisions. The new market winners will be the companies that excel at identifying and engaging with their customers across the social networks (Anderson *et al.*, 2014; Ashley & Tuten, 2015; Diaconu, Oancea, & Brinzea, 2016; Jaakonmäki, Müller, & Brocke, 2017). Social media is an innovative communication tool for retailers to interact with consumers. Brands and their consumers can now create two-way relationships and share content, news, and feedback (Lipsman *et al.*, 2012). Additionally, consumers are willing to pay more to receive only those marketing messages that resonate with them, and they are receptive to those marketing messages that are valuable, short, focused and personally communicated by friends, trusted experts or favourite companies (Anderson *et al.*, 2014). Jiao, Jo & Sarigöllü (2017) agree by saying that the unique characteristics and universal popularity of social networks enable consumers to experience the customer value and thus improve their psychological well-being. Nevertheless, not all marketing activities and communication in social networks lead to high customer engagement. Creating effective content for social media marketing campaigns is a challenge, as companies have difficulty understanding what drives the user engagement (Jaakonmäki, Müller, & Brocke, 2017).

Researchers (Merchant *et al.*, 2014; Ashley & Tuten, 2015; Diaconu, Oancea, & Brinzea, 2016; Jaakonmäki, Müller, & Brocke, 2017) highlight the main problematic areas that lead to low customer engagement: passive customers; information overload and low organic reach; lack of originality; primitive communication; focus on short-term goals; focus on the tangible aspects, not the emotional ones.

As a response to these problematic areas, R. Jaakonmäki, Müller & Brocke (2017) distinguish three key factors that lead to the customer engagement in social networks:

- The customer interfaces with the content creator (e.g. demographic characteristics, image, number of followers);

- Context of the content (e.g. time, place, topical issues);
- The main decisions of the content (e.g. visual and textual element).

The last factor is one of the most dependent on the communicating company. Despite the content marketing ability to create value for the customer, content marketing includes various types of decisions: how do we communicate? which content forms will we use? what is valuable for the customer? etc. (Ashley & Tuten, 2015; Diaconu, Oancea & Brinzea, 2016). Authors admit that social networks are favourable for various content marketing decisions, however, it is still not clear which content marketing decisions are the ones that can create the highest value for the customer.

Research design

In this study, correlation analysis is applied. Correlation is a bivariate analysis that measures the strength of association between two variables and the direction of the relationship. For correlation strength measurements, authors use Pearson's correlation coefficient, which shows the linear relationship between two sets of data and has no meaning for describing nonlinear relations.

Correlation is an effect size and so we can verbally describe the strength of the correlation using the guide that V. Kasiulevičius & G. Denapienė (2008) suggest for the estimation of correlation coefficient (r value) which describes only linear association (Table 1). In terms of the strength of linear relationship, the value of the correlation coefficient varies between +1 and -1. A value of ± 1 indicates a perfect degree of association between the two variables (Vakrina, 2007; Cohen *et al.*, 2013). A value of 0 signifies that there is no linear relationship between the variables.

With this type of analysis, authors of this paper aim to examine the correlation between the number of certain content marketing decisions (independent variable *x*) and the number of distinguished customer value indicators (dependent variable *y*). The use of correlation analysis is appropriate since it measures the overall relationship between the two sets of variables. Despite the object of the research, this method was used in previous studies related to social networks (Malik *et al.*, 2016), digital marketing (Aras *et al.*, 2017) or customer value (Zameer *et al.*, 2015). Correlation analysis and Pearson's correlation coefficient are known as the best method of measuring the relationships between variables of interest because it is based on the method of covariance. Moreover, it gives information about the magnitude of the correlation, as well as the direction of the relationship.

Table 1

Estimation of correlation coefficient (*r* value)

r value (±)	Estimation
.00-.19	very weak relationship
.20-.39	weak relationship
.40-.59	moderate relationship
.60-.79	strong relationship
.80-1.0	very strong relationship

Source: V. Kasiulevičius & G. Denapienė (2008).

However, it should be noted, that correlation analysis itself does not reveal causes of the relationships between independent and dependent variables but evaluates the strength (*r* value) and statical significance (p-value) of correlation.

