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TRANSFORMATION OF QUALITY AND QUANTITATIVE COMPOSITION OF MINERAL PHOSPHATES IN LIGHT CHESTNUT SOIL DURING LONG-TERM APPLICATION OF PHOSPHOROUS FERTILIZERS IN CROP RATOTAION AND PERMENANT SUGAR BEET SOWING

Abstract

The article presents the results of studies on the influence of long-term application of phosphoric fertilizers on sugar beet crops unchallenged for more than 50 years on the transformation of phosphate forms on light chestnut soil and its productivity in comparison with the identical options in the rotation.

Despite the large amount of practical material, the effect of the duration of application of phosphorus fertilizers on irrigated soils in Kazakhstan has not been sufficiently studied. The available isolated data on the influence of the duration of fertilizer application relate to the aspect of assessing their impact on the yield and quality of the crop and, partly, on the phosphate regime of soils. Most of the studies were carried out within the framework of short-term field experiments, which are designed, first of all, to establish specific doses of fertilizers on the productivity of agricultural crops. These field studies were carried out on a fairly narrow background and time frame of variation in soil fertility characteristics, which did not allow us to establish the qualitative and quantitative composition of phosphates and their functional relationship between the level of potential and effective fertility.

Ke ywords: *fertilizer, light chestnut soil, permanent sowing of sugar beet, beet crop rotation, sugar beet, mineral nitrogen, nitrates, ammonium nitrogen, mobile phosphorus, gross phosphorus, organic phosphorus, mineral phosphorus, fractional composition of mineral phosphates, sugar content.*

Introduction

To the problem of phosphorus in agriculture, the solution of which is associated with the knowledge of its various forms in the soil and their conversion, ways of its mobilization, transformation and conditions for the most effective use of phosphorus fertilizers in our and other countries is devoted a lot of work. In the literature there is a lot of data on the forms of different phosphates and its quantitative content in different soils. A wide variety of combinations and factors of soil formation, the contrast of soil and climatic conditions determine the variety of forms of phosphorus compounds in soils. According to the content, reserves and forms of soil phosphates in the soils of our republic, numerous materials obtained as a result of short-term and long-term studies have been published.

The purpose of our work was to establish the basic laws of quantitative and qualitative changes in various phosphates in light brown soil, depending on the long-term (more than 50 years) application of phosphorus fertilizers in crop rotation and permanent sowing of sugar beet.

An important indicator of potential soil fertility is the content of gross phosphorus in different soils. Gross reserves of phosphorus in soils are very large compared to the need for crops. However, all types of soils need phosphorus fertilizers, because this indicator cannot be judged on the degree of mobility and availability of soil phosphorus [1].

In the nutrition of cultivated plants, the most important place is given to organic and mineral forms of phosphorus, which are constantly in the process of turning into each other. The organic part of phosphorus is the main component of the "working capital" of soil phosphates and under certain conditions can be mineralized, enriching the soil with mineral forms of phosphorus [2].

The problem of phosphorus in agriculture, the solution of which is associated with the knowledge of its various forms in the soil and their transformation, the ways of its mobilization, transformation and the conditions for the most effective use of phosphorus fertilizers in our and other countries, has been devoted many works. In the literature, there is a lot of data on the forms of various phosphates and its quantitative content in different soils. A wide variety of combinations and factors of soil formation, the contrast of soil and climatic conditions determine the diversity of forms of phosphorus compounds in soils. Numerous materials have been published on the content, reserves and forms of soil phosphates in the soils of our republic that were obtained as a result of short-term and long-term studies. [3-5].

The purpose of our work is to establish the main regularities of quantitative and qualitative changes in various phosphates in light chestnut soil depending on the long-term (more than 58 years) application of phosphorus fertilizers on permanent sowing of sugar beet.

An important indicator of potential soil fertility is the content of gross phosphorus in various soils. Gross reserves of phosphorus in soils are very large compared with the need for crops. However, all types of soils need phosphorus fertilizers, because this indicator cannot be used to judge the degree of mobility and availability of phosphorus in soils.

In the nutrition of cultivated plants, the most important place is given to the organic and mineral forms of phosphorus, which are constantly in the process of becoming one another. The organic part of phosphorus represents the main component of the "working capital" of soil phosphates and, under certain conditions, can be mineralized, enriching the soil with mineral forms of phosphorus [6-7].

Methods and materials

Field studies were conducted at the experimental station of mineral nutrition and agroecology department of "Kazakh Agricultural and Crop Production Research Institute" LLP, on irrigated open dark-brown soil. The studies were carried out in long-term stationary experiments, founded in 1961 in the conditions of 7 - fields beet crop rotation and to compare the productivity of sugar beet the experiments with its permanent sowing was also laid.

Agrochemical characteristics of light-chestnut soil of experimental were: humus content in the arable layer of soil - 2.4%, of the total nitrogen – 0.227%, phosphorus – 0.221%, potassium 1.9%, hydrolyzable nitrogen – 90-100 mg, mobile phosphorus (by Machigin) – 24 mg/kg, exchange potassium – 558 mg/kg of soil, CO_2 of carbonates – 3.0-4.3%.

