The Effect of Agronomic Factors on the Yield of Winter Wheat in Crop Rotation with Livestock Production

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Summary

The aim of the study was to evaluate the influence not only of the year, but also of the three agronomic factors, namely pre-crops, soil tillage, and application of fungicides on the subsequent grain yield of winter wheat. The field trial was carried out at the Field Trial Station in Žabčice (South Moravia, Czech Republic), between 2014 and 2016, as part of a long-term field experiment focused on management of soil with livestock production. Winter wheat was grown after two pre-crops, namely alfalfa and silage maize. The soil was treated using three technologies, namely conventional tillage (CT) – ploughing to a depth of 0.24 m, minimum tillage (MT) – shallow loosening to a depth of 0.15 m, and no-tillage (NT) – direct sowing. In terms of fungicide treatment, two treatments were used and compared to a non-treatment variant. The obtained results suggest that the statistical significance was not found in the influence of the pre-crop. On the contrary, the influence of not only the year but also of the soil tillage technology and fungicide treatment was confirmed. Higher yields by 0.59 t/ha were achieved after shallow loosening and direct sowing as compared with after traditional ploughing and after application of fungicides. In addition, inconclusive influence of interaction between pre-crop and soil tillage as well as between soil tillage and fungicide treatment was also found.

Key words

winter wheat, yield, pre-crop, soil tillage, fungicides

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Introduction

On a global scale, wheat is the most important crop as well as cereal crop. At the same time, it is also the most popular crop grown in the European Union, where it covers almost half of arable land (Hlisnikovský et al., 2016). Its winter form, which is a major commodity on the world cereal market (Lithourgidis et al., 2006), is of major importance. At the same time, it is the main cultivated cereal throughout Europe (Chloupek et al., 2004) but especially in the Czech Republic where it has an irreplaceable and dominant position among cultivated agricultural crops.

In recent years, however, an increasing effort has been made to increase the yields of winter wheat in order to achieve the greatest possible economic valorisation of its cultivation. However, the winter wheat yield itself is considerably influenced by many factors (Vrkoč et al., 1990). Apart from the influence of the year, soil and climatic conditions of a given habitat (Vrkoč et al., 1990, Lithourgidis et al., 2006, Márton, 2008, Olesen et al., 2009), there is also the influence of regulated factors. Regulated factors comprise agronomic factors, among which we can especially include a suitable sequence of crops (pre-crops) in the sowing process, soil tillage technology and last but not least, balanced nutrition, fertilization, and treatment. However, it is necessary to know how these agronomic factors act individually, but also with each other. For example, it is well documented that grain yields of wheat are usually lower by 10 to 30 per cent when cultivated in a monoculture or in a short cropping process, especially after broadleaf pre-crops (Smagacz et al., 2016). In addition, it has also been found that the yield of winter wheat can be significantly influenced by the use of suitable pre-crop in interaction with soil tillage technology (Houšť et al., 2012; Ercoli et al., 2017). These results were also published earlier by Cox and Shelton (1992) and Borghi et al. (1995). However, we cannot overlook the influence of the weather conditions in the given year, which, together with the agronomic factors, can fundamentally influence the subsequent yield of winter wheat.

Material and methods

Our study evaluates data from the years 2014 to 2016 of a field trial at the Field Trial Station in Žabčice (Southern Moravia, Czech Republic). This is within the framework of a long-term field trial, which was established already in 2003, and is focusing on soils with livestock production. This field station is a research facility in the area of plant production of the Mendel University in Brno. It is located approximately 25 km south of the South Moravian metropolis of Brno. It is located in a maize production area, at an altitude of 179 m, with heavier grain fluvisol soil type. The local average annual air temperature is 9.2 °C and the thirty-year average annual precipitation is 480 mm (Table 1). Thus this location ranks among the warmest and driest areas in the Czech Republic.

The field trial evaluated not only the influence of the year, but also the influence of three agronomic factors, namely pre-crops, soil tillage, and application of fungicides on the subsequent grain yield of winter wheat. Winter wheat was grown after two pre-crops, namely alfalfa and silage maize. The soil was treated using three technologies, namely conventional tillage (CT) – ploughing to a depth of 0.24 m, minimum tillage (MT) – shallow loosening to a depth of 0.15 m, and no-tillage (NT) – direct sowing. From the point of view of application of fungicides, two fungicidal treatments for foliar and ear diseases were used and compared to the non-treated variant.