Facebook page of organic farm 'Ilzenberg manor' was taken for the field research to be performed. This particular farm, which is located in Lithuania, was chosen because of several reasons: a wide range of services and goods; a large number of followers (15 550); consistent communication and various forms of content marketing decisions in their posts. The main activity of 'Ilzenberg manor' is trade of organic food products and services for private recreation and celebration. The main target group is city residents who are interested in ecological lifestyle and like to be in nature. Until now, the main flow of followers was achieved organically.

In order to determine the linear relationship between content marketing decisions and created customer value indicators, data from Facebook posts of organic farm 'Ilzenberg manor' was collected. Research sample includes all posts from June to December of the year 2017 (N=120). This period was chosen taking into account the peak of activity. Research was conducted in January, 2018.

The number of content forms (photos, emoji, hashtags, etc.) given in a particular post were counted as content marketing decisions (independent variable *x*). The number of the customer's reactions, comments, shares and post engagement rate was counted as the outcome – customers' value perception (dependent variable *y*). Post engagement rate is derived as the total number of reactions, comments and shares for a particular post to the total number of page followers. Before correlation analysis, authors tested collected data in order to be sure, what data meet the main assumptions of the Pearson's correlation coefficient (e.g. absence of outliers, normality of variables etc.). MS Excel was used for data processing and correlation analysis.

Results and Discussion

Table 2 contains overall results of correlation analysis between different content marketing decisions and customers' value perception.

Analysis of 'Ilzenberg manor' Facebook posts indicates the strength of the relationship between the two variables and determines which content marketing decisions create the highest value for the consumer. During the research, the greatest attention was paid to the association between the content marketing decisions and the post engagement rate. Correlation results between the text lengths and created customer value indicator analysis shows a positive relationship – 0.124, with p-value of < 0.05. It indicates a very week linear relationship and significance of the result obtained. Despite the fact that researchers and marketing experts (Merchant *et al.*, 2014; Holliman & Rowley, 2014; Kidane & Sharma, 2016) say that internet users avoid long texts, conducted analysis revealed opposite results. Therefore, it provokes assumptions for deeper research.

Another content marketing decision, which was taken into account, is the number of photos. It was noted that the vast majority of the 'Ilzenberg manor' photos capture professional images of nature, manor surroundings and farm production. The result shows the highest positive *r* value – 0.714, with p-value of < 0.05. It shows that the usage of photos in Facebook posts is a very good tool to increase user's engagement, especially in case of reactions.

However, this is not valid for banners. The obtained correlation coefficient is negative (*r*=-0.331) and p-value is statistically highly significant (p<0.01). Hence, it means that usage of banners has a negative effect on user's engagement in the particular case. It could be explained by the fact that Facebook policy is to avoid banner-type posts and reduce organic reach. On the other hand, all banner-type posts from 'Ilzenberg manor' were very commercial.

In recent years, researchers and experts (Lipsman *et al.*, 2012; Merchant *et al.*, 2014; Kose & Sert, 2017) have been highlighting the importance and advantages of video format in social networks. Notwithstanding, in this case video has no strong and significant linear realationship (*r*=0.026; p≥0.05). And even if the duration of the video has a weak positive correlation (*r*=0.332) with user's engagement, result is not significant (p≥0.05) as well.

Correlation results between the number of emoji and user's engagement indicate the most negative

Correlation between content marketing decisions and created customer's value perception

Content marketing decision (unit of measurement)		Reactions	Comments	Share	Post engagement rate
Text (characters (no spaces))	$r =$	.138*	.008*	.033*	.124*
Photos (number of photos)	$r =$	.728*	.604**	.453**	.714*
Banners (number of banners)	$r =$	-.316**	-.199*	-.296*	-.331**
Video (number of video)	$r =$	-.022	.188*	.191*	.026
Video duration (in seconds)	$r =$	.397	.329**	.166*	.332
Emoji (number of emoji)	$r =$	-.586**	-.506***	-.556*	-.621**
Hashtags (number of hashtags)	$r =$	.497**	.177*	.517**	.502**
Sitelinks (number of sitelinks)	$r =$	-.420**	-.396**	-.343*	-.411**
External links (number of external links)	$r =$	-.019	-.029	.069	-.010
Tags (numbers of tags)	$r =$	.020	-.025	.009	.167
Action buttons (number of action buttons)	$r =$	-.170	-.068	-.136	-.172
Location tags (numbers of location tags)	$r =$	.336	-.010	.062	.298

Source: prepared by authors using the data provided by MC Excel.
N=120
*p<0.05; ** p<0.01; *** p<0.001

relationship. The correlation coefficient is (–0.621) and the p value is (<0.01). This shows that the result is highly significant. It also indicates that if the firm uses a lot of emoji, it will adversely affect user's engagement.

