NUTRIENT MANAGEMENT ANALYSIS IN FIELD PEA (*PISUM SATIVUM* L.) CULTIVATED IN THE NO-TILLAGE TECHNOLOGY

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The object of study was to analyse nutrient management (nitrogen, phosphorus, potassium) in pea (*Pisum sativum* L.) cultivated in the no-till technology. The trial was established in the years 2001–2003 on gleyic Fluvisol (locality Milhostov). The territory has continental character of climate with average precipitation for year 559 mm, for vegetation period 348 mm and with average daily temperature for year 8.9°C, for vegetation period 16.0°C.

The field treatments with field pea were realized in natural conditions without irrigation. Sowing was realized by equipment Great Plains with sowing rate 290 kg ha^{-1}. There were two variants of fertilization compared in the trial, fertilized (25 kg ha^{-1} N, 30 kg ha^{-1} P a 40 kg ha^{-1} K) with non fertilized.

The results show that the deficit of observed nutrients was not found in condition with mineral fertilizers. Balance of nitrogen, phosphorus and potassium was positive (+23.97 kg ha^{-1} year^{-1} N, +18.36 kg ha^{-1} year^{-1} P and +23.28 kg ha^{-1} year^{-1} K) and its compensation amounted 157.54%, 238.46% and 177.45% respectively. Important holding in positive balance had N_2-fixation. Quantities of N_2-fixation calculated in straw and root remains were in average 21.64 kg ha^{-1} N. Air nitrogen provides for positive balance of nitrogen in condition without mineral fertilization as well, with average input 16.76 kg ha^{-1} N. Nitrogen balance was +3.81 kg ha^{-1} year^{-1} and nitrogen compensation achieved level of 111.93%. Phosphorus and potassium balance in condition without mineral fertilization was negative. Deficit of phosphorus represented 8.53 kg ha^{-1} year^{-1} (compensation 15.96%) and deficit of potassium represented 9.24 kg ha^{-1} year^{-1} (compensation 59.08%).

Despite the negative balances of phosphorus and potassium (in conditions without mineral fertilization) we can prove that field pea cultivation in no-tillage technology did not reduce the content of available nutrient in the soil.

Key words: nutrients balance, gleyic Fluvisol, no-till, field pea, nitrogen, phosphorus, potassium

Field pea belongs among agricultural plants with great agronomical importance. The primary importance of legumes is their ability of atmospheric nitrogen fixation. Bielek (1998) reported they fixed from 10 kg ha^{-1} year^{-1} to 30 kg ha^{-1} year^{-1} of nitrogen in condition of Slovakia. The potencial of field pea is markedly higher, pea may fix about 48–167 kg ha^{-1} N (Nielsen et al. 2009). Despite that the important fact is, that the actual amount of fixed nitrogen concentration in soil depend on the purpose of cultivation Kováčik (1997).

Nutrients balance is suitable way to quick diagnosing of nutrients management (Klír 2000).

Nutrients balance at the side of inputs, except for the mentioned biological nitrogen fixation depends on the commercial and organic fertilizers, seeds and atmospheric deposition of nitrogen and potassium. At the side of outputs is the output of nutrients by grain and straw yields. Balance of items depends on the used method (Jurčová and Falťanová 1994; Klír 2000; Kováčik 2001a; Bujnovský 2002).

The aim of this work was to evaluate the balance of nutrients during the growth of field pea at no-tillage in conditions of gleyic Fluvisols.

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MATERIAL AND METHODS

We established the field trials in years 2001–2003 at the experimental station of the Agroecology Research Institute in locality Milhostov (maize growing area) on gleyic Fluvisols (Table 1). Mentioned soil subtype, according to Novak classificatory scale (Hraško and Bedrna 1988), belongs to heavy and clayey-loamy soils with determined average content of clay elements higher than 50%.

