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EFFICACY OF DIFFERENT FUNGICIDE DOSES AND APPLICATION TIMES IN WINTER WHEAT AGAINST LEAF BLOTCHES

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Abstract
Leaf blotches, caused by *Pyrenophora tritici-repentis* and *Zymoseptoria tritici* are among the most devasting and widespread diseases in Latvia and other regions where wheat is extensively grown. Two field experiments were conducted over three years (2022-2024) in farmer's fields situated in the Central region of Latvia. The aim of research was to evaluate various fungicide and biological product application schemes, with wheat sown following preceding crops of either wheat or oilseed rape. Application schemes included fungicide application in different wheat growth stages and doses, as well as one biological product. Obtained data indicates that tan spot, caused by *Pyrenophora tritici-repentis*, was the predominant disease with severity ranging from 3 to 32% depending on a year and pre-crop. Level of tan spot was notably higher in repeated wheat sowings. The severity of Septoria leaf blotch ranged from 0% to 7%, and was not influenced by pre-crop. Fungicide application reduced the severity of leaf blotches; however, effectiveness varied significantly both across and within treatments. On average, more effective results were observed when a single fungicide treatment was applied at the end of heading and the beginning of flowering. The efficacy of the lowest fungicide dose was inconsistent, exhibiting greater variability compared to higher doses. Additionally, split spraying did not provide remarkable results compared to a single application. Application of biological product did not provide control of diseases. Strong, positive correlation was observed between the reduction in leaf blotches severity and the additional yield obtained.
Keywords: *Pyrenophora tritici-repentis*, *Zymoseptoria tritici*, severity, yield, plant protection.

Introduction

Wheat is one of the most widely cultivated and economically important crops in Latvia and globally. However, the spread of various diseases, particularly leaf diseases, poses one of the most significant risk to crop production. Leaf blotches, caused by *Pyrenophora tritici-repentis* and *Zymoseptoria tritici* are among the most devasting and widespread diseases in Latvia and other regions where wheat is extensively grown (Savary et al., 2019; Švarta et al., 2023).

The severity of leaf blotches and the associated yield losses are well documented, but results vary depending on region and others factors. Comprehensive review of the significance of these diseases has been conducted in the Nordic and Baltic countries. The severity fluctuated between 2% to 77% for tan spot and from 3% to 46% for Septoria leaf blotch respectively, depending on the year and agronomic practises (Jalli et al., 2020). According to the research by Jalli et al. (2020), yield losses reached between 529 and 1208 kg ha^{-1} due to these diseases.

Effective control of leaf blotch requires complex approach, in which agronomic practises and application of fungicides play principal role. Crop rotation and soil tillage may reduce level of leaf blotches, particularly tan spot. However, importance of agronomic practise in controlling of Septoria leaf blotch remains unclear, as the results of trials are inconsistent (Švarta et al., 2023). The life cycles of tan spot and Septoria leaf blotch differ under conditions of Latvia (Bankina et al., 2021). The causal agent of tan spot, *Pyrenophora tritici-repentis*, primarily survives in crop debris. Pseudothecia form in the straw at the end of vegetation season and continue to develop into the following spring. Consequently, the amount of residues determines level of tan spot. In contrast, *Zymoseptoria tritici* overwinters in living wheat as pycnidia. The intensity of disease is influenced by the potential for conidia to be transferred to the upper leaves, which is dependent on meteorological conditions.

Numerous experiments worldwide have been conducted to determine the best strategies for fungicide application against wheat leaf blotches. However, the results have been contradictory. Various doses of fungicides, timings of application and their interactions have been evaluated. Effectiveness of control depends on multiple factors, including the resistance level of cultivars, weather conditions, agronomic practices and the pressure of diseases (Cruppe et al., 2021; Breunig et al., 2022).

Recent research focuses on the potential to reduce fungicide applications and develop alternative methods for wheat leaf blotches control. Although some promising results have emerged, the effectiveness of control and convenience of application remain insufficient for practical use.

The aim of presented research is to evaluate efficacy of fungicide schemes and biological product for controlling wheat leaf blotches.

Materials and Methods

Field studies were conducted over three years (2022-2024) in farmer's fields situated in the Central region of Latvia, specifically at coordinates 56.318117° N, 24.03363° E and 56.330209° N., 24.032006° E. This region is characterized by its highly fertile soils and significant proportion of wheat in the sowing structure.

