

DEVELOPMENT OF WINTER WHEAT BLOTCHES DEPENDING ON FUNGICIDE TREATMENT SCHEMES AND NITROGEN RATES

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Abstract

One of the factors affecting winter wheat grain yields are leaf blotches. The two-factorial trial was conducted in the Research and Study farm 'Pēterlauki' in 2017/2018 and 2018/2019 (Latvia). Four nitrogen rates and five fungicide treatment schemes were used. The aim was to clarify the impact of leaf blotches on the winter wheat yield. In winter wheat plots, the tan spot (caused by *Pyrenophora tritici-repentis*) dominated but also Septoria leaf blotch (caused by *Zymoseptoria tritici*) was found. The severity of leaf blotches in winter wheat was low in both years due to dry and warm weather. The development of leaf blotches was influenced by fungicide application schemes, but not by nitrogen fertilizer rate. The total disease impact during the vegetation period was estimated by calculation the area under the disease progress curve (AUDPC). AUDPC for both diseases were significantly higher in the variant without fungicides (F0) and in the variant, where half of dose of fungicides at the growth stage (GS) 55–59 (F1) was used. The using of full dose of fungicide at the GS 55–59 (F2) as well as using of fungicides two (F3) or three (F4) times in growing season significantly decreased the values of AUDPC for both diseases, but differences among AUDPC values in mentioned three variants were not significant. Results showed that the nitrogen fertilization significantly increased the average per both years grain yield until the nitrogen rate N180. Fungicide treatment schemes had no significant effect on the average grain yield.

Key words: *Pyrenophora tritici-repentis*, *Zymoseptoria tritici*, control, yield, values of AUDPC.

Introduction

The grain yield is influenced by the interaction of a number of factors such as cultivar, meteorological conditions and nitrogen fertilizers. Researches confirm that nitrogen fertilization significantly increased winter wheat grain yield, but increase of yield depends on the used rate of nitrogen (Litke, Gaile, & Ruža, 2017; Linina & Ruža, 2018).

An important factor affecting winter wheat grain yields is leaf blotches. In Latvia, the most widespread wheat leaf diseases are tan spot (caused by *Pyrenophora tritici-repentis*) and Septoria leaf blotch (caused by *Zymoseptoria tritici*) (Bankina *et al.*, 2014; Bankina *et al.*, 2018a).

The losses of winter wheat yield can range from 10–74% (Wegulo, Breathnach, & Baenziger, 2009; Wiik, 2009; Jevtić *et al.*, 2017; Bhatta *et al.*, 2018) and depend on development stage at which the infection occurs (Serrago *et al.*, 2011). The occurrence of diseases depends considerably on meteorological conditions (Wyczling, Lenc, & Sadowski, 2010; Bankina *et al.*, 2014; Jevtić *et al.*, 2017; Bankina *et al.*, 2018a), agrotechnical practices (Bankina *et al.*, 2018a) and fertilisation (Castro *et al.*, 2018).

The leaf blotches decrease green leaf area (Wyczling, Lenc, & Sadowski, 2010; Bhatta *et al.*, 2018), but the photosynthesis during grain filling period ensure dry matter accumulation in the grain, including nitrogen. The fungicide treatment strategies are aimed to protect leaves, particularly the flag leaf, and delay the senescence (Castro *et al.*, 2018). The yield benefits from fungicide application and not only depends on the amount of rainfall at all important growth stages for yield formation (Bhatta *et al.*, 2018),

but also on the frequency of the rainfall. Frequent rainfall provided conditions for continued pressure of tan spot and Septoria tritici blotches (Wyczling, Lenc, & Sadowski, 2010; Ronis & Semaškiene, 2011; Byamukama *et al.*, 2019).

The aim of this research was to clarify the impact of leaf blotches on the winter wheat yield under four nitrogen rates and five fungicide treatment schemes.

Materials and Methods

Two-factorial field trials were conducted at the Research and Study farm 'Pēterlauki' of Latvia University of Life Sciences and Technologies (56° 54.367' N and 23° 72.220') in the growing seasons of 2017/2018 and 2018/2019. Researched factors were: (A) five different fungicide treatment schemes (Table 1) and (B) four nitrogen fertilizer rates were used (N120(80+40), N150(80+70), N180(80+70+30) and N210(80+80+50). In total, twenty variants were arranged in four replications.

