

EFFECT OF DIFFERENT TILLAGE INTENSITY ON YIELDS AND YIELD-FORMING FACTORS IN WINTER WHEAT

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Abstract

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The paper presents results of a study on application of minimum tillage technologies when growing winter wheat. Experiments were performed in the sugar-beet-growing region with loamy chernozem within the period of 2005–2009. Analysed and evaluated were effects of different methods of soil processing on yield-forming factors in stands of winter wheat grown after three different preceding crops (i.e. alfalfa, maize for silage and pea). Evaluated were the following four variants of tillage: (1) conventional ploughing to the depth of 0.22 m (Variant 1); (2) ploughing to the depth of 0.15 m (Variant 2); (3) direct sowing into the untilled soil (Variant 3), and (4) shallow tillage to the depth of 0.10 m (Variant 4).

The effect of different tillage intensity on winter wheat yields was statistically non-significant after all forecrops. After alfalfa, the highest and the lowest average yields were recorded in Variant 2 (i.e. with ploughing to the depth of 0.15 m) and Variant 3 (direct sowing into the untilled soil), respectively. After maize grown for silage, higher yields were obtained in Variant 2 and Variant 1 (conventional ploughing) while in Variants 4 and 3 the obtained yields were lower. When growing winter wheat after pea as a preceding crop, the highest and the lowest average yields were recorded after direct sowing (Variant 3) and in Variant 1 (i.e. ploughing to the depth of 0.22 m), respectively.

Results of studies on effect of different tillage technologies on yields of winter wheat crops indicate that under the given pedological and climatic conditions it is possible to apply methods of reduced tillage intensity. However, the choice of the corresponding technology must be performed with regard to the type of preceding crop.

tillage, winter wheat, yields, yield-forming factors

Tillage and soil processing belong to those basic agrotechnical measures that significantly contribute to yield formation of cultivated field crops. The mechanical processing of soil is also an important tool when controlling or killing weeds, pests and plant diseases. The main task of tillage is to create favourable conditions for growth and development of plants and for a proper course of various processes taking place in soil. The mechanical processing changes the general physical condition of soil, which determines aeration of soil and also its hydraulic, thermal and biological properties. Opinions concerning proper methods and

technologies of soil processing are continuously developing and changing.

Nowadays, technologies of minimum tillage are considered worldwide as an important alternative of conventional methods of soil processing based on ploughing. In the Czech Republic, research studies on the application of minimum and zero tillage technologies have a long-standing tradition. The most important expansion and application of these technologies took place after the year 1990 and it is estimated by many experts that at present they are used on more than 40% of arable land. Main reasons of this expansion and development of minimum tillage technologies can be found out above all in

domains of ecology, economics and mechanised agriculture. It is expected that minimum tillage and, above all, soil-protecting and anti-erosion technologies will significantly contribute to the improvement of quality of both soil and environment. For farmers, economic consequences of minimum tillage technologies are also very important because they lead to savings of labour and energy. A wider application of various forms and types of minimum tillage methods was enabled by new designs and construction of agricultural machinery (Koller and Linke, 2006; Lal *et al.*, 2007; Hůla, Procházková *et al.*, 2008).

The development of minimum and zero tillage systems was based on observations that the yield response of a majority of crops to minimum tillage and the depth of soil processing is slight and inexpressive. Besides, it was also found out that cereals responded positively to compacted soils with a higher volume density, i.e. to soils corresponding to intact, natural and untilled soil (Suškevič, 1994).

In the Czech Republic, winter wheat is the most important cereal. This crop is grown in practically all production regions and is cultivated on more than one quarter (28%) of the total acreage of arable land; today, it occupies about 60% of the total area of cereals. Of all cereal species, winter wheat has the best parameters of and assumptions for the intensification of production. A positive rate of profitability is reached above all on fields situated in sugar-beet and maize-growing regions (Zimolka *et al.*, 2005).

