EFFECT OF DIFFERENT FERTILIZATION ON DURUM WHEAT (*Triticum durum* Desf.) YIELD AND QUALITY PARAMETERS

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Abstract: *On the course of three vegetation periods 2009/2010-2010/2011-2011/2012 the effect of applied mineral fertilizers and post harvest residues of precrop of common pea (Pisum sativum* L.*) on yields and content of crude protein in grain of winter wheat (variety Istrodur) was investigated. Field experiment was established at the experimental site of the Slovak University of Agriculture in Nitra. Under the conditions of organic fertilizers deficit the primary aim of the experiment was to evaluate the effect of post harvest residues (as alternative source of organic matter) on uptake of nutrients by aboveground phytomass, balance of nutrients and energetic effectiveness of nitrogen fertilizers. There were examined four treatments of fertilization in the experiment: 0 – unfertilized control, PZ – post harvest residues of precrop incorporated into soil by ploughing, PH – rational fertilization with mineral fertilizers based on soil and plant analyses, PH+PZ – rational fertilization with mineral fertilizers + incorporation of precrop post-harvest residues into soil. Grain yields were highly significantly influenced by experimental year and fertilization, respectively. On the average of three experimental years the highest yield of grain (4.63 t ha^{-1}) was gained in treatment fertilized by mineral fertilizers. Incorporation of post harvest residues into soil (treatment PZ and PH+PZ) decreased the average grain yields to 3.88 and 3.99 t ha^{-1}, respectively which were lower ones in comparison to control unfertilized treatment. There was found out high significant correlation between nutrients uptake by aboveground phytomass and grain yield (r = 0,8766^{xxx}). Energetic effectiveness of nitrogen fertilizers achieved value E = 4.7 on the average of experimental years and fertilization treatments. Comparing treatment PH+PZ with unfertilized control coefficient of energetic effectiveness was very good (E = 7.5) only in year 2012 when 30 kg ha^{-1} N was applied. The highest average content of crude protein in grain (11.81%) was determined in treatment PH+PZ and the highest production of crude protein per hectare (544 kg) in treatment fertilized by mineral fertilizers. Rational fertilization with mineral fertilizers in combination with pea post-harvest and root residues ploughing down into soil represents treatment which is getting closest to the sustainable farming on soil. On the average of three experimental years balance surplus of nitrogen was low (10.3 kg ha^{-1} yr^{-1}), phosphorus medium (18.4 kg ha^{-1} yr^{-1}) and potassium high (51.7 kg ha^{-1} yr^{-1}). Decrease of potassium inputs into soil through the mineral fertilization application in year 2012 seems to be very effective measure for reducing high balance surplus of potassium in treatment PH+PZ.*

Key words: *post-harvest residues, mineral fertilization, grain yield, crude protein, balance of nutrients*

INTRODUCTION

Durum wheat of winter form (*Triticum durum* Desf.) has favourable soil-climatic conditions in warm areas of corn region of Slovakia. In comparison with summer form of wheat it reaches lower grain yield by 15-20% as a consequence of lower number of productive stalks formation, lower compensation ability of cover, lower productivity of ear and weaker winterhardness (MOLNÁROVÁ et al., 2012).

Variety of Istrodur contributed to the stabilization of durum wheat growing areas in Slovakia. It reaches the highest grain yield and quality on warm, humic fertile soil with good texture, optimum water regime and neutral reaction (ZALABAI AND CSEMY, 2006).

Regular and sufficient input of organic substances into soil is of prime importance for soil fertility maintenance. Effective utilization of post-harvest residues enables at least partially to compensate losses of humus resulting from mineralization of organic matter and soil erossion (SZOMBATHOVÁ, 2010) as well as from farm-yard manure deficit releted to drop of livestock numbers.

Proteins represent one of the most important component of wheat grain. Their content depend mainly on locality, year, variety and agrotechnics applied (MUCHOVÁ, 2001). However, the most relevant factor for proteins synthesis in plant and their storage in wheat grain seems to be nitrogen fertilization (UŽÍK ET AL., 2009; ZEBARATH AND SHEARD, 1992). Content of proteins in grain is positively influenced particularly by nitrogen application in later growth stages of durum wheat (AMMES ET AL., 2003; BLY AND WOODARD, 2003).

