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Transformation of Nutrient Compounds of Plants in Grey Forest Loamy Soils.

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ABSTRACT

The transformation of organic matters and insoluble phosphates (PO_4^{3-}) in many years of experience under the condition of only organic fertilizers application are considered in the research. Effects of moisture and soil temperature on transformation of organic and mineral nutrient compounds in grey forest loamy soils are revealed. The solubility of phosphates in the soil moisture in autumn-winter-spring period sharply rises with the increase in moisture content and is less dependent on the soil temperature.

Keywords: soil analysis, microrelief, soil moisture, soil temperature, phosphates.

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INTRODUCTION

Due to the expanding use of biological technology the questions, related to the study of transformation of organic compounds and mineral elements of plant nutrition throughout the year, have appeared. Petersburgski [6] gives the data of organic and inorganic compounds transformations and of increase in the elements of plant nutrition by next spring compared with the previous autumn.

The aim of this work is to study the dependence of transformation of organic and mineral nutrient compounds on soil moisture and temperature in the topsoil and subsurface during the hydrological year.

THE EXPERIMENTAL PART

The investigations were carried out on the stationary experiment field of the Bryansk State Agrarian University, founded in 1983 (State Registration Number 046369) in the following hydrological years: 2006/07, 2007/08, 2008/09.

One variant of many years' experience was chosen to study the substances transformation, with the application of only organic fertilizers (manure+green manure+straw) from 1983 to 2009. Winter rye (10-12 t/ha, $N_{12}P_6K_{20}$) was used as green manure. Straw as a fertilizer was applied in the powdered form in the dose of 5 t/ha of organic matter ($N_{25}P_{12}K_{40}$). Manure was applied on tilled crops (rotted corn silage, potatoes) in the doses of 40 and 50 t/ha ($N_{180\text{-}220}P_{80\text{-}100}K_{200\text{-}260}$). In 2007, 2008 and 2009 the following crops: winter rape, barley, buckwheat were cultivated.

In the first decade of April and September 2007, 2008 and 2009 the soil samples were taken from each soil layer of 10 cm up to 1 m depth on two forms of microrelief (microhighs and microlows) in the plot of 237.6 m^2. The content of mobile nutrients (NO_3^-, P_2O_5, K^+, NH_4^+) in the samples was tested by generally accepted methods of soil analysis. Soil moisture was determined by gravimetric method [5]. The data of the total P content were taken from the database of Testing Laboratory of the Bryansk State Agrarian University.

Meteorological data of Meteorological station of the Bryansk State Agrarian University were used to calculate the precipitation-evaporation ratio (PER) [1].

RESULTS AND DISCUSSION

Figure 1 shows K^+, NO_3 content (kg/ha) as well as mobile phosphorus compounds (total content, %) and moisture content (mm) in the layers of 0-20 cm and 21-100 cm in different years. As it can be seen in the figure, maximum of nutrients synchronized with moisture maximum. The higher the moisture maximum is, the higher the nutrient content is. Organic fertilizers, coming into the topsoil and root remnants in the topsoil and subsurface during the year, transform into mineral compounds under the influence of microorganisms.

Some nutrients, formed as a result of biological transformation of organic fertilizers in the topsoil, come with the infiltration flows of moisture into the subsurface 21-100 cm layer.

Table 1 shows the PER in the autumn-winter-spring and spring-summer-autumn periods of three hydrological years.

Table 1: Precipitation-evaporation ratio in the autumn-winter-spring and spring-summer-autumn periods of three hydrological years

2006/07		2007/08		2008/09	
X.06-III.07	IV.07-IX.07	X.07-III.08	IV.08-IX.08	X.08-III.09	IV.09-IX.09
2,49	0,68	2,72	0,67	3,85	0,96

The evaporation is calculated by the formula of N.N. Ivanov (1954).

As it is shown in Table 1, leaching moisture regime (PER=2.49-3.85) happens in the autumn-winter-spring period, whereas non-leaching moisture regime (PER=0.67-0.96) takes place during the vegetation period. Therefore, the excess of nutrient contents in spring over those in autumn of the previous year is higher in the subsurface layer in comparison with the topsoil.