The system of tillage and establishment of field crops represents an important part of technologies used for growing of cereals. As far as the winter wheat is concerned, there is a wide spectrum of tillage technologies available. When selecting the most suitable technology of soil processing and stand establishment, it is necessary to take into account the existing growing conditions, i.e. locality, position of winter wheat in the crop rotation, management and processing of post-harvest residues, and soil condition after the harvest of the preceding crop (Hůla, Procházková *et al.*, 2008).

This paper deals with effects of different intensity of tillage on yields and yield-forming factors of winter wheat grown after various forecrops (i.e. alfalfa, maize for silage, and pea) on loamy chernozem in a sugar-beet-growing region.

MATERIAL AND METHODS

In 1989, field experiments enabling to monitor effects of various methods of tillage on yields and yield-forming factors have been established (and are still in running) in the Research Station of the Research Institute of Plant Production in Ivanovice na Hané, Czech Republic. The station is situated in the sugar-beet-growing region. Analysed and presented in this paper are data collected within the period of 2005–2009.

Soil and climatic conditions of the experimental site

Experiments were established on fields with loamy chernozem at an altitude of approximately 225 m. The depth of humus horizon ranged from 0.40 to 0.50 m. Soil reaction was neutral and the content of humus was 2.6%. Soil reserves of P, K, Ca and Mg were good. The experimental site was classified as the climatic region T2 (warm, moderately dry). The average annual temperature and the average sum of precipitations were 9.13 °C and 539.91 mm, respectively (18-year average).

Experimental variants

Technological systems of soil processing for winter wheat crop were evaluated after three forecrops and within the framework of three crop rotations with different percentages of cereals (33,3%, 50%, 66,6%).

II: Variants of tillage for the winter wheat crop

Variant	Method of tillage
1	Ploughing to the depth of 0.22 m
2	Ploughing to the depth of 0.15 m
3	Direct sowing to untilled soil
4	Shallow disc loosening to the depth of 0.10 m

Method of crop establishment

Experiments were established in four replications using the Lot Plot method.

The size of each harvested plot was: $9.80 \times 2.25 = 22 \text{ m}^2$

Varieties, dressing and chemical protection

Until now (i.e. 2010), the variety Sulamit has been grown since 2004. Mineral fertilisers were applied

I: Crop rotation with a different concentration of cereals

Plot	I. (33,3%)	II. (50%)	III. (66,6%)
1	Alfalfa	Pea	Winter wheat
2	Alfalfa	Maize for silage	Pea
3	Winter wheat	Winter wheat	Winter wheat
4	Maize for silage	Winter wheat	Spring barley
5	Sugar beet	Sugar beet	Sugar beet
6	Spring barley	Spring barley	Spring barley

III: Doses of mineral fertilisers to the winter wheat crop

Total N	Mineral fertilisation (kg of pure nutrients. ha ⁻¹), of this:		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
120	60 prior to sowing	40	80
	30 for regeneration		
	30 for production		

according to the methodology of a complex plant nutrition. Uniform doses of nutrients were applied in all variants of this experiment. Protection against diseases, weeds and pests was performed with regard to their actual occurrence and in accordance with valid methodologies issued by the State Phytosanitary Administration.

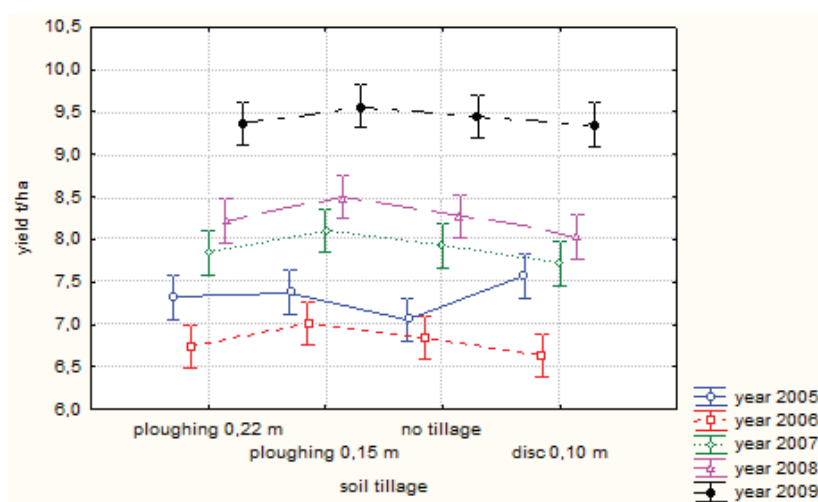
Statistical processing and evaluation of obtained results

