THE INFLUENCE OF AGRONOMIC FACTORS ON THE GRAIN YIELD OF WINTER WHEAT

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Abstract: In the conditions of the Czech Republic, winter wheat is one of the most widely grown crops as well as cereals on arable land. The aim of the contribution was to find out the influence of different agronomic factors (pre-crop, soil tillage) as well as the year on the subsequent winter wheat grain yield in the conditions of dry land of Southern Moravia. The field experiment was conducted at the Field Trial Station in Žabčice (Czech Republic) in 2015–2017, located in the maize production area. The pre-crops for winter wheat included winter wheat, pea, alfalfa and silage maize. Two ways of soil tillage were used in the experiment, namely ploughing (to a depth of 0.24 m) and shallow loosening (to a depth of 0.15 m). From the results obtained in three years it was found that winter wheat grain yield was influenced especially by the year, the pre-crops and by combination of these two factors with soil tillage. On the other hand, statistical significance for the influence of soil tillage was not found. The yield difference between both methods of soil tillage amounted to negligible 0.11 t/ha. In terms of pre-crop, the highest winter wheat grain yields were achieved after alfalfa as a pre-crop (10.60 t/ha), the lowest yields were after winter wheat as a pre-crop (9.53 t/ha). Statistical significance was found among the pre-crops. The results from 2015–2017 also showed that the year is one of the generally most unpredictable factors which can cause different results and play an important role in generating yields. Statistical significance among individual interactions was also confirmed.

Key Words: maize production area, winter wheat, yield, pre-crop, soil tillage

INTRODUCTION
Winter wheat is one of the most widely grown crops not only in the world but also in the Czech Republic. It is our most significant as well the most grown cereal. In the Czech Republic, it takes up almost a quarter of arable land and a half of the cereals areas (Zimolka 2005). Due to the high production potential, it has gradually begun to expand significantly to higher locations, replacing the constantly reduced areas of rye and oats. Currently, it is grown virtually in all production areas (Badalíková and Bartlová 2011). Despite being grown in all production areas, locations in the maize production area can be considered the most suitable conditions for growing the winter wheat. In these areas, there is a higher probability of drier periods at the time of ripening which is necessary in order to achieve the food quality. In terms of yield generation, there is, however, the risk occurrence of drier periods in the spring period. A properly chosen growing technology consisting of different agronomic interventions can eliminate these risks to a certain extent (Smutný et al. 2007).

In order to achieve high yields when growing winter wheat, it is necessary to pay enough attention to agronomic factors whereby certain higher production ability can be achieved. The agronomic factors can include a suitable crop sequence in the crop rotation (pre-crops), in addition a suitable method of soil tillage in the particular locality conditions, the date of sowing, a suitable selection of the variety as well as sufficient fertilisation, nutrition and treatment of the stand. For instance, it has been the found that the yield can be significantly influenced under the joint action of a suitable crop and the soil tillage method (Ercoli et al. 2017). In addition to the properly used crop management practices also the soil-climate conditions of the given location as well as a particular course of the weather in the particular year are to be respected.
MATERIAL AND METHODS

The influence of agronomic factors (pre-crop, soil tillage) on winter wheat grain yields was evaluated at the Field Trial Station in Žabčice (Czech Republic) in 2015–2017, in the conditions of dry Southern Moravia. This station is located in the maize production area, which is one of the warmest and driest areas in the Czech Republic, in an altitude of 179 m and is located 25 km south from the city of Brno. The average annual precipitation for thirty years in this location amounts to 480 mm and the average yearly temperature amounts here to 9.2 °C (Table 1). Four pre-crops for winter wheat were used: winter wheat, pea, alfalfa and silage maize. Two soil tillage methods were used in the experiments: ploughing (to a depth of 0.24 m) and shallow loosening (to a depth of 0.15 m).

In 2015 and 2016, the grown variety of winter wheat was Sultan. In 2017, already the Rumor variety. The sowing rate amounted to 4 MGS/ha (millions of germinating seeds per hectare) and the sowing was done to a depth of 3 cm in the agronomic date. The total applied nitrogen dose amounted to 170 kg N/ha. In addition, P and K mineral fertilizers (90 kg P₂O₅/ha and 120 kg K₂O/ha), 1× herbicide, 1× insecticide 1× fungicide and 2× growth regulators were applied. The harvest in 2015–2017 was carried out in the first half of the month of July, using small-plot SAMPO Rosenlew SR 2010 combine harvester. The achieved yields from the harvest areas with a size of 22.5 m² (in four repetitions in each variant) were recalculated per hectare at the grain moisture of 14%.