The winter wheat cultivar 'Skagen' was used in the trial. This cultivar is characterized by good productivity and winterhardiness. Sowing rate depended on sowing time and trial meteorological conditions: 450 germinable seeds m⁻² in 2017/2018 and 500 germinable seeds m⁻² in 2018/2019. In 2018, wheat sowing was delayed to the end of September due to adverse weather conditions, and in this case, sowing rate was increased a little.

The soil at the site was loamy, stagnogley. The soil is characterized by the following indicators depending on the year: pH KCL = 6.4–7.0, organic matter content 29–42 g kg⁻¹, P₂O₅ content 118–138 mg kg⁻¹ and K₂O content 208–262 mg kg⁻¹ of the soil.

Table 1

The fungicide treatment schemes

Variant	Used fungicides		Treatment timing – growth stage (GS) according BBCH*
	active ingredients of fungicides	dose, L ha ⁻¹	
F0	Without fungicides	–	–
F1 (one treatment)	Protrioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
F2 (one treatment)	Protrioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	1.500	55–59
F3 (two treatments)	Protrioconazole 160 g L ⁻¹ ; spiroxamin 300 g L ⁻¹	0.625	32–33
	Protrioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
F4 (three treatments)	Protrioconazole 160 g L ⁻¹ ; spiroxamin 300 g L ⁻¹	0.625	32–33
	Protrioconazole 130 g L ⁻¹ ; bixafen 65 g L ⁻¹ ; fluopyram 65 g L ⁻¹	0.750	55–59
	Metconazole 90 g L ⁻¹	1.000	63–65

*BBCH – the phenological growth stages of cereals according to the ‘Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie’ (BBCSH) scale.

Before sowing, fertilizer was applied N – 25 kg ha⁻¹, P₂O₅ – 65 kg ha⁻¹, K₂O – 65 kg ha⁻¹. Weeds were controlled using herbicides in both years: in 2018, granstar premia 50 SX (methyl-tribenuron 500 g kg⁻¹) 22 g ha⁻¹ + Primus (florasulam 50 g L⁻¹) 0.1 L ha⁻¹ at 07.05.2018., in 2019, biathlon 4D (tritosulfuron 714 g kg⁻¹; florasulam 54 g kg⁻¹) + adjuvant Dash 0.5 L ha⁻¹ in were used. In spring, after the vegetation renewing, nitrogen fertilizer (NH₄NO₃; N 34.4%) was applied for all investigated variants. The second top-dressing was done at GS 29–31 using ammonium sulphate ((NH₄)₂SO₄; N 21%, S 24%) at the rate 100 kg ha⁻¹. The remaining amount of needed nitrogen was added using ammonium nitrate (NH₄NO₃; N 34.4%). The third top-dressing was done at GS 47–51 with ammonium nitrate. The rate of nitrogen was divided into two applications for variants N120 and N150, and into three applications – for variants N180 and N210.

After harvesting, grain was weighed, grain purity and moisture content detected and yield data were recalculated to standard moisture (14%) and 100% purity.

The incidence and severity of the disease were evaluated for the whole plant at the growth stage (GS) of the beginning of stem elongation (GS31), for the 3 upper leaves at the stages ‘Flag leaf just visible’ till ‘flag leaf stage: flag leaf fully unrolled, ligule just visible’ (GS 37–39) and the full flowering (GS

63–65), for the 2 upper leaves – at the stage of early milk (GS 73) and at the stage of late milk (GS 75–79). Growth stages were noted according to BBCH scale. In the first assessment, 50 plants were evaluated. In further assessments, 50 leaves were evaluated from every plot, proportionally taking the flag leaves, the first leaves and the second leaves. The total disease impact during the vegetation period was estimated by calculating the area under the disease progress curve (AUDPC).

For data statistical processing the analysis of variance was used. R-Studio for data processing was used. Bonferroni test was used for the comparison of means, the differences were considered statistically significant when p < 0.05. Significantly different means were labelled with different letters in superscript (a, b). The relationship between the winter wheat yield and the development of leaf blotch was analyzed by correlation analyses.

