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NITROGEN AND PHOSPHORUS BALANCES AS DEPENDENT ON DURUM WHEAT FERTILIZATION

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Abstract

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The nitrogen and phosphorus balance under the influence of fertilization on durum wheat Progress cultivar was determined in a long-term fertilizer experiment, carried out at the Field Crops Institute - Chirpan on a soil type Pellic Vertisols during the period 2011-2013. Phosphorus and combined NP fertilization in rates N_0P_0, P_{80}, P_{120}, P_{160}, $N_{120}P_{80}$, $N_{120}P_{120}$, N_{120} and P_{160} were applied. It was found that P fertilization increased insignificantly the grain yield (11.6-24.3% above the unfertilized control), and after NP fertilization the yield increased by 115.9-128.6% compared to the control. The total biological yield (grain + straw) without N fertilization were nearly two times lower (5900-6687 kg.ha^{-1}) than that with the NP system (11087-11797 kg.ha^{-1}). At P fertilization the plants uptook from 61.4 to 70.4 kg N.ha^{-1}, and at NP fertilization - 146.9-165.7 kg N.ha^{-1}. At P_{120} the plants absorbed 41.0 kg P_2O_5.ha^{-1}, and at $N_{120}P_{160}$ the uptake was the highest - 77.2 kg.ha^{-1}. The nitrogen balance was negative with a deficiency of -26.9 to -45.7 kg.ha^{-1} fertilization with N_{120}. At incorporation of straw in the soil the balance was from 6.6-17.7 kg.ha^{-1}. At fertilization with 80, 120 and 160 kg P_2O_5.ha^{-1} the phosphorus balance was positive and the soil accumulated from 45.4 to 120.4 kg P_2O_5.ha^{-1}, and at combined fertilization of phosphorus with N_{120} - from 11.4 to 82.8 kg P_2O_5.ha^{-1}. When incorporating straw in the soil at NP fertilization significant amounts of available phosphates were accumulated - 41.1-117.5 kg P_2O_5.ha^{-1}.

Key words: durum wheat; nutrient balance; fertilization; nitrogen; phosphorus

Introduction

The balanced fertilization on crops in rotation is one of the main circumstances for creating an optimal nutrient level in the soil. Maintaining a non-deficit nutritional balance is a prerequisite for obtaining high and sustainable yields from crops and a guarantee to increase soil fertility. Studies on the effects of fertilization on soil changes are of particular relevance due to the annual use of mineral fertilizers, the introduction of intensive cultivars into practice and the need to obtain environmentally clean and cost-effective production. A number of authors studied these aspects (Dinchev, 1982, 1983; Ikonomova, 1986; Petrova, 1984; Tomov et al., 1995).

In most studies on the long-term fertilizer experiments conducted in Bulgaria and abroad for different soil types, the applied fertilizers provide a deficient nitrogen balance except for the high levels of fertilization (Cook, 1968; Ivanov et al., 1988, 1989; Koteva, 1993).

For nitrogen, phosphorus and potassium balances during the period 1970-1995 under the conditions of Germany, Bach and Frede (1998) pointed out that phosphorus and potassium surpluses in agriculture declined with 60% since 1980, and the nitrogen surplus has decreased with 23% since 1987; i.e. the effectiveness of nutrient use has improved.

Berry et al. (2003) summarized 88 N, P and K nutrient budgets for crop rotations in the UK and other temperate countries. All the nitrogen (N) budgets showed an N surplus (average 83.2 kg N ha-1.year^{-1}). The phosphorus (P) and potassium (K) budgets showed both surpluses and deficits (average 3.6 kg P ha^{-1}.year^{-1}, 14.2 kg K ha^{-1} year^{-1}) with horticultural

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systems showing large surpluses resulting from purchased manure.

Data from Eurostat (2013) for the period 2005-2008 for most European countries show a decrease in the gross phosphorus budget per hectare. In the EU-27 the phosphorus balance remained relatively stable for this period, with an average of 2 kg P.ha^{-1}. The phosphorus budgets in the EU-15 reduced with an average of 3 kg P in the period 2005-2008 compared to the average of 5 kg P.ha^{-1} in 2000-2004. In the ten countries of Central and Eastern Europe that joined the EU in 2004 and 2007 (PL, SI, SK, EE, LT, LV, CZ, HU, RO and BG) the gross phosphorus balance for the period 2005-2008 was lower than in the EU-15, with an average value of 0 kg.ha^{-1}. In the Mediterranean countries Malta and Cyprus and Northwest Europe (NO, NL, UK, DK) the phosphorus balances were higher, while the same was negative in Italy and Greece and most of the countries in Central and Eastern Europe.