In crop rotation as well as on the field and permanent sugar beet crops experience scheme was the same. For the study of the transformation of phosphates during prolonged application of phosphorus fertilizers we have taken 4 variants of the experiment: 1 control; 2, NK; 3 NPK; 4 NP1,5K. A single dose of mineral fertilizers was $N_{60\text{-}100}P_{60\text{-}100}K_{60\text{-}150}$ depending on the culture and predecessor in the rotation. On the field with permanent sowing of sugar beet the annual fertilizer rate was $N_{100}R_{80}K_{70}$.

Phosphorus fertilizers were introduced in the forms of simple and double superphosphate, nitrogen as an ammonium nitrate and urea, potassium as a potassium chloride and potassium salt.

The size of the plot in the first rotation was 432 m^2, in the second and permanent crops – 216 m^2. Experience replication was 4 times. Agricultural machinery in the experiments was generally accepted for the zone.

Analytical studies were carried out in an accredited laboratory (№ Kz.И.04.1403).

The soil samples were determined: total phosphorus by K. E. Ginzburg and K. A. Shcheglova with further colometry by Denige; mobile phosphorus - by the method of B. P. Machigin; gross phosphorus – by the method of META; organic phosphorus by Lito –Chango– Jackson and Hedley; composition of mineral phosphorus by Ginzburg – Lebedeva

Results and discussion

Despite the large practical material, the impact of the duration of application of phosphate fertilizers is not sufficiently studied on irrigated soils of Kazakhstan. Available single data on the impact of the duration of fertilizer use relate to the aspect of assessing their impact on crop and crop quality and partly on the phosphate regime of soils. Most of the studies were conducted in short-term field experiments, which are designed primarily to establish specific doses of fertilizers on crop productivity. These field studies were performed on rather narrow backgrounds and time frames of variation of soil fertility characteristics, which did not allow to establish qualitative and quantitative composition of phosphates and their functional relationship between the level of potential and effective fertility [4,5].

The first research on this study was conducted in 1961-1975. B.S.Baisibekov and R. E.Yeleshev [6,7]. The data showed that as a result of application of phosphoric fertilizers within 15 years there is a significant change in qualitative and quantitative composition of phosphoric compounds (table 1).

The increase in the gross reserves of phosphorus in its long-term use mainly depended on the rate of fertilizers. More phosphorus was introduced with fertilizers, higher amounts accumulated in the soil. When applying phosphate fertilizers in the norm of 780 kg, in 15 years the content of gross phosphorus in the layer of 0-20 cm was 0.229%, when applying 1170 kg of phosphorus - 0.285%, with a marching content of 0.221%. In the variant without application of the phosphorous fertilizers, the content of total phosphorus decreased from 0,221 to 0,218%. The content of total phosphorus in the 20-40 cm layer changed slightly.

Phosphorus fertilizers in soils eventually turn into less mobile forms. As a result of the systematic application of phosphorus fertilizers, phosphorus accumulates in the soil, mainly in the form of minerals and partially in the form of organic compounds. In irrigated light chestnut soils, fertilizer phosphorus, even with long-term interaction with the soil, is almost all in the composition of “active” phosphates extracted by the Ginzburg and Lebedeva method. In this case, several groups of phosphoric compounds are formed, differing in different solubility. Due to the introduction of phosphorus, loose-bound phosphates decrease with the formation of different-base and partially high-base phosphates. In the soil of crop rotation fields, the most soluble phosphates (Ca-PI + Ca-PII) contain less than under permanent crops, which is associated with a significantly higher yield of sugar beet [13].

Mobile phos in soil of the sizes of the forms of the fore increase of weeds the effect is very great [14]. Agricultural phosphorus fertilizer in the ecosystem use of grain, agriculture Phosphorus absorption for crops temporarily elevates forms, and the application of its high standards bioavailability in the soil environment changes [15, 16]. Phosphorus reaction in the soil very capable and lobbies belong to the higher elements [17]. Hedley MJ. and others studies, when using phosphorus Phosphorus in the soil is different forms are created. For soil type, On the surface of soil with high pH phosphorus with various elements (AI, Fe, Ca) adsorption mobility and bioavailability are different things can also be shared [18, 19].

The application of phosphorus fertilizers on permanent crops of sugar beet in the same norms contributes to a more significant increase in the reserves of gross phosphorus. The content of gross phosphorus in the soil with permanent crops of sugar beet for 15 years on the control and nitrogen potash variants practically does not undergo changes, whereas when applying phosphorus fertilizers, there is a noticeable increase in its content in the upper layer (0-20 cm) of the soil. In the version with the annual introduction of a single norm (for 11 years 780 kg/P_2O_5 per hectare) of phosphorus fertilizer, its content increased by 0,130% and with the introduction of a one-and-a-half norm - by 0,170%.