The meteorological data were summarized according to growth stages when the evaluation of diseases was done (Table 2). The weather conditions slightly differed during the years of investigation. The air temperatures were higher than long-term observations in the both trial years. There was a significant difference between vegetation starting dates (respectively – on 3 April 2018 and on 15 March 2019). The time from the starting of vegetation till the stage of stem elongation was relatively short (34 days)

Table2

Meteorological conditions during the period of investigation

Year	Growth stages	Average temperature, °C	Amount of precipitation, mm	Number of rainy days (>2mm)
2018	31–39	16.2	4	1
	39–65	17.6	2	0
	65–73	17.9	0	0
	73–79	15.8	14	3
2019	31–39	13.3	14	1
	39–65	16.3	5.8	0
	65–73	20.5	1.6	0
	73–79	18.8	6.2	1

and with an increased amount of precipitation in April 2018, but in 2019, this period was 52 days long. There was no precipitation in April 2019. Lack of moisture at all important growth stages for yield formation was observed. Overall, the meteorological situation was unfavourable for the plant growth and development in both trial years.

Results and Discussion

The development of leaf blotches

In winter, wheat plots, the tan spot (caused by *Pyrenophora tritici-repentis*) dominated, but also Septoria leaf blotch (caused by *Zymoseptoria tritici*) was found. Differences in the development of leaf blotches in each trial year separately were described in previous publications (Bankina, Stanka, & Grickeviča, 2018b; Stanka, Bankina, & Daugaviņa, 2019).

The incidence and severity of leaf blotches in winter wheat was low in both years. Dry and warm weather delayed the development of leaf blotches. It is known, that precipitation is necessary for the development of leaf blotches. Especially the causal

agent of Septoria leaf blotch requires a moist leaf surface for successful infection. The pathogen spread throughout the crop canopy via rain splash originating (Castro *et al.*, 2018).

The tan spot progression during the vegetation period is shown in Figure 1. The first symptoms of tan spot were observed already at GS 31–32, but the development of disease was slow and similar till GS 71–73 in all fungicide treatment schemes. Rapid development of tan spot began at the time of ripening of grains. The highest severity of tan spot (10.4%) was obtained in control variant where winter wheat was grown without the application of fungicides. With the application of fungicides, the severity of tan spot decreased until 3.6–6.1%.

Septoria leaf blotch started later, the first symptoms were observed only at the flag leaf stage (GS 37–39). Overall, the progression of Septoria leaf blotch was slower than that of tan spot (Figure 2). The highest severity of Septoria leaf blotch (3.7%) was obtained in control variant where winter wheat was grown without the application of fungicides. The application

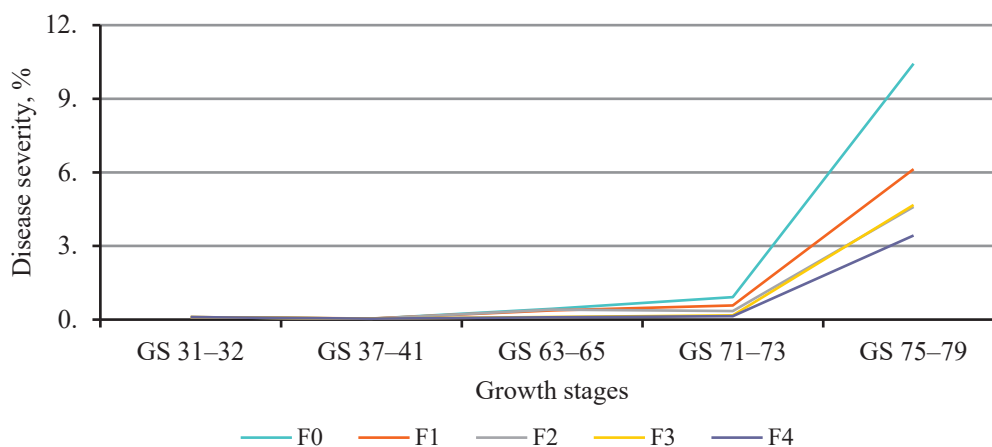


Figure 1. Development of tan spot depending of fungicide treatment schemes (average data per 2017/2018–2018/2019).

