THE EFFECT OF AGROECOLOGICAL FACTORS ON YIELD AND FLAVONOIDS CONTENT OF GLOBE ARTICHOKE

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Abstract
Artichokes (*Cynara cardunculus* L.) contain many minerals, vitamins, fibres, polyphenols. Environmental conditions and climate change on a global scale affects the overall agriculture and food supply. Composition of biological active compounds in plants depends on the climate and growing conditions, cultivar properties, plant development stage, harvesting time and other factors. The aim of research was to evaluate the effect of agroecological factors on yield and flavonoids content of globe artichoke. An experiment was carried out under open field conditions in Institute of Horticulture, in Pūre investigation fields during the vegetation period of 2014 and 2015. The experiment was arranged in two different soils: brown soil with residual carbonates and the soil strongly altered by cultivation. The yield and its quality were analyzed during the whole vegetation period. Higher yield was observed in the soil strongly altered by cultivation. The results showed tendency that the higher flavonoids content in artichoke heads was observed in 2014 than in 2015. Significant differences between flavonoid content per harvest time are observed in both soils.
Key words: soil, flavonoids, biochemical composition, *Cynara cardunculus.*

Introduction

Artichoke has a long history, it has been used as a herbal medicine plant in traditional medicine since Roman times (Christaki, Bonos, & Florou-Paneri, 2012). The globe artichoke (*Cynara cardunculus* var. *scolymus* (L.) Fiori), (Fam. *Asteraceae*) is widely distributed all over the world and especially in the South Europe, Middle East, North Africa, South America, United States and also in China (Pandino *et al*., 2013). The production of artichokes in the world has a tendency to increase by years. In Europe, they are mainly grown in Italy, which had the production of 547 799 tonnes in 2013. In Baltic countries, artichokes are commercially grown in Lithuania with the production of 100 tonnes in 2013 (http://faostat3.fao.org/download/Q/QC/E). In Latvia, artichokes are not grown on commercial scale, but only in home gardens. Globe artichoke is a perennial herbaceous plant. In Latvia, artichoke is cultivated mostly as an annual plant because winter periods are characterized with low soil and air temperature damaging plants. Long periods without snow or thaws are typical in the wintering period. It has a negative influence on plant overwintering ability (Bratch, 2014).

The edible part of the plant is immature inflorescence, commonly called capitulum or head. Artichoke heads are characterized by low protein and fat, high content of minerals, vitamins, carbohydrates, inulin and polyphenolic compounds (Kolodziej & Winiarska, 2010; Pandino *et al*., 2013). All these compounds have strong antioxidant properties, although their content varies between different artichoke varieties and plant parts (Ciancolini *et al*., 2013). Caffeoylquinic acid derivatives, particulary chlorogenic acid and flavonoids are the most common and widely distributed group of plant phenolic compounds in artichokes (Lombardo *et al*., 2010). They have an important role in human diet due to their antioxidative activity (Yao *et al*., 2004; Kumar & Pandey, 2013).

The aim of research was to evaluate the effect of agroecological factors on artichoke yield and flavonoids content of globe artichoke in Latvia.

Materials and Methods

The investigation was carried out in Pūre village (Tukums district, Latvia 57°2′9″N 22°54′25″E) in vegetation seasons of 2014 and 2015. At the beginning of March, artichoke variety ‘Green Globe’ seeds were germinated in Petri dishes on filter paper saturated with water. After 10 days, sprouts were planted in trays and then after two weeks transplanted in 12 cm diameter plastic pods. Two different soils were compared for artichoke growing: strongly altered by cultivation soil (Ant), with high content of nitrogen and phosphorus, low content of potassium (total N 0.21%, P_2O_5 – 352.1 mg·kg^{-1}, K_2O – 133.5 mg·kg^{-1} and organic matter 5.4%) and brown soil with residual carbonates (BRk), with optimal content of nitrogen, phosphorus and potassium (total N 0.10%, P_2O_5 – 190.4 mg kg^{-1}, K_2O – 191.8 mg·kg^{-1} and organic matter 2.8%). In the middle of May, plants were planted on the field, in 4 replicates, with planting scheme 0.7 × 0.9 m. Plant vegetative parameters (plant diameter and height) were evaluated at the end of July. The first artichoke heads were harvested at the end of July in 2014 and beginning of August in 2015. Artichoke heads were harvested continuously every week until October both years.