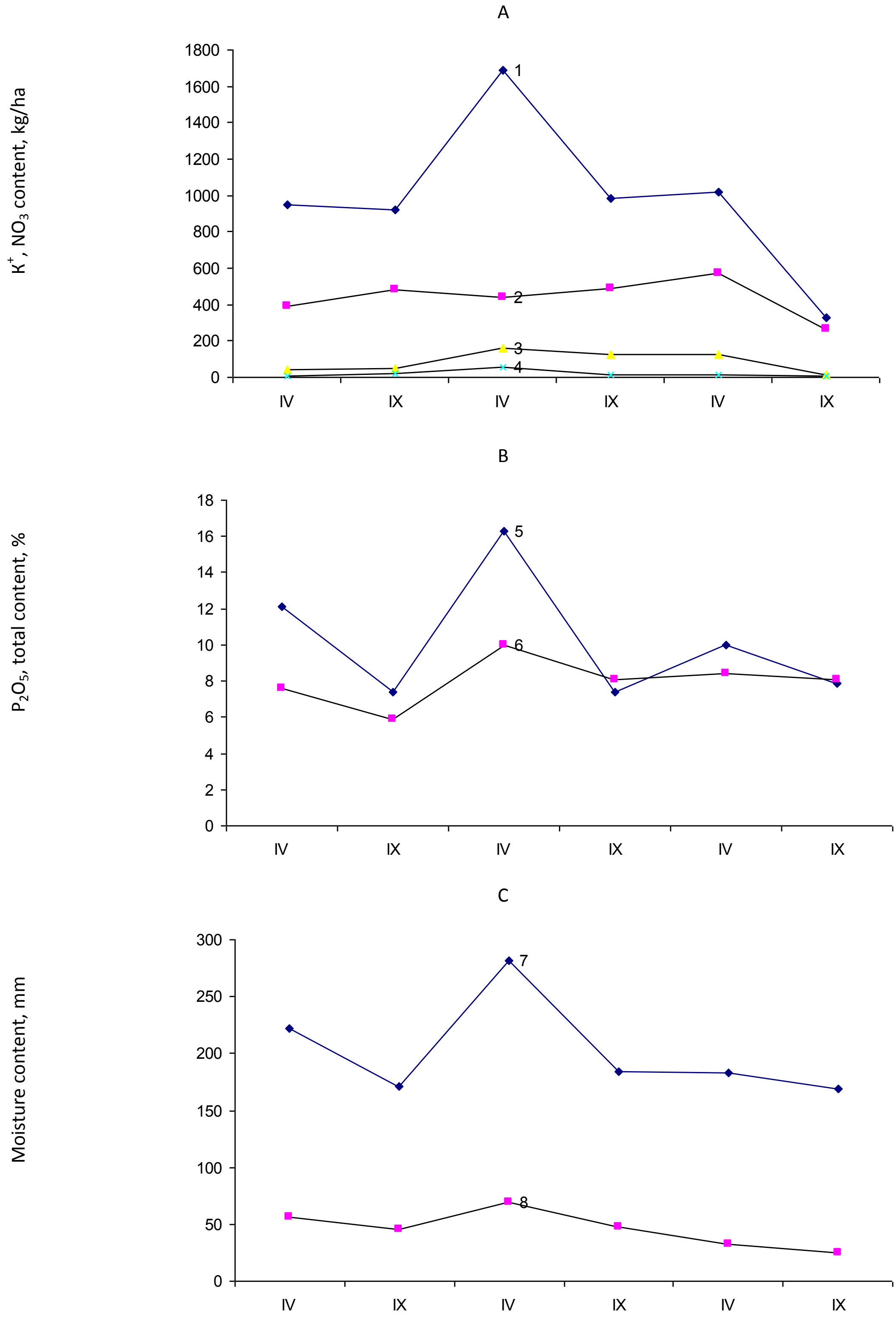

Figure 1: Curves of the distribution of K^+, NO_3 (kg/ha) (A), P_2O_5, (B) and moisture (C) in the soil layers of 21-100 cm (1, 3, 5, 7), 0-20 cm (2, 4, 6, 8)

Thus, the content of nutrients in the topsoil by next spring is determined by the rate of transformation of organic fertilizers and root remnants, as well as their carry-over from the topsoil, whereas in the subsurface layer it is due to the transformation rate of root remnants and incoming of nutrients with the infiltration flows of moisture.