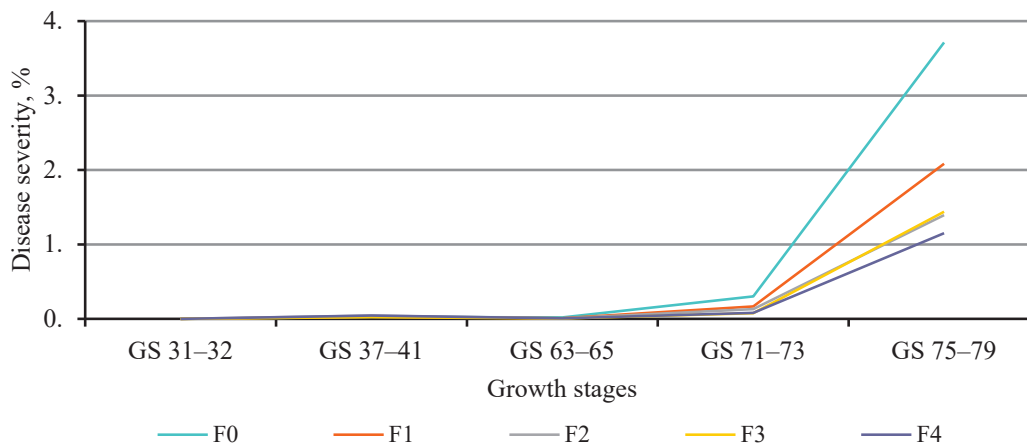


Figure 2. Development of Septoria leaf blotch depending on fungicide treatment schemes (average data per 2017/2018–2018/2019).

of fungicides decreased the severity of Septoria leaf blotch until 1.2–2.1%.

The total impact of diseases during the vegetation period depending on fungicide treatment scheme is shown by AUDPC (Figure 3). The development of leaf blotches was influenced by fungicide application schemes ($p < 0.001$ for both diseases), but not by nitrogen fertilizer rate ($p = 0.47$ for tan spot, $p = 0.97$ for Septoria leaf blotch). Some studies have reported that N fertilization may also affect distribution of foliar diseases. For example, in Argentina researchers found that only in the wettest years with more disease pressure, severity of Septoria leaf blotch and tan spot significantly decreased when the N rate increased, but in the dry years no differences were detected (tested variants – N0, N70 and N140 kg ha⁻¹) (Castro *et al.*, 2018). In another research Fleitas *et al.* (2018) found that, in untreated variants, the values of AUDPC for tan spot were lower with higher N rates.

Differences of AUDPC values for tan spot between variants of fungicide treatment schemes ranged between 24.4 and 77.4 units. Values of AUDPC were the highest in the control variant without fungicides (F0). The differences among the variants of different schemes were also significant. In variant F1, where half of dose of fungicides at the GS 55–59 was applied, the decrease of AUDPC units was not significant ($p = 0.06$) in comparison with control variant (F0). The significant decrease of the development of tan spot was obtained in variant with full dose of fungicide application at the GS 55–59 (F2) and in variants where winter wheat was treated with fungicides two (F3) or three (F4) times in the growing season. The differences of AUDPC values among these fungicide treatment schemes (F2, F3 and F4) were not significant.

The differences of AUDPC values for Septoria leaf blotch (Figure3) between variants of fungicide treatment schemes ranged between 8.4 and 26.0 units.

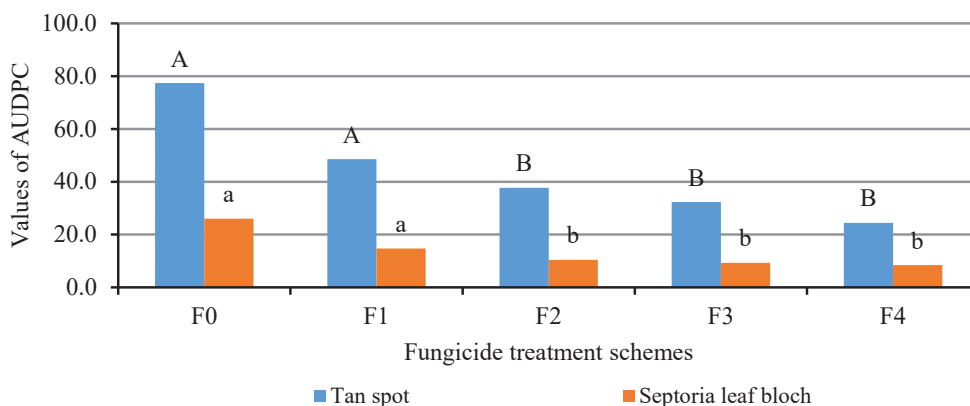


Figure 3. Values of areas under the disease progress curve (AUDPC) of leaf blotches depending on fungicide treatment schemes (average data 2017/2018–2018/2019).

