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DIFFERENT CROP MANAGEMENT PRACTICES FOR WINTER WHEAT PRODUCTION*

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Abstract. This study demonstrates the importance of individual factors that influence the growing technology of winter wheat. It was found that a suitable forecrop played the most important role in winter wheat production. The grain yield can be increased also by the application of fungicides. In the majority of cases, different methods of tillage and/or various variants of application of liquid fertilisers on straw did not show any effect on grain yield of winter wheat. These results provide valuable information not only for wheat growers in drier regions of the Czech Republic but also for those farmers who want to eliminate negative effects of more and more frequent periods of draught.

Keywords: winter wheat, crop management practices, soil tillage, straw management

INTRODUCTION

In the Czech Republic, there are about 1.6 million hectares of cereals and approximately half of this area is under winter wheat. Regions with a less frequent occurrence of precipitation during the period of ripening are favourable for production of high quality bread wheat. However, a lack of water in earlier growth

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stages can be a limiting factor of yields. For this reason it is necessary to adapt the crop management practices of winter wheat to given climatic and pedological conditions in such a way that sufficient supply of water to plants would be assured. The method of tillage represents one of the most important factors that could influence the water management of crops in the course of growing season. A numbers of field trials with various methods of tillage (Hrubý 1989, Miština 1992, Procházková and Dovrtěl 2000) brought some new data about positive effects of both minimum and zero tillage on the production of field crops. In each region, appropriate practices of conservative tillage may take reasonable use of cultivation to address soil and climatic constraints and use tillage for straw incorporation to avoid the adverse effect of crop residues on the growth of the following crop (Hakansson 1994). Especially on farms without animal production, greater and greater attention is now being paid to the problem of efficient use of straw that would enable to supply organic matter into the soil. Due to this fact different preparations are being tested that would support the decomposition of straw (Dryšlová *et al.* 2005). Yields of winter wheat may be influenced also by other intensification factors, e.g. by application of fertilisers (above all of nitrogen) and by protection against biotic pests (weeds, diseases and pests). The importance of crop rotation should also not be neglected because winter wheat belongs to crops that are very demanding as far as the forecrops are concerned. All aforementioned factors can be, to a certain extent, influenced by the grower. However, it also should not be forgotten that there are some factors that cannot be controlled in a direct way. They involve both the amount and the time distribution of rainfalls in the course of the growing season. In this context the problem of the occurrence of draught periods and their impacts on plant production is being more and more discussed, also under the climatic conditions of Central Europe. The years 2000, 2001 and 2003 can be mentioned as examples of such an occurrence of draught periods (Trnka *et al.* 2007).

The data mentioned above demonstrate that in future properly selected growing technologies can play a more and more important role not only from the viewpoint of yields but also of the quality of grain.

MATERIALS AND METHODS

The impacts of different agronomical factors were evaluated in a field trial established in Žabčice in the years 2004-2006. This locality (179 m above sea level, 49°01′ N, 16°37′ E) is situated 25 km southwards from Brno (South Moravia region, Czech Republic). It is a warm and dry region with average annual temperature and precipitation of 9.2°C and 480 mm, respectively July and January are the warmest and the coldest months with average daily air temperatures of 19.3°C and –2.0°C, respectively. June and March are the months with the highest and the lowest precipitation (68.6 mm and 23.9 mm, respectively; Tab. 1). The annual sum of solar irradiation ranges from 1.800 to 2.000 hours.

Table 1. Long-term temperature and precipitation standards (1961-1990)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
Average 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
Sum of precipitation (mm)	24.8	24.9	23.9	33.2	62.8	68.6	57.1	54.3	35.5	31.8	36.8	26.3	480

According to the taxonomic system of soils of the Czech Republic, the soil in the Field Experimental Station in Žabčice is classified as gleic fluvisol which has developed on alluvial sediments of the Svratka River. These soils are without any marked diagnostic horizons and the parent substrate consisting of alluvial material is situated below a thin humus horizon. More marked symptoms of gley proceeses can be observed in the depth of below 0.6 m. In the course of the year, the groundwater level fluctuates between 0.8 and 2.5 m. As far as the soil texture is concerned, the soil is classified as heavy to very heavy.

