Impact of Crop Rotation and Soil Tillage on the Severity of Winter Wheat Leaf Blotches

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Abstract. Reduced tillage is considered as one of the main tools to save biological diversity; however, it increases pressure of diseases, including wheat leaf blotches. The aim of present study was to clarify the impact of reduced soil tillage on the development of winter wheat leaf blotches in different schemes of crop rotation. The impact of different growing technologies on the severity of winter wheat disease was evaluated in a two-factorial experiment: A – soil tillage system, and B – different combinations of wheat pre-pre-crop and pre-crop (wheat, oilseed rape, barley and faba beans). Diseases were assessed every 10 days approximately and total impact of diseases was evaluated by calculating AUDPC (Area under Diseases Progress Curve). Tan spot, caused by *Pyrenophora tritici-repentis* was dominated disease over the long period, regardless of meteorological conditions. Development of Septoria leaf blotch was not influenced by neither crop rotation nor soil tillage. The level of tan spot was essentially higher after wheat, regardless of the pre-pre-crop. Reduced soil tillage promoted severity of tan spot. Ploughing mitigated effect of previous crops and differences in tan spot level were insignificant. Despite many positive effects of conservation tillage, increasing of fungicide treatment could be necessary, in conditions, when the tan spot is most devastating and widespread wheat disease.

Key words: *Pyrenophora tritici-repentis*, *Zymoseptoria tritici*, pre-crop, pre-pre-crop, reduced tillage.

Introduction

Soil loss and necessity to save and improve fertility of soil is a global problem for the long-term sustainability of agriculture systems. Conservation soil tillage is considering management tool for reducing soil erosion and maintenance of soil microbiological diversity. Previous research proved significant increasing of soil organic carbon in reduced soil tillage plots in comparison with ploughing (Conyers *et al.*, 2019; Fernandez *et al.*, 2019).

This method also allows us to save time and resources, at the same time it did not decrease the yield of wheat over a long-term period (Cárcer *et al.*, 2019). Several findings proved that reduction of soil tillage increased the yield and quality of wheat (Biberdzic *et al.*, 2020; Pagnani *et al.*, 2019).

However, several researches showed disadvantages of the implementation of this method. One of the most important problems is augmentation of weediness in fields with lower intensity of soil treatment (Kadziene

et al., 2020). Spreading of different harmful cereal diseases is promoted by reduced soil tillage, including ear scab, caused by *Fusarium* spp. (Matušinsky *et al.*, 2016). Significantly lower level of mycotoxins (DON) was detected in ploughed fields. Combination of reduced soil tillage and short crop rotation or continuous wheat is the most conductive factor for the development of wheat diseases (Bankina *et al.*, 2018; Vega *et al.*, 2019).

Winter wheat leaf diseases is a considerable risk factor of wheat production; therefore, it is necessary to understand importance of agronomic practice on the development of this disease. It is found that leaf blotches are the dominant leaf diseases across Europe (Willoquet *et al.*, 2020). Tan spot, caused by *Pyrenophora tritici-repentis* and Septoria leaf blotch caused by *Zymoseptoria tritici* are the most important wheat leaf diseases in many regions of wheat cultivation, including Uruguay, Canada, Baltic region etc. (Bankina *et al.*, 2014; Fernandez *et al.*, 2016a;

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Mazzilli *et al.*, 2016). Our previous investigations showed that reduced soil tillage and continuous wheat sowings significantly increase development of tan spot, but did not reveal the impact of pre-crop (Bankina *et al.*, 2018).

The aim of present study is to clarify the impact of reduced soil tillage on the development of winter wheat leaf blotches in different schemes of crop rotation.

Materials and Methods

This study is a continuation of the previous research in a field experiment established at the Study and Research Farm “Peterlauki” of the Latvia University of Life Sciences and Technologies (56° 30.658°N and 23° 41.580°E) in the autumn of 2008 (Bankina *et al.*, 2015, 2018). Soil type at the site was Cambic Calcisol (Bathyrptic, Episiltic, Protostagnic), soil texture was clay.

The present research included results of the years 2017–2020. This period of time was chosen because a full crop rotation after including faba beans was implemented.

The impact of different growing technologies on the severity of winter wheat diseases was evaluated in a two-factorial experiment: A – soil tillage system (A1 – traditional soil tillage with ploughing at the depth of 22–24 cm (TT); A2 – reduced soil tillage with disc

harrowing up to the depth of 10 cm (RT)); and B – different combinations of wheat pre-crop and pre-crop (B1 – continuous wheat (W–W); B2 – wheat, oilseed rape, (W–OR); B3 – oilseed rape, wheat (OR–W); B4 – barley, faba beans (B–FB). The field trial was arranged in a two-factorial split-plot design in two blocks. Each plot in every block was split in half, thus forming four replications.

