Journal of Engineering and Applied Sciences 13 (Special Issue 8): 6527-6532, 2018
ISSN: 1816-949X

Influence of Percentage Fertilizer Systems on Change of Agrochemical Properties of the Arable Layer of Leach Chernozem and on the Crops Productivity of Crop Rotation

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Abstract: At present, the problem of fertility, use, conservation and restoration of soils is acute. The results of the study of the effect of percentagefertilizer systems on the productivity of crops of crop rotation for 2011-2017 are considered. We studied changes in the properties of chernozems on the territory of the Southern Urals with grain-steaming crop rotation without the use of fertilizers in versions using mineral organic and organic-mineral fertilizers. The results of the study of the content, stock, balance of fertilizer elements for agricultural use are shown. It has been established that the cultivation of crops without the use of fertilizers is accompanied by a slight increase in acidity, a decrease in the degree of saturation with bases and the process of dehumification, the use of mineral fertilizers provoked a clear increase in acidity. The introduction of organic fertilizers somewhat inhibits these processes. The results of a study of the influence of local ameliorants on yields of crops and agrochemical properties of soil are presented. It was established that waste from JSC "Soda" soda production and organo-mineral fertilizers on the basis of brown coal from the Kumertau deposit increased crop yields without worsening the agrochemical indices of the soil. And on the contrary, reducing the exchange acidity, enriching the content of the amount of phosphates, water-soluble and exchangeable potassium.

Key words: Leached chernozem, productivity, manure, green manure, phosphorus, potassium, balance of elements of nutrition, removal

INTRODUCTION

At present, the problem of fertility, use, conservation and restoration of soils is acute. Increased use of arable land, irrational use of fertilizers and reclamation means leads to a gradual deterioration of soil fertility. When cultivating crops, we must rationally use traditional and non-traditional agrochemicals to increase the biological activity of soils, taking into account the ecological aspect of this impact (Nurlygaianov and Karoma, 2016; Calderon *et al*., 2017; Eisenhauer *et al*., 2017; Sienkiewicz *et al*., 2017).

Assessment of the state of balance of nutrients in the system: soil, plant, fertilizer is an important characteristic of the effectiveness of fertilizer use in agricultural production. It gives an opportunity to improve the fertilizer system forecast the changes in agrochemical indicators of fertility, the needs of plants in different types of fertilizers followed by agroecological evaluation (Dhillon *et al*., 2017). The results of studies by numerous domestic and foreign researchhers show that the results of the balance of nutrients provide an objective assessment of the correctness of fieldwork (Asmamaw, 2017; Barakat *et al*., 2016; Reddy *et al*., 2017; Rycewicz-Borecki *et al*., 2017; Smith, 2017; Zhu *et al*., 2016). For example, from the early works of researchers, one can single out the studies of Portuguese scientists on the effect of active agricultural use of the arable layer on the variation of soil fertility. Experiments showed that phosphorus and potassium accumulated in the soil but potassium deficiency increased somewhat (Calderon *et al*., 2017), German researchers studying the effect of active use of organic fertilizers showed surplus nitrogen, phosphorus and sulfur in the soil but deficient potassium levels (Schlegel *et al*., 2017). In Germany (Zikeli *et al*., 2017), the introduction of manure also, led to the accumulation of nitrogen, phosphorus and sulfur while the pH does not change. In Australia, the

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researchers J.F. Angust and P.R. Grace (Donia *et al*., 2017) made conclusions about the need to increase the nitrogen balance. Thus, this method of determining the rationality of the use of fertilizers is actively used in world practice which indicates a correct evaluation of the results of the research.

The balance of nitrogen, phosphorus and potassium in the whole of the Republic of Bashkortostan, calculated for the period from 1998-2016, fairly objectively reflects the nature of the use of mineral and organic fertilizers (Mustafina *et al*., 2013). Due to the insufficient application of mineral and organic fertilizers, the balance of nutrients in the plowland of the republic in the 10th cycle in 2016 was negative (the intensity of the balance decreased from 101% in 2006-67% in 2016). We can asamounte that under such conditions of introduction of agriculture in the republic, the balance of nitrogen will steadily approach the non-deficit, the balance of potassium will be negative. And according to the balance of phosphorus in the Southern forest-steppe zone, a deficit value is predicted but in the pre-Urals and Trans-Ural steppe zones, the tension will remain mainly due to erosion processes (Ivanova *et al*., 2015).

