THE NUTRIENTS BALANCE OF CROP ROTATION

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***Abstract**: During 2004-2006, the nutrient balance of crop rotation pattern under conventional and minimum tillage and influence of different fertilization treatments at the experimental station of Slovak Agricultural University in Nitra was investigated. The fundamental tillage treatments were as follows: CT - conventional mouldboard ploughing to the depth of 0.3 m (under maize), mouldboard ploughing to the depth of 0.2 m followed by surface cultivation of topsoil (winter wheat, spring barley and common pea); MT - minimum tillage - offset disc ploughing to depth of 0.15 m and combine cultivator. Plots were divided into subplots (11 x 40 m) and were subjected to tillage and fertilization treatments with three replications. Three fertilization management practices were applied as follows: 0 - control without organic or mineral fertilization, PH - mineral fertilizers calculated to the designed yield level, PZ - mineral fertilizers together with forecrop incorporation of plant biomass into soil.*

The crop sequence of maize (Zea mays L.) - winter wheat (Triticum aestivum L.) - spring barley (Hordeum vulgare L.) under seeded with red clover - red clover (Trifolium pratense) - common pea (Pisum sativum L.) and mustard as catch crop was used. The most serious deficit of nitrogen (-57.4 kg ha^{-1} yr^{-1}), phosphorus (-21.8 kg ha^{-1} yr^{-1}) and potassium (-87.8 kg ha^{-1} yr^{-1}) was in control treatments under conventional tillage. Deficit of nitrogen was also found-out in treatments with mineral fertilizers application. However higher deficit of nitrogen (-34.6 kg ha^{-1} yr^{-1}) in an average was noted under conventional tillage. Combination of mineral fertilizers together with incorporation of forecrop plant biomass into soil (PZ) produced small surplus in the nitrogen balance (5.7 kg ha^{-1} yr^{-1} in conventional tillage and 6.7 kg $ha^{-1}yr^{-1}$ in minimum tillage treatments). The positive results in the phosphorus balance achieved in treatments with incorporation of forecrop plant biomass into soil in both soil tillage treatments, in an average value of 5.25 kg ha^{-1} yr^{-1}, contribute to the good soil phosphorous supply. The negative balance of potassium varying from -87.8 kg ha^{-1} yr^{-1} (control) to -14.6 kg ha^{-1} yr^{-1} (PZ) is acceptable owing to high content of available soil potassium of experimental stand.

Key words: *nutrients balance, crop rotation, soil tillage, mineral fertilizers, post harvest residue, nutrients uptake*

INTRODUCTION

The nutrients balance as an indicator of sustainable farming of specific crop rotation pattern was described in a previous study by HANÁČKOVÁ et al. (2008). Nutrient balance and study of nutrient effectivity is suitable tool for diagnostics of nutrient management on different level of agroecosystem (KLÍR, 1999; BUJNOVSKÝ and MIKLOVIČ, 2002, KAJANOVIČOVÁ et al., 2010).

The effect of tillage and crop rotation has significant influence on soil organic matter, amount of residue and composition, due to changes in mineralization process. As a consequence, tillage and crop rotation affect soil N, P and K. The inadequate fertilization regarding soil conditions and plant needs, can cause severe nutritional unbalances, manifested through the apparition of some characteristic plant phenotype symptoms which lead to a significant regression of production and quality (COLE et al. 1990; CIOBANU et al., 2007; ONDRIŠÍK et al., 2009; GONET et al., 2009). Precondition of more precise balance of nutrients in soil is depend on data quantifying the input and output of nutrients for suitable input output calculation model (KOVÁČIK, 2001; DUMITRU, 2009).

The aim of the research was to evaluate the nutrient balance in specific crop rotation pattern under conventional and minimum tillage with interaction of different fertilization input and plant biomass.

MATERIAL AND METHODS

The nutrients balance of five crop rotation systems under conventional and minimum tillage and different fertilization treatments was investigated at the experimental station of Slovak Agricultural University in Nitra at Dolná Malanta, during 2003/2004-2005/6.The experimental site belongs to warm and moderate arid climatic region in the south-western Slovakia. The long term average precipitation is 561mm, for the growing season 327 mm, altitude of 173 m. Average air temperature is 9.7°C. The main soil type is Orthic Luvisol with medium supply of available P, high content of available K and good content of available Mg and pH 6.4 in an average (Table 1). The bulk density (before establishment of experiment) of topsoil was 1.46 t m^{-3}. The five-year crop rotation of maize (*Zea mays* L.) - winter wheat (*Triticum aestivum* L) - spring barley (*Hordeum vulgare* L.) under seeded with red clover - red clover (*Trifolium pratense*) - common pea (*Pisum sativum* L.) and mustard as catch crop was used.