The statistical analysis of obtained results was performed by means of the program Statistica CZ

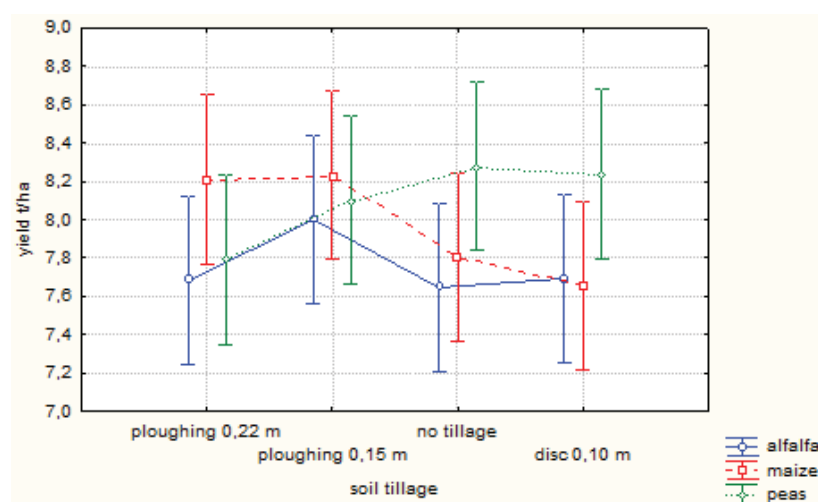
v. 8, using the method of variance analysis and Tukey's test (graphical presentations of significance are at the probability level of 95 %).

RESULTS AND DISCUSSION

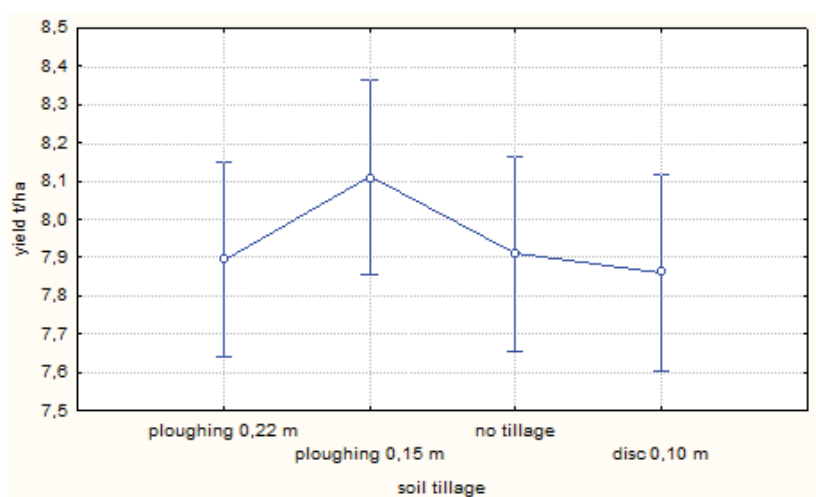
Results of studies on effects of experimental conditions on yields and yield-forming factors of winter wheat cultivated within the period of 2005–2009 are presented in Figs 1–7.