Using the general methodology of Eurostat, Özbek (2014) informed that in Turkey's agriculture the values of the phosphorus surplus in agriculture and the efficiency of phosphorus use in 2011 were respectively 2 kg P.ha^{-1} per year and 77% of the phosphorus values budget, ranged from -2 to 15 kg P.ha^{-1} in various regions. In 2008 phosphorus surplus and phosphorus efficiency in Turkey (0 kg P.ha^{-1} and 96%, respectively) were lower than the average values for the EU (3 kg P.ha^{-1} and 104%). The author emphasized that the effect of phosphorus in agriculture varied considerably between both regions of Turkey and European countries due to the high differences in phosphorus surplus.

Syers et al. (2008) reported that the two main factors controlling the presence of phosphorus for plants are the concentration of phosphate ions in the soil solution and the P-buffer capacity, i.e. the ability of the soil to provide these ions when the plants utilize them. The crops ability to absorb fertilizer's phosphorus in the short term is often only 10-20%.

The aim of the present study was to determine the balance of nitrogen and phosphorus under the influence of phosphorus and combined nitrogen-phosphorous fertilization in different rates and ratios between the two nutrients in the cultivation of durum wheat cultivar Progress in the conditions of Central South Bulgaria.

Material and methods

During the period 2011-2013 under the conditions of a long-term field fertilizer trial, carried out at the Field Crops Institute - Chirpan, the durum wheat cultivar Progress reaction to phosphorous fertilization was studied. Alone phosphorus and combined NP fertilization in rates N_0P_0; P_{80}; P_{120}; P_{160}; $N_{120}P_{80}$; $N_{120}P_{120}$; $N_{120}P_{160}$ were applied. The control was durum wheat grown without fertilization (N_0P_0).

The experiment was set in four replications of 10 m^2 harvest plots. Durum wheat was grown in two-year rotation with cotton, wherein the cotton fertilization was the same as wheat. Nitrogen fertilization of durum wheat was in the form of ammonium nitrate, where 1/3 was applied pre-sowing, and 2/3 - as feeding at the beginning of spring vegetation. Phosphorus in the form of triple superphosphate was incorporated before sowing of wheat.

Soil samples were analyzed at two depths by Kjeldahl's analysis for mineral nitrogen and by the acetate-lactate method of Ivanov (1984) for mobile PK forms, as well as plant samples (grain and straw) for NP concentration.

The balance of nitrogen and phosphorus (kg.ha^{-1}) for the tested fertilization levels was determined as the difference between the applied fertilizing element and the uptake of element with grain and straw.

In terms of weather conditions, during the vegetation period of durum wheat, the high temperatures during the April-June period in the three years and the heavy rainfall in May-June of 2012 and 2013 had an adverse effect. The critical negative temperatures were not reported during the winter period and there was no frost damage on the wheat. Precipitation and temperatures characterized the harvest 2011 and 2013 as favorable for the development of durum wheat and obtaining good yield, and 2012 - as a less favorable year (Figures 1 and 2).

Results and discussion

The soil in the field was *Pellic Vertisols* (FAO). It is characterized by high humidity capacity and small water-permeability, defined by the sand-clay composition. The test field had a bulk weight of the plough soil layer of 1.2 g/m^3 and specific gravity - 2.45. The sorbcium capacity was 35-50 mequ/100 g soil. The soil has a neutral to slightly acid soil reaction. The effect of different fertilizing systems on the contents of mineral nitrogen and the available forms of phosphorus and potassium in the soil is presented in Table 1.

The content of mineral nitrogen as a sum of NH_4-N and NO_3-N in the arable layer and in the 20-40 cm layer was 19.63-44.34 mg.kg^{-1} and 14.24-33.11 mg.kg^{-1} soil, respectively, and higher values were observed with nitrogen-phosphorus fertilization. Phosphorus fertilization led to a boost of mobile phosphates. The soil in the plow layer from low rate of psospates (3.3 mg/100 g soil at the unfertilized control) reached well-supplied with available phosphate (21.65 mg/100 g at P_{160}). The analyzes showed that the soil was well supplied with mobile potassium - 17.95-20.1 mg/100 g soil in