In the vegetation period (IV-IX months) nutrient contents dramatically reduce both due to decrease in moisture and soil microbiologic activity and to their biological carry-over by plants.

In Figure 1 the content minimums synchronize with the end of vegetation period. Similar processes happen in microlows in the 21-100 cm layer with moisture content 30-100 mm more than in microhighs.

Microbiologic activity is dependent not only on humidity but also on soil temperature. The data of soil temperature in the 5 and 80 cm depths in the autumn-winter-spring and spring-summer-autumn periods of three hydrological years are given in Table 2.

Table 2: The average temperature of the soil in the 5 and 80 cm depths for three hydrological years. Data of Meteorological station of the Bryansk State Agrarian University (Agrometeorological Bulletin 2006-2010)

2006/07		2007/08		2008/09	
X.06-III.07	IV.07-IX.07	X.07-III.08	IV.08-IX.08	X.08-III.09	IV.09-IX.09
5 cm depth					
3.1	16.2	0	15.7	0.2	14.7
80 cm depth					
6.0	17.3	4.4	17.7	4.9	15.7

The 5 and 80 cm depths were chosen because the soil temperature is measured only in these depths within meter layer during the year.

Table 2 shows that in the autumn-winter-spring period the temperature (>4°C) in the topsoil is sufficient for the activity of fungi, involving in the processes of mineralization of organic remnants. The biological processes in the topsoil die down due to the lower temperature.

The replenishment of mobile phosphates happens not only due the mineralization of organic fertilizers and root remnants, but also due to the processes of dilution of insoluble phosphates (phosphorites, apatites, iron compounds, aluminum compounds, etc.).

The Bryansk phosphorite plant started operating in 1955 and the farms of the Bryansk regions and neighboring ones began using ground phosphate rock. The application of this phosphate fertilizer led to the increase in the total content of phosphorus (P) in the gray forest loamy soils of the experiment field of the Bryansk State Agrarian University. On the investigated plot the total P content in the 21-100 cm topsoil and subsurface was 0.37% and 0.19% (9.7 and 21.3 t/ha), respectively. According to Petersburgski the total P_2O_5 content in the topsoil of Russia was 0.11-0.23%. It is necessary to apply 5-10 t/ha of P_2O_5 for phosphate saturation of the topsoil [6]. That implies that the soils of the experimental field are close to phosphate saturation. According to Soil science [8] the total P_2O_5 content in loess-like loamy is 0.8%, or 2.4 times less than in the subsurface layer of the plot.

The phosphates comprise the compounds with different degrees of dissolubility: hydroxyapatite [($Ca_5(PO_4)_3OH$, solubility percent (SP)=1.6 x 10^{-58})]; calcium triphosphate [$Ca_3(PO_4)_2$, SP = 2.0 x 10^{-29}]; calcium hydrophosphate [$CaHPO_4$, SP = 2.7 x 10^{-7}]; fluorapatite [$Ca_5(PO_4)_3$ F; SP = 4 x 10^{-3}]; calcium dihydrogen phosphate [$Ca(H_2PO_4)_2$, SP = 1 x 10^{-3}] and others [6]. Generally, the HPO_4^{2-} and $H_2PO_4^-$ ions are moving into the soil solution at the dissolution of these salts [6].

In the previous paper [2] the process of salt dissolving in the pore solution of soils could be identified according to:

$$C_2=C_0\exp[(T_0-T_2/T_0-T_1)\ln C_1/C_0)]\exp[(Q_0-Q_2/Q_0-Q_1)\ln C_1/C_0)], \qquad (1)$$

Where C_0, C_1,C_2, T_0, T_1, T_2, Q_0, Q_1, Q_2 are ion contents, the absolute temperature and moisture content, respectively, except the contents at hygroscopic moisture in a certain soil layer at different time points (t_0,t_1,t_2).