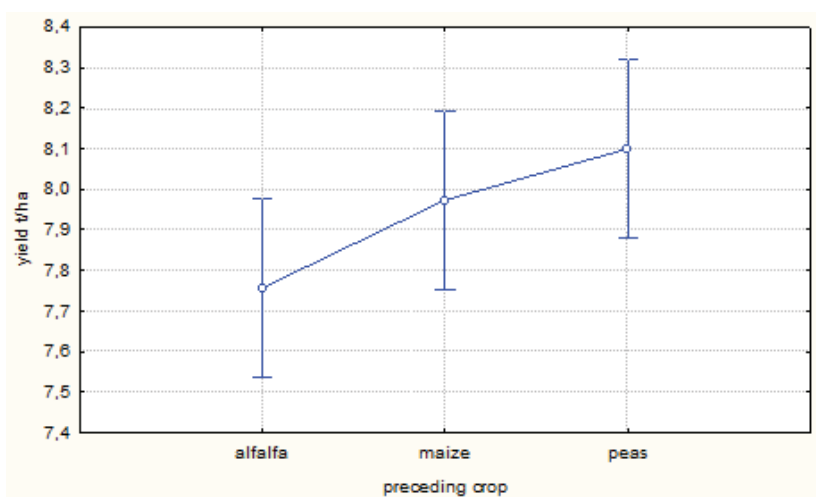
1: Effects of various methods of soil processing on yields of winter wheat (2005–2009)



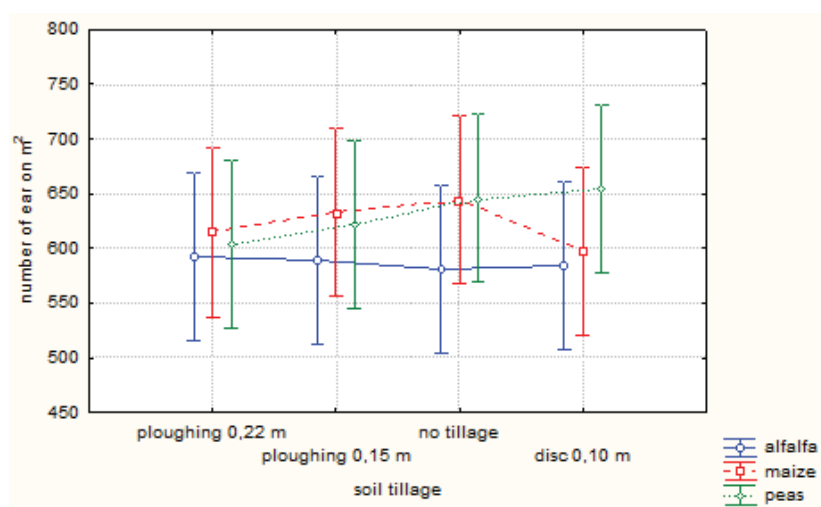
2: Effects of a various intensity of soil processing on yields of winter wheat grown after individual forecrops (2005–2009)



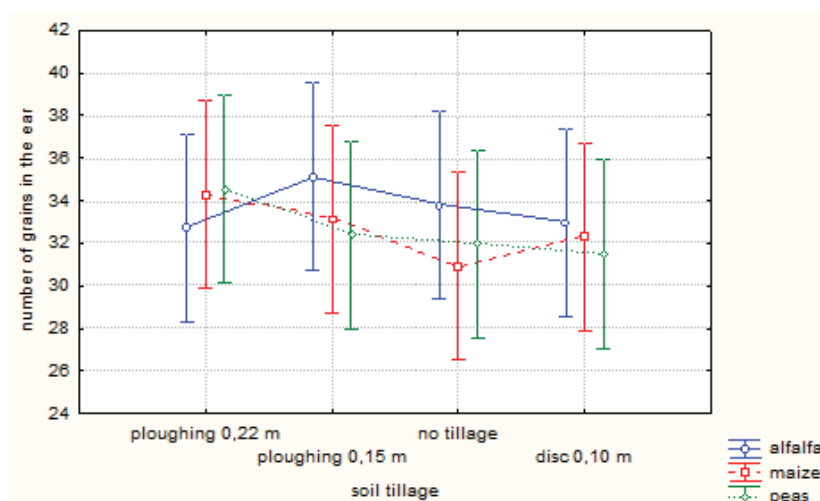
3: Effects of a various intensity of soil processing on yields of winter wheat (2005–2009)