T a b l e 1

Characteristics of locality Milhostov and experimental soil

Parameter		Value
Absolute altitude		106 m
Growing region		maize
Climatic region		warm and very arid
Average air temperature [°C]	for year	8.9
	for vegetation	16.0
Average sum of precipitation [mm]	for year	559
	for vegetation	348
Soil type		Fluvisol
Soil subtype		gleyic Fluvisol
Content * [mg kg^{-1}]	$N_{an.}$	22
	avail. P (M2)	38
	avail. K (M2)	242
	avail. Mg (M2)	252
Humus* (Tj.) [%]		3.0
pH/KCl*		6.2

* three years average content (2001–2003) in depth of topsoil (0–0.3 m)
$N_{an.}$ – inorganic nitrogen
avail. – available for plants
M2 – by Mehlich II method
Tj. – by Tyurin method

The teritory has a continental character of climate with an average year temperature 8.9°C, during vegetation period 16.0°C and with average annual precipitation of 559 mm, during vegetation period 348 mm (Petrovič and Šoltís 1984). The evaluation of meteorological factors during vegetation periods is presented in Table 2. We used the percentage of long-time normal for the evalution (Ivančo et al. 2004).

We cultivated field pea (cultivar Jantar) in no-tillage technology without irrigation and with winter wheat as forecrop. Sowing was realized by the equipment Great Plains with sowing rate 290 kg ha^{-1}. There were two variants of fertilization compared in the trial, fertilized (F – 25 kg ha^{-1} N, 30 kg ha^{-1} P and 40 kg ha^{-1} K) with non fertilized (NF). The trial was arranged in a block design and variants were repeated for four times.

Soil samples were taken before pre-sowing soil treatment and after harvesting from sampling depth 0–0.3 m. Soil samples were used to determine the content of available nutrients. Applied methods of analysis were as follows: available nitrogen, resp. amonium nitrate with Nessler's reagent and nitrate nitrogen with phenoldisulphonic acid (Javorský 1987), available phosphorus and potassium by Mehlich II method (Fiala et al. 1999).

After harvesting we determined nitrogen, phosphorus and potassium content in the seeds and nitrogen content in the straw (Table 3). The applied methods were the following: nitrogen by Kjeldahl method (Javorský 1987) and after wet mineralization, phosphorus by colorimetry method (Davídek et al. 1981) and potassium by flame photometry (Fiala et al. 1999). We had determined the yield of seeds and straw per unit of area before agrochemical analyses (Table 3). We used the obtained results to calculate the rates of symbiotic nitrogen and output of nutrients by the yield of main product. Symbiotic nitrogen share 50% of total nitrogen content in pea biomass (Kováčik 2001a). We used index 0.4088 to convert seed yield to the quantity of root residues, and index 1.1747 to convert the content of nitrogen in the pea straw to the content of nitrogen in the root residues (Jurčová and Torma 2001). We chose the rate of nitrogen input by atmospheric deposition under the authority of Bielek (1998) results, he specifies nitrogen deposition on territory of Slovakia at interval 10–30 kg per hectare and year. We took over also the value of atmospheric deposition of potassium. Kováčik (2001b) reported that atmospheric deposition of potassium is at interval 10–20 kg per hectare and year. We applied lower limits of presented intervals in both cases. Input of nutrients by seeds was calculated from their content in the seed: 3.1% N, 0.56% P and 1.15% K (Kováčik 2001a). Balance items of nutrients are presented in the Table 4.

The nutrients balance in the growth system was considered according to methodology Kováčik (2001a).

Obtained data were evaluated by the multi-factorial analysis of variance and in the multiplied test comparisons.

T a b l e 2

Evaluation of meteorological factors for vegetation period (April–August)

Year	Sum of precipitation [mm]	% LT	Characteristic of vegetation season	Average air temperature [°C]	% LT	Characteristic of vegetation season
2001	439	126.1	very humid	16.5	103.1	normal
2002	401	115.2	humid	17.6	110.0	normal
2003	315	90.5	normal	17.6	110.0	normal