Table 1 -Transformation of phosphates in light chestnut soil with prolonged use of phosphate fertilizers on permanent sugar beet crops and crop rotation (for 14 years, the data of B.S. Basibekov, R.Y. Yeleshev, 1961-1975 and 57 years, R.Y. Yeleshev, B.E. Alimbekova and others 2017-2019)

Trials	Total added P_2O_5 kg/ha a.s.	P_2O_5 in soil (0-20 cm)												
		gross, mg/kg	organic mg/kg	mineral mg/kg	mobile, mg/kg	mineral phosphates according to Ginzburg-Lebedeva								
						$Ca\text{-}P_I$		$Ca\text{-}P_{II}$		$Ca\text{-}P_{III}$		(Al+Fe)P		the sum of fractions
						1*	2*	1	2	1	2	1	2	
beet crop rotation (herbal component, 1961-1975, 2 rotation)														
Original background,1961	0	2210	510	1700	24,0	100	7,9	282	22,3	742	58,7	141	11,1	1265,0
Control, 1961-1975	0	2180	517	1663	14,7	96	7,8	262	21,2	740	59,8	140	11,2	1238,0
NK, 1961-1975	0	2176	513	1663	14,0	88	7,2	264	21,4	745	60,3	139	11,1	1236,0
NPK, 1961-1975	780	2290	568	1722	38,3	124	8,8	356	25,4	778	55,4	146	10,4	1404,0
$NP_{1,5}K$, 1961-1975	1170	2353	670	1683	44,7	134	9,1	386	26,3	798	54,3	152	10,3	1470,0
permanent sowing of sugar beet, 1961-1975														
Control, 1961-1975	0	2270	460	1810	32,7	82	6,3	294	22,4	788	60,2	146	11,1	1310,0
NK, 1961-1975	0	2260	460	1800	30,0	86	6,3	318	23,4	810	59,5	147	10,8	1361,0
NPK, 1961-1975	780	2400	460	1940	60,3	133	8,8	375	24,9	828	55,0	169	11,2	1505,0
$NP_{1,5}K$, 1961-1975	1170	2440	460	1980	68,3	152	9,5	397	24,8	882	55,1	170	10,6	1601,0
beet crop rotation, 2016-2018, 12 rotation														
Control, 2016-2018	0	2050	490	1560	15,1	21,0	1,7	247,5	20,5	790,0	65,3	150,5	12,4	1209,0
NK, 2016-2018	0	2095	530	1565	17,0	29,5	2,3	252,5	19,9	825,5	65,2	159,0	12,6	1266,5
NPK, 2016-2018	3250	2647	632	1737	50,0	115,1	7,4	402,5	26,0	867,5	56,1	161,0	10,4	1546,1
$NP_{1,5}K$, 2016-2018	4455	2814	666	1890	65,2	145,0	8,9	419,0	25,7	887,5	53,8	198,0	12,0	1650,0
permanent sowing of sugar beet, 2016-2018														
Control, 2016-2018	0	2100	480	1815	17,3	17,5	1,4	256,5	20,8	816	66,2	142,5	11,6	1232,5
NK, 2016-2018	0	2140	500	1810	16,6	14,5	1,1	263,0	20,5	846,5	60,0	160,0	12,5	1284,0
NPK, 2016-2018	4400	2660	597	2063	66,1	102,5	6,5	435,0	27,5	879,0	55,6	164,5	10,4	1581,5
$NP_{1,5}K$, 2016-2018	6600	2860	602	2098	70,6	138,0	8,2	455,0	30,0	907,5	53,8	187,0	11,0	1687,5
*Note:1 - P_2O_5 mg/kg of soil; 2 - % from the amount of mineral phosphates.														

Organic phosphates in light chestnut soil contain 15.6-23.2% of the gross phosphorus. In our experiment in the soil of crop rotation fields, the content of organic phosphorus on fertilized variants was: in the layer 0-20 cm 546-670 mg, which is 24.9-28.5 % of the gross phosphorus, with its initial soil content of 23.1%. With respect to control (NK), the increase in organic phosphorus content in fertilized variants was 6-66%, that is, when applying phosphorus fertilizers, the content of organic phosphorus in the soil of crop rotation fields increases significantly compared to the initial content and control, which should be considered as a very positive fact.

The content of organic phosphorus is influenced by crop rotation. Thus, during the cultivation of sugar beet in the formation and turnover of the alfalfa layer, the content of organic phosphorus remained elevated compared to the initial and amounted to 594 - 631 and 587-604 mg, respectively, or about 25-28% of the gross phosphorus.

When sugar beet is placed by the third crop after alfalfa, there is a decrease in organic phosphorus in the soil. These data indicate that when cultivated in the rotation of alfalfa, the content of organic phosphorus in the soil increases significantly from the original and remains elevated not only in the formation, but also in the turnover of the alfalfa layer. Under permanent crops of sugar beet, the application of phosphorus fertilizers does not contribute to the accumulation of organic phosphorus in the soil, and, conversely, there is a decrease in it by 2.6-3.3% compared to the initial background. The marked difference in the change of the content of organic phosphorus could be due to more intensive mineralization of organic matter in the soil of "monoculture".

Studies have shown that long-term use of phosphorus fertilizers has a significant impact on the content of mobile phosphorus in the soil.

The content of mobile phosphorus when laying the experiment (1961) in the layer 0-20 cm was equal to 24 mg per kg of soil. In the variant without fertilizers (control), the content of P2O5 in the fields of crop rotation was 14.7 mg, and in the monoculture 32 mg.