The aim of this research was to evaluate the effect of post-harvest residues as an alternative source of organic matter on grain yield of durum wheat, content of proteins in grain, balance of nutrients, uptake of nutrients and energetic effectiveness of nitrogen fertilizers.

MATERIAL AND METHODS

The field experiment was established in years 2009/2010-2011/2012 in three repetitions on Experimental Base of the Slovak University of Agriculture in Dolná Malanta (48° 19' N, 18° 09' E). The area belongs to the maize growing region, agro-climatically to very hot and dry sub-area. Altitude of the site is 175-180 m. The long-term average annual temperature of the site is 9.8°C and average rainfall is 540 mm. Soil type was classified as Haplic Luvisol on proluvial sediments with loess. From the point of texture it is loamy soil.

There were examined four treatments of fertilization in the experiment: 0 – unfertilized control, PZ – post harvest residues of precrop incorporated into soil by ploughing, PH – rational fertilization with mineral fertilizers based on soil and plant analyses, PH+PZ – rational fertilization with mineral fertilizers + incorporation of precrop post-harvest residues into soil.

The content of available phosphorus was satisfactory, potassium was good and soil reaction was slightly acidic (Table 1).

Applied rates of nutrients are illustrated in table 2.

Table 1

Agrochemical soil analysis

Year	Content of available nutrients in soil (mg kg^{-1})				pH_{KCl}	Humus (%)
	P	K	Ca	Mg		
2009/2010	68	240	990	240	6.08	1,88
2010/2011	79	285	1 250	283	6.13	1,96
2011/2012	82	350	1 100	266	6.20	1,95

Nitrogen was applied in the form of ammonium nitrate with lime, phosphorus in the form of 19 % superphosphate and potassium in the form of 60 % potassium salt (KCl).

As a preceding crop of winter wheat (variety Istrodur) was common pea (variety Xantos).

Total nitrogen was determined according to the standard method of Kjeldahl in the durum wheat grain and protein nitrogen according to Barstein (JAVORSKÝ 1987). Total and protein nitrogen contents were multiplied by the coefficient of 5.7 and thus crude protein and pure protein contents were calculated.

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

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

Net Balance = Inputs - Outputs

Table 2

Rates of nutrients for durum weath fertilizing

Year	Treatment	Rate of nutrients (kg ha^{-1}) N Fertilizing regeneration	productional	qualitative	Total	P	K
2009/2010	PH	30	30	20	80	30	60
	PH+PZ	30	30	20	80	30	60
2010/2011	PH	30	-	15	45	30	60
	PH+PZ	30	-	10	40	30	60
2011/2012	PH	30	30	-	60	30	20
	PH+PZ	0	30	-	30	30	20

Nitrogen balance was calculated according inputs of nitrogen via mineral fertilizers, seeds, 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.

Obtained results were evaluated by statistical software Statgraphics *Plus*. Evaluation of importance of individual factors on studied parameters was done by multifactorial analysis of variance (ANOVA, Statistica 5). Differences between variants were assessed by LSD test with a minimum significance level $P \leq 0.05$ and $P \leq 0.01$. Correlation analysis was used for detection of interactions between qualitative properties.

Weather conditions during the experimental period are shown in Figure 1 and 2.

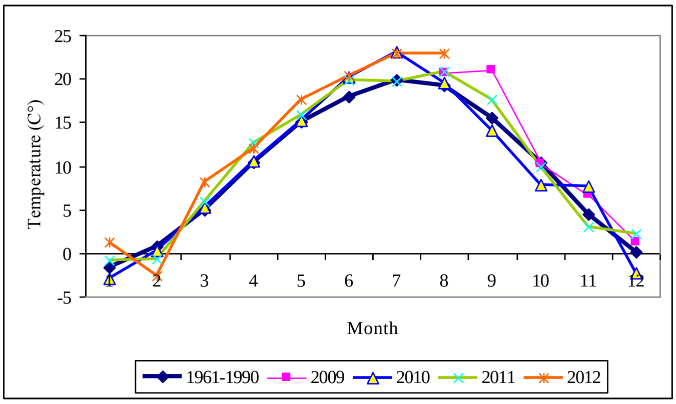

Figure 1 Weather conditions of years 2009-2012 - average daily temperature (°C)