LT – Long-time normal

T a b l e 3

Seed and straw yield of pea and nutrients contents

Fertilization	Year	Seed				Straw	
		yield [t ha^{-1}]	N	P	K	yield [t ha^{-1}]	N
			[%]				[%]
Fertilized	2001	2.54	3.40	0.51	1.10	2.45	1.15
	2002	2.31	3.99	0.77	1.78	2.97	1.27
	2003	1.79	3.93	0.52	1.21	1.86	1.30
	$\bar{x}$Y	2.21	3.77	0.60	1.36	2.43	1.24
Non fertilized	2001	1.89	3.28	0.46	0.97	1.72	1.29
	2002	1.73	3.86	0.81	1.81	1.73	1.35
	2003	1.63	3.81	0.48	1.08	1.74	1.18
	$\bar{x}$Y	1.75	3.65	0.58	1.29	1.73	1.30

$\bar{x}$Y – average for experimental years

RESULTS AND DISCUSSION

Active items of balance include mainly the values given by soil management (nutrients input by fertilizers, by seed and straw management) and by locality (atmospheric deposition of nitrogen and potasium). Based on the data presented in the Table 4 results, where the average annual input of nutrient by mineral fertilizers into the soil was 25 kg ha^{-1} N, 30 kg ha^{-1} P and 40 kg ha^{-1} K and by seed 8.99 kg ha^{-1} N, 1.62 kg ha^{-1} P a 3.34 kg ha^{-1} K, we defined the average annual deposition of nitrogen and potassium at the rate 10 kg ha^{-1}.

The important active item at field pea (fabaceous plants) is symbiotically fixed nitrogen. Soil enrichment by symbiotic fixation was at the rate 10–30 kg ha^{-1} y^{-1} (Bielek 1998). Quantity of biological nitrogen depended on straw yield and nitrogen content in the straw (Table 3). Straw yield of pea and nitrogen content depend on fertilization, soil type, seed inoculation and soil cultivation (Brkić et al. 2004; Hanáčková et al. 2008). Higher production of post harvest remains (besides root remains) at no-tillage technology by application of fertilization found also Halvorson et al. (1999). The potential of post harvest remains and roots remains represents the important source of nutrients and they are the essential segment of nutrient cycle at arable land (Kumar and Goh 2002; Hanáčková et al. 2008). Soil enrichment by straw was, on variant with fertilization, in average at the rate 15.07 kg ha^{-1} of nitrogen per year and at the variant without fertilization was at average rate 11.25 kg ha^{-1} of nitrogen per year (calculated from data presented in the Table 3). We calculated besides biological nitrogen fixed in straw also biological nitrogen fixed in roots. The average amount of roots remains, determined by the conversion from yield of seed and used for the calculation of biological nitrogen fixation, was 0.90 t ha^{-1} at fertilized variant, or 0.72 t ha^{-1} at variant without fertilization (for calculation see the part Material and methods). Content of nitrogen in roots remains was converted from nitrogen content determined in the straw. Average content of nitrogen calculated in roots remains was at fertilized variant 1.46% and at non fertilized variant 1.53%. Annual nitrogen soil enrichment by roots remains was, on variant with fertilization, in average at rate 6.57 kg ha^{-1} y^{-1} and at variant without fertilization it was at average rate 5.51 kg ha^{-1} y^{-1} (mentioned results are not presented in the tables), which represented 50% from the total quantity of nitrogen at roots remains (i.e. 13.14 kg ha^{-1} y^{-1} or 11.02 kg ha^{-1} y^{-1}). The total soil enrichment by biological nitrogen at pea cultivation was 21.64 kg ha^{-1} of nitrogen per year at fertilized variant and 16.76 kg ha^{-1} of nitrogen per year at variant without fertilization (Table 4).

The passive item of nutrient balance consisted of output of nutrient by seed crop, which depends on the content of nutrient and production per unit of area (Table 3). Determined average content of phosphorus in pea seeds was similar to the published by Kovačik (2001a) and Bujnovský (2002). Content of nitrogen and potassium was slightly higher than mentioned standards, in the case of nitrogen it was higher by 0.41% and in the case of potassium by 0.15%. Different content of nutrients in the plants is already evident from compared standards. Differential nutrient contents in the identical plant materials can be explained as the results of different agroclimatic conditions, intenzity of fertilization and of used cultivars. Different offtake of nutrients per unit of produce by pea plants showed also other studies (Šariková and Hnát 2005; Hanáčková et al. 2007), in dependence on fertilization, management of postharvest remains, seeds inoculation and soil cultivation.