The variety 'Skagen' was selected for the study due to its extensive cultivation in Latvia, good winter hardiness, and moderate resistance to leaf diseases.

Two field experiments were established to evaluate various fungicide and biological product application schemes, with wheat sown following preceding crops of either wheat or oilseed rape.

Crop management practices mirrored those used on the specific farm and were typical of commercial fields with an intensive growing system characteristic of this region. Reduced soil tillage was implemented through disk harrowing to a depth of 18 cm. Nitrogen fertilization rates ranged from 139 to 160 kg ha^{-1}.

The seed was treated with fungicide at a rate of 1 L t^{-1}, containing fludioxonil (50 g L^{-1}) and tebuconazole (10 g L^{-1}). Growth retardants were applied twice during season of vegetation, with no insecticides used.

One-factor trials were designed with nine variants and four replicates, arranged in a randomized design. Experimental plots, each measuring 2.5 × 10 m, were established within production fields. Various doses of fungicides and application timings were evaluated, and one biological product (the product is not yet registered; therefore, the composition of the microorganisms has not been disclosed) was included as a treatment (Table 1).

The severity of diseases was assessed visually at the milk ripeness stage (GS 73 to 77 according to BBCH scale), by evaluating severity (%) on the two upper leaves.

The relative increase in yield (%) depending on treatment and relative decrease in leaf blotches severity (%) were calculated.

Significance of differences in disease severity was evaluated using the nonparametric Kruskal–Wallis test followed by Dunn's post-hoc test with the rstatix package (Kassambara, 2023). Pearson correlation coefficients were generated using the ggpairs function from the GGally package (Schloerke et al., 2025) and visualised with the ggplot2 package (Wickham, 2016).

Table 1

Fungicide and biological product application scheme

No.	***Designation***	***Product***	****Dose, L ha^{-1}***	***Growth stages according BBCH***
1.	A	Control (fungicide was not used)		
2.	B	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	1.50	59-61
3.	C	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	1.15	59-61
4.	D	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	0.75	59-61
5.	E	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	1.50	51-53
6.	F	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	1.15	51-53
7.	G	Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	0.75	51-53
8.	H	Prothioconazole 160 65 g L^{-1}; spiroxamine 200 65 g L^{-1}; proquinazid 40 65 g L^{-1}	0.75	32-33
		Bixafen 65 g L^{-1}; prothioconazole 130 g L^{-1}; fluopyram 65 g L^{-1}	0.75	59-61
9.	I	**BIF-BEAUB	15.00	32-33
		BIF-BEAUB	15.00	51-53

*Fungicide doses based on main active ingredient (prothioconazole).

**Code of biological product developed by commercial company Bioefekts Ltd.

Results and Discussion

Meteorological conditions varied throughout the experimental period 'Figure 1'. Spring of 2023 was notably dry, with higher temperature compared to other years, which significantly influenced the development of leaf blotches.

Obtained data indicates that tan spot, caused by *Pyrenophora tritici-repentis*, was the predominant disease affecting wheat from 2022 to 2024, with the severity ranging from 3 to 32% depending on the year and pre-crop 'Figure 2'. Level of tan spot was notably higher in repeated wheat sowings ($p<0.001$).

Figure 1
Meteorological conditions during the period of vegetation in the years 2022-2024