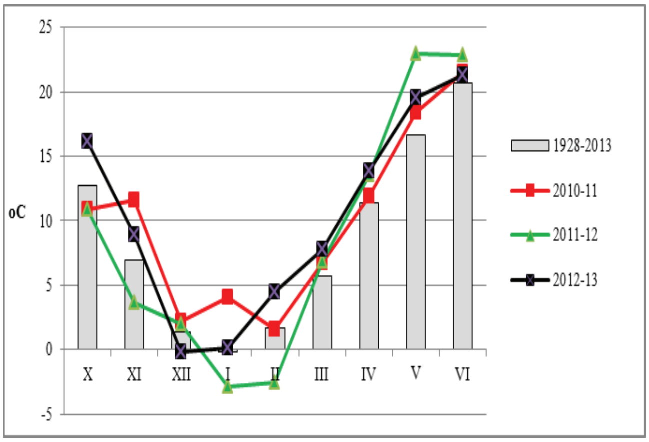

Figure 1. Average air temperatures during the vegetation of durum wheat, 2011-2013

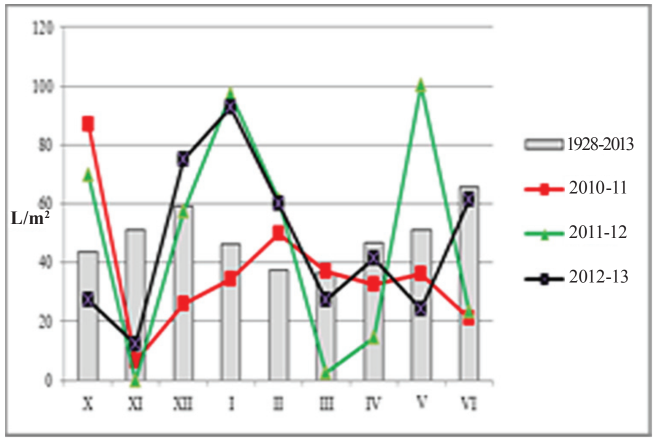

Figure 2. Sum of rainfall during the vegetation of durum wheat, 2011-2013

Table 1
Content of mineral nitrogen and available phosphorus and potassium in the soil as dependent on fertilization

Treatment	Depth, cm	N_{min}, mg.kg^{-1}	P_2O_5, mg.100g^{-1}	K_2O, mg.100g^{-1}
N_0P_0	0-20	19.63	3.3	17.9
	20-40	14.24	1.95	16.4
N_0P_{80}	0-20	20.02	18.6	18.2
	20-40	16.94	16.2	16.4
N_0P_{120}	0-20	19.74	19.7	18.4
	20-40	16.18	18.0	16.8
N_0P_{160}	0-20	21.56	21.6	18.6
	20-40	16.56	19.6	17.3
$N_{120}P_{80}$	0-20	43.12	19.9	20.1
	20-40	28.49	17.9	17.6
$N_{120}P_{120}$	0-20	43.82	19.8	19.4
	20-40	33.11	18.0	18.8
$N_{120}P_{160}$	0-20	44.34	21.2	19.2
	20-40	27.52	20.2	18.6

the plow layer and 16.40-18.80 mg/100 g soil in layer 30-60 cm. The enrichment of the plow layer with phosphorus and potassium was more intense compared to that in the 30-60 cm layer. Phosphorus fertilization enriched the subsoil with mobile phosphates - from 1.95 mg/100 g at P_0 to 18.02 mg at P_{120}, and to 19.65 mg/100 g at P_{160}. This was the result of long-term fertilization with phosphorus.

There are a number of factors affecting the nutrient content of the soil: changes in nitrogen and phosphorus in the soil due to its overall fertility; rates of fertilization; structure of crops in the crop rotation; assimilated amounts of N and P with the crop, residual nutrients in the roots and above-ground plant residues.

For the period of 2011-2013 alone, phosphorus fertilization in rates of P_{80}, P_{120} and P_{160} resulted in a higher average grain yield of 11.6; 24.3 and 13.8% over the untreated control, but the increase of yield at these fertilization levels was not significant (Table 2). The results showed that high phosphate supply due to long phosphorous fertilization and applied high phosphorus rates P_{160} reduced grain yields. After combining different phosphorus rates with N_{120}, the average yields were proven higher regardless of the phosphorus rate. With NP fertilization the grain yield increased with 115.9-128.6% compared to the control.

