EFFECT OF SOIL CULTIVATION TECHNOLOGY AND FERTILIZATION ON SPRING BARLEY (*HORDEUM VULGARE* L.) PRODUCTION PROCESS

Eva HANACKOVA, Pavol SLAMKA

Slovak Agricultural University in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic
E-mail: Eva.Hanackova@uniag.sk

Abstract: *The influence of conventional and minimal soil cultivation in interaction with mineral fertilization and utilization of the by-product on the spring barley yield, uptake of nutrients by yield and energetic effectiveness in experimental years 2004-2006 was investigated in the experiment. Within each cultivation method, three treatments of fertilization were applied: 0 - control without fertilizing, PH - rational fertilization with mineral fertilizers, PZ - rational fertilization with mineral fertilizers and incorporation of post harvest residues into soil. Different soil cultivation did not influence grain yield of spring barley statistically significantly. It was confirmed that barley does not react substantially onto the depth of soil cultivation. The highest average yield of grain (average of years and soil cultivation methods) was found in treatment with incorporated (ploughed-down) post-harvest residues (PZ). Higher grain yield was achieved under their shallow incorporation into soil (B_2). On the average of three experimental years 54.4 kg of spring barley grain were produced per one kilogramme of NPK nutrients. Higher value was achieved under conventional soil cultivation than under minimalization one. In treatment where post harvest residues were incorporated into soil (PZ) the production of grain was by 6.3 kg higher than in treatment fertilized with mineral fertilizers. The highest amount of grain per 1 kg of applied nutrients (on the average of three years) was produced in treatment B_1 - PZ (67 kg), but under minimalization it was only 48 kg of grain. The values were changing in dependence on experimental year and were decreasing with increasing rate of nutrients. TNT seems to be relatively steady value. It expresses weight of grain in kilogrammes falling on 1 kilogramme of NPK nutrients taken up by the yield. In respective experimental years it ranged from 27.1 kg of grain (year 2004) to 29.9 kg (year 2006). Percentual portion of real natural production from theoretical one SNP/TNP = 192.7 %. Higher energetic effectiveness (E = 6.35) was obtained under conventional soil cultivation. The highest energetic effectiveness (E = 9.58) was calculated at the application of 40 kg ha^{-1} N in all 3 experimental years in treatment B_1-PZ. When post harvest remains of forecrop were incorporated by ploughing into soil the values of energetic effectiveness were 3-times higher than in treatment fertilized with mineral fertilizers in all three experimental yearsxt.*

Key words: *spring barley, tillage of soil, mineral fertilizers, post harvest residue, nutrients uptake, energetic effectiveness*

INTRODUCTION

Weather conditions, variety, forecrop, nutrition, seed material and complex plant protection seem to be the most important factors influencing amount and the quality of yield (KOVÁČ et al. 2006). Nutrition and fertilization belong among the most significant intensification and rationalization measures at spring barley growing. Sensitivity of spring barley to fertilization resulted from weaker developed root system and shorter growing season during which barley has to take up relatively large amount of nutrients (CANDRÁKOVÁ, 2011, Ložek et al., 2009). To create one tone of grain and adequate amount of straw spring barley needs 20 - 24 kg N, 3.5 - 6.5 kg P, 16.8 - 18.0 kg K, 5.7 - 8.5 kg Ca, 1.2 - 2.4 kg Mg and 4.0 - 4.2 kg S (HŘIVNA, RYANT, 2005).

Rational fertilizing contributes to yielding stability and lowers dependence on less favourable weather conditions during growing season (UŽÍK, 2008).

Nitrogen from soil or fertilizers in harmonic ratio with other nutrients decisively influences formation of quantity as well as quality of yield.

Growing of malting barley has a long-term tradition in Slovakia. With regard to achieve greater competitive ability it is important re-evaluate up to now applied technologies with an aim to reduce productional (growing) cost. One of the possibilities for such reduction seems to be utilization of minimal technologies at the establishment of spring barley cover.