In the individual years between 2014 and 2016, the same cultivation technology was used for all variants. The cultivated winter wheat variety was Sultan, with 4 MGS/ha (millions germinating seeds per hectare) and a total nitrogen amount of 160 kg N/ha. Other applications included phosphorous and potassium mineral fertilizers (specifically 90 kg P_2O_5/ha and 120 kg K_2O/ha), 1x herbicide, 1x insecticide and 2x growth regulator. Sowing winter wheat was carried out to a depth of 0.03 m, until October 15th. The subsequent harvest took place between July 15th and 20th. The harvest was carried out by the SAMPO Rosenlew SR2010 small-size combine harvester. Yields from areas of 22.5 m^2, in four replicates per variant, were subsequently recalculated per hectare at grain moisture of 14%.

Results and discussion

The achieved results of the winter wheat grain yield were evaluated using analysis of variance - ANOVA (Table 2), followed by testing of the mean value differences using the statistical confidence intervals method in Statistica 12.0 (StatSoft software Inc., Tulsa, OK, USA).

Figures 1 to 7 show the statistical significance of agronomic factors and the interaction between agronomic factors. However, no statistically significant differences were found after the pre-crop and the interaction of the pre-crop*soil tillage and soil tillage*fungicide treatment.

Figure 1 clearly shows that the effect of the year was significantly statistically demonstrated on the yield of grain of winter wheat The highest yield was achieved in 2014, namely 11.33 t/ha. In 2015, the yield was 0.32 t/ha lower and in 2016 0.60 t/ha lower.

Table 1. The average air temperatures and the sum of precipitation in the period between 2014 and 2016, compared with temperature and precipitation averages between 1961 and 1990 at the Field Trial Station in Žabčice

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I–XII
2014–2016													
Average temperature (°C)	0.6	3.1	6.5	10.6	15.0	19.2	21.9	20.3	16.5	10.0	5.9	1.6	10.9
Sum of precipitation (mm)	22.5	28.2	21.3	20.7	46.2	33.5	85.5	94.9	50.0	49.6	26.3	17.7	496.6
1961–1990													
Normal temperature (°C)	-2.0	0.2	4.3	9.6	14.6	17.7	19.3	18.6	14.7	9.5	4.1	0.0	9.2
Normal precipitation (mm)	24.8	24.9	23.9	33.2	62.8	68.6	57.1	54.3	35.5	31.8	36.8	26.0	479.7

Table 2. Analysis of variance (ANOVA) - grain yield of winter wheat

Source of variability	Degrees of freedom	Average square yield
Year	2	4.36**
Pre-crop	1	0.01
Soil tillage	2	5.02**
Fungicide treatment	1	12.22**
Year×pre-crop	2	23.22**
Year×soil tillage	4	4.35**
Pre-crop×soil tillage	2	0.07
Pre-crop×fungicide treatment	2	8.32**
Pre-crop×soil tillage	1	2.15**
Soil tillage×fungicide treatment	2	0.15
Error	108	0.22

*Statistically significant difference (P = 0.05); **Statistically highly significant difference (P = 0.01)

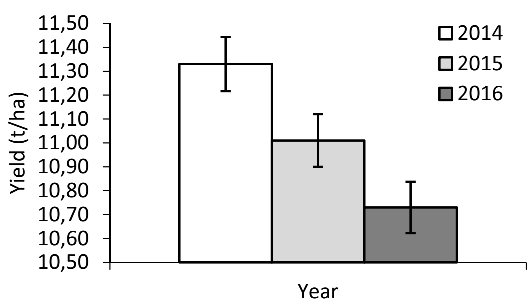

Figure 1. Influence of the year on grain yield of winter wheat

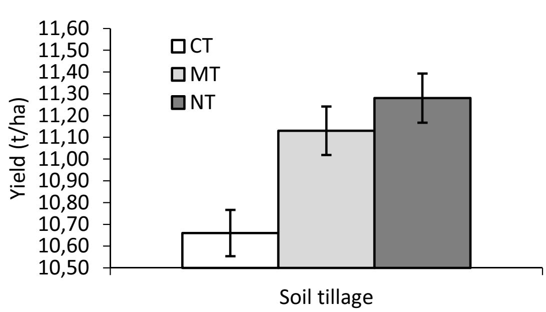

Figure 2. Influence of the soil tillage on grain yield of winter wheat

The effect of soil tillage on the subsequent grain yield of winter wheat was found to be statistically significant between the CT and both methods of soil tillage with lower intensity, i.e. MT and NT (Figure 2). The lowest yield was achieved after CT (10.66 t/ha). On the other hand, higher yields occurred after less intensive soil tillage (MT and NT), but no statistically significant difference was found between them. The difference between them was only 0.15 t/ha, where the highest yield was achieved after NT, namely 11.28 t/ha.