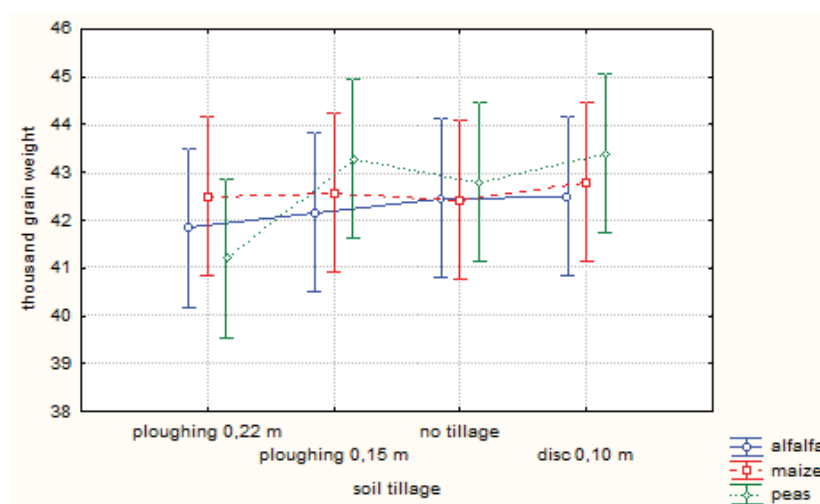
4: Effect of preceding crops on yields of winter wheat (2005–2009)



5: Effects of a various intensity of soil processing and of preceding crops on the number of ears per 1 square meter of winter wheat crop (2005–2009)



6: Effects of a various intensity of soil processing and of preceding crops on the number of kernels per ear of winter wheat (2005–2009)



7: Effects of a various intensity of soil processing and of preceding crops on the Thousand Kernels Weight – TKW (2005–2009)

Effect of year on winter wheat yields

The effect of year on yields of winter wheat was marked and statistically significant (Fig. 1). Yields were affected above all by the sums of precipitations and temperatures within the growing season. The highest and the lowest yields were recorded in 2009 and 2006, respectively.

Effect of tillage on winter wheat yields

The effect of elimination of ploughing on yields of winter wheat grown under dry and warm conditions was mentioned by several authors (e.g. Larney and Lidwal, 1994; Kováč, 1998; Procházková and Dovrtěl, 2000; Hemmat and Eskandari, 2006; Wang *et al.*, 2009 and others).

In our experiments, established and performed under conditions of a slightly more humid sugar-beet growing region, the positive effect of minimum tillage on winter wheat yields was not so marked. The

effect of soil processing on yields of winter wheat grown after all three forecrops (i.e. alfalfa, maize for silage and pea) was statistically insignificant.

When evaluating average yields of winter wheat grown after alfalfa as a forecrop it was found out that the highest and the lowest yields were obtained in Variants 2 (8 t.ha⁻¹) and 3 (7.65 t.ha⁻¹), respectively.

After maize grown for silage as a preceding crop, higher yields were recorded in Variants 2 (8.21 t.ha⁻¹) and 1 (8.23 t.ha⁻¹) while lower ones were obtained in Variants 4 (7.64 t.ha⁻¹) and 3 (7.8 t.ha⁻¹). Higher yields were obtained thanks to a thorough incorporation of post-harvest residues by ploughing and a subsequent sowing into well prepared seed beds, while lower yields might be associated with an imperfect placing of seeds into the soil due to greater amounts of maize post-harvest residues.

When winter wheat was cultivated after pea, the highest and the lowest yields were recorded in Variants 3 (8.27 t.ha⁻¹) and 1 (7.8 t.ha⁻¹), respectively.

In these experiments, it was observed that yields of winter wheat showed a tendency to decrease with the increasing intensity of tillage. This might be caused by a very good establishment of the crop even in variants with reduced tillage because of small amounts of post-harvest residues of pea forecrop and a better hydraulic condition of soil due to a lower intensity of soil processing. Similar results were published also by Procházková and Dovrtěl (2000). As compared with the conventional ploughing, higher yields were obtained also in variants with a shallow tillage and direct sowing into the untilled soil.