The late winter wheat cultivar ‘Zentos’ in 2017, and later on ‘Skagen’ was used in this period. Cultivars were changed, because ‘Zentos’ lost topicality among producers. Both cultivars are late, moderately resistant against leaf blotches and has good winterhardiness.

Assessment of disease was carried out approximately every 10 days, from tillering until milk ripeness. Detailed methods of evaluation were described in previous publication (Bankina *et al.*, 2018).

The total disease impact during the vegetation period was estimated by calculating the area under the disease progress curves (AUDPC).

Foliar commercial fungicide epoxiconazole (62.5 g L⁻¹) +pyraclostrobin (85.0 g L⁻¹), dose 1 L ha⁻¹, was sprayed across all wheat plots at the heading stage (according to BBCH) every year.

Meteorological conditions differed among the years of investigations (Table 1).

The effects of the year, soil tillage method and

Table 1

Meteorological conditions during the period of investigations

Year	Growth Stages	Number of Rainy Days	Average Temperature, °C	Amount of Precipitation, mm
2017	32–55	12	34	12.4
	55–75	24	106	16.3
	32–75	36	140	14.6
2018	32–55	2	6	17.2
	55–75	2	2	15.2
	32–75	4	8	16.8
2019	32–55	17	21	12.8
	55–75	4	4	20.7
	32–75	21	25	15.1
	32–55	19	88	10.1
2020	55–75	4	26	19.8
	32–75	23	113	12.4

schemes of crop rotation (pre-pre-crop and pre-crop) on the total level of both diseases were evaluated by using one-way or two-way ANOVA with interaction effects ($p < 0.05$). The post hoc multiple comparison least significant difference (LSD) test was used to determine which groups were significantly different. The main effect of years compared the levels of years (2017–2020) after averaging the levels of soil tillage method and schemes of crop rotations. The main effect of soil tillage method (ploughed and without ploughing) was evaluated after averaging the levels of years and schemes of crop rotations. The main effect of scheme of crop rotation (pre-pre-crop and pre-crop) compared the levels W–W, W–OR, OR–W, B–FB after averaging the levels of years and soil tillage method. The soil tillage method by crop rotation interaction evaluated the interaction of the soil tillage system and crop rotation after averaging the years.

Results

Tan spot was the dominant leaf disease during the whole period of observation, but severity of disease fluctuated depending on the year ($p < 0.001$ for both diseases). Septoria leaf blotch were observed every year, but the level of this disease was significantly lower if compared to tan spot. Both diseases developed similarly only in 2020 (Figure 1).

Soil tillage method significantly influenced severity of both wheat leaf blotches. Ploughing significantly decreased development of tan spot ($p = 0.015$) and increased development of Septoria leaf blotch ($p = 0.017$) (Figure 2).

Development of tan spot was significantly influenced ($p = 0.005$) by schemes of crop rotation. The level of tan spot was significantly higher after wheat, regardless of pre-pre-crop – using oilseed rape as pre-pre-crop did not decrease the severity of tan spot

Figure 1. Development of wheat leaf blotches depending on a year (significantly different means are labelled with different letters: A, B – significant difference for AUDPC of tan spot; a, b, c – for Septoria leaf blotch).

Figure 2. Development of winter wheat leaf blotches depending on soil tillage methods (significantly different means are labelled with different letters: A, B – significant difference for AUDPC of tan spot; a, b – for Septoria leaf blotch).

Figure 3. Development of tan spot depending on scheme of crop rotation (pre-pre-crop and pre-crop): W – wheat; OR – oilseed rape; B – barley; FB – faba bean (significantly different means are labelled with different letters).

Figure 4. Development of tan spot depending on crop rotation (pre-pre-crop and pre-crop) and soil tillage method: W – wheat; OR – oilseed rape; B – barley; FB – faba bean (significantly different means are labelled with different letters: A, B – significant difference for AUDPC of unploughed fields; a, b – for ploughed fields).

compared to continuous wheat sowings (Figure 3).

The impact of crop rotation was influenced by the method of soil tillage in relation to tan spot ($p=0.002$). Wheat as pre-crop significantly increased the development of tan spot in un-ploughed fields, regardless of pre-pre-crop. Ploughing mitigate effect of previous crops and differences in tan spot level were insignificant (Figure 4).

Rapid development of Septoria leaf blotch started only after heading. The level of this disease was not influenced by crop rotation ($p=0.506$) or by combination between soil tillage and pre-pre-crop ($p=0.698$).

Discussion

Control of wheat leaf diseases is one of the most

important problems of grain production in many countries, where wheat is important agricultural crop, accordingly the research of factors that promote development of these diseases is meaningful. Tan spot and Septoria leaf blotch are the most important in Nordic-Baltic region, other diseases – mildew (caused by *Blumeria graminis*) and rusts (caused by *Puccinia striiformis* and *P. recondita*) are harmful only occasionally. However, in Latvia, similar to Lithuania tan spot dominates almost each year, but Septoria leaf blotch is considered the most devastating disease of wheat, regardless of the cultivar, year and management in the rest of other countries in this region, also elsewhere in Europe (Bankina et al., 2018; Hýsek, Vavera, & Růžek, 2019; Jalli et al., 2020).