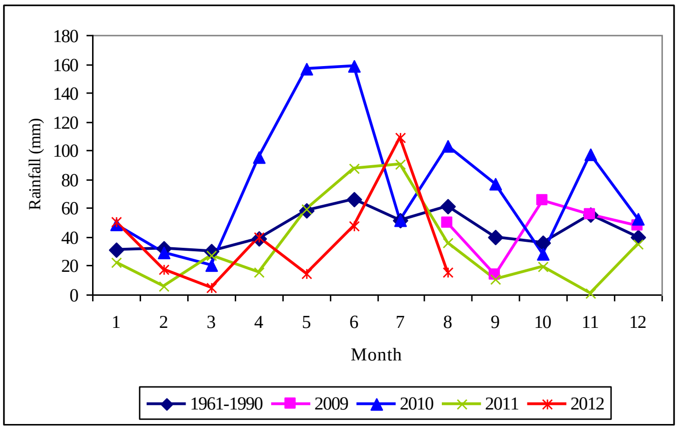

Figure 2 Weather conditions of years 2009-2012 - sum of precipitation (mm)

RESULTS AND DISCUSSION

Under the good agrotechnical conditions variety of Istrodur usually provides grain yield of 5-6 t ha^{-1}**.** In our experiment average yield of 4.14 t ha^{-1} was achieved during the years 2010-2012. The highest average grain yield (4.63 t ha^{-1}) was reached in treatment rationally fertilized by mineral fertilizers which one was significantly higher in comparison with unfertilized control as well as with treatments where post-harvest residues were ploughed down into soil (treat. PZ, PH+PZ) (table 3). The treatments with incorporated post-harvest residues provided even lower average grain yields than unfertilized control. Several authors (KARABÍNOVÁ AND UPOHLAV, 2005; CANDRÁKOVÁ ET AL., 2013) found out an appropriate impact of incorporated post-harvest residues of precrop on the yield-forming elements and grain yield of Istrodur variety. In our experiment higher grain yield in treatment with incorporated post-harvest residues than in control treatment was achieved only in year 2012. The higher yield of grain (5.67 t ha^{-1}) was gained in treatment fertilized by mineral fertilizers in year 2011 under the application of substantially lower nitrogen doses (45 kg ha^{-1}) than in 2010 (4.75 t.ha^{-1}; 80 kg ha^{-1}N) and 2012 (4.63 t.ha^{-1} 60 kg ha^{-1}N).

Grain yield of durum wheat was significantly influenced by course of weather conditions. In comparison with years 2010 and 2012 significantly higher yield (4.83 t ha^{-1}) was achieved in 2011 in spite of uneven distribution of precipitation during growing season. Weather in year 2010 was very wet, sum of precipitation reached 170% of long-term normal. The months of April to July were extraordinary wet when amount of precipitation achieved 240 to 270% of long-term normal. Grain yield achieved in this year was highly significantly higher (by 0.92 t ha^{-1}) than in experimental year 2011/2012 which was typical of precipitation deficit in both autumn and spring period. KARABÍNOVÁ ET AL. (1999) AND GUINTA ET AL. (1993) assume optimal amount of precipitation to be of 320-360 mm during growing season.

Significant effect of vegetation year on winter wheat grain yield forming is described by several authors (DUCSAY AND RYANT, 2005; PRUGAR ET AL., 2008; HANÁČKOVÁ AND SLAMKA, 2011).

Mineral fertilization as well as post-harvest residues incorporation highly significantly influenced yield of durum wheat straw in comparison with unfertilized control. The highest average yield of straw (6.42 t ha^{-1}) was achieved in treatment rationally fertilized by mineral fertilizers which is yield higher by 0.83 t ha^{-1} compared to unfertilized control treatment.

Uptake of macronutrients by variety of Istrodur (table 4) in respective years and treatments matches with achieved yields of phytomass. There was found out high significant correlation between nutrients uptake by aboveground phytomass and grain yield (r = 0,8766^{xxx}).

