The Effect of Different Soil Tillage on Grain Yield of Spring Barley (*Hordeum vulgare*)

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Summary

The aim of the study was to evaluate the effect of different soil tillage on yield of spring barley from a long-term stationary field experiment. The experiment was conducted in period from 1990 to 2014 on loamy chernozem soil in a sugar beet growing region. Spring barley was grown in three crop rotations, always after sugar beet which was set after silage maize, winter wheat and spring barley. Four variants of soil tillage were evaluated: 1. ploughing to the depth of 0.22 m; 2. ploughing to the depth of 0.15 m); 3. direct sowing into non-prepare soil; 4. loosening to the depth of 0,10 m. Influence of experimental factors on yield was evaluated in 1990–2014. Influence of experimental factors on yields was statistically significant. The highest average yield was reached in the crop rotation – spring barley, sugar beet, spring barley and the lowest yield in the crop rotation - silage maize, sugar beet, spring barley. In all three crop rotations the highest average yield was on variant with ploughing to 0.15 m (6.68 $t \cdot ha^{-1}$) and the lowest on variant with ploughing to 0.22 m (6.54 $t \cdot ha^{-1}$). Minimum soil tillage technologies with direct sowing (6.64 $t \cdot ha^{-1}$) and loosening to 0.10 m (6.62 $t \cdot ha^{-1}$) had a middle grain yields. Results of this observation shows that lower intensity of soil tillage in case of spring barley grown after sugar beet, under conditions of the given locality, is a suitable alternative to traditional way of soil tillage.

Key words

spring barley, yield, soil tillage, crop rotation

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Introduction

Yields of crops, as well as the quality of their production, are the results of the combined effect of many factors. Beside the influence of meteorological conditions of the year the yield potential of spring barley is considerably influenced by agro-technological treatments. The most attention is devoted to pre-crop, soil tillage, level of nitrogen fertilizing and crop variety. Nowadays the systems of soil tillage are generally revised. Besides labor and energetically intensive technologies with ploughing technologies without ploughing are used. The main reasons for development of these minimum soil tillage technologies are due to ecological, economical and technical reasons.

Use of minimum soil tillage technologies for spring barley was studied by number of researchers (Hrubý, 1986; Procházka and Hudcová, 1989; Procházkova et al., 2011; Smutný et al., 2015; Candráková and Macák, 2015, etc.). Results show that the influence of minimum soil tillage technologies on spring barley grain yield depends mainly on site conditions and pre-crop. In general, the best conditions for minimum soil tillage technology are on moderately heavy, structural soils with higher natural fertility (maize and beet growing areas).

Use of minimum tillage technologies in case of spring barley grown after different pre-crops describes Zimolka et al., (2006); Hůla, Procházková et al., (2008); Procházková et al., (2011) and etc. Sugar beet is a traditional pre-crop for spring barley which creates good conditions for yield and grain quality of spring barley. Long-term results and also practical experiences of farmers show that spring barley grown after sugar beet is responding to reduction of depth and intensity of soil preparation.

Material and methods

Influence of different intensity of soil preparation on yields of spring barley was observed in a long-term stationary field experiment conducted in 1990–2014 at the field experimental station of Crop Research Institute in Ivanovice na Hané. The year 2006, when stands were destroyed by abnormal amount of rainfalls, was not involved in evaluation.

The experiment was conducted in a beet growing area in an altitude 225 m above sea level on loamy fluvic chernozem soil (Němeček et al., 2011). The depth of humus horizont is about 0.40–0.50 m. Content of available nutrients is good (P 102; K 245; Mg 215; Ca 3100 mg.kg^{-1}), soil pH is neutral (6.9) and content of humus is 2.6 %.

According to climatic conditions Ivanovice na Hané belongs to the climatic region T2–hot, slightly dry (Tolasz et al., 2007). Average year temperature of air of period from 1990 to 2014 was 9.27°C and average precipitation was 552.9 mm (Table 1).

Spring barley was grown in three crop rotations after sugar beet (Beta vulgaris) which was set after silage maize (*Zea mays*), winter wheat (*Triticum aestivum*) and spring barley (*Hordeum vulgare*).