The field trial was established in this locality as a model concept for farming without animal husbandry (all straw is cut and incorporated into the soil). The principle of this experiment was a 5-year crop rotation with a high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, corn). As far as the winter wheat was concerned, the following four experimental factors were assessed: forecrop (safflower – *Carthamus tinctorius* or winter wheat), soil tillage (conventional or minimum tillage), straw treatment with different fertilisers and fungicide treatment (treated or untreated). The variant of conventional tillage consisted of stubble breaking after harvest and ploughing down to the depth of 0.20-0.24 m. The variant of minimum tillage included stubble breaking after harvest followed by a shallow loosening to the depth of 0.15 m. Straw and crop residues of all crops were treated with four different liquid fertilizers (variants A-D); the aim of this treatment was to increase microbial activity and straw decomposition by nitrogen addition. The individual variants were as follows: Variant A involved the application of Beta-liq liquid fertiliser at the dose of 1 t ha^{-1}, Variant B the application of DAM 390 at the dose of 100 kg ha^{-1}, and in Variant C the fertiliser Unifert was applied at the dose of 230 kg ha^{-1}. All doses of fertilisers mentioned above corresponded to 30 kg of nitrogen ha^{-1}. The last variant, D, was used as control and it was without any fertiliser.

More detailed characteristics of fertilisers used:
A – Beta-liq – (a liquid molasses-based organo-mineral fertiliser containing 3% of N and 5% of K_2O); the applied dose was 1 t ha^{-1},
B – DAM 390 – (a nitrogen fertiliser solution composed of urea and ammonium nitrate, containing 30% N) – the applied dose was 100 kg ha^{-1}
C – Unifert – (liquid organo-mineral fertiliser on the base of alimentary waste products, containing 13% of N and 3% of K_2O) – the applied dose was 230 kg ha^{-1}
D – Control – without fertilisers

In the variant treated against leaf and ear diseases of winter wheat, fungicides were applied twice, at the beginning of stalk shooting (BBCH 32, TANGO SUPER – 84 g epoxiconazole + 250 g fenpropimorph) at the dose of 1.0 l ha^{-1} and in the growth stage of heading (BBCH 55, FALCON 460 EC – 250 g spiroxamine + 167 g tebuconazole + 43 g triadimenol) at the dose of 0.6 l ha^{-1}.

The winter wheat variety Sulamit was sown at the rate of 4 million of germinating seeds (MGS) per hectare. The experimental dose of fertilisers was 120 kg N ha^{-1} (30 kg N prior to sowing as ammonium sulphate, 50 kg N in the spring for regeneration as calcium ammonium nitrate (CAN, 27.5%) and 40 kg N till the end of tillering as DAM 390. Experimental plots were harvested with a small combine harvester SAMPO 2010.

The impact of all these factors was assessed on grain yields of winter wheat. Results were statistically processed using the method of variance analysis and the statistical software Statistica 7.0; the significance of differences of mean values was tested by means of the Fisher LSD (least square difference) test.

RESULTS AND DISCUSSION

The three-year results showed that all three factors under study, i.e. forecrop (in all years), fungicide treatments (only in 2004 and 2005) and soil tillage (only in 2006) showed a statistically significant impact on yields of winter wheat. The results of variance analysis are presented in Table 2 and the effects of a combination of all the factors in Table 3.