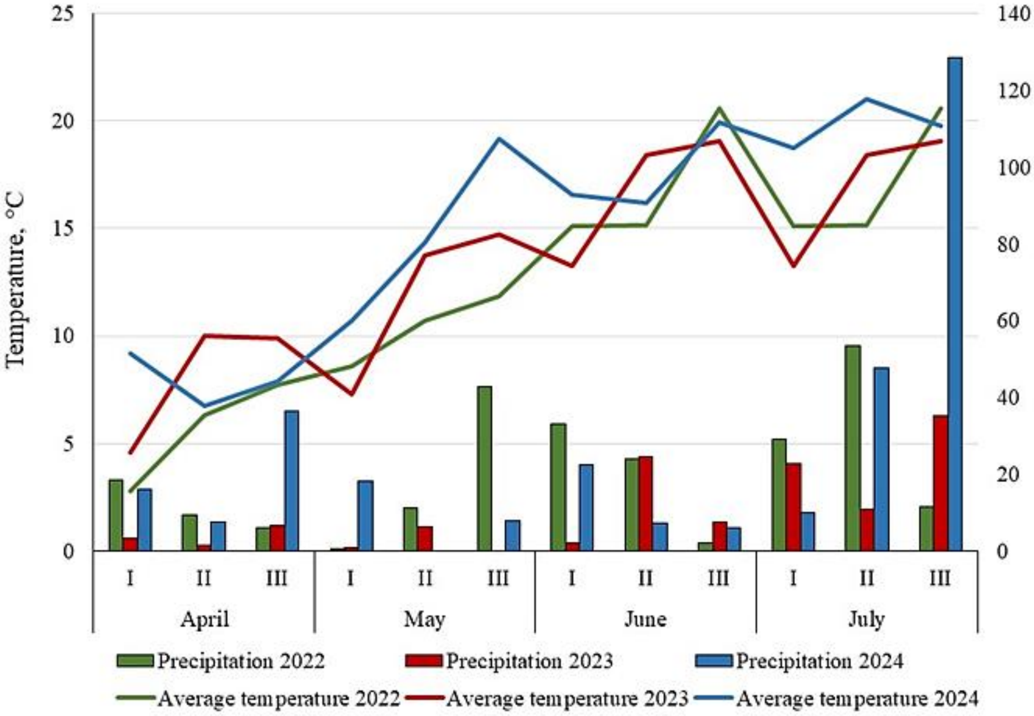
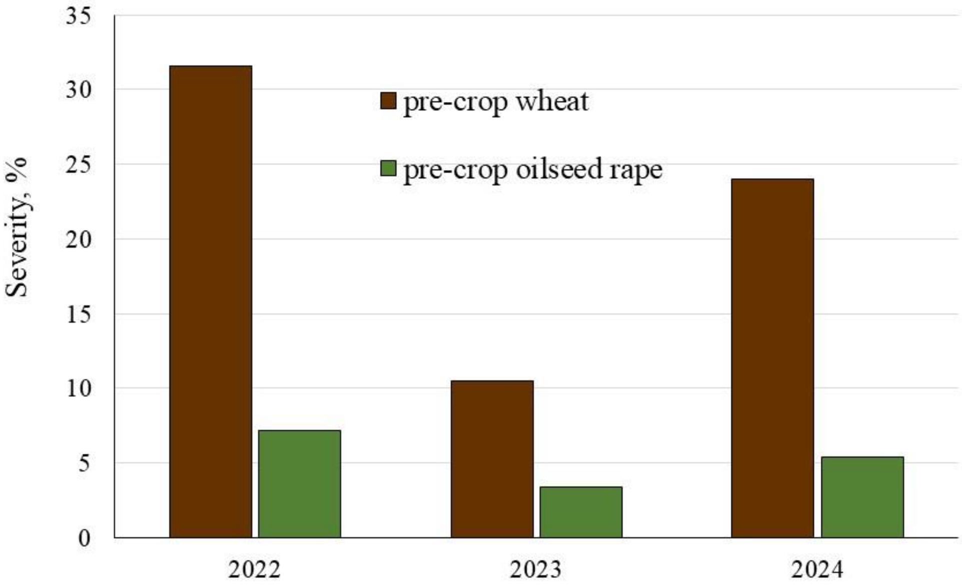


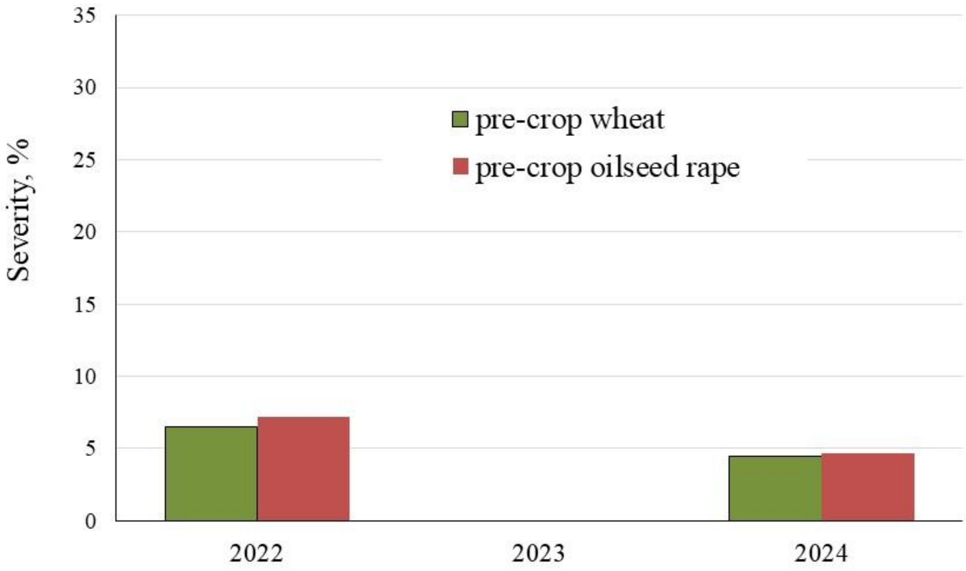
Figure 2
The severity of tan spot, caused by Pyrenophora tritici-repentis at the milk stage of ripening depending on year and pre-crop