With the introduction of phosphorus fertilizers in the norm of 780 kg P_2O_5, the content of mobile phosphorus in the soils of beet crop rotation fields increased in the layer 0-20 cm from 24.0 to 38.3 mg, or 1.5 times, with the introduction of a one-and-a-half norm - 1170 kg of phosphorus, it was increased to 44.7 mg, i.e. 1.8-2.0 times compared to the initial background, and compared with the control, the content of mobile phosphorus in these options increased 2.5-3 times. The content of mobile phosphorus in crop rotation was also significantly influenced by crop rotation.

The application of phosphorus fertilizers on permanent crops of sugar beet has a similar effect on the change of mobile phosphorus in the soil. When phosphorus fertilizers are applied on permanent crops of sugar beet, there is a greater accumulation of mobile phosphorus in the soil than in the conditions of beet crop rotation. Thus, with the introduction of 780 and 1170 kg of P2O5, the content of mobile phosphorus increased in the 0-20 cm layer by 2.0-2.1 times, in comparison with the control and 2.5 times in comparison with the initial background. Long-term use of phosphate fertilizers enriches the soil with mobile phosphorus and subsurface layer.

The application of nitrogen-potassium fertilizers, both in crop rotation and on permanent crops of sugar beet does not affect the change in the content of mobile phosphorus in the soil.

It is interesting to note that in the control variant in all our experiments the content of mobile phosphates did not decrease to the value of less than 10-14 mg/kg of soil, although the depletion of soil by mobile forms of phosphates affected the development and appearance of plants.

However, this led to a decrease in the yield of sugar beet. Based on these data, it can be assumed that the Machigin method with a mobile phosphorus content of less than 10-14 mg/kg of soil does not reflect the true stock of plant-digestible phosphates in the soil. In such cases, to determine the degree of availability of soil digestible phosphorus, apparently, it is necessary to use indicators of the fractional composition of mineral phosphates.

The study of the fractional composition of phosphates by Ginzburg-Lebedeva showed that the systematic application of phosphorus fertilizers for 15 years led to an increase in the content of the amount of "active" mineral phosphates in which the number of loosely bound ($Ca\text{-}P_I$) and dissimilar ($Ca\text{-}P_{II}$) calcium phosphates increased not only in absolute, but also in relative terms to gross phosphorus.

If in the arable layer of soil without phosphorus fertilizers the amount of loosened ($Ca\text{-}P_I$) and multibasic phosphates ($Ca\text{-}P_{II}$) amounted to 30.2% of the amount of "active" mineral phosphates, when introducing 280, 780 and 1170 kg/ha of phosphorus for 15 years, their value increases to 33.0; 34.2; 35.0%, respectively, the number of phosphates of one-and-half oxides practically did not change, and phosphates of high-base fractions decreased in relative terms to 56.2; 55.2 and 54.3% of the use of 280, 780 and 1170 kg/ha of phosphate fertilizers

Studies conducted in 2017-2019 show that there is a further enrichment of light chestnut soil with soil phosphates. Thus, the data of table 1 show that as a result of the application of phosphate fertilizers for more than 50 years, there is also a significant change in the qualitative and quantitative composition of phosphorus compounds in the soil.

The increase in the gross reserves of phosphorus in its long-term use mainly depended on the rate of fertilizers. The more phosphorus is introduced with fertilizers, the more it accumulates in the soil. So, if you make phosphate fertilizers in the amount of 2860 kg D. V. for 57 years, the content of total phosphorus amounted to 2647 mg/kg, the introduction of 4455 kg a.s. – 2814 mg/kg, with initial content (in 1961) 2210 mg/kg. In the variant without application of the phosphorous fertilizers, the content of total phosphorus decreased to 2050 mg/kg.

The introduction of phosphorus on permanent crops of sugar beet contributes to a more significant increase in the reserves of gross phosphorus. The content of gross phosphorus in permanent crops for 57 years on the control and nitrogen-potassium options are practically unchanged, while the application of phosphorus fertilizers is a noticeable increase in its content in the arable layer of the soil.

In the variant with the annual introduction of a single norm of phosphorus and of its total amount for 57 years (4400 kg/ha a. s.) the content increased by 2660 mg/kg, and with the introduction of a one-and-a-half of its norm (6600 kg a. s.) by 2860 mg/kg of soil.

Light chestnut soil contains 15.0-25.5% of organic phosphates from total phosphorus amount.

In our experience in the soil of the field of beet crop rotation, the content of organic phosphorus fertilized with a single and one and a half norm of phosphorus fertilizer in the options was: 615-640 mg/kg, which is 25.1-25.4% of gross phosphorus, with its content in the initial soil 23.1%.

Regarding the option only with the introduction of nitrogen-potassium fertilizer, the increase in organic phosphorus is 16-20,8%, i.e., when applying phosphorus fertilizers, the content of organic phosphorus in the beet crop rotation increases significantly compared to the initial content and control, which should be considered as a positive fact.