Table 2. ANOVA table

Source of variability	Degrees of freedom	Mean square		
		2004	2005	2006
(1) Forecrop	1	10.91**	22.001**	68.04**
(2) Tillage	1	0.03	0.159	19.44**
(3) Fertilisation of straw	3	0.51**	0.488**	0.523
(4) Fungicide treatment	1	42.50**	32.86**	0.311

1*2	1	0.01	5.956**	25.91**
1*3	3	0.25	0.454	0.872**
2*3	3	0.52**	0.186	0.268
1*4	1	2.58**	4.69**	0.053
2*4	1	0.44	0.018	0.073
3*4	3	1.31**	0.417	0.249
1*2*3	3	0.96**	0.112	0.242
1*2*4	1	0.02	0.204	0.176
1*3*4	3	0.12	0.364	0.038
2*3*4	3	0.22	0.225	0.288
1*2*3*4	3	0.09	0.267	0.151

** Statistically highly significant effect (P = 0.99).

Table 3. Yield of winter wheat obtained by combinations of all factors

Factors				Yield ($t\ ha^{-1}$)		
Forecrop	Soil tillage	Application of liquid fertilisers on straw	Fungicide treatment	2004	2005	2006
Safflower	I	A	yes	9.17	8.07	7.63
	I	A	no	8.53	7.11	7.71
	I	B	yes	9.88	8.46	8.35
	I	B	no	9.22	6.68	8.06
	I	C	yes	10.03	8.54	8.05
	I	C	no	8.30	6.40	7.80
	I	D	yes	9,68	8.34	8.02
	I	D	no	8.68	7.21	8.14
	II	A	yes	9.93	8.32	7.93
	II	A	no	8.99	7.45	7.89
	II	B	yes	9.37	8.89	8.30
	II	B	no	8.82	7.47	8.38
	II	C	yes	9.28	8.64	8.16
	II	C	no	8.46	7.33	7.98
	II	D	yes	9.43	8.59	8.04
	II	D	no	8.82	7.01	8.06

Winter wheat	I	A	yes	9.63	7.61	7.30
	I	A	no	8.36	6.64	7.60
	I	B	yes	9.30	7.22	7.70
	I	B	no	8.16	6.98	7.36
	I	C	yes	9.66	7.46	7.36
	I	C	no	7.27	6.58	7.27
	I	D	yes	8.82	7.67	7.33
	I	D	no	7.50	7.47	7.38
	II	A	yes	9.27	6.84	6.46
	II	A	no	7.98	6.27	5.82
	II	B	yes	8.91	7.05	5.74
	II	B	no	8.14	6.11	5.68
	II	C	yes	9.45	7.07	5.57
	II	C	no	7.47	6.19	4.91
	II	D	yes	9.35	7.21	5.68
	II	D	no	8.00	6.86	6.00

Impact of forecrop

As compared to winter wheat after winter wheat, winter wheat after safflower gave statistically significantly higher (P = 0.95) yields in all experimental years (2004 – 9.16 t ha^{-1}/8.58 t ha^{-1}, 2005 – 7.78 t ha^{-1}/6.95 t ha^{-1}, and 2006 – 8.03 t ha^{-1}/6.57 t $ha^{-1,}$ Fig. 1). This difference indicated the role of forecrop in the yield formation of winter wheat. It was found that the repeated growing of winter wheat after winter wheat caused lower yield. This decrease may be also dependent on concentration of cereals in the crop rotation. It can be also expected that with the increasing duration of the experiment the differences in yields obtained after both forecrops will be greater and greater. The yield decrease observed after the repeated growing of winter wheat after winter wheat may be caused not only by unsuitable soil texture but also by an increased pressure of infectious diseases. Pokorný *et al.* (2006), in the same trial, mentioned an increased occurrence of *Mycosphaerella graminicola* in a stand of winter wheat grown after winter wheat in the experimental variant with reduced soil tillage. On the other hand, the succession winter wheat-safflower can be recommended also for drier conditions because safflower does not require so much water.