In contrast, Septoria leaf blotch, caused by *Zymoseptoria tritici*, was recorded on the upper two leaves only in 2022 and 2024. Its severity ranged from 0% to 7%, significantly lower comparing with tan spot 'Figure 3'. Level of Septoria leaf blotch was not influenced by pre-crop used.

Figure 3

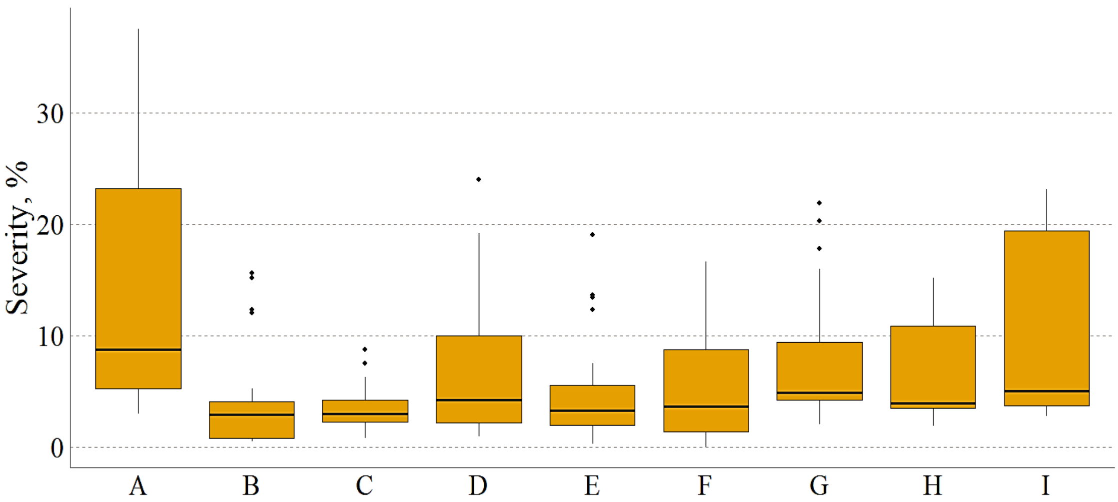
The severity of Septoria leaf blotch, caused by Zymoseptoria tritici at the milk stage of ripening depending on year and pre-crop



Fungicide application reduced the severity of tan spot; however, its effectiveness varied significantly both across and within treatments ʻFigure 4'. Neither the year of cultivation nor the pre-crop had a significant impact on the effectiveness of fungicides.