In the case of combined NP fertilization, the highest values for grain yield average for the period were achieved at $N_{120}P_{120}$ - 4320 kg.ha^{-1}, but the differences between the tested rates were not proven. The combined fertilization was the most effective in 2011 - by 201-210 % above the control, followed by 2013 - by 98-118% in excess, while in 2012 the increase was with 68-79% (Table 2). In 2011, against a background of N_{120} phosphorus rates of > 80 kg.ha^{-1} did not significantly affect yields, with the difference being 161 and 49 kg.ha^{-1} of wheat grain. The highest value for the period was obtained during the harvest year of 2011 at $N_{120}P_{120}$ - 5002 kg.ha^{-1}, and the lowest at N_0P_0 - 1610 kg.ha^{-1}. In 2012 the highest phosphorus rate combined with N significantly reduced the yield with 280 kg.ha^{-1} in comparison to the optimal $N_{120}P_{120}$ (4320 kg.ha^{-1}). The results obtained from the study for 2011-2013 correspond to data by Panayotova and Dechev (2003), which established the highest productivity of durum wheat varieties after fertilization with 120 kg N.ha^{-1}. The effect of independent phosphorus fertilization in 2012 was higher than in the other two years due to good humidity in both the autumn-winter months, as well as in May, which is a crucial month for the formation of good yield. In 2013, the yields from combined fertilization ranged from 3311 to 3642 kg.ha^{-1} and the effect was lower compared to the previous two years. Over the years, the average grain yield was highest in 2012 - 3314 kg.ha^{-1}, followed by 2011, while the lowest yield

Table 2
Grain yield (kg.ha^{-1}) of durum wheat cultivar Progress as dependent on nitrogen and phosphorus fertilization, 2011-2013

Fertilization	2011	2012	2013	Average for fertilization	
				kg.ha^{-1}	% to N_0P_0
N_0P_0	1610 b	2410 e	1670 c	1890 b	100.0
N_0P_{80}	1661 b	2801 cd	1870 bc	2110 b	111.6
N_0P_{120}	1830 b	2950 c	2291 b	2350 b	124.3
N_0P_{160}	1891 b	2560 de	1990 bc	2150 b	113.8
$N_{120}P_{80}$	4841 a	4120 ab	3480 a	4150 a	219.6
$N_{120}P_{120}$	5002 a	4320 a	3642 a	4320 a	228.6
$N_{120}P_{160}$	4890 a	4040 b	3311 a	4080 a	215.9
Average for year	3102 ab	3314 a	2608 b	3008	-

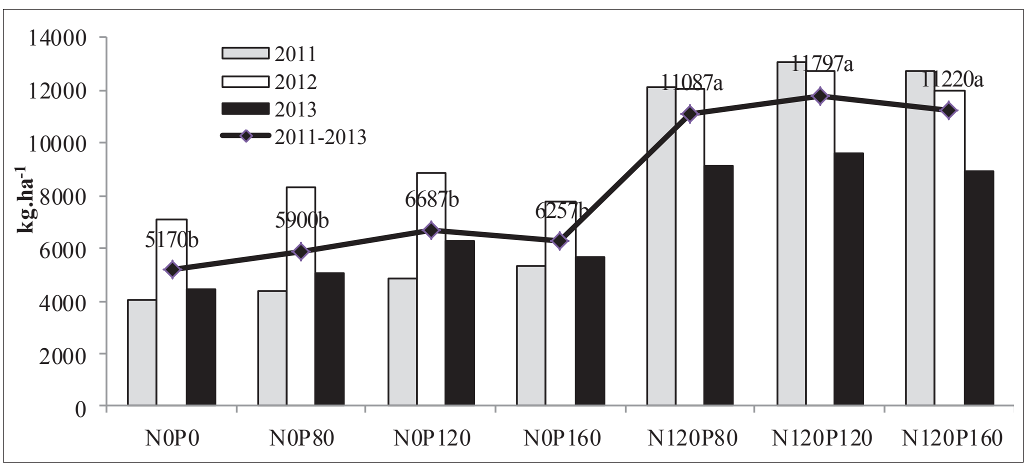

Figure 3. Total yield of grain + straw (kg.ha^{-1}) of durum wheat Progress as dependent on fertilization

was 2013 - 2608 kg.ha^{-1}, 19 % and 27% lower productivity than the previous two years, respectively.

Independent phosphorus fertilization slightly affected the total yield of grain + straw. The increase of total yield was not proven against the control. Regardless of the phosphorus rate, the yields of grain + straw without N were nearly two times lower compared to those at NP fertilization (11087-11797 kg.ha^{-1}). The $N_{120}P_{120}$ system with the highest yield was proven to exceed the control with 128.2%. The formed amount of grain and above-ground biomass was highest at fertilization of durum wheat with $N_{120}P_{120}$ and there was no proven effect of phosphorous fertilization against a background of nitrogen rate of 120 kg N.ha^{-1} (Figure 3). The highest economic yield was formed in 2012 - 9820 kg.ha^{-1}, while the lowest was in 2013 - 7020 kg.ha^{-1}. Average values of grain+straw yield - 8070 kg.ha^{-1} were established in 2011.