The content of organic phosphorus under the permanent sugar beet was lower than in the crop rotation. The application of phosphorus fertilizers does not contribute to the accumulation of organic phosphorus in the soil, but on the contrary, it is reduced by 1.1-3.4% compared to crop rotation.

The marked difference in the change of the content of organic phosphorus could be due to more intense mineralization of organic matter in the soil of monoculture.

Thus, the content of organic phosphorus on the control version was 480 mg, on the nitrogen-potassium version 500 mg, the introduction of a single and one-and-a-half phosphorus norm on the permanent sowing of sugar beet reduced the content of organic phosphorus compared to the crop rotation to 585 and 590 mg/kg or 2.1-3.4%, respectively.

The content of mineral phosphorus in the soil increased from the application of phosphorus fertilizers. Thus, the introduction of a single and one-and-a-half norm of phosphorus in beet crop rotation increased it from 1737 to 1890 mg, with permanent cultivation on these options; the increase in mineral phosphorus was higher and ranged from 2063 to 2098 mg/kg. In general, the content of mineral phosphorus in light chestnut soil was higher than organic and ranged from 76.6-78.0%.

With the introduction of phosphorus fertilizers in beet crop rotation for 57 years of research the norm 2860 kg increases the content of mobile phosphorus in the arable layer to 50.0 or 2-3 times, with the introduction of a one-and-a-half norm or 4455 kg of phosphorus it was increased to 65.2 mg, i.e. 2.5-3.5 times, compared to its initial content and control option

When phosphorus fertilizers are applied on permanent crops of sugar beet, there is a greater accumulation of mobile phosphorus in the soil than in the conditions of beet crop rotation, also one

of the reasons for the increase in mobile phosphorus in permanent sowing can be annual stable norms of phosphorus fertilizer, whereas in crop rotation, the norms can change depending on the needs of crop rotation. So, when introducing 4400 and 6600 kg of a.s of phosphorus the content of mobile phosphorus increased in the arable layer to 66.1-70.6 mg, or 2-3 times compared to its initial content and 3-4 times compared to the control version.

Based on these data, it can be assumed that the method of B. Machigin with a mobile phosphorus content of less than 15 mg/kg of soil does not reflect the true stock of phosphates assimilated for plants in the soil.

The study of the fractional composition according to Ginzburg-Lebedeva showed that the systematic application of phosphorus fertilizers for 57 years led to an increase in the content of the amount of "active" mineral phosphates in which the number of loosely bound ($Ca\text{-}P_I$) and dissimilar ($Ca\text{-}P_{II}$) calcium phosphates increased not only in absolute, but also in relative terms to gross phosphorus.

If in the rotation in the arable soil layer on the initial background and on the control version the amount of loosened and mixed from was 22.2 to 30.2% of the amount of "active" mineral phosphates, then with the introduction of 3250 and 4455 kg/ha of phosphorus for 57 years, their value increases to 33.0 and 34.6%, respectively. The amount of phosphates of one and a half oxides practically did not change, their relative amount (percentage to the sum of phosphates) remained at the level of the initial and control variant, the quantitative composition changed insignificantly.

In light chestnut soil under crop rotation, the amount of high-basic phosphates (Ca-PIII) decreased in relative terms to 56.1 and 54.4% of the use of 3250 and 4455 kg/ha of phosphate fertilizers. On the initial background, control and nitrogen-potassium variants the relative content of high-basic phosphates was 58.7; 65.3 and 65.2%.

With the continuous cultivation of sugar beet, the relative decrease in high-base phosphates was 55.9 and 53.8% of the use of 4400 and 6600 kg/ha of phosphorus fertilizers. In the control and nitrogen-potassium variants their content was 66.2 and 65.9%.