In connection with the current trend in the transition of agriculture to organic farming, it is necessary to analyze the changes in the indices of soil fertility under the influence of only mineral organic and organomineral fertilizers (Antosovsky *et al*., 2017; Barjolle *et al*., 2017; Donia *et al*., 2017; Marsh *et al*., 2017).

Thus, we must conduct experimental field studies with subsequent analysis of soil and plant samples and also to determine the effect of calculated fertilizer systems on the use of nutrient and soil elements by fertilizer elements (removal of fertilizer elements, balance coefficients of their use).

The aim of the research was to study the effect of the application of mineral organic and organomineral fertilizers on the productivity of crop rotation crops and the agrochemical properties of the arable layer of soils of leached chernozems.

MATERIALS AND METHODS

The leached chernozems are distributed throughout the territory of the Republic of Bashkortostan and make up 1, 828, 800 ha (12% of the republic's area). The granulometric composition of the soils is heavy loamy with the density of the arable horizon in the range of 1.0-1.19 g/cm^3. The water resistance of arable aggregates in the arable layer is high and amounts to 80-90%. The soil has a high degree of humus content and drainage. These soils lie on carbonate heavy loamy soil-forming rocks.

The experiments were carried out at the Educational and Scientific Center of the Bashkir State Agrarian University in 2011-2017 according to the scheme: 1-control; 2-mineral fertilizers; 3-organomineral fertilizers (NPK+manure and NPK+green manure (peas)) The studies were carried out in a five-field grain-crop rotation with the following alternation of crops: steams, Winter wheat, Spring wheat, Spring rapeseed and maize for silage. The calculation of yields was carried out by a three times continuous method and the soil sample was taken to the depth of the arable horizon. The plot area was 108 m^2. Statistical analysis of the obtained results was carried out by the method of variance analysis according to B.A. Dospekhov.

When calculating fertilizer doses, the balance coefficients of nutrient use from fertilizers and soil and the removal of nutrients with planned crop yields were applied. Mineral fertilizers were introduced in the form of ammonium nitrate, double superphosphate, potassium chloride and ammophos (Kirillova and Yusupova, 2015).

Plant and soil samples were analyzed in "SAS" Ishimbayskaya". The following determinations of plant samples were carried out: the content of dry matter and gyroscopic moisture according to State Standard 8719-58, nitrogen content using the Nesler reagent, the phosphorus content by the vanadomolybdate method, the content of potassium by the method of flame photometry (State Standard 26726-85). Agrochemical analysis of arable layer of soil: humus by the Tyurin method (State Standard 26213-91), hydrolytic acidity, according to Kappen (State Standard 26212-91), mobile phosphorus and exchange potassium by the Chirikov method (State Standard 26204-91); the amount of absorbed bases according to Kappen-Gilkowitz (State Standard 27821-88), nitrate nitrogen was determined by the disulfophenol method according to Grandval-Liazhu (State Standard 26488-91), the content of ammonium nitrogen by the colorimetric method (State Standard 26489-91), reaction of soil solution (saline) by the CIANO method, State Standard 26483-85.

RESULTS AND DISCUSSION

The climate in the region is quite variable and periodic droughts are observed which affects the yield and quality of products (Ghahramani and Moore, 2016; Poudel and Shaw, 2016). Since, the yield of crops and the content of nitrogen, phosphorus and potassium in the products obtained varied significantly not only in terms of options but also in the analyzed years, it was important to calculate the effect of the fertilizer systems and weather

Table 1: The effect of percentage fertilizer systems on crop yields and productivity of crop rotation on average for 2011-2017, ton/ha (unit)

	Yield				Crop rotation productivity,	
Variants	Winter wheat	Spring wheat	Spring rapeseed	Maize for green mass	units	Surplus, units
Control	2.70	1.90	1.70	34.20	3.0	-
$N_{100}P_{45}K_{65}$*	3.40	2.50	2.10	43.40	3.9	0.9
Manure-40t/ha	2.90	2.30	1.70	35.60	4.4	1.4
Manure+$N_{100}P_{45}K_{65}$*	3.40	2.90	2.00	43.30	5.5	2.5
Green manure	2.90	2.11	1.50	35.20	5.3	2.3
Green manure+$N_{100}P_{45}K_{65}$*	3.50	2.80	2.10	43.10	6.5	3.5
HCP_{05}	0.09	0.15	0.10	0.79	-	-

*For each crop the doses of fertilizers are different: Winter wheat-N100P45K65, Spring wheat-N80P35K45, Spring rapeseed-N125P60K50, maize for green mass-N120P50K95

conditions on the variability of these indicators. Analysis of crop yields showed that crop variations by 68% were determined by weather conditions and only by 30% by applied fertilizer systems. The variability of the content of nitrogen, phosphorus and potassium in crop yields was determined in different ways. Fluctuations in the Nitrogen content of products were determined almost equally by weather conditions and calculated fertilizer systems. Fluctuations in phosphorus content mainly depended on weather conditions and the content of potassium in the more commonly used fertilizer systems was 50 and 44% with weather conditions.