It is assumed that the process of salt dissolving is continuous in time and is divided into equal periods: t_0-t_1 =t_1 -t_2. The value of C_2 can be evaluated by the formula (1) when there are experimental values of C_0, C_1, T_0, T_1, T_2, Q_0, Q_1 Q_2.

Table 3 shows the experimental values of the variables in the formula (1).

Table 3: The experimental values of the variables in the formula (1)

Variable	Microhighs						Microlows					
	IV.07	X. 07	IV.08	X. 08	IV.09	X. 09	IV.07	X. 07	IV.08	X. 08	IV.09	X. 09
	0-20 cm soil layer											
T, ^{0}K	273	281	273.9	281.3	271.9	277.8	273	281	273.9	281.3	271.9	277.8
Q, mm	56	46	69	48	33	25	61	42	60	54	33	28
	21-100 cm soil layer											
T, ^{0}K	275	286.1	275.4	285.7	275.2	282.7	275	286.1	275.4	285.7	275.2	282.7
Q, mm	211	160	271	173	172	158	310	248	288	292	287	260

T, ^{0}K is the absolute soil temperature;
Q, mm is the moisture content in the soil, except the contents at hygroscopic moisture

The calculation of the mobile phosphates content, formed by dissolving of insoluble phosphates is carried out as follows. To determine the calculated value (C_{cal}) in the period of IV.08, the periods of IV.07; X.07; IV.08 were taken as t_0, t_1, t_2. To determine C_{cal} in the period of X.08, the periods of X.07; IV.08; X.08 were taken as t_0, t_1, t_2. And so on until X.09.

Table 4 shows the experimental (C_{exp}) and calculated by the formula (1) (C_{cal}) values of the mobile phosphates content in the topsoil and subsurface on two forms of microrelief.

Table 4: Experimental (C_{exp}) and calculated (C_{cal}) by the formula (1) values of the mobile phosphates content (total content, %) in the topsoil and subsurface at different times

P_2O_5 content, (total content, %)	Microhighs				Microlows			
	IV.08	X. 08	IV.09	X. 09	IV.08	X. 08	IV.09	X. 09
0-20 cm soil layer								
C_{exp}	10.0	8.1	8.4	8.1	9.2	10.3	11.1	7.0
C_{cal}	10.3	6.0	7.4	8.7	8.1	7.8	14.8	11.5
21-100 cm soil layer								
C_{exp}	16.3	7.4	10.0	7.9	14.9	10.9	15.2	11.6
C_{cal}	21.1	8.4	7.2	9.4	13.6	15.0	16.0	21.8

As it is shown in Table 4, C_{cal} is close to the experimental value with the exception of the period X.09, when buckwheat was grown. During this period in the microlow the calculated content of mobile phosphorus was 1.6-2 times higher than the experimental value.

Such large discrepancy between the experimental and calculated values can be explained by the fact that buckwheat, being a phosphorus concentrator, carries out P in large quantities [7]. Besides, a more favorable water regime for plant growth and development in the vegetation period is marked in the microlow as compared to the microhigh.

CONCLUSION

The transformation of organic and mineral substances take place in the topsoil and subsurface in grey forest loamy soils during the hydrological year. Biological transformation of organic matters and dissolution of insoluble phosphate compounds depend on soil moisture and temperature.

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These processes in the autumn-winter-spring period lead to the increase in the elements of plant nutrition in the topsoil and subsurface by next spring compared with the previous autumn.

Insoluble phosphate compounds dissolve in the gray forest loamy soils with a high total P content according to their solubility product.

The solubility of phosphates in the soil moisture in autumn-winter-spring period sharply rises with the increase in moisture content and is less dependent on the soil temperature.

The dissolution evaluation of the insoluble phosphates in the system «soil solution – soil» with the algorithm by L.N. Gorev – V.I. Peleshenko [2] results in the data comparable with experimental ones.

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