The fundamental tillage treatments were as follows: CT - conventional mouldboard ploughing to the depth of 0.3 m (under maize), mouldboard ploughing to the depth of 0.2 m followed by surface cultivation of topsoil (winter wheat, spring barley and common pea); MT - minimum tillage - offset disc ploughing to depth of 0.15 m and combine cultivator. Plots were divided into subplots (11 x 40 m) and were subjected to tillage and fertilization treatments with three replications. Three fertilization management practices were applied as follows: 0 - control without organic or mineral fertilization, PH - mineral fertilizers calculated to the designed yield level, PZ - mineral fertilizers together with forecrop incorporation of plant biomass into soil.

Table 1

Agrochemical soil analysis

Year	Content of available nutrients in soil (mg kg^{-1})			pH_{KCl}	K : Mg
	$P_{Mehlich\ III}$	$K_{Mehlich\ III}$	$Mg_{Mehlich\ III}$		
2003/2004	83	367	221	6.58	0.60
2004/2005	87	374	227	6.36	0.61
2005/2006	88	367	221	6.37	0.60

Plants samples were taken at flowering (red clever) and physiological maturity (maize, winter wheat and spring barley). On the base of yield of grain, straw and aboveground biomass of red clover and content of macronutrients the nutrient uptake was calculated

Nutrient balance of N, P, and K was calculated according to formula:

Net Balance = Inputs - Outputs

Nitrogen balance was calculated according inputs of nitrogen via mineral fertilizers, seeds, biogenic fixation and atmospheric deposit via rainfalls. For phosphorus and potassium input we count only with mineral fertilizers and seeds. Output of N, P and K nutrients from agricultural system was calculated according uptake of the nutrients by main product and straw. Nutrient balance was calculated for each crop in crop rotation in an average.

RESULTS AND DISCUSSIONS

The nutrient balance was influence by nutrients uptake by biomass of growing crops in crop rotation and management of aboveground biomass (removing or incorporation). The crops yields were influence by fertilization treatments, tillage and year conditions. In the year

2005, the significantly less yield was received in all evaluated crops except maize. Dry period during June and August 2004, significantly decrease the yield of maize with comparison to 2006 (Table 2).

Table 2

Yield of main products and crops straw (1000 ha^{-1}) during 2004-2006

Year	Maize	Winter wheat	Common pea	Spring barley	Red clover
	Yield of main product				
2004	9.046 a	7.43 b	4.48 b	5.17 b	2.93 b
2005	9.175 ab	5.62 a	3.76 a	3.44 a	2.46 a
2006	10.308 b	7.11 b	4.53 b	4.80 b	2.96 b
	Yield of straw				
2004	10.771 a	7.79 a	3.48 a	3.30 b	-
2005	10.631 a	8.22 b	3.94 a	2.55 a	-
2006	12.777 b	8.15 b	6.11 b	3.00 ab	-

The yield followed by the same letter are not significantly different at P < 0.05 probability level

In winter wheat, common pea and spring barley, fertilization statistically increases the grain yield and straw of winter wheat, spring barley and common peas (Table 3). Fertilization stimulates grain yield more than straw yield in an average.

Table 3

Yield of main products and crops straw (1000 ha^{-1}) for different fertilization during 2004-2006

Fertilization treatments	Maize	Winter wheat	Common pea	Spring barley	Red clover
	Yield of main product				
0	8.88 a	10.77 a	3.76 a	3.91 a	2.83 a
PH	9.79 a	11.60 a	4.52 b	4.64 a	2.86 a
PZ	9.86 a	11.85 a	4.49 b	4.86 b	2.66 a
Yield of straw					
0	10.77 a	6.84 a	3.48 a	2.71 a	
PH	11.60 a	8.04 a	3.94 a	2.84 a	
PZ	11.85 a	7.50 a	6.11 b	3.29 b	

The yield followed by the same letter are not significantly different at P < 0.05 probability level.
0 – control without mineral or organic fertilization, PH - mineral fertilizers calculated to the designed yield level, PZ - mineral fertilizers together with forecrop incorporation of plant biomass into soil

The conventional tillage and minimum tillage creates comparable soil environment for maize, winter wheat, spring barley and red clever. Common pea was more susceptible to reduce tillage with significant decreased of yield up to 9%.

Maize for grain was the biggest consumers of nutrients. In an average of tillage treatments and years, canopy of maize uptakes 355.3 kg ha^{-1} of N, P, K pure nutrients followed by winter wheat and common peas (Tab. 4). Higher uptake of pure nutrients was on treatments with mineral and organic input of nutrients under conventional tillage totally (273.5 kg ha^{-1}) followed by mineral fertilization treatments (269.1 kg ha^{-1}).

The highly significant dependence between biomass of growing crops and nutrient uptake is documented in the table 5.