Meteorological parameters used in the investigation (precipitation and average air temperature) were collected by an automatic meteorological station ‘Lufft’ located in Pūre (Fig. 1.).

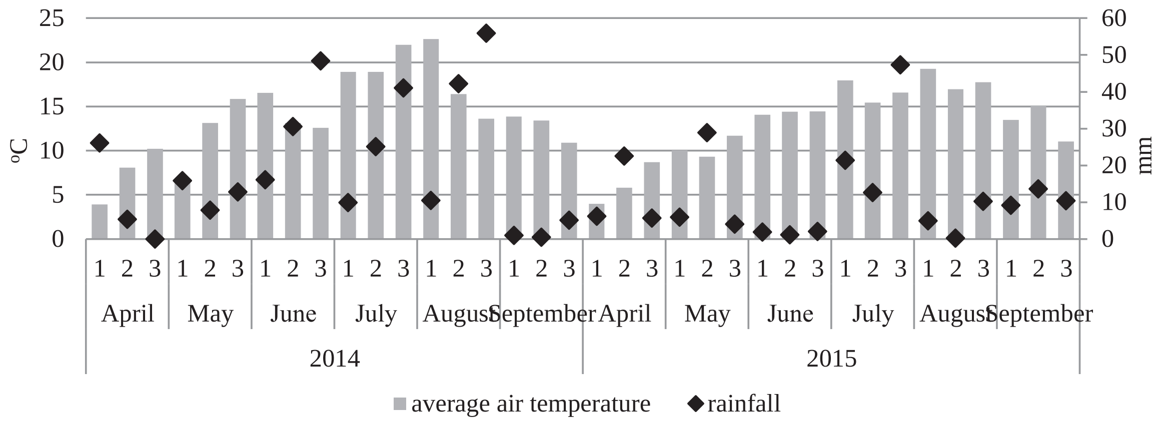


Figure 1. Meteorological parameters 2014/2015th season in decades.

Biochemical analyses were performed in Latvia University of Agriculture, Institute of Soil and Plant Sciences. The content of flavonoids was analysed spectrophotometrically (Shimadzu Spectrophotometer UV-18000) in three replicates (Kim *et al*., 2003). Average sample of artichoke heads from all replicates was blended and weighted 1 ± 0.01 g of sample. It was placed in a graduated tube filled up to 10 mL of ethanol and centrifuged (HermleZ383). 2 mL distilled water and 0.15 mL 5% sodium nitrite $NaNO_2$ were added to 0.5 mL aliquot of ethanolic artichoke extracts. After five minutes 0.15 mL 10% aluminium chloride $AlCl_3$ was added, again after five minutes 1 mL 1M sodium hydroxide NaOH was added and after fifteen minutes optical density of solution at 415 nm wavelength was determined. Results were expressed as mg catechin equivalent (CE) per 100 g of fresh mater (FM).

The results were analyzed using ANOVA at significance level of $\alpha = 0.05$.

Results and Discussion

Results show that yield per plant in both years ranged between 231 – 400 g (4 – 6 heads). Significant differences between years were not observed, but soils had a significant influence on artichoke yield ($p = 0.04$) (Fig. 2.).

Artichokes better grew and developed in strongly altered by cultivation soil than in brown soil with residual carbonates (Tab. 1.). This is in accordance to findings of others referring to the fact that artichokes better perform in the soils with higher concentrations of nutrients (Colla *et al*., 2013). Plants height and diameter were significantly higher ($p = 0.3 \times 10^{-2}$) in Ant than in BRk. In 2015, the plant developed much better than in 2014 (height difference – $p = 0.04$). For plant diameter, significant differences depending on soils and years were not observed.