Applied fertilizers positively affected the productivity of agricultural crops in 2011-2017 (Table 1). From the obtained data on the productivity of Winter wheat, it follows that the increase in yields in variants with the use of fertilizers, compared with the control variant amounted to 2.9-3.5 ton/ha which gives an increase of 0.2-0.8 ton/ha. The greatest increase was obtained with mineral fertilizers with green manure and manure which amounted to an increase of 0.8-0.7 ton/ha, respectively. The same results were obtained in the Czech Republic (Antosovsky *et al*., 2017) where the increment from the application of the green manure was 0.7 ton/ha.

Additions of grain crops of Spring wheat in variants with application of mineral fertilizers with manure and green manure also allowed to receive an increase of 0.2-1.0 t/ha. The studies of Jagman Dhillon (USA) confirm the results of the influence of phosphorus on the yield of cereal crops (Dhillon *et al*., 2017). The application of fertilizers under spring rapeseed had no effective influence on the yield of seeds. In maize crops, the options with the use of mineral fertilizers with manure and green manure were higher compared to only mineral fertilizers by 7.7-7.9 t/ha. The increase in the green mass of maize was 1-9.2 t/ha. The productivity of crops of crop rotation on fertilized variants increased by 0.9-3.5 units and reached 3.9-6.5 t/ha units.

When calculating fertilizer doses, the removal of nutrients with a unit of primary production with an appropriate amount of secondary is one of the necessary

Table 2: Balance coefficients of nutrient use by crops of crop rotation (%)

	Years					
	2011			2017		
Variants	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Control	-	-	-	-	-	-
$N_{100}P_{45}K_{65}$*	70	69	138	78	71	140
Manure-40t/ha	-	-	-	-	-	-
Manure+ $N_{100}P_{45}K_{65}$*	79	72	145	78	70	138
Green manure	-	-	-	-	-	-
Green manure+ $N_{100}P_{45}K_{65}$*	75	70	148	76	70	145

*For each crop the doses of fertilizers are different: winter wheat-N100P45K65, spring wheat-N80P35K45, spring rapeseed-N125P60K50, maize for green mass-N120P50K95

regulatory indicators (Sienkiewicz *et al*., 2017). Therefore, we calculated the economic removal of nutrient elements with a crop of crop rotation. With the application of fertilizers, the removal of Nitrogen and Potassium from grain of Winter and Spring wheat, Spring rapeseed and green mass of maize increased, respectively by 6, 3-4; 9-10; 0.4 and 5-6, 4, 9-10, 0.5-0.6 kg. The removal of phosphorus by a unit of yield in this case either did not change or increased somewhat.

The next indicator of the rationality of the applied fertilizers is the balance of nutrients in the system "Soil, plant, fertilizer" (Table 2). During the period of research by 2017, all the variants of the experiment had a positive nitrogen balance (BC-76-78%), phosphorus (BC-70-71%) and negative potassium (BC-138-145%). And the calculated balance coefficients of potassium use turned out to be at the level of the planned ones and nitrogen and phosphorus are lower. This fact can be explained by the fact that the yields were lower than planned and possibly, the normative indicators used in the calculations, namely the removal of nutrients from 1 ton of the crop with the corresponding amount of by-products did not correspond to either the biological characteristics of the cultivated varieties or the soil and climatic conditions.

Studies by Portuguese scientists who also used balance methodologies for carrying out a comprehensive

Table 3: Changes in agrochemical properties of leached chernozems under the influence of calculated fertilizer systems from 2011-2017. (0-25 cm)

