

АГРОХИМИЯ

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APPLICATION OF MINERAL FERTILIZERS IN LAND CULTIVATION OF THE REPUBLIC OF KAZAKHSTAN

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Abstract. The effect of prolonged systematic application of fertilizers on the main indicators of fertility of irrigated light chestnut soils and productivity of agricultural crops is presented. Regression equations that describe a close positive interaction between the intensity of application of fertilizers, agrochemical soil indices, yield and product quality with a high degree of probability are calculated.

Key words: fertilizers, humus, nutrition elements, productivity, efficiency.

INTRODUCTION

Growth of productivity and development of domestic crop production on the basis of intensification, extensive use of natural and climatic potential of the republic, land and water resources, possibilities of new varieties is a strategic task of domestic land cultivation

The soils of Kazakhstan, with the exception of the northern regions, have a low level of natural fertility, and are subject to degradation, risk of desertification, manifestation of wind and water erosion. Most of arable land is characterized by a low concentration of humus and mobile forms of nitrogen, more than half of which are not provided with mobile forms of phosphorus, that is, they need the use of nitrogen and phosphorus fertilizers. In this connection, solution of the problem of effective use of arable land, preservation and improvement of soil fertility and, on this basis, productivity of agricultural crops in the republic, depends to a large extent on fertilizers application.

OBJECTS AND METHODS

An analysis of the efficiency of mineral fertilizer use on productivity of crops in sugar beets crop rotation and indices of fertility of irrigated light chestnut soils in the southeast of the republic was carried out on the basis of stationery experiments (long-term and multifactor) and data from

the Agency for Statistics of the Republic of Kazakhstan.

RESULTS AND DISCUSSION

Modern agriculture is in a state of permanent agro-technological revolution. It began in the 60-s of the last century with the development of intensive agricultural crop varieties, development and dissemination of intensive science-intensive agrotechnologies. The process of intensification of agriculture has covered practically all countries of the world. As a result, the average world yield of grain crops by the beginning of the new century exceeded the threshold of 3 t/ha, and in the advanced West European countries - 8 t/ha. It is important to note that in all countries the level of yield capacity directly depends on the level of application of mineral fertilizers [1, 2].

Currently, fertilizers are one of the main factors influencing crop productivity. Since 1950, the volume of fertilizers produced in the world has increased steadily and reached 148.8 mln tons by the beginning of the twenty-first century. Further high growth in production and consumption of fertilizers is forecasted, up to 20 % per year and by 2030 their consumption can reach 180 mln tons of a.s., mainly by developing countries - India, China, Vietnam, Brazil, Mexico, Venezuela, while leading industrial countries set the task of

more efficient use of the aftereffect of the long-term application of high fertilizer rates into soil [2, 3].

The perspective of the crop production development is associated with the use of modern intensive technologies, which increase the efficient use of the potential of new highly productive varieties, natural climatic and soil conditions [4]. In Krasnodar region of Russia fertilizers are used in a larger volume than in other regions and grain yields are about 5 t/ha. This is a significant merit of breeders and seed breeders in providing production with new highly-productive varieties of winter wheat [5].

Studies conducted by the research institutions of the republic and the practice of agricultural production convincingly proved the high efficiency of fertilizers in all natural and climatic zones of Kazakhstan. The results indicate a close interdependence between the level of fertilizers application, provision of soil with nutri-

tion elements and yield capacity of agricultural crops. It has been determined that rational scientifically based application of fertilizers contributes to the preservation and improvement of the basic indicators of soil fertility, ensuring increased yields and improved quality of crop production.

In Kazakhstan during the period of the chemicalization of agriculture from 1965 to 1986, the total amount of used mineral fertilizers increased from 170,4 to 1039.1 thous. tons of a.s., or 6.1 times. The amount of fertilizers applied per hectare of arable land increased from 3,6 to 29 kg NPK, and the fertilized area was 47 % (almost half) of the total area of arable land, versus 6,6 % in 1965 (figures 1-3).

The increased volume of application of mineral fertilizers during the chemicalization of agriculture contributed to a significant increase in the level of provision of arable lands of the country with basic nutrients (table 1).