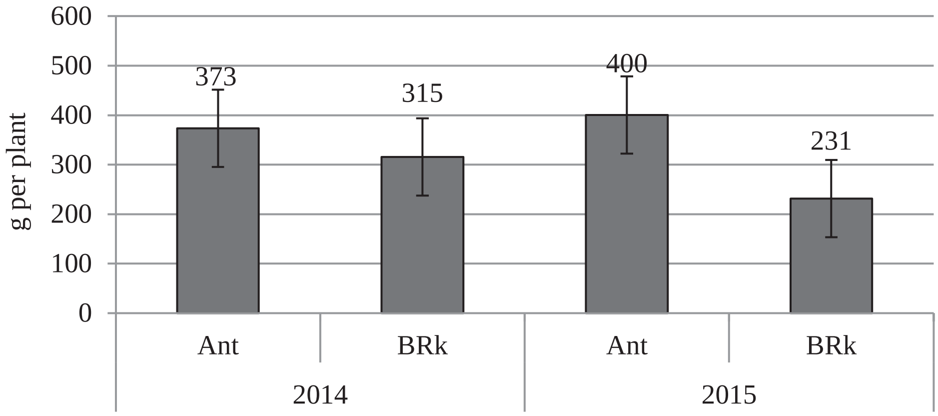


Figure 2. Yield of artichoke heads depending on soil, in 2014 and 2015.

Table 1

Plant vegetative parameters, 70 days after planting in 2014 and 2015

Year	Soil	Plant height, m	Plant diameter, m
2014	Ant	0.43	0.97
	BRk	0.29	0.82
2015	Ant	0.47	0.84
	BRk	0.38	0.74
$RS_{0.05}$		0.08	0.18

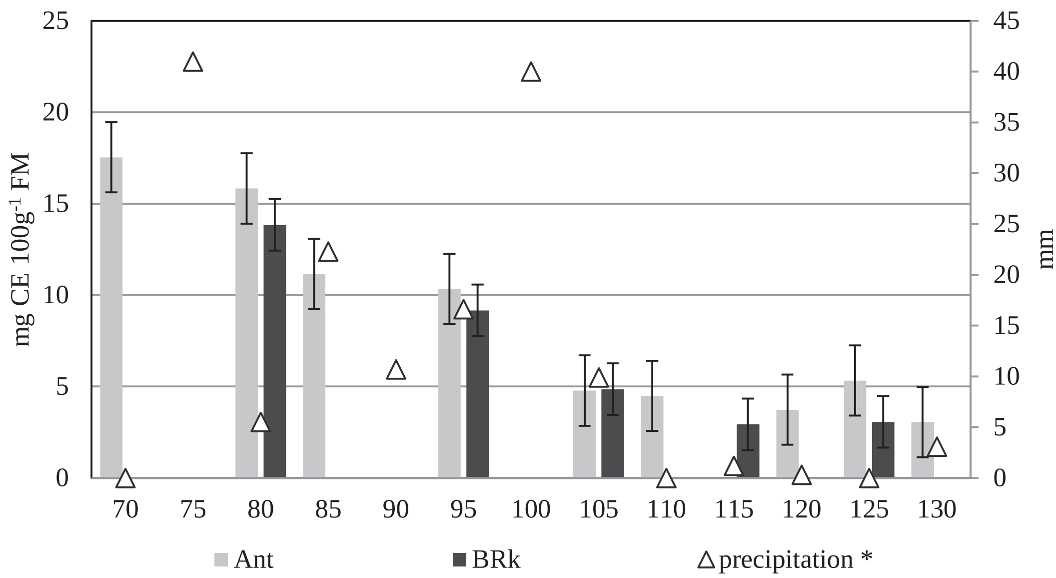
In the field located on strongly altered by cultivation soil organic matter was detected 5.4%. For many years different vegetables have been grown in this field, it was abundantly fertilized. In other field of brown soil with residual carbonates plants did not have so vigorous plant habit; plants also developed less heads.