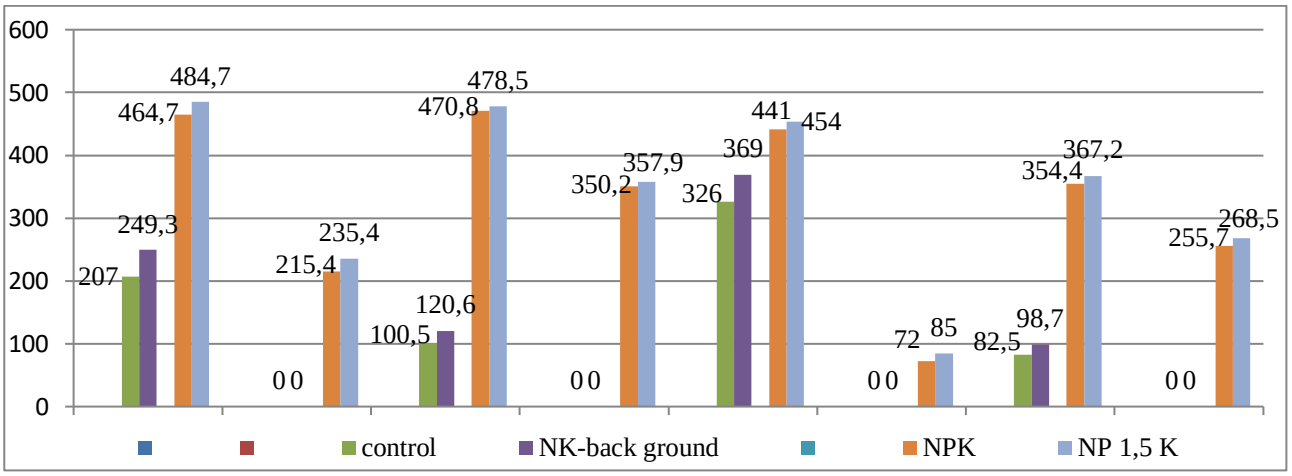
Thus, the long-term and systematic use of mineral fertilizers, in particular phosphorus, in the studied crop rotations increases the content of gross phosphorus in the soil. Moreover, the share of mineral phosphorus in irrigated chestnut soils is higher than that of organic phosphorus. The determination of the fractional composition of mineral phosphates showed that the content of the most soluble fractions of calcium phosphates ($Ca –P_I + Ca –P_{II}$) and high-basic calcium fractions ($Ca–P_{III}$) increased from the long-term and systematic use of single and one-and-a-half norms of phosphorus fertilizer both in crop rotation and in the permanent cultivation of sugar beet. However, when determining the fractional composition of mineral phosphates in autumn showed that there is a decrease in the content of the first two fractions ($Ca –P_I + Ca –P_{II}$), and the quantitative content of high-basic calcium fraction ($Ca–P_{III}$) increases. This is explained by the fact that the most soluble fractions of mineral forms of phosphates were used in the process of vegetation of cultivated plants, while the increase in the highly basic forms of mineral forms of phosphorus was due to the transition of soluble forms of phosphorus into a hard-to-reach form for plants. The content of phosphates of one and a half oxides (Al-P and Fe-P) in the studied soils is not more than 11-12% of the amount of mineral phosphates of the soil. The greatest number of phosphates of aluminum and iron is concentrated in the upper soil horizons, down the profile their number decreases.

The maximum yield of sugar beet was obtained with the systematic use of one-and-a-half norms of phosphorus fertilizers in crop rotation (in 1961-1975, 484.7 c and in 2012-2014, 478.5 centners/ha). However, there is a slight decrease in the yield of root crops, due to the accumulation of mobile phosphorus (44.7 mg), and the amount of loosely bound, dissimilar phosphates (520 mg/kg) in the soil as a result of the systematic use of increased norms of phosphorus fertilizers for previous crops. The yield of the control and the variant with only nitrogen and potassium (NK-background) fertilizers made 207,0 and 249,3 c/ha; 100.5 and 120.6 centners/ha respectively. The increase in the yield of root crops from phosphorus fertilizers in the crop rotation was 215.4-235.4 centners/ha for 15, and 350.2-357.9 centners/ha for 57 years (table 2, picture 1).

The data in table 2 show that phosphate fertilizers are also highly effective on permanent sugar beet crops. For 15 years of permanent sowing, the average yield increased from the introduction of phosphates by 72-85 centners/ha compared to the background.

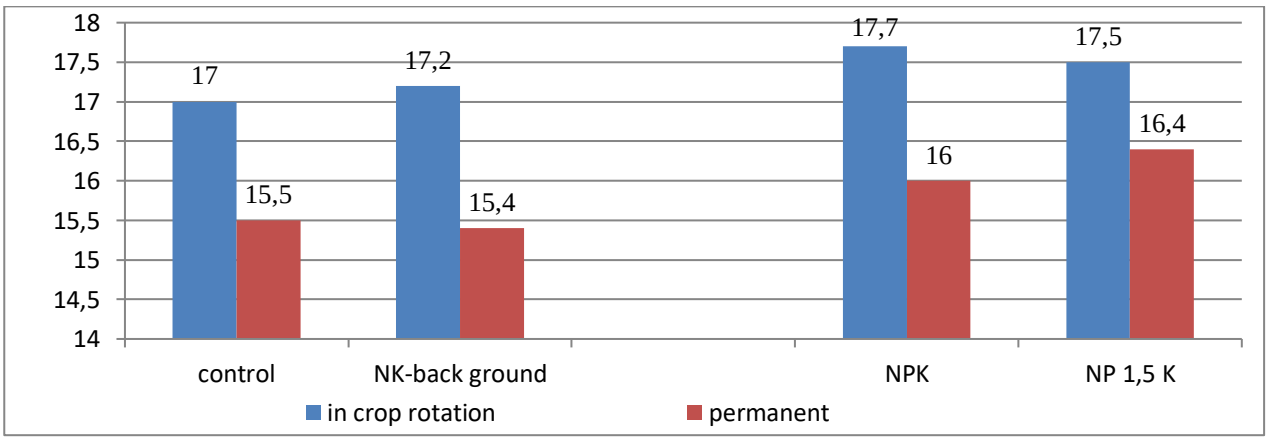
Table 2 - Effect of long-term use of fertilizers on sugar beet yield