Variants of soil tillage:

1. ploughing to the depth of 0.22 m
2. ploughing to the depth of 0.15 m
3. direct sowing into non-prepared soil
4. loosening to depth of 0.10 m

Fertilizing of spring barley

Fertilizing by mineral fertilizers was unified for all variants:

N – 40; P – 30; K – 60 kg of pure nutrients per hectare.

Scabies of sugar beet were beat out and spread by chopper. On variants with ploughing to 0.22 and 0.15 m plant residues were incorporated into the soil. On variant with shallow soil tillage the residues were incorporated into the depth 0.10 m and on the variant with direct sowing left plant residues on the surface.

Fertilizing of pre-crop (sugar beet):

40 t of farmyard manure per hectare; N – 135; P – 50; K – 125 kg of pure nutrients per hectare.

Spring barley varieties:

1990–1996 Rubin, 1997 Akcent, 1998–2007 Kompakt, 2008–2011 Jersey, 2012–2014 Bojos.

Plant protection was made according to the actual state and according the methodology of the State Phytosanitary Administration (Bulletin of the central institute for supervising and testing in agriculture. Series: Plant protection products division).

Establishment and design of the experiment:

The design of this experiment was based on the method of strip plots with four replications. The area of experimental plots was 300 m^2 (6 x 50 m), the area of harvested parcels was 22.05 m^2 (2.25 x 9.00 m).

Statistical evaluation of results:

The statistical evaluation of observed factors on yields of spring barley was made by a multifactor analysis of variance and followed by testing of significance of differences among variants by a method of confidence intervals. Evaluation was made on a level of significance 0.05 (i. e. level of probability 95 %) in program STATISTICA 12.0 (StatSoft software Inc., Tusla, Oklahoma, USA).

Results and discussion

Observed influence of experimental factors on grain yields of spring barley period from 1990 to 2014 are presented in Tables 2-3 and in Figures 1–3.

Long-term observation of influence of different ways of soil tillage and position of spring barley in a crop rotation on grain production creates preconditions for more reliable evaluation. As some authors refer, due to wide variability of weather conditions among years and possible cumulative effects on soil processes, evaluation of influence of experimental factors on yields of grown

Table 1. The average air temperatures and the sum of precipitation in the period between 1990 and 2014 at the Field Trial Station in Ivanovice na Hané

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
Average temperature (°C)	-1.6	-0.1	4.0	9.7	14.8	17.9	19.9	19.5	14.5	9.2	4.1	-0.7	9.27
Sum of precipitation (mm)	24.7	22.0	29.1	36.2	64.2	73.6	73.7	69.9	53.5	38.9	39.1	28.0	552.9

Table 2. Influence of experimental factors on grain yield of spring barley, average yield (t·ha^{-1}) period from 1990 to 2014

Variants of soil tillage	Crop rotations			Average
	SM–SB–B	W–SB–B	B–SB–B	
Ploughing to 0,22 m	6.44	6.52	6.66	6.54
Ploughing to 0,15 m	6.60	6.65	6.79	6.68
Direct sowing	6.52	6.63	6.78	6.64
Loosening to 0,10 m	6.50	6.64	6.71	6.62
Average	6.52	6.61	6.74	6.62

SM-silage maize, SB-sugar beet, W-winter wheat and B-spring barley

Table 3. Analysis of variance (ANOVA) – grain yield of spring barley

Source of variation	Degrees of freedom	Average square	F value
Year	23	131.73	1168.2
Crop rotation	2	4.71	41.8
Soil tillage	3	0.98	8.7
Year×crop rotation	46	0.91	8.1
Year×soil tillage	69	1.17	10.4
Crop rotation×soil tillage	6	0.06	0.5
Year×crop rotation×soil tillage	138	0.29	2.6
Error	864	0.11	