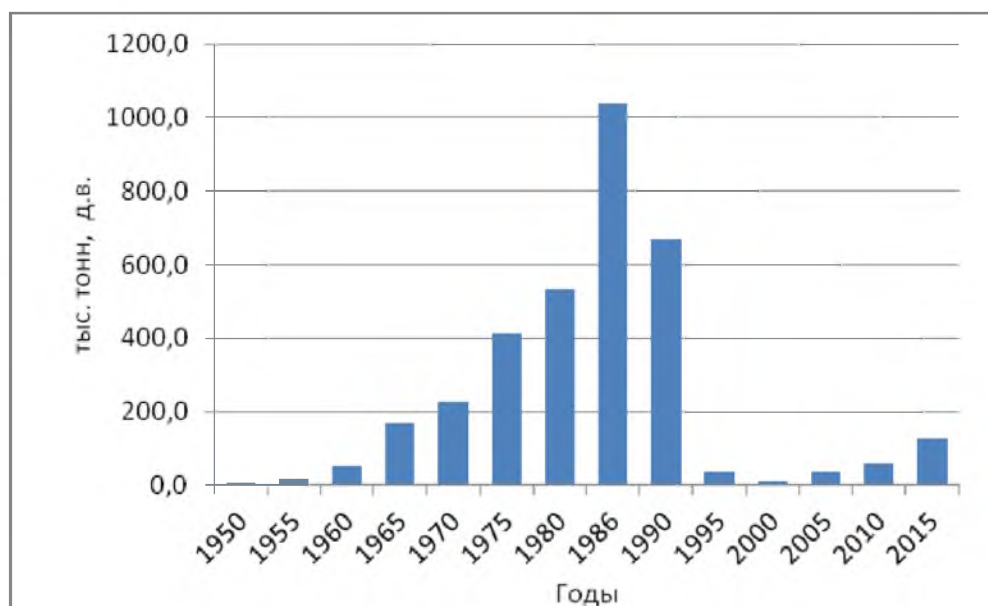


Figure 1 - Dynamics of the volume of application of mineral fertilizers in agriculture of the Republic of Kazakhstan for 1950-2015.

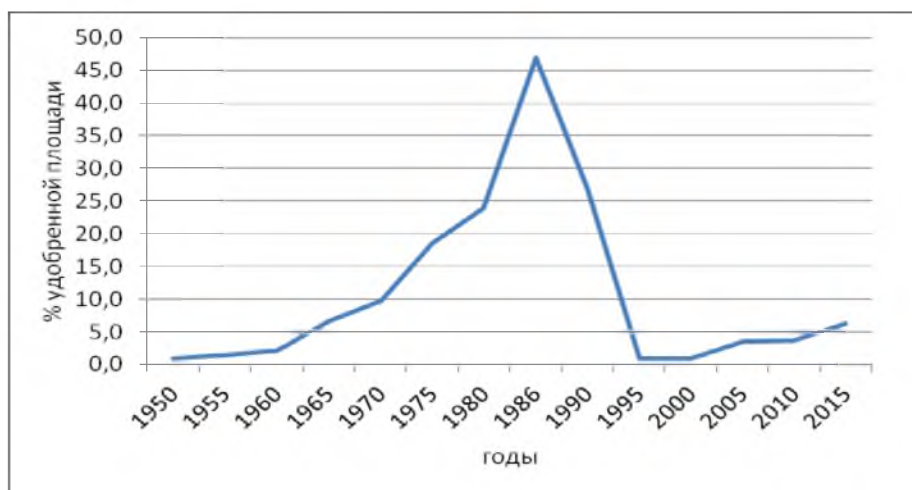


Figure 2 - Dynamics of the share of arable land fertilized with mineral fertilizers in the Republic of Kazakhstan for 1950-2015.