Experience variants	Average yield of root crops, centners/ha								Sugar content %	
	in crop rotation				permanent sowing				in crop rota-tion	perman ent
	1961-1975		2017-2019		1961-1975		2017-2019			
	1*	2*	1	2	1	2	1	2		
control	207,0	-	100,5	-	326,0	-	82,5	-	17,0	15,5
NK-back ground	249,3	-	120,6	-	369,0	-	98,7	-	17,2	15,4
NPK	464,7	215,4	470,8	350,2	441,0	72,0	354,4	255,7	17,7	16,0
NP $_{1,5}$ K	484,7	235,4	478,5	357,9	454,0	85,0	367,2	268,5	17,5	16,4
1* - average yield of root crops; 2* - yield increase from phosphate fertilizers										



Picture 1. Effect of long-term use of fertilizers on sugar beet yield

However, since 1973, the introduction of a one-and-a-half norm of phosphorus does not give an increase in yield compared to the single norm. The longer the duration of permanent cultivation of sugar beet, the more reduced the yield of root crops. While permanent cultivation it is a significant accumulation of pathogenic fungi, which have a detrimental effect on the growth and development of sugar beet (picture 2).



Picture 2. Sugar content, %

It is also possible to note an increase in the sugar content of sugar beet roots in the crop rotation (17.0-17.7%) than in its permanent (16.0-16.4%) cultivation.

Conclusion

For 57 years of light brown soil use under crops of 7 fields beet crop rotation and in permanent sowing of sugar beet there is a significant change in the qualitative and quantitative composition of phosphorus compounds in the soil. The increase in the gross reserves of phosphorus in its long-term use mainly depended on the rate of fertilizers. Thus, when applying phosphoric fertilizers in the amount of 3250 kg of a. s. for 57 years, the content of gross phosphorus was 2647 mg/kg, when making 4455 kg of a. s. – 2814 mg/kg, at the initial content (in 1961) of 2210 mg/kg. In the variant without application of the phosphorous fertilizers, the content of total phosphorus decreased to 2050 mg/kg. The introduction of phosphorus on permanent crops of sugar beet contributes to a more significant increase in the reserves of gross phosphorus. The content of total phosphorus under permanent crops in the control and nitrogen-potassium variants practically do not undergo changes, while the application of phosphorus fertilizers has significantly increased its content in the arable layer of the soil. Annual introduction of a single norm of phosphorus and its amount (4400 kg/ha of a. s.) led to its increased content by 2660 mg/kg, and with the introduction of one and a half of its norm (6600 kg a. s.) by 2860 mg/kg of soil.

In the experiment (2017-2019), the content of organic phosphorus in the crop rotation on fertilized single and one and a half norm variants was: 615-640 mg/kg, which is 25.1-25.4% of the gross phosphorus, with its content of 23.1% in the initial soil.

With respect to the option only with the introduction of nitrogen-potassium fertilizer, the increase in organic phosphorus is 16-20,8%, i.e., with the introduction of phosphorus fertilizers, the content of organic phosphorus in the crop rotation increases significantly compared to the initial content and control, which should be considered as a positive fact. The content of organic phosphorus in permanent sowing was lower than in crop rotation. The application of phosphorus fertilizers does not contribute to the accumulation of organic phosphorus in the soil, but on the contrary, it is reduced by 1.1-3.4% compared to crop rotation. This could be due to the more intense mineralization of organic matter in the soil of the monoculture.

When introducing phosphate fertilizers in crop rotation in the norm of 3250 kg during 57 years, it increases the content of mobile phosphorus in the arable layer to 30.0 or 1.3-2 times, when making a one-and-a-half norm or 4455 kg of phosphorus the value increased to 45.2 mg, i.e. 1.9-3 times, compared to its original content and control option. When phosphorus fertilizers are applied on permanent crops, there is a greater accumulation of mobile phosphorus in the soil than in the conditions of crop rotation. One of the reasons for the increase in mobile phosphorus in permanent sowing is the annual stable norms of phosphorus fertilizer, whereas in crop rotation, the norms can change depending on the needs of crop rotation. Thus, with the introduction of 4400 and 6600 kg of phosphorus, the content of mobile phosphorus increased in the arable layer to 36.1-50.6 mg, or 1.5-2.5 compared to its initial content and 2.1-3.5 times in comparison with the control option.

Thus, studies have shown that the efficiency of phosphate fertilizers is twice higher in crop rotation than in permanent crops. At the same time, the efficiency of phosphoric fertilizers is determined by the content of mobile phosphorus and its close, direct reserves - the amount of loosely bound and dissimilar calcium phosphates. Conditions of phosphorus nutrition of sugar beet are dependent on the availability of soil mobile forms of phosphorus (the degree of fertilization with phosphorus), as well as from the predecessor.

Phosphorus fertilizers in soils eventually turn into less mobile forms. As a result of systematic application of phosphorus fertilizers phosphorus accumulates in the soil mainly in the form of mineral and partly in the form of organic compounds. In irrigated light chestnut soils phosphorus fertilizers, even with long-term interaction with the soil, almost all are in the form of "active" phosphates extracted by the method of Ginzburg-Lebedeva. In this case, several groups of phosphoric compounds are formed, characterized by different solubility. Due to the introduced phosphorus, the loosely bound phosphates decrease with the formation of multi-basic and partially high-basic ones. In the soil of crop rotation fields the most soluble phosphates (Ca-PI + Ca-PII) are less than under permanent crops, which is associated with a significantly higher yield of sugar beet.