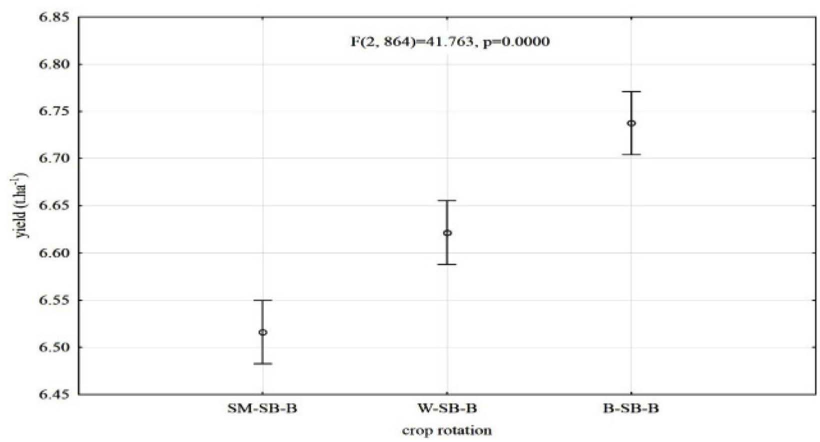

Figure 1. Statistical evaluation of influence of crop rotation on grain yield of spring barley (period from 1990 to 2014)

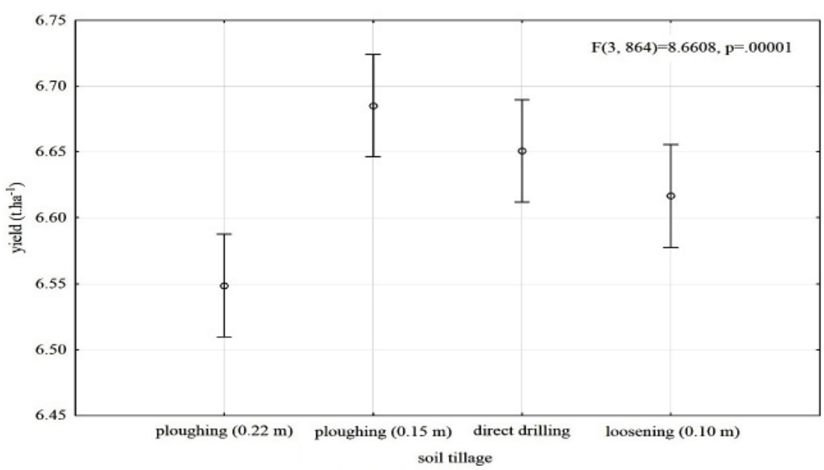

Figure 2. Statistical evaluation of influence of soil cultivation on grain yield of spring barley (period from 1990 to 2014)

crops is more exact in long-term experiments (Arshard, 1999; Hůla, Procházková et al., 2008; Kováč et al., 2010, atc.).

Influence of a year on grain yields of spring barley was, in our observations, statistically significant (data not presented in this paper). Low average yields of grain in a frame of whole complex of the experiment were registered in year 1993 (3.44 t·ha^{-1}), 2000 (4.22 t·ha^{-1}), 2003 (4.42 t·ha^{-1}) and primarily in a year 2012 (2.44 t·ha^{-1}). In these years the yields were negatively influenced mainly by insufficient water support of plants (as a result of lack of precipitation and higher temperatures) in the critical period of thermodynamic faze of spring barley growing (from April to June). The highest average yields of spring barley grain were in years 2011 (9.33 t·ha^{-1}), 2009 (8.84 t·ha^{-1}), 2001 (8.27 t·ha^{-1}), 2014 (8.27 t·ha^{-1}) and 2004 (8.24 t·ha^{-1}). Water support of plants in a critical period of the spring barley development was good in these years.

More authors confirm significant influence of precipitation and temperatures in the first part of vegetation of spring barley on grain yield (Tichý et al., 1991; Cerkal et al., 2001; Příkopa et al., 2005; Zimolka et al., 2006; Váňová et al., 2006; Křen et al., 2014. Trnka et al. (2007) found out that water support of plants in the period April–June significantly influenced production of spring barley on 51 from 62 evaluated fields in the Czech Republic.

Influence of position of spring barley in a crop rotation on the grain yields was statically significant. The lowest yields was reached in a crop rotation silage maize – sugar beet – spring barley (6.52 t·ha^{-1}) in which two water demanding corps followed after each other. The highest average yield was in a crop rotation spring barley – sugar beet – spring barley (6.74 t·ha^{-1}). Grain yield in crop rotation winter wheat – sugar beet – spring barley (6.61 t·ha^{-1}) occupied the middle position (Tables 2-3, Figure 1).