Table 3

Yield of winter wheat grain, variety Istrodur

Year	Treatment	Yield of grain		Yield of straw	
		t ha^{-1}	rel. %	t.ha^{-1}	rel. %
2010	[1]0	4.73	100.0	4.84	100.0
	[2]PZ	3.57	75.5	4.26	88.0
	[3]PH	4.75	100.4	6.48	133.9
	[4]PH + PZ	3.99	84.4	5.69	117.6
	$\bar{x}$	**4.26**	-	**5.32**	-
2011	0	4.61	100.0	8.46	100.0
	PZ	4.42	95.9	7.26	85.8
	PH	5.67	123.0	8.78	103.8
	PH + PZ	4.63	100.4	8.29	98.0
	$\bar{x}$	**4.83**	-	**8.20**	-
2012	0	2.88	100.0	3.47	100.0
	PZ	3.66	127.0	3.14	90.5
	PH	3.46	120.1	4.00	115.3
	PH + PZ	3.35	116.3	4.11	118.4
	$\bar{x}$	**3.34**		**3.68**	-
Average years	0	4.07	100.0	5.59	100.0
	PZ	3.88	95.3	4.89	87.5
	PH	4.63	113.6	6.42	114.8
	PH + PZ	3.99	98.0	6.03	107.9
	$\bar{x}$	**4.14**	-	**5.73**	-

[1]0 - unfertilized control, [2]PZ - post-harvest residues, [3]PH - mineral fertilizers, [4]PH+PZ - mineral fertilizers + post-harvest residues

Grain: years: P 0.05 = 0.0997; P 0.01 = 0.1397; treatment: P 0.05 =0.1151; P 0.01 = 0.1613;

Straw: years: P 0.05 = 0.1290; P 0.01 = 0.1809; treatment: P 0.05 = 0.1490;P 0.01 = 0.2089.

One ton of grain and relevant amount of straw of variety Istrodur took up 24.6 kg of N, 4.0 kg of P, 12.6 kg of K, 5.1 kg of Ca and 3.4 kg of Mg from soil on the average of 3 years (table 5). MOLNÁROVÁ ET AL. (2012) state higher uptake of nitrogen (29 kg t^{-1}), phosphorus (4.8 kg t^{-1}) and potassium (15 kg t^{-1}) by durum wheat than it was determined in our experiment.

Content of crude protein (CP) in durum wheat grain was significantly influenced by fertilization and year, respectively. The highest content of crude protein (11.81%) was determined in treatment PH+PZ (table 6). Significantly lower content of crude protein was determined in grain of unfertilized control and in treatment with incorporated post-harvest residues. MICHALÍK ET AL. (2006) state average content of crude protein in durum wheat grain amounting 11.20%, UPOHLAV AND MOLNÁROVÁ (2005) specified 12.68% crude protein content in Istrodur variety grain.

The highest content of crude protein (13.10%) was determined in year 2012 when the lowest grain yield was achieved and oppositely the lowest content (10.73%) was analyzed in year 2011 under the highest yield of grain. The differences of CP content in grain between the experimental years are statistically significant. Optimal course of weather for high grain yield and quality achieving is given by rich precipitation up to the growth stage of flowering and subsequent higher air temperature and average soil moisture. In last decade before harvest evaporation should prevail over precipitation, that means dry and warm weather but without extreme temperatures (MUCHOVÁ, 2001).

Table 4

Uptake of nutrients by winter wheat (average of years 2010-2012)