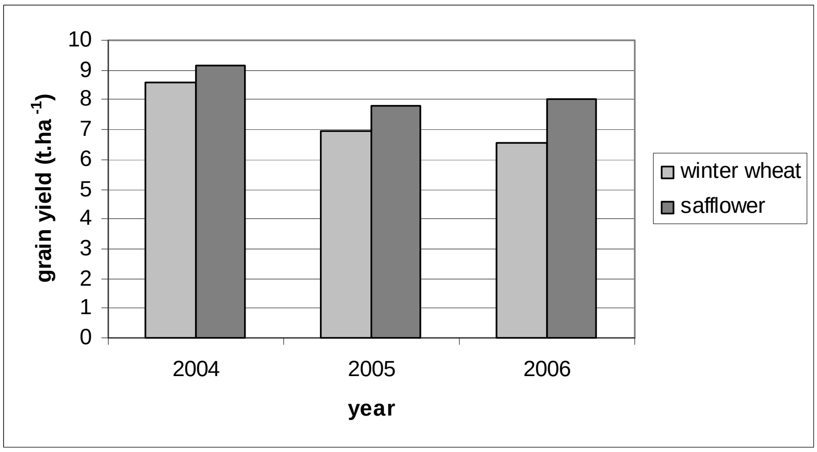

Fig. 1. Impact of forecrop on the yield of winter wheat

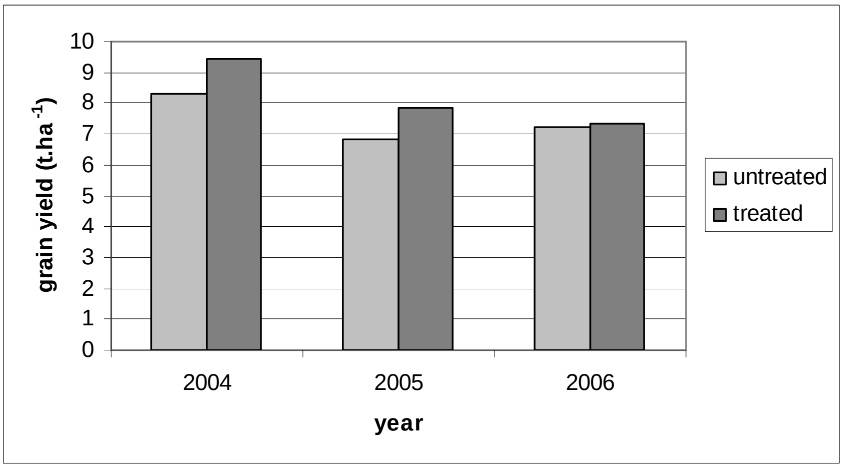

Fig. 2. Grain yield of winter wheat as influenced by fungicide treatment

Impact of fungicide treatment

Significant yield differences between fungicide-treated and untreated variants were found in 2004 (8.29 t ha^{-1} and 9.45 t ha^{-1} in the untreated and the treated variants, respectively) and in 2005 (6.86 t ha^{-1} and 7.87 t ha^{-1}). Only in 2006 the differences were not significant (7.25 t ha^{-1} and 7.35 t ha^{-1}, Fig. 2). This could be associated with a lower infection pressure of fungal diseases that year. The highest differences between treated and untreated variants were recorded in the years 2004 and 2005. In 2004, the yield of fungicide-treated winter wheat grown after winter wheat was, on average, higher by 1.44 t ha^{-1} while in 2005 it was higher by 1.40 t ha^{-1} in the variant with winter wheat grown after safflower. These results corroborate the justification of fungicide treatments also from the economic point of view. However, it is necessary to remember that the cultivar Sulamit is sensitive to fungal diseases.

Yet, it is still not clear if in the years with a lower infection pressure and when growing less sensitive cultivars under drier conditions it would not be possible to use fungicides only once. This is a question which should be answered by growers themselves because their correct decisions could show a marked effect on the economic results of their farming activities.

Impact of soil tillage

A significantly higher winter wheat yield was recorded only in 2006 (7.69 t ha^{-1} and. 6.91 t ha^{-1} in variants with ploughing and soil loosening, respectively). The differences between these two variants of tillage were not significant in the years 2004 and 2005. This corresponded with a similar course of weather (above all precipitation) in both years. When plotting the sum of precipitation for the period of March – June (which is important from the viewpoint of yield formation of winter wheat) we can see that it was 187 mm and 169 mm in 2004 and 2005, respectively (Tab. 4). In 2006, when in the same period the sum o precipitation was 243 mm, the yield differences between two methods of tillage were marked only in the variant with winter wheat grown after winter wheat. As compared with soil loosening, the grain yield in the ploughed variant was significantly higher (7.41 t ha^{-1} *vs.* 5.73 t ha^{-1}; Fig. 3). After safflower comparable grain yields were obtained in both tillage variants (i.e. ploughing and loosening). These results suggest that in years with a higher sum of precipitation reduced tillage can have a negative effect on yields. This can be caused by reduced mineralization due to a lower content of air in soil because aeration shows a strong effect on this process. In wet years the majority of soil pores are filled with water and this can have a negative effect on the development of the root system.