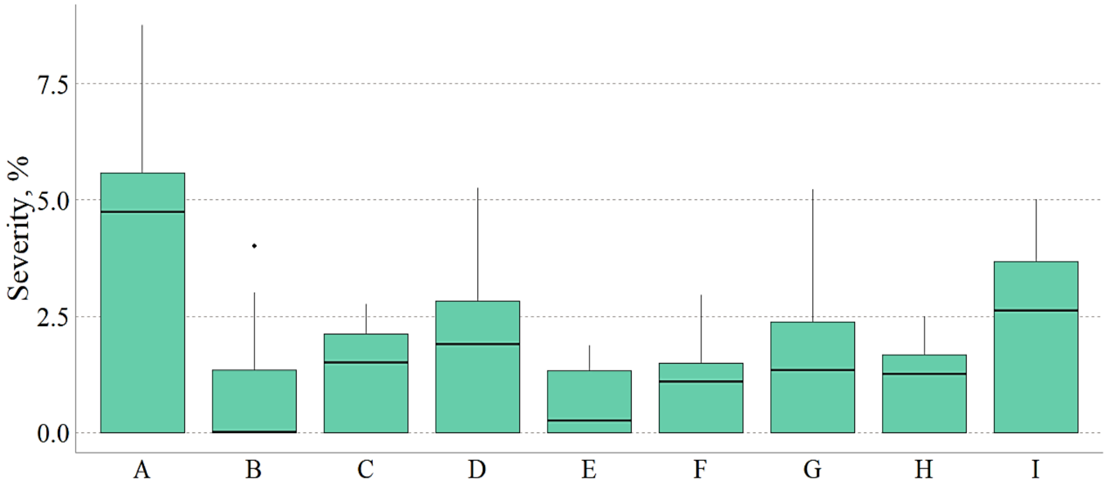
Figure 4

The severity of tan spot, caused by Pyrenophora tritici-repentis, depending on treatment scheme: A – without fungicide; B – fungicide at the BBCH 59–61, dose 1.5 L ha^{-1}; C – fungicide at the BBCH 59–61, dose 1.15 L ha^{-1}; D – fungicide at the BBCH 59–61, dose 0.75 L ha^{-1}; E – fungicide at the BBCH 53-55, dose 1.5 L ha^{-1}; F – fungicide at the BBCH 53-55, dose 1.15 L ha^{-1}; G – fungicide at the BBCH 53-55, dose 0.75 L ha^{-1}; H – fungicide at the BBCH 32.-33. and 59.-61., doses 0.75 L ha^{-1} and 0.75 L ha^{-1}, I – BIF-BEAUB at the BBCH 32.-33. and 51.-63., doses 15 L ha^{-1} and 15 L ha^{-1}



Applying a single fungicide application at the end of heading and the start of flowering generally produced better results. The efficacy of the lowest fungicide dose was inconsistent, exhibiting greater variability compared to higher doses. Additionally, split spraying did not provide superior results compared to a single application. Efficacy of Septoria leaf blotch control is difficult to evaluate, because level of disease was low. In general, level of disease was reduced in all schema of fungicide application, but the best variant was not clear ʻFigure 5'.

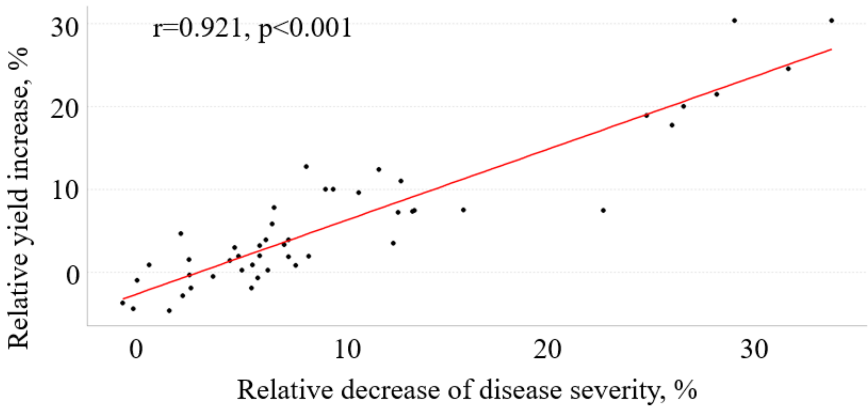
Figure 5
The severity of Septoria leaf blotch, caused by Zymoseptoria tritici, depending on treatment scheme: A – without *fungicide; B – fungicide at the BBCH 59–61, dose 1.5 L ha^{-1}; C – fungicide at the BBCH 59–61, dose 1.15 L ha^{-1}; D – fungicide at the BBCH 59–61, dose 0.75 L ha^{-1}; E – fungicide at the BBCH 53-55, dose 1.5 L ha^{-1}; F – fungicide at the BBCH 53-55, dose 1.15 L ha^{-1}; G – fungicide at the BBCH 53-55, dose 0.75 L ha^{-1}; H – fungicide at the BBCH 32.-33. and 59.-61., doses 0.75 L ha^{-1} and 0.75 L ha^{-1}; I – BIF-BEAUB at the BBCH 32.-33. and 51.-63., doses 15 L ha^{-1} and 15 L ha^{-1}*



The biological product proved mostly ineffective, resulting in notably higher both leaf blotches severity compared to chemical treatments.