Table 1 The average air temperatures and sum of precipitation in years 2014–2017, compared with temperature and sum of precipitation normal (1961–1990) at the Field Trial Station in Žabčice

<table>
<thead>
<tr>
<th>Month</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
<th>IX</th>
<th>X</th>
<th>XI</th>
<th>XII</th>
<th>I-XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>1.1</td>
<td>2.7</td>
<td>8.5</td>
<td>11.8</td>
<td>14.5</td>
<td>18.8</td>
<td>21.5</td>
<td>17.9</td>
<td>15.6</td>
<td>11.5</td>
<td>7.5</td>
<td>2.4</td>
<td>11.2</td>
</tr>
<tr>
<td>Sum of precipitation (mm)</td>
<td>22.0</td>
<td>12.6</td>
<td>5.6</td>
<td>11.2</td>
<td>62.8</td>
<td>43.4</td>
<td>85.0</td>
<td>113.6</td>
<td>116.2</td>
<td>46.4</td>
<td>29.2</td>
<td>28.7</td>
<td>576.7</td>
</tr>
<tr>
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<td>1.8</td>
<td>1.6</td>
<td>5.5</td>
<td>10.1</td>
<td>14.7</td>
<td>19.1</td>
<td>22.9</td>
<td>23.6</td>
<td>15.9</td>
<td>9.6</td>
<td>6.2</td>
<td>2.9</td>
<td>11.2</td>
</tr>
<tr>
<td>Sum of precipitation (mm)</td>
<td>20.0</td>
<td>7.4</td>
<td>28.0</td>
<td>9.4</td>
<td>33.8</td>
<td>22.4</td>
<td>22.4</td>
<td>106.0</td>
<td>23.8</td>
<td>48.0</td>
<td>24.8</td>
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<td>363.2</td>
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<tr>
<td>2016</td>
<td>-1.2</td>
<td>5.1</td>
<td>5.5</td>
<td>9.8</td>
<td>15.7</td>
<td>19.8</td>
<td>21.3</td>
<td>19.5</td>
<td>17.9</td>
<td>9.0</td>
<td>3.9</td>
<td>-0.5</td>
<td>10.5</td>
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<tr>
<td>Sum of precipitation (mm)</td>
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<td>64.7</td>
<td>30.4</td>
<td>41.6</td>
<td>42.0</td>
<td>34.8</td>
<td>149.2</td>
<td>65.0</td>
<td>10.0</td>
<td>54.4</td>
<td>24.9</td>
<td>7.2</td>
<td>549.8</td>
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<tr>
<td>2017</td>
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<td>2.0</td>
<td>8.0</td>
<td>9.2</td>
<td>16.0</td>
<td>21.0</td>
<td>21.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sum of precipitation (mm)</td>
<td>0.3</td>
<td>2.1</td>
<td>2.3</td>
<td>58.7</td>
<td>24.6</td>
<td>33.9</td>
<td>96.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1961–1990</td>
<td>-2.0</td>
<td>0.2</td>
<td>4.3</td>
<td>9.6</td>
<td>14.6</td>
<td>17.7</td>
<td>19.3</td>
<td>18.6</td>
<td>14.7</td>
<td>9.5</td>
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</tr>
<tr>
<td>Sum of precipitation normal (mm)</td>
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<td>24.9</td>
<td>23.9</td>
<td>33.2</td>
<td>62.8</td>
<td>68.6</td>
<td>57.1</td>
<td>54.3</td>
<td>35.5</td>
<td>31.8</td>
<td>36.8</td>
<td>26.0</td>
<td>479.7</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

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

The influence of the year was statistically demonstrated on the amount of winter wheat grain yield (Figure 1). The lowest yield was achieved in 2017, namely 8.60 t/ha. On the other hand, the highest winter wheat grain yield was in 2016 (10.74 t/ha), when the difference against 2015 amounted to the negligible amount of 0.03 t/ha and 2.14 t/ha more in comparison with 2017.
Table 2 ANOVA (Analysis of variance) – grain yield of winter wheat

<table>
<thead>
<tr>
<th>Source of variability</th>
<th>Degrees of freedom</th>
<th>Average square yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>year</td>
<td>2</td>
<td>87.14**</td>
</tr>
<tr>
<td>pre-crop</td>
<td>3</td>
<td>10.25**</td>
</tr>
<tr>
<td>soil tillage</td>
<td>1</td>
<td>0.49</td>
</tr>
<tr>
<td>year*pre-crop</td>
<td>6</td>
<td>5.68**</td>
</tr>
<tr>
<td>year*soil tillage</td>
<td>2</td>
<td>0.97*</td>
</tr>
<tr>
<td>pre-crop*soil tillage</td>
<td>3</td>
<td>1.57**</td>
</tr>
<tr>
<td>year<em>pre-crop</em>soil tillage</td>
<td>6</td>
<td>0.49</td>
</tr>
<tr>
<td>error</td>
<td>216</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Legend: * Statistically significant difference (P = 0.05), ** Statistically highly significant difference (P = 0.01)

Figure 1 The influence of the year on the winter wheat grain yield

Within the influence of the pre-crops on winter wheat grain yield it was found that the highest yield was achieved after alfalfa as a pre-crop (10.60 t/ha). The lowest yield was after winter wheat as a pre-crop (9.53 t/ha). The difference between these two pre-crops amounted to 1.07 t/ha. At the same time, there was found a statistically significant difference between winter wheat and alfalfa (Figure 2) as well as between these pre-crops and silage maize and pea. Not between the pre-crops of silage maize and pea.