Table 4. Course of precipitation in years 2004-2006

Year	Months												Annual precipitation
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2004	42	28	60	34	28	65	29	33	44	66	35	18	482
2005	19	44	6	50	67	46	103	81	33	6	23	30	509
2006	22	26	46	51	75	71	78	151	9	14	21	20	587

A similar situation occurred in 2006 on the experimental plot with winter wheat after winter wheat: in the variant with reduced tillage, the grain yield was lower by 1.68 t ha^{-1}. Similar results may be expected after forecrops which deteriorate soil structure. In variants with reduced tillage, the specific density and soil porosity are markedly reduced and this can limit the soil aeration under conditions of increased soil humidity.

In this context one should emphasize the importance of safflower which as a forecrop that exercises a positive effect on soil texture and thus enables its better aeration. Regarding the aforementioned results it is necessary to reconsider the suitability of various methods of tillage for various site and climatic conditions. In years with normal and/or lower sums of precipitation it is possible to recommend some of the methods of reduced tillage. In such cases it is possible not only to obtain grain yields that are comparable with ploughed variants and but also to save fuel. However, the reduced tillage can be recommended only in that case when the problem of killing of permanent weeds is effectively solved from the economic point of view. Costs associated with the control of creeping thistle (*Cirsium arvense*) and common couchgrass (*Elymus repens*), the abundance of which increased in Žabčice above all in variants with reduced tillage, may rapidly shift the economy of winter wheat growing in favour of the ploughing variant.

Yield results of experiments with a long-term monoculture of spring barley were obtained under the same site conditions. After the conventional tillage, the highest yield was obtained in the variant with burned straw, followed by the variant with straw incorporated into the soil; the lowest yield was recorded in the variant with harvested straw. As compared with inversion tillage, after shallow tillage lower yields were recorded in all variants of straw management. The ranking of variants was identical to that of inversion tillage; however, after straw burning, the yield was higher than after its incorporation into the soil. Grain yields increased regularly with increasing doses of nitrogen. When evaluating long-term effects of straw incorporation on yields and yield trends (as compared with straw harvesting), a statistically significant decrease in yields was observed after shallow tillage, while after deeper straw incorporation the yields increased (Procházková 2002).

Similarly, Javůrek *et al.* (2005) mentioned that there were no differences in grain yields of winter wheat and spring barley after conventional, minimum and zero tillage in their experiments performed in Praha-Ruzyně in the years 2001 – 2005. Also Dzienia *et al.* (1999) in and Poland, and Kováč *et al.* (2005) in Slovakia recorded only minimum yield differences among differently intensive methods of tillage. However, there were also different results published in the literature. For example, Cannell and Hawes (1994) obtained a higher yield in a variant with reduced soil tillage, while Šimon and Javůrek (1999) recorded higher grain yields in a variant with a conventional method of tillage.