Different letters denote significant differences:

A, B – for average values of AUDPC for tan spot;

a, b – for average values of AUDPC for Septoria leaf blotch.

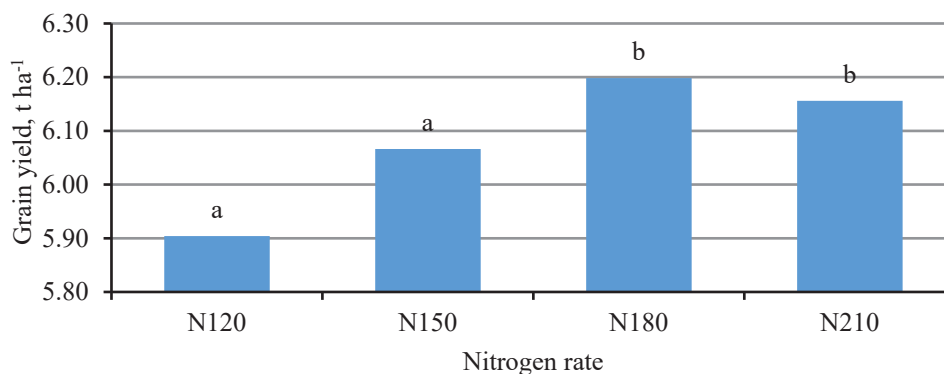


Figure 4. Winter wheat grain yield depending on the nitrogen rate (average data, 2017/2018–2018/2019). Different letters denote significant differences: ^{a, b} – for average yields of two trial years.

The influence of fungicide treatment schemes on the development of Septoria leaf blotch was similar to that of tan spot.

The results of researches about effectivity of various fungicide treatment schemes in different countries were contradictory. The researches showed that two fungicide applications are not necessary (Bankina *et al.*, 2014), but Wyczling, Lenc & Sadowski (2010) obtained a better effect after two applications. The results from a research in Nebraska showed that the effect of fungicide application timing at the GS 31 (first node on the stem detectable) versus GS 39 (ligule/collar of flag leaf just visible) on the intensity of leaf blotches or on yield was not consistent. The best predictor of yield losses caused by leaf blotches is disease severity at flowering, and fungicides used at this time can prevent significant yield losses (Wegulo, Breathnach, & Baenziger, 2009).

Wheat yield

Both trial years were unfavourable for winter wheat yield formation; the average winter wheat yield per two trial years was 5.90–6.20 t ha⁻¹ depending on variants. A year as a factor significantly influenced wheat yield ($p < 0.001$). Lower yields (5.03–5.57 t ha⁻¹) were obtained in 2018/2019, when the meteorological conditions from sowing until harvesting were worse for high yield formation even if compared with 2017/2018 which also was not appropriate for high yield development. Other researchers also found that limited water availability significantly reduces grain yield (Racz *et al.*, 2015; Smutná, Elzner, & Středa, 2018; Hlaváčová *et al.*, 2018).

The results show that nitrogen fertilization significantly increased the average grain yield per both years ($p < 0.001$). The influence of nitrogen rate differed during trial years ($p < 0.05$). In 2018, a significant yield increase was observed at the nitrogen fertilizer rate N210 but in 2019 – even at N180. It coincides with other studies which demonstrated that nitrogen application significantly increases the grain yield (Litke, Gaile, & Ruža, 2017). Assessing

the average two-year yield (Figure 4) depending on nitrogen rate, a significant increase of yield was obtained at the rate N180. Further increase of nitrogen rate did not cause a significant increase if compared with N180.

In 2018, when the average wheat yield was higher (6.33–7.33 t ha⁻¹), a significant distinction was found between variants in which different fungicide treatment schemes were applied, and higher yield on average was gained in the variants without fungicide treatment and in the variant with reduced fungicide dose at GS 55–59. It could be explained by stress for the plants due to the usage of fungicides, drought and hot weather. Fungicides may have negative effects on crop physiology, especially on photosynthesis, resulting in a decrease in both growth and yield of crop plants (Petit *et al.*, 2012). The researchers from Canada reported that using fungicides under dry conditions decreased the yield. Wheat were more resistant to drought than other tested crops, the application of fungicides one time in a growing period (flag leaf was fully emerged) only stressed plants. As a result, the grain yield was similar to non-treated variant although in years with normal amount of precipitation the use of fungicide increased grain yield by 5.2–15.0% (Kutcher *et al.*, 2011).