In the analyzed posts, hashtags have been frequently used (3.7 hashtags per post). Usually, hashtags mark specific themes, products, slogans, type of the content or brand name, e.g.: #cheese, #beautifulnature, #noconservant, etc. This kind of tagging makes it possible for the customers easilyfind messages with a specific theme or content (Lipsman *et al.*, 2012; Azad, AliAkbar, & Zomorodian, 2016). Moreover, it could be used not only as a tag, but as a short message form as well. Accordingly, the association between the number of hashtags and user's engagement was moderately strong and positive (*r*=0.502) and statistically highly significant (p<0.01).

In terms of links usage, analysis revealed noticeable results. Various authors (Archer-Brown, Piercy, & Joinson, 2013; Aguilera-Moyano, Baños-González, &

Ramírez-Perdiguero, 2015) note that the use of links, especially to other websites, is not a good step from the perspective of valuable content creation. But in 'Ilzenberg manor' case, results indicate a different situation. Both sitelinks and external links have no positive effect on user's engagement. Therefore, the effect of the inner link was much stronger (*r*=-0.411) and statistically highly significant (p<0.01). This may be because of the fact that most of the sitelinks were focused on direct sales.

By assessing the numbers of tags (*r*=0.167), action buttons (*r*=-0.172) and location tags (*r*=0.298) linear relationship with user's engagement, authors of this paper did not notice any strong and/or statistically significant correlation. It indicates that these content marketing decisions are not useful for the customer value creation.

Taking all the aforementioned into account, it could be stated that the application of different content marketing decisions throughout Facebook posts indicates linear relationship with user's engagement.

Although, not all the relationships are positive or significant, thus the choice of content marketing solution should be made deliberately in order to create value for the customer chosen.

Conclusions

1. Due to the worldwide digitization, information overload, increased competition, changed customer habits and globalization, companies are constantly looking for new ways to become more successful. Marketing activities are perceived as one of those ways. However, marketing itself does not guarantee a good result and victory in the battle for the customer. Therefore, new and more effective marketing strategies are being developed. One of the newest marketing trends and types is content marketing.

2. Theoretical substantiation shows that the main idea of applying content marketing is to create valuable content to the target audience in order to facilitate profitable customers' actions. Literature review also reveals that one of the content marketing keywords is value for the customer. Thus, there are connections between content marketing and value for the customer creation, especially in the context of emotional and social value. Therefore, the application of content marketing decisions in social networks, one of the most popular media channels, can create the customer value and increase customer's engagement.

3. In order to indicate the strength of the association between the two variables and determine which content marketing decisions create the highest value for the consumer in social networks, correlation analysis was performed. Analysis of the obtained results makes it possible to conclude that if a company wants to increase customer's engagement as the indicator of customer value, content creation decisions should include the usage of photos and hashtags when posting. However, the research revealed that some decisions can have a negative effect on the customer perceived value. These are the number of banners, emoji's and links which should be reduced. It could be noted, that strong and significant linear relationship between some content marketing decisions, such as the number of actions buttons, tags or location tags, and the customer value does not exist.

4. Restrictions of this research offer some opportunities for further research. Considering the fact that there are several content marketing decisions applied in one post, it is necessary to expand the field of study by examining relationships between various combinations of content marketing decisions and customers' engagement. Moreover, the expansion of the cases to be investigated and the assessment of post messages can be included as well.