The uptake of nutrient elements depended on the concentration of elements in the plants and on the yield of grain and straw. At P fertilization plants uptook from 61.4 to 70.4 kg N.ha^{-1}, and the highest value was at P_{120} (Table 3). Significantly greater amount of nitrogen - 146.9-165.7 kg N.ha^{-1} was uptaken and removed from the field after combination of N and moderate and high phosphorus rate compared to P fertilization. This was related to better plant development and larger aboveground biomass. The uptake decreased after combining the N rate with high phosphorus rate, which was due to the lower economic yield. Grain yield uptook up to 113.4 kg N.ha^{-1} at $N_{120}P_{120}$.

Unfertilized durum wheat uptook a total of 22.5 kg P_2O_5.ha^{-1}, and only with the grain - 12.6 kg P_2O_5.ha^{-1} (Table 4). The phosphorus uptake by the plants increased to 41.0 kg P_2O_5.ha^{-1} at alone phosphorous fertilization P_{120}, while at combined fertilization $N_{120}P_{160}$ the uptake was the highest - 77.2 kg.ha^{-1}. Average for the period at different levels of fertilization the grain absorbed from 12.6 to 42.5 kg P_2O_5.ha^{-1}. Under the influence of the weather conditions in 2012 the absorbed P quantities were the highest, and in 2013 - the lowest.

In the N balance were only included nutrients imported with fertilizers and exported with crops. Other income and costs of N were not included in the balance due to the insignificant difference between them. According to the literature data (Enikov, 1976; Faytondzhiev and Slavov, 1997) average on soil type leached vertisol per year there was an income of 6 kg N.ha^{-1} with precipitation, and biologically fixed atmo-

Table 3
Uptake of nitrogen (kg N.ha^{-1}) during maturity of durum wheat Progress as dependent on nitrogen and phosphorus fertilization

Fertilization	2011	2012	2013	2011-2013	% to N_0P_0
Total uptake of N, kg.ha^{-1}					
N_0P_0	44.4	67.5	46.0	52.6	100
N_0P_{80}	48.4	82.0	53.8	61.4	116.7
N_0P_{120}	54.4	88.9	67.8	70.4	133.8
N_0P_{160}	55.5	74.2	57.0	62.2	118.3
$N_{120}P_{80}$	175.0	151.0	124.2	150.1	285.4
$N_{120}P_{120}$	192.3	167.1	137.7	165.7	315.0
$N_{120}P_{160}$	175.9	146.3	118.4	146.9	279.3
Average	106.6	111.0	86.4		
Uptake of N in the grain, kg.ha^{-1}					
N_0P_0	35.3	51.6	36.3	41.1	100
N_0P_{80}	36.8	60.9	41.1	46.3	112.7
N_0P_{120}	40.8	64.6	50.6	52.0	126.5
N_0P_{160}	41.5	55.1	43.1	46.5	113.1
$N_{120}P_{80}$	126.2	101.7	88.2	105.3	256.2
$N_{120}P_{120}$	133.8	110.5	95.8	113.4	275.9
$N_{120}P_{160}$	125.4	98.3	83.0	102.3	248.9
Average	77.1	77.5	62.6		

Table 4
Uptake of phosphorus (kg P_2O_5.ha^{-1}) during maturity of durum wheat Progress as dependent on nitrogen and phosphorus fertilization

Fertilization	2011	2012	2013	2011-2013	% to N_0P_0
Total uptake of P_2O_5, kg.ha^{-1}					
N_0P_0	19.5	29.1	19	22.5	100
N_0P_{80}	27.7	46.3	29.8	34.6	153.8
N_0P_{120}	31.8	52.1	39.1	41.0	182.2
N_0P_{160}	35.8	47.1	35.9	39.6	176.0
$N_{120}P_{80}$	79.7	69.8	56.3	68.6	304.9
$N_{120}P_{120}$	87.5	78.2	62.2	76.0	337.8
$N_{120}P_{160}$	92.7	77.5	61.5	77.2	343.1
Average	53.5	57.2	43.4	51.4	
Uptake of P_2O_5 in the grain, kg.ha^{-1}					
N_0P_0	11.2	15.5	11.1	12.6	100
N_0P_{80}	15.6	25.1	17	19.3	153.2
N_0P_{120}	17.8	27.5	21.7	22.3	177.0
N_0P_{160}	19	24.6	19.3	21.0	166.7
$N_{120}P_{80}$	46.4	37.9	32.3	38.9	308.7
$N_{120}P_{120}$	49.6	42.2	35.8	42.5	337.3
$N_{120}P_{160}$	52.2	40.6	34.6	42.5	337.3
Average	30.3	30.5	24.5	28.4	