Variants of experiment	Humus (%)	pH salt	Hr (mg equiv./100g)	S (Mg equiv/100g)	P_2O_5 (mg/kg)	K_2O (mg/kg)
Control$_{(2011)}$	7.2	5.2	4	50	94	120
Control$_{(2017)}$	6.8±0.2	5.1±0.1	3±0.1	49±0.1	92±0.2	118±0.2
NPK $_{(2017)}$	6.9±0.1	5.3±0.2	3±0.2	48±0.1	93±0.2	118±0.1
Manure-40 t/ha$_{(2017)}$	6.9±0.1	5.2±0.1	3±0.1	50±0.1	94±0.1	119±0.2
Manure+NPK $_{(2017)}$	7.0±0.1	5.2±0.2	4±0.2	50±0.2	95±0.1	120±0.1
Green manure$_{(2017)}$	6.9±0.2	5.1±0.2	3±0.2	49±0.1	94±0.1	120±0.1
Green manure+NPK $_{(2017)}$	6.9±0.1	5.3±0.2	4±0.1	50±0.1	94±0.2	120±0.2

Table 4: Changes in agrochemical properties of soil in the application of waste products of soda production (WSP) of JSC"Soda", Ishimbai from 2015 to 2017

Variants	Year of analysis	Humus (Mg/kg %)	(mg-equiv/100 g of soil) P_2O_5	K_2O	pH	(mg-equiv/100 g of soil) Hr	Ca	Mg	Heavy metal Sulfur (mg/kg)	Ni	Pb	Zn
Control	2015	8.9	66	128	5.8	3.03	29.9	3.6	6.1	22.7	4.6	8.2
	2017	8.4	86	125	5.8	3.27	28.9	5.6	4.6	33.3	3.2	9.3
WSP-10 (t/ha)	2015	9.0	68	135	5.8	3.03	29.8	3.7	3.0	22.9	4.7	8.5
	2017	8.6	85	200	5.8	3.06	29.7	5.2	5.6	31.7	3.1	9.2
WSP-15 (t/ha)	2015	8.8	65	140	5.7	3.27	29.4	4.1	6.4	23.5	4.4	7.9
	2017	8.5	92	210	5.7	3.06	29.2	5.1	7.8	31.0	3.7	9.0
WSP-20 (t/ha)	2015	8.6	70	140	5.7	3.24	29.4	4.3	3.4	23.1	4.4	8.3
	2017	8.6	95	210	5.6	3.05	28.9	5.2	7.8	31.7	3.9	9.1

assessment of the functioning and nutrient cycling show very different results. Here, there is a constant deficit of nitrogen and accumulation of phosphorus and potassium in the soil. This, of course is first of all, the dependence of the balance of the elements of nutrition on the applied fertilizers in the national economy (Carmo *et al*., 2017).

During the 7 years of research, a certain change in the agrochemical properties of the arable layer of soils under the influence of the calculated fertilizer systems has been traced (Table 3). For example, the amount of humus in control variants decreased by 5% and the dynamics of the reaction of the soil environment showed that the acidity of the soil under the influence of mineral fertilizers increased, shifting the pH to 0.1-0.2 units in comparison with the control. The results of the analysis of the hydrolytic acidity of the soil in variants with the use of organomineral fertilizers, showed an increase in the index. The content of mobile phosphorus and exchangeable potassium in the arable layer of the soil in the variant without the use of fertilizers was reduced and in the variants with manure and green manure increased somewhat.

In variants without fertilizers, it is possible to trace the decrease in fertility and the increase in the process of dehumification. Variants with the use of mineral fertilizers slightly increase the acidity of soils and in variants with the use of manure and green manure, soil fertility increases.

About 33 years old research of scientists from China on the use of mineral and organic fertilizers confirm our data. Here, only the use of mineral fertilizers increased the content of fertilizer elements but this increase was small (Reddy *et al*., 2017).

Continuing research in the direction of the transition of agriculture to organic farming, we conducted an analysis of the effect of new types of fertilizers on the yield of several crops and the fertility of soils. This problem should be considered primarily because of the lack of manure in the region which is due to a sharp decrease in the number of livestock (Udayana *et al*., 2017; Won *et al*., 2017). The research was carried out by two new kinds of fertilizers. One was created on the basis of brown coals of the Kumertau deposit and the other wastes from soda production of JSC "Soda" Ishimbai.

Field research of the application of soda production waste of JSC "Soda", Sterlitamak as liquid fertilizers on spring wheat were carried out in 2015-2017. The fertilizer was introduced as a fertilizer at the stage of tillering of spring wheat. The fertilizer is a concentrated solution containing $Ca_3(PO_4)_2$-180, Kcl-120, $CaSO_3$-5 and NaCl-20 g/L. The experiment was carried out according to the following scheme: 1-control; 2-waste of soda production in the form of 1% solution with a dose of 10 ton/ha (in terms of dry matter); 3-waste of soda production as 1% solution with a dose of 15 ton/ha; 4-waste of soda production in the form of a 1% solution with a dose of 20 ton/ha.