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PROCEDURES FOR THE CONTROL AND QUALITY ASSURANCE OF E-LEARNING MATERIALS

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Abstract
With the growing demand for e-learning, as well with the striving for excellence, everyone worldwide is encouraged to improve and ensure the quality of e-learning. Quality assurance requires a supportive environment. The purpose of this paper is to propose procedures for evaluating and controlling the quality of e-learning materials. The article reflects on the approach, which is often mentioned in the field of quality assurance, procedures that characterize the processes, helps to sort them, track their progress sequence and identify those responsible. Clearly, the quality of online learning has many dimensions, but this article deals only with the part that relates to the quality of e-learning materials. In January 2018, experts from European Distance Education Secondary School, Riga Distance Education Secondary School and Riga 1st Distance Education Secondary School were interviewed. The questionnaire included questions about the quality assessment of the study materials. Based on the findings of scientific research literature and taking into account the good practice, procedures for the quality control of electronic learning materials were created. The article offers four procedures that include the use of a web-based checklist developed by the author. Activities of procedures can be divided into areas of responsibility that deal with developers of the material, methodological commission, material evaluators and IT administrator. Distance learning program implementers can use the proposed procedures in the process of making and monitoring electronic learning materials. In addition, the checklist helps to identify important conditions and requirements that affect the quality of the study material.
Key words: e-learning, quality, quality assurance, procedure.

Introduction

Nowadays traditional forms of teaching and learning are often substituted by e-learning to achieve better learning outcomes (Mason & Rennie, 2008) Due to the significant advantages of e-learning such as accessibility, flexibility, portability, etc., the e-learning offer has grown over recent years. This in turn leads to discussions about the quality of used systems, quality of process provision and quality of e-material (Artal et al., 2007). Thus, it is still unclear how to ensure the quality of e-learning. The quality of e-learning is a complex concept, since e-learning includes a number of dimensions (Masoumi & Lindström, 2012) that affect organizational, administrative, teaching and technological risks. Quality improvement and provision are crucial to the success of education institutions involved in e-learning (Inglis, 2005; Ehlers & Pawlowski, 2006).

Several agencies, such as the European Association for Quality Assurance in Higher Education (2009), the Council for Higher Education Accreditation (1998) and Swedish National Agency of Higher Education (2008)) have made a major contribution in shaping distance learning quality assurance approaches. These agencies have promoted the implementation of quality management systems nationally and internationally. However, in order to ensure the implementation of quality, the culture of quality must be promoted. The culture of quality results from the quality assurance measures, implementation of the internal quality assurance system and brings responsibility to the public at national and international level (Jung, 2004).

Defined processes can support the product development and implementation of services in several sectors, such as industry, commerce and service areas. Process identification and management is also important for the development of educational products or the implementation of educational services. Quality management is an approach which is borrowed from business and which focuses on continuous improvement and customer satisfaction. According to Becket and Brookes (2005), quality management has the potential to capture the internal and the external perspectives of both stakeholders, enabling a comprehensive approach to quality assurance, facilitating change and innovation. Nowadays process management is widely used and it is considered that in many areas it is necessary to promote the management of human activities for the provision of product or services. In fact, the processes are formal components in many types of organizations and they define the logical order in the production area.

Procedures in the quality assurance systems are for specifying what is to be done, who should do it and on what standards it should be done. In addition, quality assurance is not the same as evaluation. Evaluation is about what is already done. If a distance education course is created, then quality assurance is the process used in creation of the course. The first step in the quality assurance system is the establishment of procedures. Procedures are a description of the way we do things. There are two purposes of the procedure:
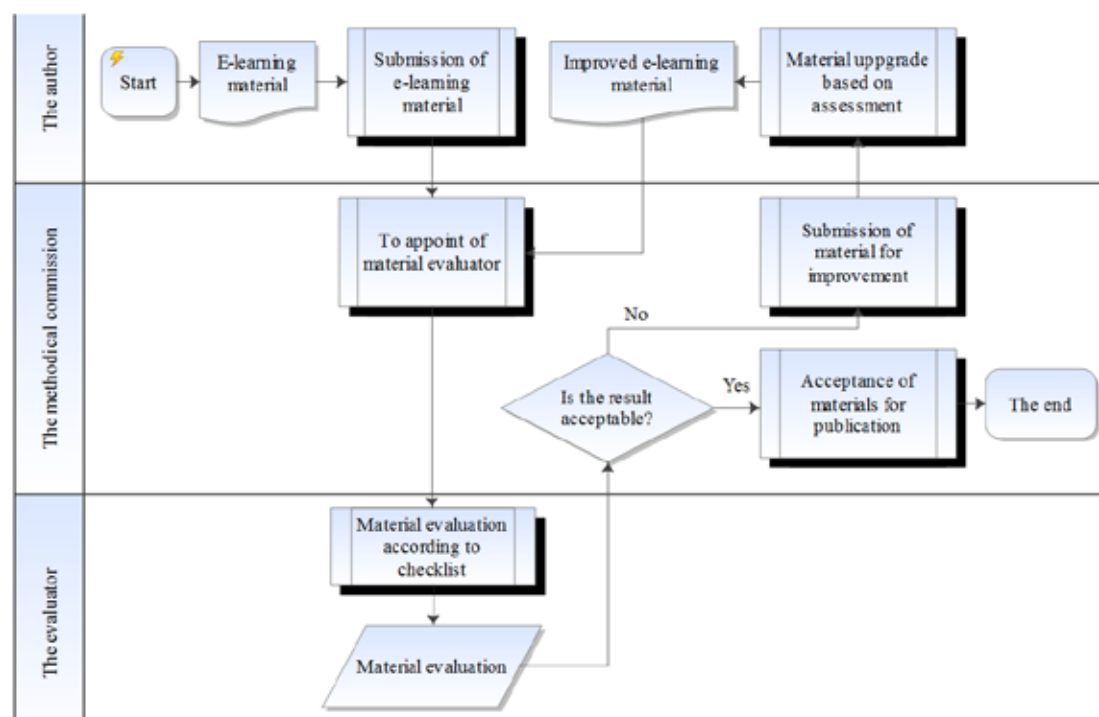- to define what the organization considers to be good practice;