MATERIAL AND METHODS

Field experiment was established in three replications on the fields of experimental basis of SPU Nitra at Dolná Malanta locality in the year 2003/2004 – 2005/2006. The locality is situated in maize productional region belonging to very warm and dry subregion with altitude of 175-180m above sea level. Average year air temperature is 9.7°C and average annual sum of precipitation accordingly to long-term normal represents 561mm. Soil is loamy brownsoil originated on proluvial loessial sediments. Agrochemical soil characteristics are stated in table 1.

Table 1

Agrochemical soil analysis

Year	Content of available nutrients in soil ($mg.kg^{-1}$)			pH_{KCl}	K : Mg
	P	K	Mg		
2003/2004	86	355	208	6.55	1.7
2004/2005	73	305	203	6.39	1.5
2005/2006	98	327	236	6.55	1.4

In the experiment two methods of soil cultivation were examined: B_1 – conventional mouldboard plough tillage to the depth of 0.2m followed by surface cultivation of topsoil, B_2 - minimal cultivation - offset disc ploughing to depth of 0.15m and combined cultivator.

Within each cultivation method, three treatments of fertilization were applied: 0 - control without fertilizing, PH - rational fertilization with mineral fertilizers, PZ - rational fertilization with mineral fertilizers + incorporation of post harvest residues into soil.

The rates of mineral fertilizers were determined on the basis of soil analysis for contents of available nutrients and planned grain yield of spring barley (5 t ha^{-1}).

Nitrogen was applied in the form of ammonium nitrate with dolomite, phosphorus in the form of 19 % superphosphate and potassium in the form of 60 % potassium salt (KCl). Applied rates of nutrients are illustrated in table 2.

Energetic effectiveness of spring barley fertilization is nitrogen was calculated as follows: $E = \Delta P / N$, where: ΔP = increment of grain yield, N = rate of nitrogen

Table 2

Rates of nutrients for spring barley fertilizing

Year	Treatment	Rate of nutrients (kg ha^{-1})		
		N	P	K
2003/2004	B_1 – PH	40	30	0
	B_1 – PZ	40	25	0
	B_2 – PH	60	25	20
	B_2 – PZ	60	30	20
2004/2005	B_1 – PH	55	30	20
	B_1 – PZ	40	26	0
	B_2 – PH	55	26	0
	B_2 – PZ	55	26	20
2005/2006	B_1 – PH	55	20	20
	B_1 – PZ	40	25	20
	B_2 – PH	40	20	20
	B_2 – PZ	40	20	20

As a preceding crop of spring barley (variety Nitran) was maize (*Zea mays* L.) in years 2004 and 2006. In experimental year 2005 the forecrop was winther wheat (*Triticum aestivum* L.). Sampling of plant material was carried out in full maturity of spring barley. Uptake of nutrients was calculated on the basis of spring barley yield and content of macronutrients in main and by-product.

The aim of the contribution is evaluate productional process of spring barley under conventional and minimal soil cultivation in interaction with mineral fertilization and utilization of organic matter of by-product in experimental years 2004-2006.

RESULTS AND DISCUSSIONS

Average grain yield of spring barley achieved 4.47 t ha^{-1} in experimental years 2004-2006 (table 3). Genetic potential of Nitran variety was utilized only for 71.4 %. Higher average yield in fertilized treatments was obtained when offset discs ploughing was used.

Different soil cultivation did not influence grain yield of spring barley statistically significantly. It was confirmed that barley does not react substantially onto the depth of soil cultivation and its growth does not require loose soil (KOVÁČ et al., 2003). The highest average yield of grain (average of years and soil cultivation methods) was found in treatment with incorporated (ploughed-down) post-harvest residues (PZ). Higher grain yield was achieved under their shallow incorporation into soil (B_2).