Treatmnet	Year	Uptake of nutrients (kg ha^{-1}) Grain					Fytomass				
		N	**P**	**K**	**Ca**	**Mg**	**N**	**P**	**K**	**Ca**	**Mg**
Control	2010	78.91	13.70	21.55	6.88	8.60	110.44	19.51	48.04	20.00	16.05
	2011	69.12	14.67	13.34	5.03	9.37	103.21	19.58	42.01	26.63	22.13
	2012	53.64	6.90	13.54	0.92	3.29	74.57	9.03	42.88	8.43	6.13
	$\bar{x}$	**67.22**	**11.76**	**16.14**	**4.28**	**7.09**	**96.07**	**16.04**	**44.31**	**18.35**	**14.77**
post – harvest residues	2010	61.36	12.95	16.23	4.32	5.83	85.16	17.89	44.69	17.66	12.47
	2011	68.11	14.40	12.80	4.80	7.74	98.88	17.78	42.55	30.16	17.88
	2012	71.62	8.86	17.22	1.19	4.38	86.22	10.29	49.33	8.52	7.19
	$\bar{x}$	**67.03**	**12.07**	**15.42**	**3.44**	**5.98**	**90.09**	**15.32**	**45.52**	**18.78**	**12.51**
mineral fertilizers	2010	78.88	15.78	20.20	8.24	7.71	121.44	23.31	64.15	30.06	16.74
	2011	95.07	16.45	17.27	6.85	14.05	149.15	22.61	61.23	37.67	24.32
	2012	71.93	8.33	18.14	1.11	4.12	94.41	10.71	63.75	10.86	7.59
	$\bar{x}$	**81.96**	**13.52**	**18.54**	**5.4**	**8.63**	**121.67**	**18.88**	**63.04**	**26.20**	**16.22**
mineral fertilizers + post – harvest residues	2010	69.76	14.47	18.13	8.29	6.51	100.68	20.39	56.05	22.77	12.43
	2011	77.10	14.60	13.70	5.62	8.42	112.01	19.88	50.46	31.51	19.93
	2012	66.46	8.23	16.77	1.01	3.79	89.29	9.92	62.31	10.60	7.40
	$\bar{x}$	**71.11**	**12.43**	**16.18**	**4.97**	**6.24**	**100.66**	**16.73**	**56.27**	**21.62**	**13.25**

Table 5

Uptake of nutrients by one ton of grain and respective amount of straw (variety Istrodur)

Treatment	N	P	K kg t^{-1}	Ca	Mg
Control	23.60	3.94	10.89	4.57	3.63
post-harvest residues	23.22	3.95	11.73	4.84	3.23
mineral fertilizers	26.28	4.08	13.62	5.66	3.50
mineral fertilizers + post-harvest residues	25.23	4.19	14.10	5.42	3.32
Average	**24.58**	**4.04**	**12.59**	**5.12**	**3.42**

Negative correlation relation was found out between grain yield and content of CP (r = -0.7006) what is in accordance with findings of several other autors (UŽÍK et al., 2009).

Production of CP per unit of area as a result of grain yield multiplied by CP content (UŽÍK ET AL., 2009) was the highest in treatment fertilized by mineral fertilizers (543.6 kg ha^{-1}) and the lowest in treatment with incorporated post-harvest residues (443.9 kg ha^{-1}) on the average of three years.

Table 6 shows content of pure protein and percentage portion of pure protein from CP in durum wheat grain. In comparison to unfertilized control, statistically significantly higher content of pure protein was found in treatment PH (9.83%) and PH+PZ (9.77%), respectively.

High portion of pure protein in durum wheat grain conditions also its specific technological properties which are required for pasta production.

Average percentage portion of pure protein from CP was 84.1% (r = 0.9632^{xxx}). The highest portion (89.3%) was achieved in year 2012.

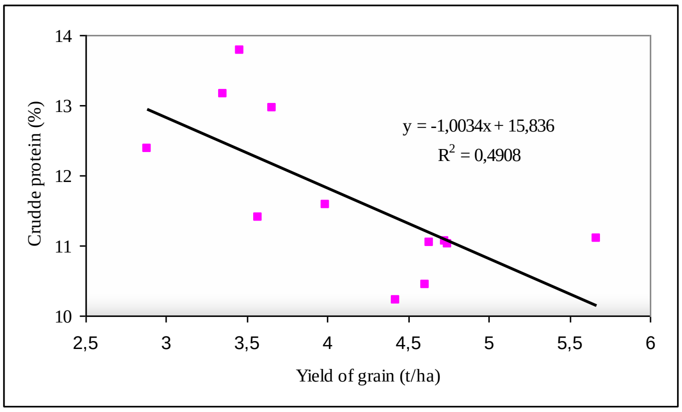

Figure 3 Relationship between yield and crude protein content in durum winter wheat