In terms of the fungicide treatment factor, it was found that a higher yield was obtained after fungicidal treatment (11.32 t/ha). The difference with the untreated variant was higher by 0.59 t/ha

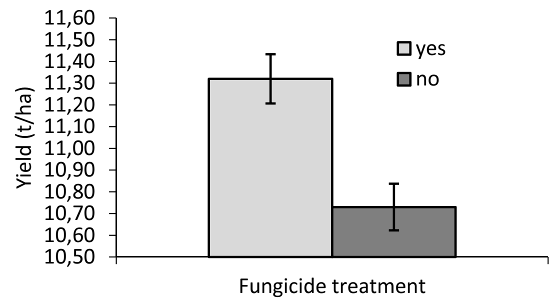

Figure 3. Influence of the fungicide treatment on grain yield of winter wheat

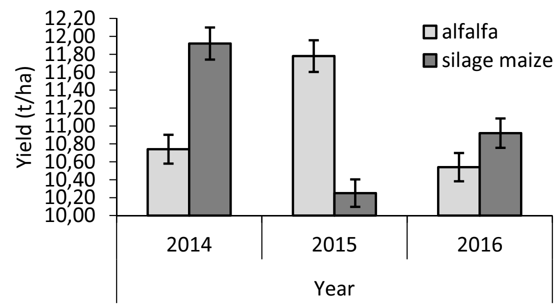

Figure 4. Influence of interaction of the year and pre-crop on grain yield of winter wheat

(Figure 3). Furthermore, it was found that between the two variants, treated and untreated with fungicides, there was a statistically significant difference.

In the interaction of the year with the pre-crop it was found that the highest yield was achieved in 2014 after silage maize (11.92 t/ha). That year, the difference after alfalfa was larger by 1.18 t/ha. Also, in 2016, a higher yield occurred after silage maize, namely 10.92 t/ha. By contrast, in 2015, the after alfalfa yield was higher by 1.53 t/ha than after silage maize, even though we have expected that in 2015, which was drier than 2014 and 2016, the yield of grain of winter wheat will be higher than silage maize, because in comparison to alfalfa, in drier years, the water regime for the subsequent crop, in our case winter wheat, does not deteriorate. At the same time, Figure 4 shows statistical significance of grain yields of winter wheat after pre-crop of silage maize in all three years. After the silage maize between 2015, 2014, and 2016 there was a statistically significant difference. Statistically significant differences were also between the yields after alfalfa in 2014 and after silage maize in 2014 and 2015 as well as after alfalfa in 2015 and after silage maize in 2015 and 2016, and after silage maize in 2016 and alfalfa in 2015.

In comparison of interaction of the year and soil tillage, the grain yield was the significantly lowest in 2014 after CT (10.40 t/ha). In contrast, the highest grain yield was in the same year after NT, 11.98 t/ha (Figure 5). This shows that in 2014 the grain yield increased with the intensity of soil tillage. Statistically significant differences after individual types of soil tillage were found in 2014, while in 2015 and 2016 the values were not statistically different.

In the interaction between the year and fungicide treatment, statistically significant difference occurred only in 2016 (Figure 6), while in 2014 and 2015 the values were not statistically different.

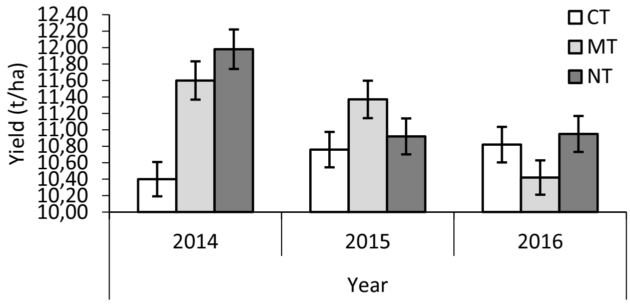

Figure 5. Influence of interaction of the year and soil tillage on grain yield of winter wheat

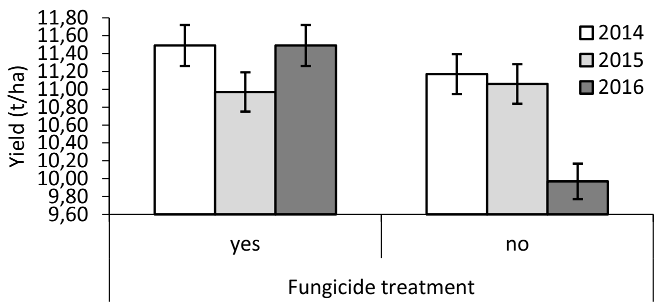

Figure 6. Influence of interaction of the fungicide treatment and year on grain yield of winter wheat