Table 5
Balance of nitrogen (± kg N.ha^{-1}) on durum wheat Progress as dependent on nitrogen and phosphorus fertilization

Fertilization	2011	2012	2013	2011-2013
Balance of nitrogen at the removal of straw (± kg N.ha^{-1})				
N_0P_0	-44.4	-67.5	-46.0	-52.6
N_0P_{80}	-36.8	-60.9	-41.1	-46.3
N_0P_{120}	-40.8	-64.6	-50.6	-52.0
N_0P_{160}	-41.5	-55.1	-43.1	-46.5
$N_{120}P_{80}$	-55.0	-31.0	-4.2	-30.1
$N_{120}P_{120}$	-72.3	-47.1	-17.7	-45.7
$N_{120}P_{160}$	-55.9	-26.3	1.6	-26.9
Average	-49.5	-50.4	-28.7	-42.9
Balance of N at incorporation of straw in the soil (± kg N.ha^{-1})				
N_0P_0	-35.3	-51.6	-36.3	-41.1
N_0P_{80}	-36.8	-60.9	-41.1	-46.3
N_0P_{120}	-40.8	-64.6	-50.6	-52.0
N_0P_{160}	-41.5	-55.1	-43.1	-46.5
$N_{120}P_{80}$	-6.2	18.3	31.8	14.7
$N_{120}P_{120}$	-13.8	9.5	24.2	6.6
$N_{120}P_{160}$	-5.4	21.7	37.0	17.7
Average	-25.7	-26.1	-11.2	-21.0

spheric N in crop rotation without legumes was about 5 kg N.ha^{-1}. Except for crops, soil N was also lost by washing with rain – an average of 5 kg.ha^{-1} and 6 kg.ha^{-1} for gaseous losses. Due to the relatively flat terrain in the field, we neglected losses from erosion. As a result, it was found that imported and spent naturally amounts of nitrogen were close and had no practical significance.

The N balance varied depending on the amount of fertilizers and the export of nitrogen with the above-ground part of plants (Table 5). Average for the period, with all tested rates the N balance was negative when grain and straw were removed from the field. Nitrogen fertilization contributed to improve the nitrogen regime of leaching vertisol, but the rate N_{120} was insufficient to reproduce the total nitrogen content. The plants developed in a soil that did not satisfying their needs and the nitrogen deficiency was 26.9-52.6 kg.ha^{-1} per year.

After incorporation of straw in the soil as cultivation practice in agricultural production, the nitrogen balance for the three-year period was positive for combined NP fertilization. Through N fertilization on crops at moderate rates in crop rotation high and sustainable yields can be obtained and also quantitative N values close to balance without deficit were maintained. The fertilizer nitrogen and its soil reserves were used effectively.

The differences between applied nitrogen in the soil and removal with yields at moderate fertilization with $N_{120}P_{120}$ were the lowest - 6.6 kg N.ha^{-1} compared to other fertilization levels. There were conditions for a positive balance of nitrogen fertilization despite long-term fertilization. A positive nitrogen balance was obtained from fertilizer levels higher than the optimal in terms of yields. After combined fertilization with $N_{120}P_{80}$ and $N_{120}P_{160}$ some of fertilizer N and soil N remained unused - 14.7-17.7 kg N.ha^{-1}. The balance was positive. Fertilization was unjustified, ineffective.

The study on the fertilizer N transformations and regulation of fertilization depending on the changing reserve of available plants phosphates is best to be carried out under conditions of long-term fertilizer experiments (Babarina and Lebedinskaya, 1987; Petrova and Gospodinov, 1986). A number of authors indicated that fertilization with phosphorus on the basis of crop removal caused reduction of mobile phosphates in the soil (Matev et al., 1995; Matsel, 1985). Annual fertilization with rates that exceed the nutrients removal leads to an increase of the mineral phosphates and the degree of their mobility (Petrova and Gospodinov, 1986). According

Table 6
Balance of phosphorus (± kg P_2O_5.ha^{-1}) at durum wheat Progress as dependent on nitrogen and phosphorus fertilization