In 2019, the fungicide treatment did not significantly affect the wheat yield. Assessing the average two-year yield (Figure 5) depending on fungicide treatment schemes, significant differences were not found. Bhatta *et al.* (2018) found that efficacy of the foliar fungicide to improve grain yield largely depends on the meteorological conditions and the level of disease severity. In investigations the severity of leaf blotches was low. The results of a research in Poland (Wyczling, Lenc, & Sadowski, 2010) show that rainfall in the later part of the winter wheat growing season influenced the yield response to fungicide application, but the amount of precipitations in both years of our trial was very low. It is also known, that susceptible cultivars had a larger response

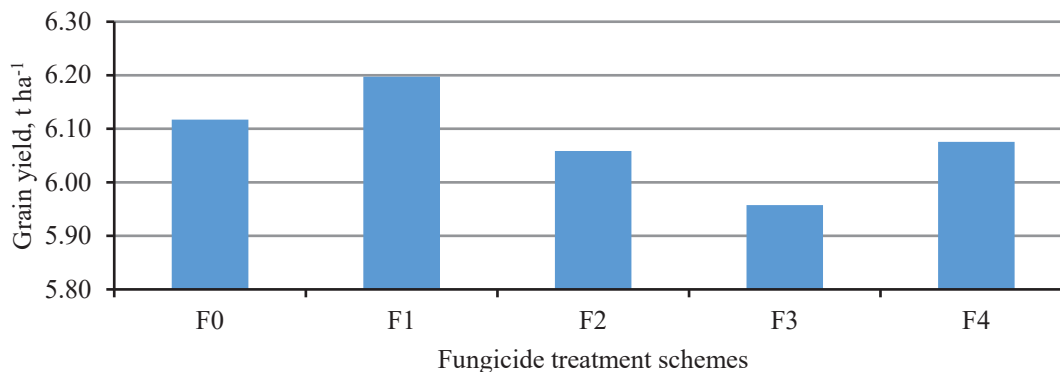


Figure 5. Winter wheat grain yield depending on fungicide treatment schemes (average data, 2017/2018–2018/2019).

to fungicides than resistant cultivars (Byamukama *et al.*, 2018; Bhatta *et al.*, 2018). Cultivar ‘Skagen’ used in our trials is characterised as comparatively resistant against diseases.

Leaf blotch disease’s severity on upper three leaves at GS 55 and upper two leaves at GS 75 significantly negatively correlated with the yield level. Wegulo, Breathnach, & Baenziger (2009) found that severity of leaf blotches at GS 60 had the strongest relationship to yield. Jevtić *et al.* (2017) found that the strongest relationship between values of AUDPC of Septoria leaf blotch and yield includes the period from the end of flowering (GS 69) to milk stage (GS 70–73). In our investigations, the severity of leaf blotches was low at this time and only a weak correlation ($r = 0.39$, $p < 0.001$) in 2018 between the total sum of AUDPC of tan spot and the yield was observed, but in 2019 – was not observed. A correlation between the total sum of AUDPC of Septoria leaf blotch and the yield was not observed.

Conclusions

The severity of leaf blotches in winter wheat was low in both years due to the dry and hot weather and did not influence the winter wheat grain yield significantly. Nitrogen fertilization increased the winter wheat grain

yield, but did not have a significant effect on the development of leaf blotches. A significant average yield increase was obtained till the nitrogen rate of N180, further increase of nitrogen rate did not cause a significant increase of yield.

Fungicide treatment schemes had no significant effect on the average grain yield but decreased the development of leaf blotches significantly. The using of full dose of fungicide at the GS 55–59 as well as using fungicides two or three times in the growing season significantly decreased the values of AUDPC for both diseases, but differences among AUDPC values in the three mentioned variants were not significant.

There was an untypically low amount of precipitation in both trial years and further studies are necessary to investigate different meteorological conditions and various levels of leaf blotch development.

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