According to average results (Table 4) it will be established, that output of nitrogen from the soil by pea yield (seed crop) was 31.94 kg ha^{-1} y^{-1} at non fertilized variant and 41.66 kg ha^{-1} y^{-1} at fertilized variant. Mentioned amount represents 50% from total quantity of nitrogen at pea seed crop (the rest – 50% was biological nitrogen). Nitrogen fertilization at fertilized variant compensated only for 60% of total soil nitrogen losses by seed crop, it is the outcome of abovementioned results. As to the phosphorus and potassium fertilization, used doses covered losses from the soil by pea seed crop. Phosphorus and potassium losses and the total compensation by applied fertilisers are presented in the Table 4. Annual balances of active and passive items of

Table 4

Nutrients balance as average of research period (2001–2003)

Items of balance	Nitrogen		Phosphorus		Potassium	
	[kg ha^{-1} $year^{-1}$]					
	F	NF	F	NF	F	NF
Active items						
Fertilizers	25.0	–	30.0	–	40.0	–
Seed	8.99	8.99	1.62	1.62	3.34	3.34
Symbiotic fixation	21.64	16.76	–	–	–	–
Atmosphere declivity	10.0	10.0	–	–	10.0	10.0
Σ	65.63	35.75	31.62	1.62	53.34	13.34
Passive items						
Seed yield	41.66	31.94	13.26	10.15	30.06	22.58
Σ	41.66	31.94	13.26	10.15	30.06	22.58
Balance	23.97	3.81	18.36	–8.53	23.28	–9.24
Compensation of nutrients [%]	157.54	111.93	238.46	15.96	177.45	59.08

F – variant with fertilization
NF – variant without fertilization

T a b l e 5

Annual balances of nutrients

Parameter	Factors					
	Fertilized			Non fertilized		
	2001	2002	2003	2001	2002	2003
	[kg ha^{-1}]					
Nitrogen	21.92	23.77	26.49	4.94	2.93	3.98
Potasium	18.67	13.83	22.31	–7.07	–12.39	–6.20
Phosphorus	25.40	12.22	31.68	–4.99	–17.97	–4.26

nitrogen, phosphorus and potassium are shown in the Table 5.

The positive balance of nitrogen was found at both variants of fertilization, +23.97 kg ha^{-1} y^{-1} at fertilized variant and +3.81 kg ha^{-1} y^{-1} at non fertilized variant. Nitrogen losses compensation represented 157.54% (fertilized variant), resp. 111.93% (non fertilized variant). Positive balances were found also by phosphorus (+18.36 kg ha^{-1} y^{-1}) and potassium (+23.28 kg ha^{-1} y^{-1}) at variant with fertilization, with nutrients losses compensation 238.46% by phosphorus and 177.45% by potassium. Phosphorus and potassium balance at variant without fertilization was negative, at phosphorus with deficit –8.53 kg ha^{-1} y^{-1} and at potassium with deficit –9.24 kg ha^{-1} y^{-1}. Nutrient compensation at mentioned balances was 15.96% in the case of phosphorus and 59.08% in the case of potassium.

Keeping the straw in the farming system, in condition without fertilization, does not guarantee the positive balance of nutrients (Danilovič et al. 2007). Negative balance is a logic state for the mentioned management because of the nutrient content in the plants and achieved yield. Presented positive nitrogen balance at fertilized and also at non fertilized conditions was provided by atmospheric fixation. The legumes are considered to be the important implement of nitrogen balance improvement at crop rotation (Drinkwater et al. 1998; Kumar and Goh 2000; Poudel et al. 2001). Superior balances of nutrients are provided by ferlilization (Hanáčková et al. 2008), even though negative in some cases. Our findings are similar to the abovementioned, but nutrients balances were possitive. Differences will probably relate to fertilizer amounts.