Table 5

Correlation between the biomass yields of grown crops and uptake of NPK nutrients

	Values of correlation coefficient				
	Maize	Winter wheat	Common pea	Spring barley	Red clover (DM)
r	0.851^{xxx}	0.817^{xxx}	0.963^{xxx}	0.977^{xxx}	0.915^{xxx}

Table 4

Nutrients uptake by biomass of growing crops in crop rotation (average for 2004 - 2006)

Tillage	Treatment	NPK uptake by aboveground biomass (kg ha^{-1})				
		Winter wheat	Spring barley	Maize	Common pea	Red clover
CT	0 PH PZ	240.5 304.5 315.2	134.4 155.0 177.6	340.1 387.6 356.0	271.6 305.1 341.0	185.0 193.2 177.5
Average CT		286.7	155.7	361.2	305.9	185.2
MT	0 PH PZ	236.4 313.5 293.5	142.9 163.3 174.6	328.0 356.2 363.7	238.6 302.7 302.2	185.1 189.4 164.5
Average MT		281.1	160.3	349.3	281.1	179.7
Average CT, MT		283.9	158.0	355.3	293.5	182.5

Inclusion of legumes into crop rotation have important share on nitrogen balance of growing system.

During three evaluated years the input of nitrogen by symbiotic fixation was 42.2 kg ha^{-1} year^{-1} of nitrogen. Wet deposition of nitrogen via rainfall for this Malanta locality estimates BABOŠOVÁ et al. (2007) as total amount of 21.5 kg ha^{-1}year^{-1}.

The N, P, K balance of evaluated treatments is on the Fig. 1. On unfertilized treatments the higher deficit of nitrogen was under conventional tillage (-57.4 kg ha^{-1} year^{-1}) with 53 % replacement of outputs by inputs.

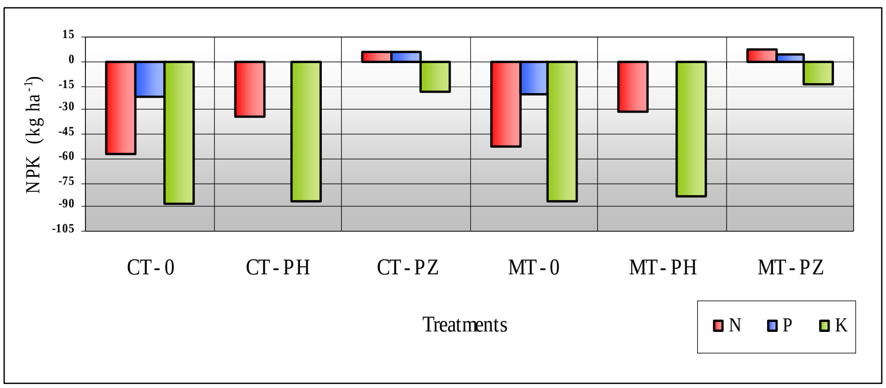

Figure 1: N, P, and K balance in crop rotation (average data in 2004 - 2006)

The treatments fertilized only with mineral fertilization with average dose of 38.8 kg ha^{-1} nitrogen has deficit balance of 30.4-34.6 kg ha^{-1} in an average.

According long term trials (1930-1992) for nitrogen balance, the yearly application of 50-150 kg ha^{-1} is needed on Chernozem or Brawn soil (NÉMETH, 1996). According BIELEK (1998) average input of 80 kg ha^{-1} of nitrogen from mineral and organic fertilizers in Slovak region are needed. Low surplus of nitrogen was reached on treatments with mineral fertilization with incorporation of straw (5.7 kg ha^{-1}, 6.7 kg ha^{-1}). Post harvest residues and aboveground biomass are important part of nutrient cycles with positive influence on nutrient balance of crop rotation as a source of nutrient for next growing crops. Incorporation of cereals, legumes oil crops straw and sugar beat post harvest residues in crop rotation in an average 10.2 kg N, 3.9 kg P_2O_5 a 24.5 kg K_2O is return into the soil per hectare (HLUŠEK et al., 2007).

Control treatment has also negative balance of phosphorus (-21.5 kg ha^{-1} $year^{-1}$). The calculated input and output of phosphorus was nearly balanced on the mineral fertilization treatments. The incorporation of straw with mineral fertilization creates the low surplus of phosphorus in range of 5 -5.5 ha^{-1} $year^{-1}$.

Absence or low level of fertilization with potassium due to high level of accessible potassium in soil negatively influenced the balance of potassium in all fertilization treatments. In an average -86.4 kg ha^{-1} $year^{-1}$ of potassium was calculated on mineral fertilization treatment. Incorporation of straw improves the deficit of potassium up to -16.6 kg ha^{-1} $year^{-1}$.

Due to optimal storage of potassium in the soil this calculated deficit is acceptable.

CONCLUSIONS

Nutrient balance of crop rotation was affected by level of inorganic and organic fertilization, yield, nutrients uptake of growing crops and by growing legumes.

The sustainable growing conditions were created on treatments with incorporation of aboveground biomass with well balanced nitrogen (+6.2 kg ha^{-1} yr^{-1}) and phosphorus (+5.3 kg ha^{-1} yr^{-1}). Negative balance of potassium (-16.6 kg ha^{-1} yr^{-1}) is acceptable owing to high content of available potassium in soil of experimental stand.

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