In general, the best and the most reliable was Variant 2 with ploughing to the depth of 0.15 m because its average yield was 8.1 t.ha⁻¹. In this case the best yield was obtained above all due to a sufficient ploughing-in of post-harvest residues and, therefore, quality processes of sowing and germination of winter wheat seeds. The shallow ploughing to the depth of only 0.15 m did not cause too high losses of water from the soil profile even in drier years and/or after water-demanding forecrops. In Variant 1 with ploughing to the depth of 0.22 m and in Variant 3 with direct sowing, identical average yields of 7.9 t.ha⁻¹ were obtained. A slight decrease in average yields (7.86 t.ha⁻¹) was observed in Variant 4 with shallow disk loosening of soil to the depth of 0.10 m.

The effect of preceding crops on yields of winter wheat was more pronounced than that of tillage. Pea showed to be the best forecrop for winter wheat because it left in soil quality organic matter with a high content of nitrogen. This forecrop also did not destroy soil texture and/or desiccate soil profile too much. Thanks to these aspects, the five-year average yield was the highest at all (8.1 t.ha⁻¹). Maize for silage was the second best forecrop with the average five-year yield of 7.97 t.ha⁻¹. Under these experimental conditions, the lowest yields of winter wheat grain were recorded after alfalfa. This forecrop consumed lots of water so that it dried up the soil profile. A decrease in yields could be therefore associated above all with a reduced supply of water to plants. In this case, the five-year average yield was 7.75 t.ha⁻¹.

Effect of tillage on yield-forming factors of winter wheat

Yields of winter wheat are determined by yield-forming factors, which involve number of ears per square meter, number of kernels per ear and TKW. Yields are calculated as a product of these three variables. Their mutual relationships indicate that a self-regulation system functions in all cereal

crops (i.e. also in winter wheat). This means that if the number of ears per square meter decreased, the number of kernels per ear and the TKW automatically increased. This capability functioned obviously also *vice versa* so that an increased number of ear per plant caused a decrease in the number of kernels per ear and a lower TKW. The final yield of winter wheat is determined by the environmental bearing capacity, which results from vegetative and production factors. From the practical point of view this means that a stand of winter wheat crop can give same yields within a certain range of number of ears per square meter and this is determined by the environmental bearing capacity.

The number of ears per square meter is determined above all by the seeding rate, number of germinated plants and number of fertile tillers. After alfalfa, the numbers of ears were nearly identical in all four variants of tillage while after maize for silage the highest and lowest numbers of ears per square meter were observed in Variant 3 (direct sowing) and 4 (disc loosening to the depth of 0.10 m), respectively. After pea as a forecrop, the highest, the second highest and the lowest numbers of ears per square meter were recorded in Variants 4, 3 and 1, respectively.

The aforementioned self-regulation of a winter wheat stand is illustrated in Figs 5 and 6. After alfalfa, the highest number of kernels was observed in Variant 2. A slightly lower result was obtained in Variant 3. In both of them, however, the numbers of plants per square meter were the lowest. After maize grown for silage as the forecrop, the lowest number of kernels per ear and the highest number of ears per square meter were recorded in Variant 3. In Variants 1 and 4, both the number of ears per square meter and the number of kernels per ear were only average. After pea as a forecrop, optimum results were obtained in Variants 4 and 3. In both of them, the number of ears was higher and that of kernels per ear lower but the yields of grain were the highest.

As one can see in Fig. 7, after alfalfa as the forecrop, TKW was about 42 g in all variants of tillage. The same trend could be observed also after maize for silage; a different intensity of tillage did not influence the value of TKW. However, after pea as a forecrop, the differences in TKW were more pronounced. The lowest TKW (41 g) was recorded in Variant 1. This could be explained by the fact that ploughing reduced the water-holding capacity of soil. The highest TKW (43 g) was observed in Variants 2 and 4.