Figure 2 The influence of a pre-crop on the winter wheat grain yield

No statistical significance between ploughing and shallow loosening was found for the influence of soil tillage on the subsequent winter wheat grain yield (Figure 3). The difference between two
methods of soil tillage was only 0.11 t/ha, when a slightly different winter wheat grain yield was after shallow loosening (10.15 t/ha).

Figure 3 The influence of soil tillage on winter wheat grain yield

![Figure 3](image)

In the interaction with the year with pre-crops, the highest winter wheat yield was achieved after alfalfa in 2015 (11.53 t/ha). In the same year, the difference in comparison with silage maize was by 1.34 t/ha more, in comparison by 0.3 t/ha more and winter maize even by 1.41 t/ha more. On the other hand, the lowest yield was after winter wheat (7.65 t/ha) in 2017. It has been also found that out of all three years, the lowest winter wheat lowest yields were achieved in 2017 (Figure 4). At the same time, statistical significance was found by all four pre-crops in all three years.

Figure 4 The influence of interaction of the year with the pre-crop on winter wheat grain yield

![Figure 4](image)

In the interaction between the year and soil tillage it has been found that statistically significant differences after both methods of soil tillage were found between the years of 2015 and 2017 and between the years of 2017 and 2016. Whereas, between the years of 2015 and 2016, the values did not differ statistically (Figure 5). Conclusively highest grain yields were in 2016 after ploughing (10.81 t/ha), on the other hand, the lowest yields were in 2017 after ploughing (8.30 t/ha). It has been also found that in the years of 2015 and 2017, grain yield was higher after shallow loosening in comparison with ploughing, namely in 2015 by 0.10 t/ha and in 2017 by 0.11 t/ha. While in 2016, the yield after shallow loosening was lower by 0.14 t/ha in comparison with ploughing.

In the interaction of soil tillage with a pre-crop it was found that the highest yield in both soil tillage methods was achieved after alfalfa, 10.48 t/ha after ploughing and 10.73 t/ha after shallow loosening. The difference of the yield after alfalfa between these two soil tillage methods was 0.25 t/ha. Further it was found that there had been found a statistically significant difference between winter wheat as a pre-crop in both soil tillage methods and alfalfa after shallow loosening (Figure 6).
The field experiment results from 2015–2017 showed that winter wheat grain yield is influenced not only by agronomic factors (pre-crop, soil tillage) but also by the year. Thus, high significance as well as statistical significance have been confirmed, as confirmed also by the results of Kunzová (2007) and Jug et al. (2011). It has also turned out that out of all three years, the lowest winter wheat yields were in the interaction of the year with a pre-crop. These yield differences among years could be linked with lower temperatures in winter 2016/17, when some days with frosts caused worse and slower regeneration of plants. It was negative, especially in dry condition in spring 2017. It is in opposite with warm winters in 2014/15 and 2015/16, when the plants can growth practically whole winter time. In 2016 the weather conditions were very suitable for grain formation in winter wheat. In 2015 there was lower amount of precipitation but very well distributed in time and it was effectively used for plants. But in 2017 there was typical uneven distributed precipitation whole vegetation period in combination with more frequent occurrence of hot days when evaporation increased. Less available soil moisture caused probably lower yield level in this year. As a result, this may indicate the cause of different yield results between the years of 2015 and 2017 and the years of 2016 and 2017 and the effect of the year and pre-crop factors. This is confirmed also by Neugschwandtner et al. (2015). High importance for the achieved winter wheat results can be also attributed to a suitable pre-crop which was confirmed also by Piekarczyk (2010). Our results show that the highest yield was achieved after the pre-crop of alfalfa and other two pre-crops (pea, silage maize) in comparison with winter wheat as a cereal. Similar results were found also by Hejman and Kunzová (2010) based on their long-term experiments. The main finding was that there was found no statistical significance in the influence of soil tillage, thus between both soil tillage methods (ploughing and shallow loosening). Similarly, also Mikanová et al. (2012) indicated the same results. In addition, Rieger et al. (2008) claims that the different results of winter wheat grain yield may not always be
caused by the different soil tillage. According to Woźniak (2013), the different soil tillage method has rather a lower influence on the amount of yield, while the influence of the weather (the year) is bigger. He also points out that if there is a higher total rainfall during the vegetation period the yield is higher after ploughing than after shallow loosening. On the contrary, after a lower rainfall, the yield is higher after shallow loosening than after ploughing. Which has been also confirmed in our results, in the interaction of the year with soil tillage. Nevertheless, confirming of the influence of different soil tillage method on the winter wheat grain yield remains difficult.

CONCLUSION

The three years results show that winter wheat grain yield in the conditions of dry maize production area is influenced especially by the year (weather), the pre-crop and partly by soil tillage. This confirms not only the significance of the influence of agronomic factors, mainly the pre-crop, but also the influence of the year (the weather) not only separately, but also in the interaction with a pre-crop and in the interaction with soil tillage.

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