Figure 1. A procedure for the acceptance of e-learning materials.

- to ensure that staff apply that good practice consistently to current projects.

A procedure simply shows how a standard task will be done and who is responsible for that task. A possible procedure for producing a course specification is shown in Figure1.

A process-oriented standard cycle was introduced analogous to the four management processes. The four phases of the standard cycle of quality management are:

- plan – define goals, define and plan processes,
- do – introduce the process or introduce changes in the processes as planned,
- check – measure, compare performance results, their compliance with the planned results,
- act – search and analyse the causes of irregularities, and also eliminate them in order to improve the performance of the process (Deming, 2000).

As W.E. Deming (Deming, 2000) himself mentioned, this standard cycle was initially developed by W. Shewhart, however, it has gained its popularity directly from W.E. Deming's publications and therefore it is often called Deming Cycle.

The Deming cycle has especially influenced many Total Quality Management approaches where it can be retrieved in several modified versions. The Deming Cycle symbolizes the principle of continuous perfection, which means that never has it been achieved so good that it could not be even better. The principle of continuous improvement is at the heart of any approach to quality management in the organization, regardless of whether the quality management system is built up to the ISO 9001:2008 standard, or the management system is based on European Foundation for Quality Management (EFQM) or some other excellence model.

The general principles of quality management are:

- continuous improvement (plan-do-check-act),
- process approach (plan, act),
- fact-based decision making (check),
- look for the causes of the problem rather than the guilty (check-act) (Leilands, 2007).

The process of preparing and developing e-materials for the needs of the distance education also has a four-phase cycle. Education materials are the most important element of the distance education (Discenza, Howard, & Schenk, 2002). Therefore, the learning resources should be organized as well as possible. The main quality issues related to learning resources are resource-structured layout of and the quality of the produced material itself (e.g. Hosie, Schibeci, & Backhaus, 2005; Oliver, 2005; Swedish National Agency of Higher Education, 2008).

The aim of the article is to describe the procedure of e-learning material evaluation using a checklist of key quality indicators.

Materials and Methods

Monographic method has been used for this article. Information was searched in electronic databases and printed publications published in Latvia and Europe.

The study analyses the literature of the period from 2005 to 2014. Wide spectrum of scientific literature has been reviewed and analysed on the research of the factors affecting the quality of e-learning and quality assurance issues.

In January 2018, experts from general educational institutions that carry out distance education programs in Latvia and are a structural unit of a commercial company were interviewed. Based on the information contained in the National Education Information System, there are six schools. Since the aim of the study was to find out how the process of accepting and evaluating the learning materials takes place, such schools were selected, where the number of students is more than 100. Ultimately, there were three schools: European Distance Education Secondary School, Riga Distance Education Secondary School and Riga 1st Distance Education Secondary School. Questionnaires were emailed to these schools and 10 responses were received. The questionnaire included 12 questions about the quality assessment of the study materials. Nine questions were closed questions with multiple-choice options and three were the free-response questions. One of these questions was – name the five most important criteria that determine the quality of electronic teaching materials. The processing of the data takes into account the sequence of the named criteria and are given importance score according to the scale (5 (most important) – 1 (less important)). The results obtained in October 2014 were compared. Twenty learners from the Distance Professional Learning Centre of Latvia were also asked to name the five most important criteria that determine the quality of electronic teaching materials.