T a b l e 6

Analysis of variance of nutrients balance

Balance	Source of variation	d.f.	F test	P
Nitrogen	fertilization	1	1202.85	++
	year	2	4.52	+
	residual	17		
	total	23		
Phosphorus	fertilization	1	7026.77	++
	year	2	183.82	++
	residual	17		
	total	23		
Potasium	fertilization	1	2308.51	++
	year	2	227.22	++
	residual	17		
	total	23		

$^{+}P<0.05$ $^{++}P<0.01$

d.f. – degrees of freedom
P – effect of a factor significant at the level α = 0.05 or α = 0.01

T a b l e 7

Multiplied test comparing the nutrients balance ($LSD_{0.05}$)

Balance	Factor		$LSD_{0.05}$	Homogenous group		
Nitrogen	fertilization	NF	3.95	×		
		F	24.06		×	
	year	2002	13.35	×		
		2001	13.43	×		
		2003	15.24		×	
Phosphorus	fertilization	NF	–8.55	×		
		F	18.27		×	
	year	2002	0.72	×		
		2001	5.80		×	
		2003	8.06			×
Potassium	fertilization	NF	–9.07	×		
		F	23.10		×	
	year	2002	–2.88	×		
		2001	10.20		×	
		2003	13.71			×

F – variant with fertilization
NF – variant without fertilization

Table 8

Average nutrients content in the soil at experimental locality Milhostov from 2001 to 2003

Sample taking	Fertilization	Content of nutrients [mg kg^{-1}]		
		$N_{an.}$	P	K
Sowing	Fertilized	15.3	30.5	211.0
	Non fertilized	12.7	34.5	194.3
Harvesting	Fertilized	24.5	39.5	291.4
	Non fertilized	35.9	47.5	271.1
Change	Fertilized	9.2	9.0	80.4
	Non fertilized	23.2	13.0	76.8

The impact of fertilization on changes of nutrient balances (N, P, K) was highly significant (Table 6) with highly significant difference between fertilized and non fertilized variant (Table 7).

The balance of phosphorus and potassium was highly significant, influenced by the year of cultivation (Table 6), whereas the impact of a given year on balance of nitrogen was significant.

It was found, by the comparison of net balances with the content of available nutrients in the soil, that nutrients content increased also in cases of negative balance of phosphorus and potassium at variant without fertilization (Table 8). Kováčik (1997) reports that the content of nutrient can increase at the expense of the precursors. The increase of nutrient content of soil is positively affected by the positive balance (Blake et al. 2003) and by fertilizers application (Malhi et al. 2006). Higher content of available nutrients in soil found at the end of vegetation period indicate that pea cultivation does not degrade soil environment.

CONCLUSION

We can draw the following conclusions on the basis of nutrient balance in field pea grown in no-tillage:

Deficit of observed nutrients in condition with mineral fertilizers application was not found. Balance of nitrogen was +23.97 kg ha^{-1} y^{-1}, of phosphorus +18.36 kg ha^{-1} y^{-1} and of potassium +23.28 kg ha^{-1} y^{-1}. Nutrient compensation amounted 157.54%, 238.46% and 177.45% respectively.

Used doses of nutrients, 25 kg ha^{-1} N, 30 kg ha^{-1} P and 40 kg ha^{-1} K, provide favourable balance.

Favourable balance was also found in conditions without fertilization in the case of nitrogen, balance was +3.81 kg ha^{-1} y^{-1} and nitrogen compensation achieved level of 111.93%. Phosphorus and potassium balance in condition without mineral fertilization was negative. Deficit of phosphorus represented 8.53 kg ha^{-1} y^{-1} (compensation 15.96%) and deficit of potassium represented 9.24 kg ha^{-1} y^{-1} (compensation 59.08%).

Soil enrichment by the air nitrogen was on the average 19.2 kg ha^{-1} N. Nitrogen fixed in straw and root remains also provide favourable balance of nitrogen. Despite negative balances of phosphorus and potassium (in conditions without mineral fertilization) we can establish, that field pea cultivation in no-tillage technology did not reduce the content of available nutrients in the soil.

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