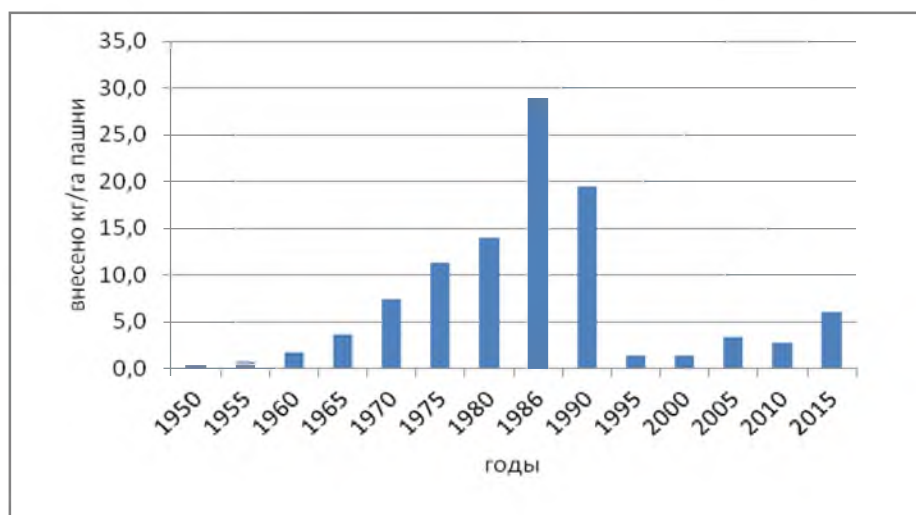


Figure 3 - Dynamics of mineral fertilizer application kg /ha a.s. in the Republic of Kazakhstan for 1950-2015.

Table 1 - Changes in the distribution of arable land by concentration of mobile forms of nutrients (in% of the surveyed area)

Survey of arable land, thous.ha	Level of content of nutrients	Mobile phosphorus				Exchangeable potassium			
		1972	1975	1987	2016*	1972	1975	1987	2016*
35505,3	low	72,3	68,8	44,5	43,9	2,2	4,1	1,9	0,9
	medium	24,5	26,4	40,5	40,3	7,3	8,8	6,4	4,4
	high	3,2	4,8	15,0	15,8	90,7	87,1	91,7	94,7
Note: * survey of arable land in 2016 - 24196,0 thous. ha									

According to the results of the first round of the entire agrochemical survey of the total area of arable land conducted in 1965-1972, 72,3 % were classified as soils that have low mobile phosphorus concentration, 24,5 % classified as a category with average concentration only and 3,2 % with a high concentration of mobile phosphorus. In a second survey conducted in 1975, the proportion of soils with a low concentration of mobile phosphorus decreased significantly, and the share of average and highly provided soils increased. In a survey conducted in 1987, the proportion of soil areas poorly provided with mobile phosphorus decreased to 44,5%, respectively, soil areas with an average and high level of provision have increased (table 1).

According to the forecast done by the Southeast branch of CINAО, if the growth rates of phosphate fertilizers keep increasing, by the year 2000 more than 75 % of the arable land will be average and well-provided with mobile phosphorus and only one-fourth of the arable land was classified as low-provided soils that are in great need of application of phosphorus fertilizers [6]. However, the results of a survey conducted in recent years (2016) showed that the availability of mobile phosphorus in the arable lands of the republic remained almost unchanged, and the proportion of soils that need phosphate fertilizers did not decrease (table 1).

Provision of soil with exchange potassium by agrochemical survey tours conducted during this period also did not change significantly, which is due to rather high concentration of this element in soils of the republic and low level of application of potassium fertilizers.

Agrochemical survey of arable land for humus concentration was conducted for the first time in the republic in 1983-1987 on an area of 31,6 mln ha (90 % of arable land). Synthesis and analysis of the data showed that 71,6 % of the surveyed lands were characterized by low humus

concentration (2,0-4,0 %), 23,9 % -average (4,1-6,0 %) and only 4,5% - high, and very high (6,1-10,0%) [6]. According to the agrochemical survey of recent years, the proportion of soils with low humus concentration has not changed and is 71,4 %. Soils with average concentration -26,6 % have increased and soils with high concentration -1,5 % decreased, which is due to the long-term use of arable land without sufficient organic fertilizer, which is the main source of humus replenishment. Scientific institutions of the Republic determined that in order to preserve and increase humus concentration in soils, it is necessary to annually apply 7-10 t / ha of manure. However, the level of application of organic fertilizers in the republic, especially in recent years, is much lower.

In general, it can be noted that increased volume of fertilizer application during the chemicalization of agriculture contributed to a significant improvement in the phosphate regime of the soils in the country, which had a positive effect on crop yields.

A sharp drop in the level of fertilization resulted in the decreased crop yields. The yield of sunflower and sugar beet decreased more than 2 times, maize for grain, rice, cotton and vegetables by one third (table 2).