During the study, based on the findings of scientific research literature and taking into account the good practice, the procedure for the quality control of electronic learning materials was created.

Results and Discussion

The results showed that all three distance learning schools (n=3) have introduced a specific procedure for the implementation of e-learning materials. However, the environment of the material implementation and quality evaluation are different. The European Distance Education Secondary School materials are integrated into the school's online learning environment and then reviewed. In the Riga Distance Education Secondary School, they are accepted and reviewed both in electronic files (mostly .docx) and then integrated into the online learning environment. It should be noted that the surveyed schools have their own e-environment, specially created for this school. A commission of methodological teaching participates in the process of quality evaluation of the

study materials. This fact was taken into account in the development of procedures.

All respondents (n=10) noted that in the evaluation process it would be useful to use a checklist which contains the main aspects of quality evaluation. This confirms the important role of the checklists in promoting the quality of e-learning materials. Existing research provides a comprehensive overview of various aspects (Kazaine, 2017), which should be taken into account to ensure the quality of e-learning material. This aspect was taken into consideration when designing a number of procedures which deal with the study materials and checklist:

- development of the course material,
- acceptance of the course material,
- evaluation of the course material according to the checklist,
- review of the checklist.

These procedures relate to the use of a web-based self-assessment tool developed by the author of the article. This tool is based on a checklist and includes the indicators affecting the quality of e-learning materials (Kazaine & Arhipova, 2017). Of course, this is just a small part because the organization's operation is characterized by many more procedures.

Procedural activities are divided into areas of responsibility: developer of the material, methodological commission, evaluator (Figure 1). The use of the checklist is included in both procedures: Development of the course material (Figure 2) and Acceptance of the course material (Figure 1). In the first phase, it is used as a self-assessment tool. When reviewing his work, the author of the material can still improve the quality of the material. Indicators affecting the quality of e-learning material can be divided into four categories: formal requirements, didactic, media and usability (Pappas, 2014; Fey, 2015; Kazaine, 2017). Checklist was prepared according to the identified quality criteria and sub-criteria. The checklist has been developed and adapted on the basis of evidence, which results from guidelines, standards and by studying best practices in instructional and web design. This list is also intended to be used as self-assessment and improvement tools used by instructional developers and by instructional technologists. They can be used throughout the process to ensure consistency and efficiency and to promote quality assurance.

In order to identify the current situation and improve the checklist questionnaire, the questionnaire included questions about which criteria are taken into account when implementing the learning material, and which criteria, in their opinion, determine the quality of electronic learning materials. Respondents were offered 15 criteria and they had to indicate which ones were used in the evaluation process of the study
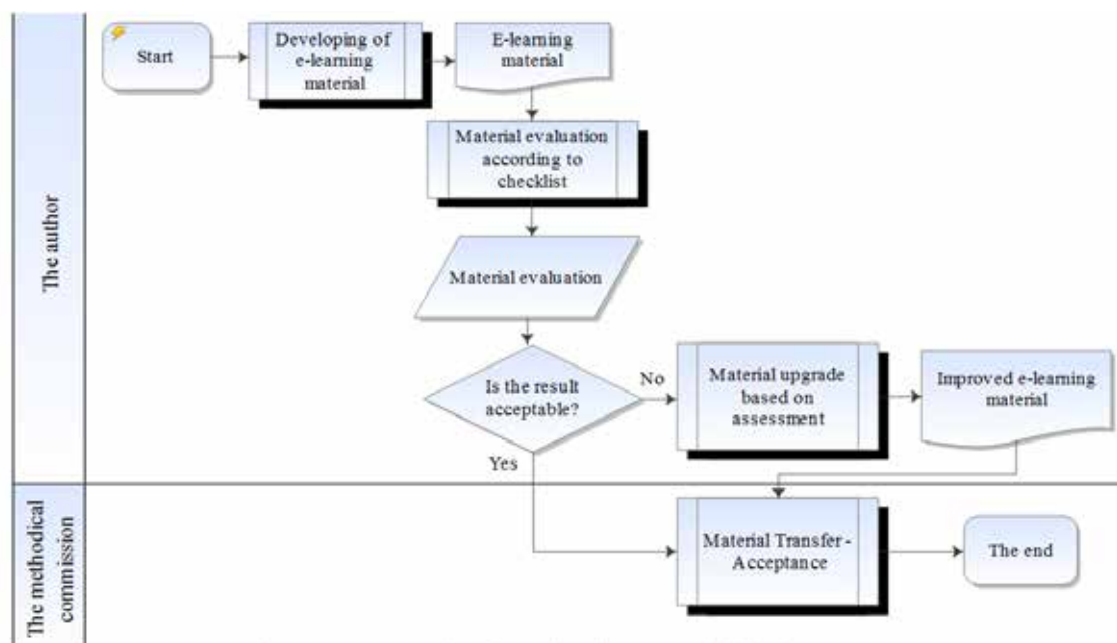
Figure 2. A procedure for e-learning material development.