Consequently, the accumulation in the soil of mobile phosphates and phosphates of loosely bound and mixed fractions is the basis for increasing the yields of sugar beet. However, soil enrichment with phosphorus above the optimal level leads to its unproductive costs, and low soil availability with phosphorus – to unproductive costs of nitrogen and potassium, and as a consequence of this to a shortage of harvest.

The optimal level of mobile phosphorus in the soil is the content of 30-45 mg/kg with the sum of loosely bound and dissimilar 385 - 445 mg/kg of soil.

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ҚАНТ ҚЫЗЫЛШАСЫН АУЫСПАЛЫ ЖӘНЕ ДАРА ЕГІСТІКТЕ АШЫҚ ҚОҢЫР ТОПЫРАҚТА ӨСІРУ КЕЗІНДЕ ФОСФОР ТЫҢАЙТҚЫШТАРЫН ҰЗАҚ ПАЙДАЛАНУДАН МИНЕРАЛДЫҚ ФОСФАТТАРДЫҢ САПАЛЫҚ ЖӘНЕ САНДЫҚ ҚҰРАМЫНЫҢ ТРАНСФОРМАЦИЯЛАНУЫ

Аңдатпа

Мақалада 50 жылдан астам дара егістіктегі қант қызылшасына фосфор тыңайтқыштарын ұзақ уақыт қолданудың әсері бойынша ашық қара-қоңыр топырағына фосфат формасын трансформациялауға және ауыспалы егістіктегі бірдей нұсқаларымен салыстырғанда оның өнімділігінің зерттеу нәтижелері келтірілген.

Ғылыми материалдың көптігіне қарамастан, Қазақстанда суармалы топыраққа фосфор тыңайтқыштарын енгізу ұзақтығының әсері жеткілікті түрде зерттелмеген. Тыңайтқыштарды қолдану ұзақтығының әсері туралы қолда бар оқшауланған деректер олардың дақылдың өнімділігі мен сапасына және ішінара топырақтың фосфатты режиміне әсерін бағалау аспектісіне қатысты. Зерттеулердің көпшілігі, ең алдымен, ауыл шаруашылығы дақылдарының өнімділігіне тыңайтқыштардың нақты мөлшерін анықтауға арналған қысқа мерзімді далалық тәжірибелер шеңберінде жүргізілді. Бұл далалық зерттеулер топырақтың құнарлылығы сипаттамаларының өзгеру уақытында және жеткілікті деңгейде жүргізілді, яғни фосфаттардың сапалық және сандық құрамын және олардың потенциалдық және тиімді құнарлылық деңгейі арасындағы функционалдық байланысын анықтауға мүмкіндік бермеді.

***Кілт сөздер*:** тыңайтқыш, ашық қара-қоңыр топырақ, дара егістіктегі қант қызылшасы, қызылшаның ауыспалы егістігі, қант қызылшасы, минералды азот, нитраттар, аммоний азоты, жылжымалы фосфор, жалпы фосфор, органикалық фосфор, минералды фосфор, минералды фосфаттардың фракциялық құрамы, қанттылық.

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ТРАНСФОРМАЦИЯ КАЧЕСТВЕННОГО И КОЛИЧЕСТВЕННОГО СОСТАВА МИНЕРАЛЬНЫХ ФОСФАТОВ В СВЕТЛО- КАШТАНОВОЙ ПОЧВЕ ПРИ ДЛИТЕЛЬНОМ ПРИМЕНЕНИИ ФОСФОРНЫХ УДОБРЕНИЙ В СЕВООБОРОТЕ И БЕССМЕННОМ ПОСЕВЕ САХАРНОЙ СВЕКЛЫ

Аннотация

В статье приводятся результаты исследований по влиянию длительного применения фосфорных удобрений на посевах бессменной сахарной свеклы более 50 лет на

трансформации форм фосфатов на светло-каштановой почве и ее урожайности в сравнении с идентичными вариантами севообороте.

Несмотря на большой практический материал, влияние продолжительности внесения фосфорных удобрений на орошаемых почвах Казахстана недостаточно изучено. Имеющиеся единичные данные о влиянии продолжительности применения удобрений относятся к аспекту оценки их влияния на урожай и качество урожая и отчасти на фосфатный режим почв. Большинство исследований проведено в рамках краткосрочных полевых опытов, которые призваны, прежде всего, установить конкретные дозы удобрений на продуктивность сельскохозяйственных культур. Данные полевые исследования проводились на достаточно узких фонах и временных рамках варьирования характеристик плодородия почв, что не позволило установить качественный и количественный состав фосфатов и их функциональную связь между уровнем потенциального и эффективного плодородия.

Ключевые слова: Удобрение, светло-каштановая почва, бессменный посев сахарной свеклы, свекловичный севооборот, сахарная свекла, минеральный азот, нитраты, аммонийный азот, подвижный фосфор, валовый фосфор, органический фосфор, минеральный фосфор, фракционный состав минеральных фосфатов, сахаристость.