In 2014, first artichoke heads were harvested in Ant soil on 28 July (70 days after planting). One week later first artichoke heads were harvested in BRk soil. Artichoke yield was harvested every week. The first decade of August characterized with low precipitation and high air temperature (22.7 °C). In this period heads developed faster and more intensively – heads were ready for cutting after 4 – 5 days.

The same tendency was in 2015 – first artichoke heads were harvested in Ant soil, on 3 August (67 days after planting). Similarly like in 2014, one week later first artichoke heads were harvested also in BRk soil. In the vegetation period of 2015, artichoke heads were harvested more rarely than in 2014. Although August and September also were dry, average air temperature was lower than in 2014 – heads were harvested once per week. Artichokes grow best at 25 °C daytime temperature (Bratch, 2014).

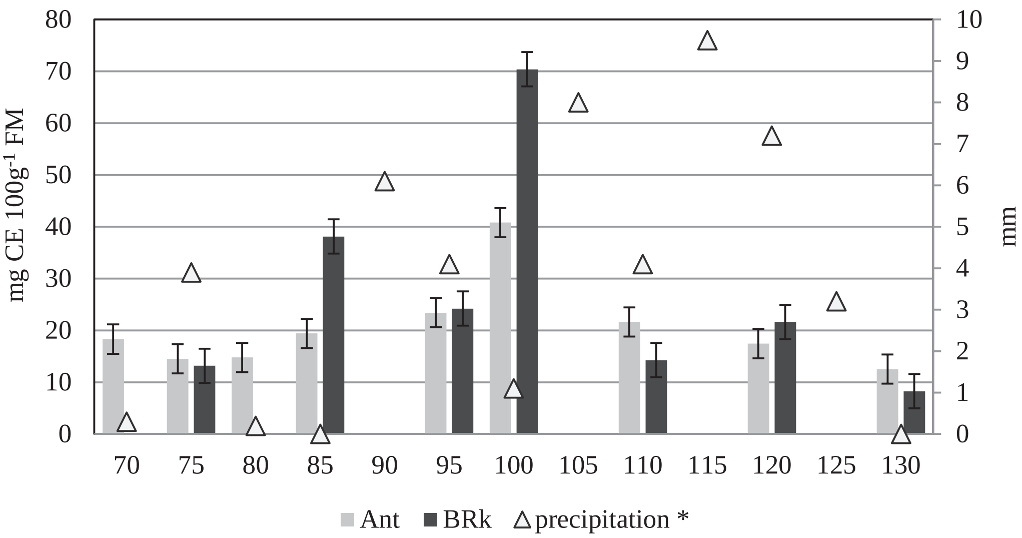
Abiotic factors (temperature, humidity, nutrients) have a significant influence on the nutritional quality of artichoke heads (Lombardo *et al.*, 2010). They cause changes in the content of biochemically active compounds in the plants and following the artichoke heads. Results obtained in the trial show that flavonoids content in 2014 ranged between 3.1 – 17.5 mg catechin equivalent (CE) 100 g^{-1} fresh matter (FM) (Fig. 3.).

The content of flavonoids in the artichoke heads is fluctuating during the harvesting period in both soils – in Ant ($p = 4.89 \times 10^{-6}$) and in BRk ($p = 0.05 \times 10^{-2}$). There is an expressed tendency to decrease the flavonoid content in heads by the end of vegetation period almost by half. It should be stressed that 2014 was characterised with dry September. Probably it had some influence on the biochemical compounds of



* sum of precipitation of 5 previous days before of each harvest

Figure 3. The dynamic of flavonoids content in artichoke heads in relation to precipitation in 2014.