Table 3

Yield of spring barley grain, variety Nitran

Year	Treatment	Tillage of soil				Average	
		B_1		B_2			
		Yield of grain					
		t ha^{-1}	Relat. %	t ha^{-1}	Relat. %	t ha^{-1}	Relat. %
2004	Control	4.69	100.0	4.50	100.0	4.60	100.0
	Mineral fertilizers	4.73	100.9	5.06	122.4	4.90	106.5
	Post harvest residue	5.41	115.4	6.60	146.6	6.01	130.7
	Average	**4.94**		**5.39**		**5.17**	
2005	Control	3.16	100.0	3.16	100.0	3.16	100.0
	Mineral fertilizers	3.44	108.8	3.88	122.8	3.66	115.8
	Post harvest residue	3.46	109.5	3.53	111.7	3.50	110.8
	Average	**3.35**		**3.52**		**3.44**	
2006	Control	3.51	100.0	4.47	100.0	3.99	100.0
	Mineral fertilizers	4.82	137.3	5.87	131.3	5.35	134.1
	Post harvest residue	5.57	158.7	4.60	102.9	5.09	127.6
	Average	**4.63**		**4.98**		**4.80**	
Average	Control	3.78	100.0	4.04	100.0	3.91	100.0
	Mineral fertilizers	4.33	114.6	4.94	122.3	4.64	118.7
	Post harvest residue	4.81	127.2	4.91	121.5	4.86	124.3
	Average	**4.31**		**4.63**		**4.47**	

Years $Hd_{0.05}$ = 0.783 Tillage of soil $Hd_{0.05}$ = 0.751 Fertilization $Hd_{0.05}$ = 0.894
$Hd_{0.01}$ = 1.044 $Hd_{0.01}$ = 1.001 $Hd_{0.01}$ = 1.191

In comparison with control treatment significant difference in spring barley grain yield in treatment PZ was found out only under conventional soil cultivation. Irregular distribution of precipitation in year 2005 during critical periods of spring barley growing (surplas of precipitation during sowing – tillering period; and deficit during earing) showed negative effect on grain yield. Yield of grain in year 2005 was highly significantly lower than in year 2004 and 2006 respectively. SLAFER et al. (2002) and KRČEK et al. (2008) state that drought stress leads to grain yield reduction in the range of from 5 to 30 % depending on the drought stress duration. Lower yield of spring barley grain can also be partially attributed to winter wheat effect which as a fore crop has (in accordance with literature data) worse fore crop value than grain maize.

Table 4

Values of real and theoretical natural production (average of years 2004 – 2006)

Factors	Real natural produktion (SNP) (kg of grain)	Theoretical natural production (TNP) (kg of grain)	% SNP from TNP
Conventional cultivation (B_1)	58.7	27.9	214.8
Minimal cultivation (B_2)	50.12	28.8	170.6
Control (0)	-	28.5	-
Mineral fertilizers (PH)	51.2	29.1	175.9
Post harvest residue (PZ)	57.5	27.6	209.5
B_1 – PH	50.3	28.0	181.1
B_2 – PH	52.1	30.2	170.0
B_1 – PZ	67.0	27.2	247.7
B_2 – PZ	48.0	27.9	171.2

To judge applied rates of fertilizers the values of real (SNP) and theoretical natural production (TNP) were calculated. They make it possible to work out agronomic model of spring barley cover and optimize the main articles of agrotechnics (ŠPALDON et al., 1987).

On the average of three experimental years 54.4 kg of spring barley grain were produced per one kilogramme of NPK nutrients. Higher value was achieved under conventional soil cultivation than under minimalization one. In treatment where post harvest residues were incorporated into soil (PZ) the production of grain was by 6.3 kg higher than in treatment fertilized with mineral fertilizers.

The highest amount of grain per 1 kg of applied nutrients (on the average of three years) was produced in treatment B_1 - PZ (67 kg), but under minimalization it was only 48 kg of grain (table 4). The value of SNP was changing in dependence on experimental year and was decreasing with increasing rate of nutrients.

TNT seems to be relatively steady value. It expresses weight of grain in kilogrammes falling on 1 kilogramme of NPK nutients taken up by the yield. In respective experimental years it ranged from 27.1 kg of grain (year 2004) to 29.9 kg (year 2006). The yield of spring barley took off from soil more nutrients than it was supplied into; what is expressed by percentual portion of real natural production from theoretical one (SNP/TNP = 192.7 %) on the average of years and fertilization treatments.

Rightly determined rate and term of fertilizer application influence economical utilization of energy. Figure 1 and 2 illustrate that energetic effectiveness was influenced by the rates of N-fertilizers, year and technology of soil cultivation. On the average of 3 years the higher energetic effectiveness (E = 6.35) was obtained under conventional soil cultivation. The highest energetic effectiveness (E = 9.58) was calculated at the application of 40 kg ha^{-1} N in all 3 experimental years in treatment B_1-PZ. When post harvest remains of forecrop were incorporated by ploughing into soil the values of energetic effectiveness were 3-times higher than in treatment fertilized with mineral fertilizers in all three experimental years. The values of energetic effectiveness in respective experimental years are depicted in table 5.