Fertilization	2011	2012	2013	2011-2013
Balance of P_2O_5 at the removal of straw (± kg.ha^{-1})				
N_0P_0	-19.5	-29.1	-19.0	-22.5
N_0P_{80}	52.3	33.7	50.2	45.4
N_0P_{120}	88.2	67.9	80.9	79.0
N_0P_{160}	124.2	112.9	124.1	120.4
$N_{120}P_{80}$	0.3	10.2	23.7	11.4
$N_{120}P_{120}$	32.5	41.8	57.8	44.0
$N_{120}P_{160}$	67.3	82.5	98.5	82.8
Average	49.3	45.7	59.5	51.5
Balance of P_2O_5 at incorporation of straw in the soil (±kg.ha^{-1})				
N_0P_0	-11.2	-15.5	-11.1	-12.6
N_0P_{80}	64.4	54.9	63.0	60.7
N_0P_{120}	102.2	92.5	98.3	97.7
N_0P_{160}	141.0	135.4	140.7	139.0
$N_{120}P_{80}$	33.6	42.1	47.7	41.1
$N_{120}P_{120}$	70.4	77.8	84.2	77.5
$N_{120}P_{160}$	107.8	119.4	125.4	117.5
Average	72.6	72.4	78.3	74.4

to the literature data, the costs of erosion and washing in the soil profile are minimal and have no practical importance (Garbuchev et al., 1975; Enikov, 1976).

The data in Table 6 showed that with all tested phosphorus rates applied alone or in combination with N, the phosphorus balance was positive, except for the unfertilized control. Upon the removal of the straw from the field at single phosphorous fertilization in the three growing rates in the soil was accumulated from 45.4 to 120.4 kg of P_2O_5.ha^{-1}. At combined phosphorus with N_{120}, the phosphorus uptake by plants was much better, and at low and moderate phosphorus rates the balance was optimal – in the soil it was from 11.4 to 82.8 kg.ha^{-1}.

The results showed that upon incorporation of the straw in the soil, with the exception of the control, significant amounts of available phosphates - 60.7 to 139.0 kg P_2O_5.ha^{-1} were accumulated along with phosphorus fertilization and NP fertilization - 41.1 to 117.5 kg of P_2O_5.ha^{-1}. Under field conditions, the application of moderate and high phosphorus rates was not an effective activity. The phosphorus balance was positive, the values were high, and phosphate reserves may have an unfavorable effect on durum wheat.

Conclusions

Independent phosphorus fertilization increased insignificantly durum wheat grain yield, and after combined NP fertilization the grain yield increased with 115.9-128.6% compared to when unfertilized. The high phosphate supply and applied high phosphorus rates P_{160} reduced grain yields. The yields of grain and above-ground biomass were highest at $N_{120}P_{120}$. The total yield of grain+straw without N was nearly twice lower compared to those at NP fertilization. The highest economic yield was formed in 2012 - 9820 kg.ha^{-1}, while the lowest was in 2013.

At P fertilization, plants uptook 70.4 kg N.ha^{-1}, and the highest value was at P_{120}. Significantly greater N amount - 146.9-165.7 kg N.ha^{-1} was uptaken and assimilated at NP fertilization. At $N_{120}P_{120}$, grain yield uptook to 113.4 kg N.ha^{-1}.

Unfertilized durum wheat took up a total of 22.5 kg P_2O_5.ha^{-1}, and when measured only at the grain - 12.6 kg P_2O_5.ha^{-1}. The P uptake increased to 41.0 kg.ha^{-1} at P_{120}, while at $N_{120}P_{160}$ the uptake was at the highest - 77.2 kg.ha^{-1}. Average for the period at the different levels of fertilization the grain absorbed from 12.6 to 42.5 kg P_2O_5.ha^{-1}.

The nitrogen balance was negative at fertilization with N_{120} with a deficiency of -26.9 to -45.7 kg.ha^{-1}, and at incorporation of straw in the soil as N fertilization the N balance was from 6.6 to 17.7 kg.

The phosphorus balance was positive at all tested phosphorus rates. Upon the removal of the straw from the field at variant with P fertilization only, it has accumulated from 45.4 to 120.4 kg of P_2O_5.ha^{-1} in the soil. At NP fertilization the phosphorus uptake by plants was much better, and at low and moderate P rates the balance was optimal. Upon incorporation of the straw in the soil at P fertilization it has accumulated from 60.7 to 139.0 kg P_2O_5.ha^{-1}, and at NP fertilization - 41.1 to 117.5 kg of P_2O_5.ha^{-1}. The moderate and high phosphorus rates were not effective. When the values for positive phosphorus balance are high, phosphate reserves may have an unfavorable effect on durum wheat.