Similar to our previous studies, tan spot strongly

dominated in all years of investigation. The level of this disease was similar in three out of four years, regardless of different meteorological conditions (Table 1). The highest level of tan spot was observed in 2019, when the period of wheat development (GS 32–75) was dry, but warmer than usual. Obtained results proved, that the development of tan spot little depends on meteorological conditions, but agronomic practice determines severity of this disease.

Septoria leaf blotch was almost not observed in extremely dry 2018, but the highest level was noticed in 2019 and 2020 although meteorological conditions (amount of precipitation and average temperature) were different in these years. However, we have considered, that the level of Septoria leaf blotch correlated with the number of rainy days during the growth stage (GS) 32–55; during this time 17 and 19 rainy days were registered accordingly (Table 1).

Conservation soil tillage becomes more and more popular around the world, and it is considered as a possibility to save biological diversity and soil fertility. On the other hand, ploughing and crop rotation have been recommended to diminish application of fungicides and herbicides (Andert *et al.*, 2016). Our results support findings of several authors, which highlighted that reduced tillage promotes the development of tan spot. The level of tan spot was significantly higher in unploughed fields. In this period of studies, we got the same result as in the previous research during 2010–2017 (Bankina *et al.*, 2015; Bankina *et al.*, 2018) – ploughing did not decrease the level of Septoria leaf blotch. Consequently, infected plant debris is not an important source of infection in our conditions.

Importance of crop rotation as the main tool to decrease the level of tan spot was revealed in several investigations, including our previous studies. In this period, we evaluated the impact of pre-crop and pre-pre-crop combination. It was proved that one-year break significantly reduced the level of tan spot, regardless of previous crop. This statement is not in agreement with previous findings (Fernandez *et al.*, 2016b). In our previous studies, the level of Septoria leaf blotch was not affected by pre-crop or combination of pre-crops. These findings agree with previous studies that the development of Septoria leaf blotch depends more on meteorological conditions compared with agronomic practice (Cotuna, Paraschivu, & Olaru, 2018).

Pseudothecia in the residues of wheat straw is the main infection source of *Pyrenophora tritici-repentis*; therefore, the rate of pseudothecia decomposition is very important, it could be influenced not only by agronomic practice, but also by soil microbiological activity and relationships between different organisms. It was found that soil dehydrogenase activity is higher in the fields with reduced soil treatment, which could

be prerequisite for faster decaying of plant residues and diversity of microbiological community (Dubova, Ruža, & Alsina, 2016; Majchrzak *et al.*, 2016). In general, reduced soil tillage increases richness of fungal communities, but this effect depends on crop rotation, particular site and meteorological conditions of year (Sharma-Poudyal *et al.*, 2017). Soil tillage systems did not significantly influence soil fungal communities in experiments conducted at the Washington State University Dryland Research Station (Schlatter *et al.*, 2017).

However, our investigations proved that all these considerations do not reflect real situations. The level of tan spot was essentially lower in all ploughed fields, ploughing completely mitigated the impact of pre-crops, even continuous wheat sowings. On the contrary, crop rotation becomes extremely important in case of reduced soil tillage. Similar results were obtained a few years ago (Bankina *et al.*, 2018; Bankina *et al.*, 2015), but importance of ploughing becomes more clearly visible during a longer period of time.

Agronomic practice did not influence the development of Septoria leaf blotch in our trials, which is in contradiction to other studies. Reduced soil tillage and monocropping of wheat essentially increased the development of Septoria leaf blotch under Mediterranean conditions (Calzarano *et al.*, 2018). It is difficult to explain our results; possibly, the level of Septoria leaf blotch was too low to make any conclusions. Early development of Septoria leaf blotch was not observed in our study, the progress of the disease started only after heading. Similar results were obtained in other trials in Latvia – severity of leaf blotches was low till the beginning of heading (Bankina *et al.*, 2014). Residues of plants were not considered as the main source of infection with *Zymoseptoria tritici*, rather this was living wheat. Possibly, the results were influenced by the relationships between *Pyrenophora tritici-repentis* and *Zymoseptoria tritici*, which has not been sufficiently studied yet.

Conclusions

Tan spot, caused by *Pyrenophora tritici-repentis* was the dominated disease over a long period regardless of meteorological conditions. The pre-crop (oilseed rape or faba beans) significantly decreased the level of tan spot independently of pre-pre-crops. Reduced soil tillage essentially increased the development of tan spot, and ploughing mitigates the impact of crop rotation. The impact of agronomic practice is not clear regarding the development of Septoria leaf blotch. Further research is required to clarify the relationships between these diseases and the traits of Septoria leaf blotch development.

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