Balance of nutrients is considered to be a reliable indicator of sustainable soil farming. The fundamental data which enable to calculate nutrient balance in spring barley growing are represented by information about input of nutrients in the form of fertilizers and seeding material. With nitrogen they are also the information on the wet deposit by precipitation. BABOŠOVÁ et al. (2002) found out the level of nitrogen input into soil by precipitation reaching

21.5 kg ha^{-1} yr^{-1} in locality Dolná Malanta. Within the balance outputs include offtake of nutrients by yield of both the main and by-products, respectively.

The results show that the highest deficit of nitrogen, phosphorus and potassium, respectively was determined in unfertilized treatment on the average of 3 years. Low balance surplus of nitrogen under convention soil tillage (1.8 kg ha^{-1} yr^{-1}) and phosphorus at both technologies were found out in treatment with rational mineral fertilization. Deficit of potassium in control treatment as well as in the one fertilized with mineral fertilizers was high, however acceptable for the reason of high natural content of potassium in soil. The lowest deficit of K (-2.3 kg ha^{-1} yr^{-1}) was in treatment with shallowly incorporated post-harvest remains. Conditions for sustainable soil farming were relatively the best fulfilled in treatment with incorporation of post-harvest plant residues into soil profile.

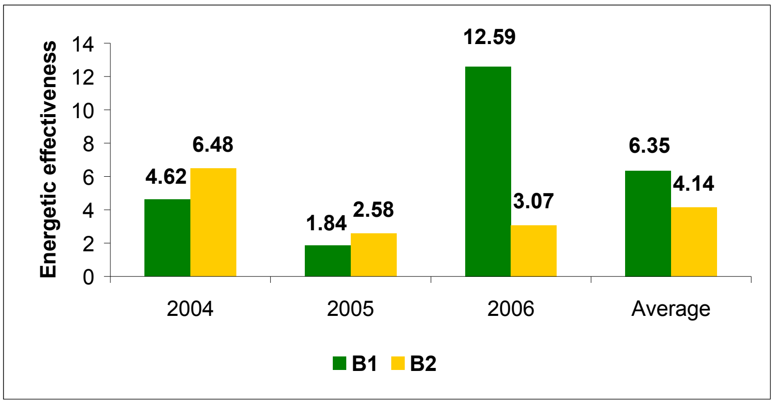

Figure1: Energetic effectiveness under different soil cultivation
B1 – conventional soil cultivation, B2 – minimal soil cultivation

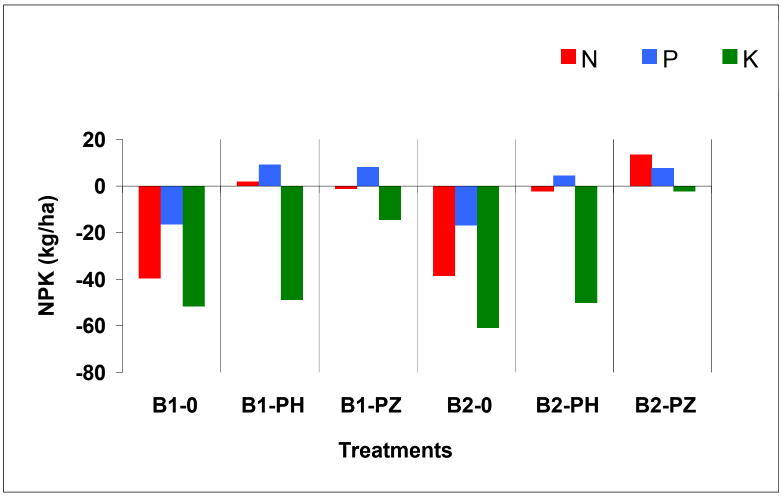

Figure 2: Energetic effectiveness under different fertilization
B1-0 conventional soil cultivation unfertilized, B1-PH conventional soil cultivation + mineral fertilization, B1-PZ conventional soil cultivation + mineral fertilization + incorporation of post harvest residues into soil, B2-0 minimal soil cultivation without fertilization, B2-PH minimal soil cultivation + mineral fertilization, B2-PZ minimal soil cultivation + mineral fertilization + incorporation of post harvest residues into soil