* sum of precipitation of 5 previous days before of each harvest

Figure 4. The dynamic of flavonoids content in artichoke heads in relation to precipitation in 2015.

artichoke. Drought is one of the main abiotic stresses limiting plant growth and development. Limited water supply is a major factor influencing physiological and metabolic processes in plant (Tahna, Ghasemnezhad, & Babaeizad, 2014). In Poland, researchers observed that irrigation positively influence flavonoids content in the plants (Kolodziej, & Winiarska, 2010).

According to our findings, air temperature had less influence on flavonoids content of artichoke heads. In both years of investigation, temperature regime was quite similar, although flavonoids content was different. In 2014, temperature was higher at the beginning of the vegetation period and gradually decreased by the end of harvesting period.

In 2015, the sharply expressed fluctuation of flavonoids content was detected for analysed artichoke heads in the trial. It ranged between 8.3 and 40.8 mg CE 100 g^{-1} FM (Fig. 4.)

Also, in 2015 similarly to 2014, differences between flavonoid content per harvest time were observed in both soils – in Ant ($p = 1.08 \times 10^{-6}$) and in BRk ($p = 6.83 \times 10^{-6}$). Although longer drought periods were registered in 2015 than in 2014, the content of flavonoids in the artichoke heads was notably higher, but more fluctuating. It is contrary to findings of others (Kolodziej and Winiarska, 2010). It can be assumed that fluctuating precipitation and less sum of precipitation in the whole vegetation period causes stress in plants which leads to increasing of physiologically active compounds in plants. Also Nakabayas et al., reported that synthesis of flavonoids increased in stress conditions (Nakabayashi *et al.*, 2010). Obtained results do not show very clear relation of precipitation and flavonoids content, just some indications on possible positive influence of drought. There are also contrary reports of others on this topic (Salata, Gruszecki, & Dyducg, 2012).

In 2015, temperature was more fluctuation (Fig. 1), but in the same amplitude as in 2014 and with general tendency to decrease towards autumn. It is referred by others that air temperature and solar radiation influence accumulation of polyphenols in globe artichoke in different harvest times. Higher temperature positively influenced content of polyphenols (Pandino *et al.*, 2013).

In California, artichoke plants were growing in the temperature amplitude from 13 to 24 °C in. Plants are tolerant of temperatures above 30 °C, but the quality of head reduced (Smith *et al.*, 2008). In our conditions, temperature was much lower (mostly between +10 and +17 °C). It leads to the assumption that temperature conditions in our trial were under optimal; therefore, fluctuation in this amplitude has not significant influence on accumulation of flavonoids.

According to the findings of our trial performed in two years in Latvia agro-climatic conditions, we see that artichoke growing is possible and this region can be assumed as boundary of artichoke growing in Latvia, since yields are obtained much less than in Europe, but still there are some consumable heads harvested. Biochemical content also differs from artichoke grown in more southern locations. In Poland, it was observed that artichoke head weight was obtained between 150 – 350 grams and weather conditions influence the content of chemical compounds in artichoke heads (Salata, Gruszecki, & Dyducg, 2012). In Portugal, it was found that content of phenols in artichoke depends not only on growing conditions (Velez *et al.*, 2012), but also on the physiological plant stage (Negro *et al.*, 2012). This is in line with our findings where common tendency to decrease the flavonoid content in artichoke heads with the plant age was found. We can assume that flavonoid content in artichoke head is detected not only by moisture availability in the soil, but also by other environmental and physiological factors.

Conclusions

Artichoke yield in strongly altered cultivation soil (Ant) was harvested one week earlier than in brown soil with residual carbonates (BRk) in both years. Higher artichoke head yield was obtained in Ant soil (373 and 400 g per plant) than in BRk (315 and 231 g per plant).

Our findings lead to the assumption that fluctuating precipitation and less sum of precipitation in the whole vegetation period causes stress in plants, which leads to increasing of flavonoids in plants. Temperature regime in Latvia agroecological conditions had no significant influence on the flavonoid content in artichoke plants. Flavonoid content in artichoke head is determined not only by precipitation, but also by other environmental and physiological factors.

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