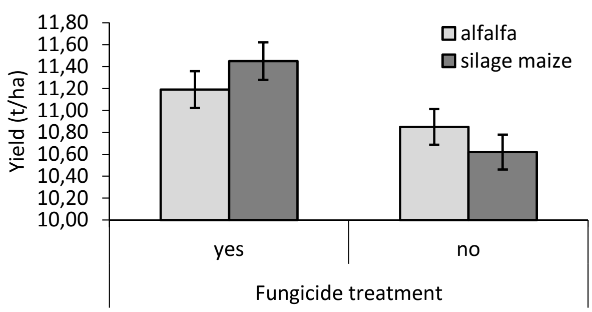

Figure 7. Influence of interaction of the fungicide treatment with pre-crop on grain yield of winter wheat

We have also found that the highest yield was in the fungicide treatment variant in 2014 and 2016 when the yields in both years reached the same values, namely 11.49 t/ha. In contrast, the lowest yield was found after the untreated variant in 2016. The difference in grain yield compared to the fungicide treatment variant in the same year (2016) was lower by 1.52 t/ha.

From the interaction between the pre-crop and fungicide treatment, it is clear that grain yield was higher after both pre-crops in the fungicide-treated variant (Figure 7). In the fungicide-treated variant, the yield after silage maize was 0.26 t/ha higher than after alfalfa. In contrast, the untreated variant was lower, by 0.23 t/ha, even though in neither case the difference was statistically significant.

The three-year field trial results showed the statistical significance and importance of the year, which was also confirmed by Jug et al. (2011). Statistical significance has also been confirmed not only in the effects of soil tillage but also in the treatment with fungicides. From the point of view of the soil tillage method, we have found that after CT, a lower grain yield (10.66 t/ha) was achieved compared to MT (11.13 t/ha) and NT (11.28 t/ha). Pernicová et al. (2014) also found higher yields after MT and NT than after CT. Furthermore, the results indicate that the variant treated with fungicides had a significant effect on grain yield, when the yield was higher by 0.59 t/ha compared to the untreated variant. The effect of fungicidal treatment on higher grain yield is confirmed by Pospišil et al. (2011), but only in a warmer year. This only shows that the year has a major influence on grain yield, even in our case when within the interaction of the year with the fungicide treatment, for which the statistical significance was found as well, the 2016 yield of fungicide-treated variant was higher by 1.52 t/ha. In 2014 the yield was only 0.32 t/ha higher and in 2015 even lower by 0.09 t/ha, which is absolutely negligible. In contrast to the other three previous influences, the statistical significance for influence of the pre-crop on subsequent yield of grain of winter wheat was not established, as the yield difference between the two pre-crops (alfalfa, silage maize) was only 0.01 t/ha. On the other hand, Hejcman and Kunzová (2010) claim that different pre-crops have a proven effect on grain yield for winter wheat. The same effect of pre-crops on yield was also confirmed by Piekarczyk (2010) and Jaskulska et al. (2013). However, a similar result as in our case, when the yield after silage maize was slightly larger, was also found by Berzsenyi et al. (2000). In addition to the interactions year*fungicide treatment, significance was also found in the interaction of year*pre-crop, year*soil tillage, and pre-crop*fungicide treatment. In contrast, it was not the case in two interactions, namely pre-crop*soil tillage and soil tillage*fungicide treatment. However, Houšť et al. (2012), Ercoli et al. (2017), and Neugschwandtner et al. (2015) found significance and subsequent influence of pre-crop with soil tillage.

Conclusion

Based on the three-year results of the multifactor field trial, not only the significance of the influence of the year, as is well known, but also of soil tillage technology and fungicide treatment were confirmed. It was confirmed that after lower intensity of soil tillage, namely after MT and NT, higher yields than after CT were achieved, by 0.55 t/ha on average. In the case of treatment by fungicides, the yield was over 0.50 t/ha higher than in the untreated variant. Furthermore, the grain yield of winter wheat has been shown to be lower in CT than in reduced soil tillage methods (MT, NT), both in interaction of soil tillage and pre-crop or fungicide treatment. It was also found that after application of fungicides, whether in interaction with year or pre-crop, the yield was higher than in the untreated variant. The results thus confirm that the use of fungicides and appropriate use of reduced soil tillage result in higher grain yields of winter wheat along with the influence of weather (year) in the crop sowing process with livestock production.

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