Table 6

Protein composition of durum winter wheat grain

Treatment	Year	Crude protein (%)	Production of crude protein (kg ha^{-1})	Pure proteins (%)	% portion of pure proteins from crude protein
Control	2010	11.05	522.7	8.93	80.8
	2011	10.45	481.7	8.65	82.8
	2012	12.38	356.5	11.47	92.6
	$\bar{x}$	**11.14**	**453.4**	**9.42**	**85.4**
Post-harvest residues	2010	11.39	406.6	9.21	80.9
	2011	10.22	451.7	8.51	83.3
	2012	12.96	474.3	11.41	88.0
	$\bar{x}$	**11.44**	**443.9**	**9.64**	**84.1**
Mineral fertilizers	2010	11.02	523.5	8.92	80.9
	2011	11.10	629.4	9.15	82.4

	2012	13.79	477.1	12.18	88.3
	$\bar{x}$	**11.74**	**543.6**	**9.83**	**83.9**
Mineral fertilizers + post-harvest residues	2010	11.59	462.4	9.05	78.1
	2011	11.04	511.2	9.07	82.2
	2012	13.15	440.5	11.59	88.1
	$\bar{x}$	**11.81**	**471.2**	**9.77**	**82.8**

Crude protein:
years: P 0.05 = 0.0636; P 0.01 = 0.0862;
treatment: P 0.05 =0.0735; P 0.01 = 0.0995;

Pure proteins:
years: P 0.05 = 0.0241; P 0.01 = 0.0326;
treatment: P 0.05 = 0.0278;P 0.01 = 0.0377;

Properly selected nitrogen dose markedly influences economical utilization of energetic inputs what is manifested by increment of produced organic matter. In treatment fertilized with mineral fertilizers coefficient of energetic effectiveness was good (E = 4.7). Comparing treatment PH+PZ with unfertilized control coefficient of energetic effectiveness was very good (E = 7.5) only in year 2012 when 30 kg ha^{-1} N was applied (Figure 5). In years 2010 and 2011 increment of phytomass in treatment PH+PZ was lower than in control treatment what resulted in low energetic effectiveness (E = 0.28; -0.55 resp.) in this treatment.

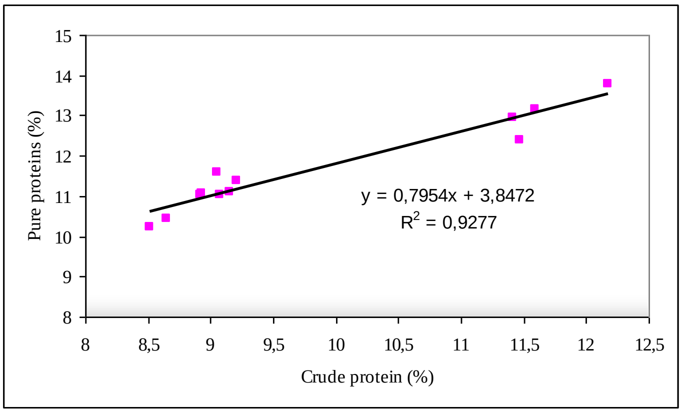

Figure 4 Relationship between content of crude protein and pure proteins in durum wheat grain

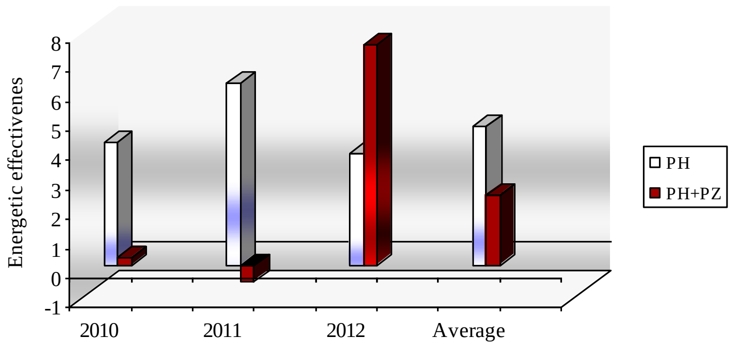

Figure 5 Energetic effectiveness of N- fertilization

Balance of nutrients and evaluation of their efficiency is suitable tool for quick diagnostics of nutrient management situation. In this sense, balance of mineral nutrients is considered to be a reliable indicator of sustainable farming on soil.