As a result of the experiment an increase in the yield of spring wheat was detected under the influence of waste of soda production in doses of 10, 15, 20t/ha per 1, 1.6, 2.6 t/ha, respectively. And the greatest increase was achieved in the version with the use of waste of soda production in maximum doses.

As a result of using a solution of waste products of soda production, we see that the content of available forms of potassium and sulfur in the soil increased by 25.8 and 17%, respectively, compared with the initial indicators (Table 4).

Table 5: Changes in agrochemical properties of leached chernozems during the application of mineral fertilizers and organo-mineral fertilizers based on brown coal from the Kumertau deposit on average for 2013-2015

							Microelements				
Variants	Humus (%)	N-NO_3	P_2O_5 (mg/kg)	K_2O (mg/kg)	pH	Sulfur (mg/kg)	B	Mn	Zn	Cu	Co
Control	7.7	29.9	185	211	5.8	8.4	2.50	14.1	0.44	0.28	0.02
$N_{75}P_{90}K_{130}$	7.7	24.1	201	242	5.7	10.4	2.55	11.5	0.46	0.30	0.02
Organo-mineral fertilizers-1 (ton/ha)	7.8	64.3	212	261	5.9	10.8	2.85	10.1	0.46	0.28	0.04

The use of a solution of waste products of soda production as a fertilizer possibly led to an increase in yield by 11% without worsening the agrochemical indices of the soil but rather enriching it with potassium and sulfur. It should be noted that the introduction of waste products of soda production reduced the coefficient of increase in nickel in the soil by 1.8-3.8 mg/kg and reduced the content of zinc.

Studies of the influence of organo-mineral fertilizers on the basis of brown coals of the Kumertau deposit were carried out in 2013-2015 on sugar beet crops. Fertilizers have an ash content of 42-50%, humidity of 4.4-15.9%, pH 5.5-7.2, contains: total nitrogen 3.1-7.5%, total phosphorus 6.6-9.2%, total potassium 7-12.8%. They contain in their composition heavy metals that do not exceed the MAC level and trace elements. The scheme of the experiment contained a control variant, a variant with application of mineral fertilizers: nitrogen -75 kg/ha, phosphorus -90 kg/ha, potassium -130 kg/ha (equivalent to organomineral fertilizers in the volume of 1 ton/ha). And the option with the application of organic-mineral fertilizer in a dose of 1t/ha.

Data on the yield of sugar beet showed that the yield increase in options with the introduction of mineral fertilizers was 14.8 t/ha or 57.7%. The use of organo-mineral fertilizer made it possible to obtain 40.7 t/ha of sugar beet increasing yield by 58.3%.

As a result of the application of mineral fertilizers and organo-mineral fertilizers on the basis of brown coals, soil fertility had some changes (Table 5).

When applying organo-mineral fertilizer, the humus content increased by the time of harvest by 0.1%, nitrate nitrogen by 34.4 mg/kg, mobile phosphorus by 27 mg/kg and exchangeable potassium by 50 mg/kg. There was also an increase in the content of microelements in the soil: boron, zinc and cobalt, respectively by 0.35, 0.02 and 0.02 mg/kg of soil. At the same time, there was a decrease in manganese which is due to the high conamountption of this element by sugar beet in fertilized variants which was also noted in other experiments with sugar beet (Piskin, 2017; Udayana *et al*., 2017).

CONCLUSION

Applied fertilizer systems increased the yield of crops and the productivity of crop rotation without reducing the quality of the products obtained. During the period of research by 2017 for all variants of the experiment, the balance of nitrogen and phosphorus was approaching a deficit-free, potassium-negative balance (BC-138-145%).

Studies have shown that on leached chernozems with the use of mineral fertilizers the acidity increased somewhat. The results of the analysis of the hydrolytic acidity of the soil in variants with the use of organomineral fertilizers, showed an increase in the index. This tells us that the acidity of the soil can only be reduced by the systematic application of lime.

The content of mobile phosphorus and exchangeable potassium in the arable layer of the soil in the variant without the use of fertilizers was reduced and in the variants with manure and green manure increased somewhat.

Waste from JSC “Soda” soda production and organo-mineral fertilizers based on brown coal from the Kumertau deposit had a positive effect on the agrochemical properties of the soil: they reduced the exchange acidity, promoted the growth of soil saturation with bases, enriched the soil with potassium and sulfur while increasing the amount of phosphate, water-soluble and exchangeable potassium.

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