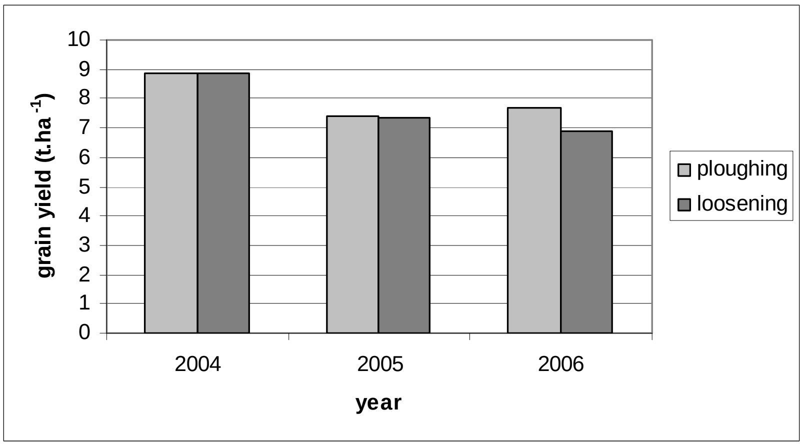

Fig. 3. Impact of soil tillage on yield of winter wheat

Impact of application of liquid fertilisers on straw

In the years 2004 and 2005, the impact of liquid fertilisers on straw was statistically significant. In 2004, a significantly higher yield was obtained in the variants with Beta-liq (A) and DAM 390 (B, Fig. 4). However, in 2005, higher yields were obtained in control (D) and in the variant with DAM 390 (B). In 2006, the differences between variants were statistically insignificant. Unfortunately, these results do not enable to conclude which of the aforementioned fertilisers can be used and/or if the supplied fertiliser has a positive effect on yields. It can be expected

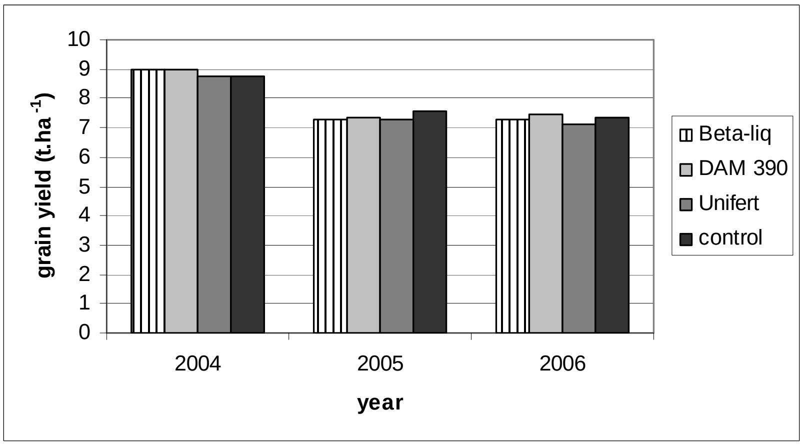

Fig. 4. Grain yield of winter wheat influenced by application of liquid fertilisers on straw

that in the years to come this effect could be more marked at the moment when non-decomposed straw would be accumulated in the soil profile (above all in the variant with reduced tillage). Procházková and Dovrtěl (2000) and Procházková (2002) found that the preparation Beta-liq had a positive effect on straw degradation and the yield of subsequent crops.

CONCLUSION

The obtained results illustrate the importance of individual factors which participate in the growing technology of winter wheat. It was demonstrated that a suitable forecrop played the most important role in winter wheat production. The grain yield could be increased also by fungicide treatment. In the majority of cases, however, neither different methods of tillage nor different variants of application of liquid fertilisers on straw had an effect on yields of winter wheat.

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ZRÓŻNICOWANIE PRAKTYK UPRAWOWYCH W PRODUKCJI PSZENICY OZIMEJ

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S t r e s z c z e n i e. Praca przedstawia znaczenie poszczególnych czynników wpływających na technologię uprawy pszenicy ozimej. Stwierdzono, że odpowiedni przedplon ma największe znaczenie w produkcji pszenicy ozimej. Wielkość plonów można także zwiększać poprzez zastosowanie odpowiednich środków grzybobójczych. W większości przypadków zróżnicowanie metod uprawy oraz/lub zastosowanie różnych wariantów nawożenia płynnego na słomę nie miało większego wpływu na plon ziarna pszenicy ozimej. Przedstawione wyniki stanowią cenne informacje nie tylko dla producentów pszenicy w bardziej suchych rejonach Republiki Czeskiej ale także dla rolników, którzy pragną wyeliminować ujemne skutki coraz częściej występujących okresów suszy.

S ł o w a k l u c z o w e: pszenica ozima, praktyki uprawowe, uprawa gleby, zagospodarowanie słomy