Balance of nutrients in experimental years 2009/2010-2011/2012 was influenced by fertilization, incorporation of by-product of precrop and weather conditions in respective years. On the average of three experimental years negative balance of nitrogen, phosphorus and potassium was found in unfertilized control (0) as well as in treatment with incorporated post-harvest residues (PZ). In treatment fertilized only with mineral fertilizers (PH) negative balance of nitrogen (-33.6 kg ha^{-1} yr^{-1}) was found out on the average of 3 years. Balance of phosphorus and potassium was positive in this treatment. Balance surpluses of phosphorus 12.0 kg ha^{-1} yr^{-1}) and potassium 4.8 kg ha^{-1} yr^{-1}) were low.

Rational fertilization with mineral fertilizers in combination with pea post-harvest and root residues ploughing down into soil represents treatment which is getting closest to the sustainable farming on soil. On the average of three experimental years balance surplus of nitrogen was low (10.3 kg ha^{-1} yr^{-1}), phosphorus medium (18.4 kg ha^{-1} yr^{-1}) and potassium high (51.7 kg ha^{-1} yr^{-1}) in this treatment (PH+PZ). Decrease of potassium inputs into soil through the mineral fertilization application in year 2012 seems to be very effective measure for reducing high balance surplus of potassium in treatment PH+PZ.

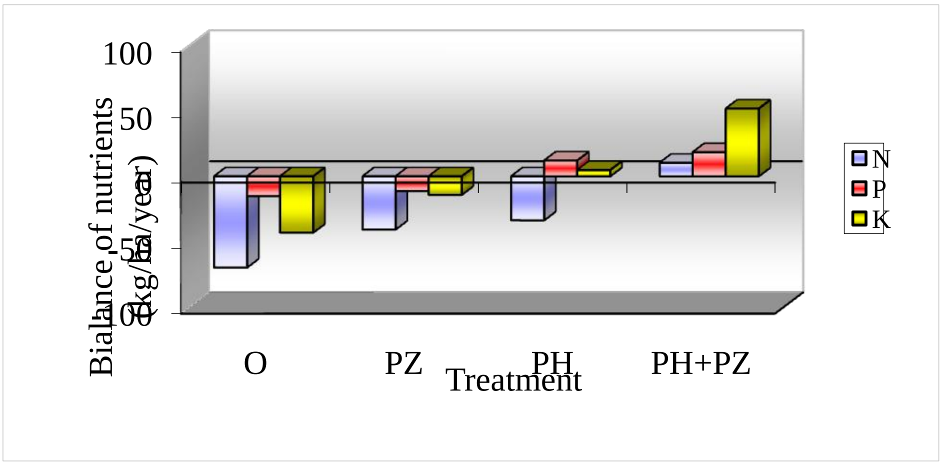

Figure 6 Balance of NPK nutrients

CONCLUSIONS

Grain yield and content of protein in grain of durum wheat were significantly influenced by fertilization and year. The highest yield of grain was achieved in treatment rationally fertilized by mineral fertilizers and highest content of CP in treatment fertilized by mineral fertilizers in combination with pea post-harvest residues (PH+PZ). There was found significant negative relation between grain yield and content of CP in durum wheat grain. Average percentage portion of pure protein from CP was 84.1%. Properly selected nitrogen dose markedly influenced economical utilization of energetic inputs. Balance surplus of nitrogen, and potassium was achieved only in the case when durum wheat was fertilized by mineral fertilizers in combination with post-harvest residues. Thus, rational fertilization with mineral fertilizers in combination with pea post-harvest aboveground and root residues ploughing down into soil represents treatment which is getting closest to the sustainable farming on soil.