SUMMARY

The aim of this study was to evaluate effects of various methods of tillage on yields and yield-forming elements of winter wheat grown in the sugar-beet growing region on loamy chernozem after three different forecrops (i.e. alfalfa, maize for silage, and pea) within the period of 2005–2009.

The obtained results indicate that, under given soil and weather conditions, it is possible to reduce intensity of tillage. However, when doing this, it is necessary to take into account also the preceding

crop. After forecrops with higher amount of post-harvest residua (e.g. maize), it is more suitable to think about ploughing because it enables a better incorporation of organic matter into the soil, which could otherwise prevent a precise establishment of a winter wheat crop. On the other hand, however, after forecrops with lower amounts of post-harvest residues (e.g. pea) it is better and more advantageous to apply technologies of minimum tillage. When evaluating results of this experiment it can be concluded that the most suitable variant is a shallow ploughing to the depth of 0.15 m because it enables not only a good incorporation of post-harvest residues into the soil but also the preparation of a good seed bed. Moreover, it also does not dry the soil profile as much as the deep conventional ploughing.

The obtained results corroborate the observation that there is a self-regulating mechanism, which influences the growth and development of the winter wheat crop. If plants produce too high numbers of ears per square meter, the number of kernels per ear decreases. If, on the other hand, the plant creates less ears per square meter, the number of kernels per ear increases. For that reason it is suitable to establish winter wheat stands with a lower number of plants per square meter and to try to increase their density by means of nitrogen doses applied in the course of the growing season so that the yield will be formed through a lower number of ears but a higher number of kernels per ear and a higher TKW. Stands created in this way (i.e. with less ears) are robust and resistant to lodging so that there are predispositions for formation of higher yields.

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REFERENCES

- HEMMAT A., I. ESKANDARI, 2006: Dryland winter wheat response to conservation tillage in continuous cropping system in northwestern Iran. *Soil and Tillage Res.*, 86, 99–109.
- HŮLA, J., PROCHÁZKOVÁ, B. a kol., 2008: Minimalizace zpracování půdy. Praha, Profi Press, s. r. o., 246 s.
- KÖLLER, K., LINKE CH., 2006: Úspěch bez pluhu. 1. vydání. Praha: Vydavatelství ZT, 192 s.
- KOVÁČ, K., 1998: Vliv roznej predplodiny, obrábania pody a hnojenia na výšku strukturu urody a efektívnoť pestovanija ozimnej pšenice. *Rostl. Výr.*, 44: 133–139.
- LAL, R. et al., 2007: Evaluation of the plow over 10,000 years and the rationale for no-till farming, *Soil and tillage research*, 93, s. 1–12.
- LARNEY, F. J., C. W. LIDWALL., 1994: Winter wheat performance in various cropping systems in southern Alberta. *Can. J. Plant Sci.*, 74: 79–86.
- PROCHÁZKOVÁ, B., DOVRTĚL, J., 2000: Vliv různého zpracování půdy na výnosy ozimé pšenice. *Rostl. Výr.*, 46: 437–442.
- PROCHÁZKOVÁ, B., DOVRTĚL, J., 2000: Effect of different soil tillage and straw management systems on the yield of wheat. In: Morisson, J. E. (Ed) *Proc. Of 15th ISTRO conf.*, Texas, 5 s.
- SOANE, B.D., BALL, B.C., ARVIDSSON, J., BASCH, G., MORENO, F., ROGER-ESTRADE, J., 2011: No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and environment. *Soil and Tillage Res.*, Article in press.
- SUŠKEVIČ, M., 1994: Dlouhodobé působení minimálního zpracování půdy k jarnímu ječmeni a ozimé pšenici na výnosy a výrobnost osevního postupu. *Rostl. Výr.* 40: 9, 817–823.
- WANG, F. et al., 2009: Wheat cropping systems and technologies in China. *Field Crops Res.*, 121: 181–188.
- ZIMOLKA, J. a kol. 2005: Pšenice, pěstování, hodnocení a užití zrna. Praha Profi Press, s. r. o., 184 s.

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