material. The results (n=10) showed (Table 1) that when evaluating the material the following things are being looked at: compliance with the curriculum, existence of self-assessment tasks, and reference to other sources of information.

However, referring to the importance of the criteria, the opinions are different. By summing up the proposed criteria and the opinions of the respondents, selecting the ten most important criteria (Table 2),

it can be concluded that from the teachers' (n=10) perspective the most relevant criteria are: material must be motivational to the students, the content should be easy to read, and it has to comply with the curriculum. In contrast, from the learners' (n=20) perspective the most relevant criteria are: easy to read, topicality, and structured layout. It should be noted that the students did not mention the motivation at all. The fact that the teaching material must be structured and

Table 1

Summary of the use of quality criteria in the evaluation process of the study material

Criteria	Frequency
Content compliance with the curriculum	10
The learning material includes self-testing tasks	9
The study material includes reference to other sources of information	8
Corresponding topic breakdown	7
The study material includes self-monitoring questions	6
The study material includes independent work	6
The study material motivates to learn its content	6
The quality of media (image, video, audio) in the study material	6
Design	6
Breakdown of implementation forms (contact hours, independent work in e-environment)	5
Topicality, modernity	5
At the end of the units there is a summary	4
The study material includes a glossary	4
Structured layout	4
Match text to target group	3

Table 2

Criteria importance the quality of electronic materials

Criteria	Teachers (n=10)	Average rating	Highest rating	Lowest rating	Learners (n=20)	Average rating	Highest rating	Lowest rating
The study material motivates to learn its content	6	4.5	5	4	0	0.0	0	0
Easy-to-read content	6	4.2	5	2	14	4.2	5	3
Content compliance with the curriculum	10	4.0	5	2	6	3.5	5	1
Structured layout	5	3.7	5	2	6	3.7	5	2
Design	6	3.5	5	1	6	2.8	5	1
Topicality, modernity	4	3.0	3	3	4	4.0	5	1
At the end of the units there is a summary	2	3.0	3	3	3	3.3	5	2
The quality of media (image, video, audio) in the study material	4	2.5	3	2	14	2.7	5	1
The learning material includes self-testing tasks	8	2.2	3	1	2	1.5	2	1
The study material includes reference to other sources of information	5	1.7	2	1	3	1.3	1	1

easy to read proves that both groups of respondents think similarly.

The current checklist includes questions about the explanation of terms and a summary, which were not mentioned by the respondents. This means that the importance of checklists can change and it needs to be reviewed. For this purpose, a procedure was developed for reviewing the checklist, which involves the methodological commission and the administrator. The planning, production and delivery of e-learning requires the collaboration of several specialists (teachers, methodological and technical support) working together in a team environment (Phillips, 2005). Information technology specialist is the one who technically makes changes to the web-based checklist.

Conclusions

Proposed procedures provide a framework for action that promotes quality assurance as a daily practice. Consequently, the application of the procedures should be the responsibility of the head of the institution, as well as checking whether they are being used. The use of the checklist in these procedures provides continuous improvement opportunities to ensure an effective learning process. High quality materials arise from the day-to-day, consistent application of good practice and from discussion and testing.

Further work should be done on improving the web-based checklist tool, by adding to the possibility of keeping track of the evaluations and to generate reports. It is also necessary to regularly review the list of criteria and the importance of the criteria.

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