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BIBLIOGRAPHY

1. AMMES, N.P. et al., 2003. Effects of nitrogen fertilizer on protein quantity and gluten strenght parameters in durum wheat (*Triticum turgidum* L. var durum) cultivars of variable gluten strenght. In *Agronomy Journal*, 2003, vol. 80, no. 2, p. 203-211. ISSN 1435-0645
2. BLY, A.G. - WOODARD, H. J. 2003. Foliar nitrogen application timing influence on grain yield and protein concentration of hard red winter and spring wheat. In *Agronomy Journal*, 2003, vol. 95, no. 2, p.335-338, ISSN 1435-0645
3. CANDRÁKOVÁ, E. - MACÁK, M. - NOSKOVIČ, J. 2013. Vplyv podmienok pestovania a vybraných faktorov na úrodu pšenice tvrdej. In *Vliv abiotických a biotických stresorů na vlastnosti rostlin 2013,* s. 243-246. © Výzkumný ústav rostlinné výroby v.v.i. Praha-Ruzyně, 2013. © Česká zemědělská univerzita v Praze, 2013, ISBN: 978-80-7427-131-1, ISBN: 978-80-213-2357-5
4. DUCSAY, L. - RYANT P. 2005. Vliv různých forem dusíkatých hnojiv aplikovaných na konci odnožování na výnos a kvalitu zrna pšenice ozimní. In : Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, LIII 2005, 4, s. 43-50.
5. GUINTA, F. - MOTZO, R. - DEIDDA, M. 1993. Effect of drouth on yield and yield components of durum wheat and triticale in a mediterranean environment. I Field Crops Research [online] vol. 3, 1993, no. 4, p. 399-409, ISSN 0378-4290
6. HANÁČKOVÁ, E. - SLAMKA, P. 2011. Production process of winter wheat (*Triticum aestivum* L.) under different soil cultivation and fertilization. In: Research Journal of Agricultural Science, 43, (1), 2011, p. 56-61.
7. JAVORSKÝ, P. 1987. Chemické rozbory v zemědělských laboratořích (Chemical analysis at agricultural laboratories). Ministry of Agric. Food of Czechoslovakia, 1987, 287 s.
8. KARABÍNOVÁ, M. - UPOHLAV, T. 2005. Vplyv obrábania pôdy a hnojenia na kvantitatívne a kvalitatívne parametre úrody pšenice tvrdej formy ozimnej. In: Zborník prednášok VII. zjazd Slovenskej spoločnosti pre poľnohospodárske, lesnícke, potravinárske a veterinárne vedy pri SAV. Bratislava, 2005, s. 40-43. ISBN 80-227-2308-8.
9. MICHALÍK, I. - GÁLOVÁ, Z. - URMINSKÁ, D. - KOLBACHOVÁ, H. 2006. Bielkovinový komplex zrna obilnín a pseudoobilnín. In: Kolektív autorov: Výživná a technologická kvalita rastlinných produktov a ich potravinárske využitie. I. vyd. Nitra : SPU, 2006, s. 67-101. ISBN 80-8069-780-9
10. MOLNÁROVÁ, J. - ILLÉŠ, L. - ŽEMBERY, J. 2012. Rastlinná výroba (obilniny, strukoviny, olejniny). Nitra: SPU, 174 s. ISBN 978-80-552-0903-6
11. MUCHOVÁ, Z. 2001. Faktory ovplyvňujúce technologickú kvalitu pšenice a jej potravinárske využitie. Nitra : SPU, 2001, 112 s. ISBN 80-7137-923-9
12. PRUGAR,J. – BARANYK, P. – BÁRTA, J. 2008. Kvalita rostlinných produktů na prahu 3. tisícletí. Praha: VÚPS, a.s., 2008, 327 s. ISBN 978-80-86576-28-2
13. UPOHLAV, T. – MOLNÁROVÁ, J.2005. Yield and quality of durum wheat under different nitrogen management in different climate conditions. In: Acta universitatis cibiniensis. Seria Stiinte Agricole, vol. 1, no. 1, 2005, ISSN 1582-8549
14. UŽÍK, M. - ŽOFAJOVÁ, A. - RÜCKSCHLOSS, Ľ. 2009. Vplyv klimatických podmienok a hnojenia na kvalitu zrna pšenice letnej f. ozimnej (*Triticum aestivum* L.). In : Agrochémia, XIII. (49), 2009, 4, s. 16-22.
15. ZALABAI, G. - CSÉMY, T. Ponuka odrôd hustosiatych obilnín. 2006 – 2007. Horné Mýto: Istropol Solary a. s., 2006.

16. ZEBARTH, B. J. - SHEARD, R. W. 1992. Influence of rate and timing of nitrogen fertilization on yield and quality of hard red winter wheat in Ontario. In: Can. J. Plant Sci., 72, 1992, 12-19.