References

Babarina, E. and V. Lebedinskaya, 1987. The effect of long-term application of fertilizers on the phosphate regime of gray podzolized soil. *Agrochemistry*, **1**: 18-22 (Ru).

Bach, M. and H. Frede, 1998. Agricultural nitrogen, phosphorus and potassium balances in Germany - methodology and trends 1970 to 1995. *Journal of Plant Nutrition and Soil Science*, **161**(4): 385-393.

Berry, P., E. Stockdale, R. S. Bradley, L. Philipps, K. Smith, E. Lord, C. Watson and S. Fortune, 2003. N, P and K budgets for crop rotations on nine organic farms in the UK. *Soil Use Management,* **19**(2): 112-118.

Cook, J., 1968. Regulation of soil fertility. *Zemizdat*, Sofia (Bg).

Dinchev, D., 1982. The possibility of a prediction and regulation of nitrogen regime in soils. *Soil Science and Agrochemistry*, **17**(2): 3-9 (Bg).

Dinchev, D., 1983. Balance on nitrogen in Bulgarian soils, *Zemizdat*, Sofia (Bg).

Enikov, K. (ed.), 1976. Fertilization in intensive farming. *Zemizdat*, Sofia (Bg).

Eurostat, 2013. Archive: Phosphorus balance in agriculture. http://www.stat.si/StatWebArhiv/en/shownews?id=6501&idp=11&headerbar=0

Faytondzhiev, L. and D. Slavov, 1997. Essence and problems of modern agroecology. *Soil Science, Agrochemistry and Ecology*, **32**(3): 3-15.

Garbuchev, I., D. Dinchev, M. Milcheva, E. Neikova and T. Palaveev, 1975. Prediction of the nutrient regime of ours soil. *Soil Science and Agrochemistry,* **10**(5): 18-24 (Bg).

Ikonomova, E., 1986. Transformation and nitrogen balance in the soil-fertilizer-plant system. Doctoral dissertation, Sofia (Bg).

Ivanov, P., 1984. New acetate-lactate method for PK mobile forms. *Soil Science and Agrochemistry*, **19**(4): 88-98.

Ivanov, P., M. Gospodinov and P. Djendova, 1988. Modification of the nitrogen regime of low-leached chernozem in long-term field experiments. *Soil Science, Agrochemistry and Plant Protection*, **23**(6): 42-47.

Ivanov, P., M. Gospodinov and P. Djendova, 1989. Modification of phosphorus regime of low-leached chernozem in long-term field experiments. *Soil Science, Agrochemistry and Plant Protection,* **24**(1): 3-9.

Koteva, B., 1993. Changes in some parameters of soil fertility of leached smolnitza under the influence of long-term fertilization in crop rotation. Doctoral dissertation, Sofia.

Matev, J., S. Gorbanov, T. Tomov, G. Rachovski, I. Manolov and S. Kostadinova, 1995. Productivity of crops in four field crop-rotation at different fertilization systems. Proc. Jubilee Sc. Session, High Agriculture Institute - Plovdiv, October 1995, **3**(1): 211-216.

Matsel, V., 1985. Reserves for increasing the effectiveness of the use of phosphate fertilizers in conditions of intensification of agricultural production. *Agrochemistry*, **12**: 37-48.

Özbek, F. S., 2014. Estimation of national and regional phosphorous budgets for agriculture in Turkey. *Spanish Journal of Agricultural Research*, **12**(1): 52-60.

Panayotova, G. and D. Dechev, 2003. Genotype-by-nitrogen interaction for yield in durum wheat. *Bulgarian Journal of Agricultural Science*, **9**(2): 173-178.

Petrova, M., 1984. Optimizing the fertilization of wheat grown on leached chernozem, *Zemizdat*, Sofia (Bg).

Petrova, M. and M. Gospodinov, 1987. Influence of long-term systematic fertilization on the phosphate and potassium regime of slightly leached chernozem. *Soil Science, Agrochemistry and Plant Protection*, **22**(4): 3-9 (Bg).

Syers, J. K., A. A. Johnston and D. Curtin, 2008. Efficiency of soil and fertilizer phosphorus use. Reconciling changing concepts of soil phosphorus behaviour with agronomic information, 110 pp., *FAO fertilizer and plant nutrition bulletin*, *18*.

Tomov, T., S. Gorbanov, Y. Matev and S. Kostadinova, 1995. Nitrogen balance in 6-crop rotation under the conditions of long-term fertilizing trial. Proceed. Jubile Scientific Session, Higher Institute of Agriculture – Plovdiv, 17-20 October 1995, **3**(1): 205-210.