As some authors refer, the location of spring barley in a crop rotation has a significant meaning from a view of yield and also quality of grain (Procházka and Hudcová, 1989; Zimolka et al., 2006; Hřivna et al, 2009; Míša 2014; etc.). Spring barley is a typical crop of old soil strength. The highest yields and quality of grain are usually reached after root crops which leave soil in a good structural and nutritious condition (Richter et al., 2004; Zimolka et al, 2006; Klem, 2009; Míša, 2014). Results of our observations in drier and warmer conditions show that when spring barley is a part of crop rotation, influence of other corps from the crop rotation and soil water regime should be taken into consideration.

In our observations was influence of different intensity of soil tillage on grain yield of spring barley statistically significant. In

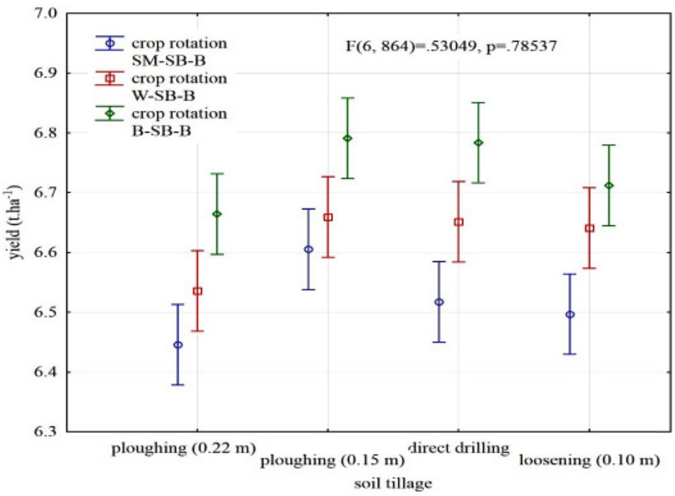

Figure 3. Statistical evaluation of influence of crop rotation and soil cultivation on grain yield of spring barley (period from 1990 to 2014)

all three crop rotations was detected higher grain yield of spring barley on the variant with ploughing to 0.15 m (average 6.68 $t \cdot ha^{-1}$) and the lowest on the variant with ploughing to 0.22 m (6.54 $t \cdot ha^{-1}$). Minimum soil tillage technologies with direct sowing into non-prepared soil (6.64 $t \cdot ha^{-1}$) and shallow soil preparation by disc equipment to 0.10 m (6.62 $t \cdot ha^{-1}$) achieved the middle positions (Tables 2-3, Figure 2-3).

The problem of soil cultivation for spring barley including the possibility of using minimal soil cultivation techniques is researched by many authors (Hrubý, 1987; Procházka and Hudcová, 1989; Procházkova et al., 2011; Smutný et al., 2015; Candráková and Macák, 2015, etc.). From the results of cited authors, and also another ones, is evident that the influence of minimum soil tillage technologies on yield and quality parameters of spring barley grain in not clear. Result depends mainly on conditions of a locality and position of spring barley in a crop rotation include of management of post-harvest residues of pre-corp. The most convenient conditions for use of minimum tillage technologies, in case of spring barley, are on moderately heavy structural soils with higher natural fertility under warmer and drier conditions. In our experiments we observed positive influence of lower intensity of soil preparation on yield of spring barley grown under favorable agro-climatic conditions after sugar-beet. Under similar conditions this observations correspond with results of another experiments conducted.

Conclusion

Results of the long-term observations of variant ways of soil preparation and their influence on grain yield of spring barley show that spring barley grown on fertile chernozem soil under relatively drier and warmer conditions of beet growing area, grown after sugar beet, reacts positively on reduction of depth and intensity of soil preparation. Positive influence of lower intensity of soil tillage on grain production of spring barley can be put in context mainly with better moisture ratio of soil and consequently with better water support of plants and also better conditions for decomposition of residues from green parts of sugar beet.

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