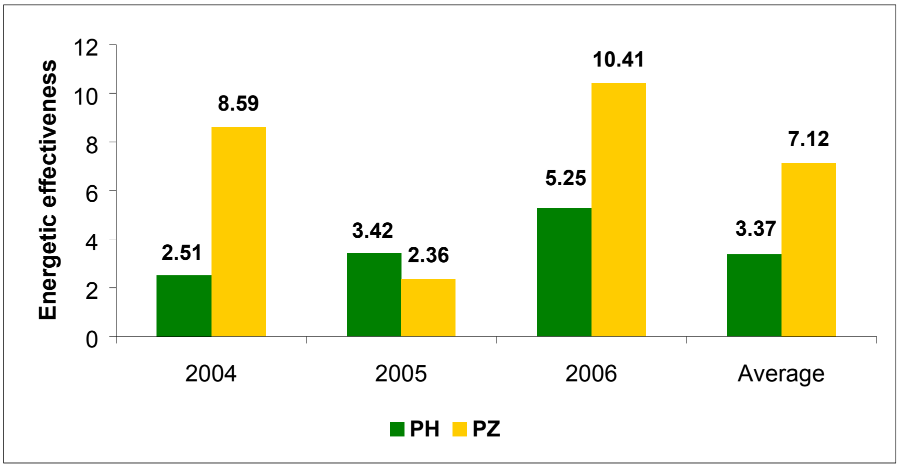

Figure 3: Balance of nutrients in spring barley growing (average of years 2004-2006)
PH – mineral fertilization, PZ – mineral fertilization + incorporation of post harvest residues into soil

Table 5

Energetic effectiveness of spring barley fertilization with nitrogen mineral fertilizers

Treatment		Year 2004 N (MJ)	2004 ΔP (MJ)	2004 E	2005 N (MJ)	2005 ΔP (MJ)	2005 E	2006 N (MJ)	2006 ΔP (MJ)	2006 E	$\bar{x}$
B_1	PH	3 300	6 696	2.03	4 538	4 520	0.99	4 538	28 793	6.34	3.12
	PZ	3 300	23 771	7.20	3 300	8 872	2.69	3 300	55 577	18.84	9.58
$\bar{x}$				4.62			1.84			12.59	6.35
B_2	PH	4 950	14 731	2.98	4 568	16 907	3.73	3 300	13 727	4.16	3.62
	PZ	4 950	49 383	9.98	4 538	9 207	2.03	3 300	6 529	1.98	4.66
$\bar{x}$				6.48			2.88			3.07	4.14
Average				5.55			2.36			7.83	5.25

N - rate of nitrogen, Δ P - increment of grain yield, E - energetic effectiveness

CONCLUSIONS

In experimental years 2004 - 2006 grain yield of spring barley achieved 4.47 t ha^{-1} on average Yielding potential of Nitran variety was utilized only for 71.4 %. Comparing with mouldboard ploughing treatment insignificantly higher yield of grain (4.63 t ha^{-1}) was obtained when offset disc ploughing was applied. Within the framework of fertilization treatments the highest average grain yield was achieved in treatment with incorporated post-harvest remains (4.86 t ha^{-1}) when higher yield was achieved under their shallow incorporation into soil in comparison to deep ploughing.

The highest energetic effectiveness of nitrogen fertilizers (E = 9.58) was achieved at the rate of 40 kg ha^{-1} N in the treatment with ploughed-down post-harvest residues.

The highest deficit of N, P and K was in control unfertilized treatment, respectively. On the average of three years and soil cultivation technologies the deficit of nitrogen was -39.1 kg ha^{-1} yr^{-1}, phosphorus -16.6 kg ha^{-1} yr^{-1} and potassium -56.25 kg ha^{-1} yr^{-1}. The treatment with rational fertilization (mineral fertilizers + incorporation of post harvest residues into soil)-PZ was closest to the farming system fulfilling conditions of sustainable agriculture.

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