The yield of winter wheat varied significantly. In untreated variants, where wheat followed wheat, yields ranged from 5.0 to 9.2 t ha^{-1}, in contrast, when wheat was grown after oilseed rape, yields were higher, ranging from 7.9 to 9.4 t ha^{-1}. On average, fungicide application enhanced yields, achieving values between 5.9 to 9.9 t ha^{-1} after wheat, and 7.7 to 9.9 t ha^{-1} after oilseed rape, depending on year and specific treatment. The harmfulness of diseases was calculated by considering the relative reduction in disease severity and the corresponding relative increase in yield. Strong, positive correlation was observed between the reduction in leaf blotches severity and the additional yield obtained 'Figure 6'.

Figure 6
The correlation between relative decrease in leaf blotches severity at the milk ripening and relative increase in winter wheat yield



Leaf blotches, caused by *Pyrenophora tritici-repentis* and *Zymoseptoria tritici* were identified as the most significant diseases over the three years. This outcome was expected, as similar results have been reported in others experiments conducted worldwide.

The severity of diseases fluctuated depending on various factors, including meteorological conditions, characteristics of varieties and agronomic practises.

Repeated wheat sowings and reduced soil tillage essentially increase level of tan spot (Jalli et al., 2021); however, the effects on Septoria leaf blotch results are contradictory (Bankina et al., 2021).

The obtained results regarding the dominance of tan spot align with previous findings in Latvia, especially in repeated wheat sowings (Bankina et al., 2021; Švarta et al., 2023). However, these data differ from the situation in most European countries, where tan spot is considered a minor disease. In contrast, Septoria leaf blotch is identified as the most devasting disease of winter wheat, including North Europe, excluding Norway and Sweden (Willocquet et al., 2021).

The number of rainy days and high relative air humidity are the most important factors that influence level of Septoria leaf blotch (Andersson et al., 2022). This disease was not observed in 2023 due to insufficient precipitation during May and first decade of June 'Figure 1', which prevented the release *Zymoseptoria tritici* conidia from pycnidia on the leaves. These conidia, mainly formed in previous autumn, typically spread to the upper leaves under favourable conditions.

The high amount of precipitation promotes the development of tan spot, as noted by Cook et al. (2024). This finding was confirmed in our trials: the highest pressure of tan spot was observed in 2022, when the first half of summer was more humid compared to other years.

Different fungicides are widely used to protect wheat and increase yield; however, prothioconazole (14α-demethylase inhibitor) is recognized as one of the most effective against tan spot (Kaņeps et al., 2024) and Septoria leaf blotch (Jorgensen et al., 2018); therefore, this fungicide has been chosen. Despite a significant number of field trials, the optimal timing and dosage of fungicide remain unclear. The results of presented study are also controversial. Although most of researchers have recognized heading as the best time for fungicide spraying (Peterson et al., 2023), the latest application produced better results according to the current study. This discrepancy can possibly be explained by variations in the spectrum of diseases. Tan spot develops quickly only after flowering, making the later treatment more suitable under specific conditions in Latvia.

Despite variations in the effectiveness of fungicide applications, treatment increased yield by an average of 0.29 ha^{-1}. Although two applications of fungicides are commonly recommended (Wang et al., 2024), the findings of this study did not support it, as Septoria leaf blotch was only a minor disease. Similarly, Wegulo et al. (2011) and Breunig et al. (2022) noted that two fungicide sprayings are necessary only during humid seasons with high pressure of diseases.

The amount of additional yield depended on various factors, including disease pressure (Cruppe et al., 2021), with the level of protection positively associated with yield (Willocquet et al., 2021). Similar conclusion was drawn in the presented study – the greatest suppression of leaf blotch severity resulted in the higher additional yield.

Conclusions

1. Fungicide treatment is essential to protect winter wheat and ensure high yields; however, the timing and dosage of application depend on the specific conditions of the year and the individual field.
2. Unfortunately, the biological product tested in this study was not effective.

Fluctuations in the results indicate that standardised treatment schemes are ineffective under changing meteorological conditions and other influencing factors.

3. Monitoring disease development and evaluating risk factors are crucial for effective and environmentally friendly disease control in winter wheat.

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