In recent years, there has been a sustainable growth trend in the intensification of agriculture in the republic. The total volume of mineral fertilizers used in 2001-2005; 2006-2010 and 2010-2015 continuously increased correspondingly to 30,2; 49,3 and 110,0 thous. tons in terms of 100% active substance and increased in comparison with 2000, respectively, 2,4; 4,3 and 9,6 times. The share of sown areas that received mineral fertilizers increased 7,4 times in comparison with 2000. At the same time, the amount of mineral fertilizers applied per a hectare of arable land, on average in the country, increased 4,6 times and was 5,1 kg/ha. (Figures 1-3). This has a positive effect on increasing crop yields (table 2).

Table 2 - Dynamics of productivity of the main agricultural crops in the Republic of Kazakhstan.

Crop	Years						
	1961-1965	1986-1990	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
Wheat	6,1	9,2	7,6	8,4	10,2	10,5	11,6
Corn, grain	20,8	38,8	24,6	24,6	41,6	46,3	52,1
Rice	19,1	45,1	32,8	29,3	31,7	35,0	39,2
Sugar beets	235,8	288,0	115,0	138,0	199,2	210,2	219,4
Cotton	17,9	25,8	20,1	17,4	21,8	20,0	25,9
Sunflower	-	9,9	3,6	3,6	6,2	5,2	6,4
Potato	75,0	106,2	95,0	92,6	139,0	151,2	176,9
Vegetables	66,1	164,6	109,0	119,6	179,4	209,1	236,9

Analysis of statistical data on fertilization of major crops for 2011-2015 in the south-east of the republic indicates that the level of mineral fertilizer application was low, significantly lower than the standards recommended by research organizations. Wheat fertilization in Almaty and Zhambyl regions was 2,3-2,8, maize for grain -45,2-51,3, rice -40,7, sugar beet -32,4-36,1, sunflower -6,1-12,4 kg/ha a.s., potatoes 6,2-24,9, vegetables 26,2-20,5 with average indices in the country 2,9; 51,6; 170,9; 71,1; 1,9; 24,7; 60,1 kg/ha of a.s. respectively. Conducted analysis of provision with fertilizers convincingly demonstrates that there are large reserves of increasing crop yields in case of application of scientifically-based fertilizer rates.

Fertilizers are one of the main factors affecting crop productivity and soil fertility. Studies of the Kazakh Research Institute of Land Cultivation and Crop Production, conducted on irrigated light chestnut soils of the southeast of the Republic, determined that long-term crop cultivation without the use of fertilizers leads to depletion, deterioration of the provision of soil with nutrients accessible to plants.

Humus plays an important role in the formation of soil fertility and in in-

creasing sustainable agriculture. The physicochemical and biological properties of the soil largely depend on humus concentration, moreover humus is a source of plant nutrition. Soil humus, its concentration and composition are subject to significant fluctuations depending on the characteristics of cultivated crops, soil cultivation, moisture and aeration regime, and the level of agrotechnics [7-9]. Preservation and increase of soil organic matter - is the most important condition for soil cultivation, fertility optimization and prevention of degradation.

In studies conducted in stationary experiments, it was determined that in long-term cultivation of crops in crop rotation without fertilizers, humus concentration in the variant without fertilizers decreased by 0,37 % in the arable layer versus the initial one, and in the subsoil layer by 0,34 % (table 3).

In systematic application of the total mineral fertilizer to the crops of the 8-field sugar beet crop rotation, humus concentration in the upper soil layer decreased by only 0,10 % by the end of the fifth rotation in comparison with the initial one and was 2,50 %, and in the lower layer 0,15 %. In using a full mineral fertilizer together with 60 t/ha of manure, humus concen-

tration in the upper soil layer increased by 0,09 % versus the original and was 2,69 % once for crop rotation. In the lower soil layer, humus concentration during this period decreased, but to a lesser extent than in the variant without fertilizers (table 3).

Table 3 - Change in humus concentration and mobile nutrient elements in irrigated light chestnut soil for 40 years.

Variant	Humus, %		Mobile P ₂ O ₅ , mg/kg		Exchangeable K ₂ O, mg/kg	
	Soil layer,cm					
	0-20	20-40	0-20	20-40	0-20	20-40
Without fertilizer	2,23	2,16	16,9	14,0	119	418
NPK	2,50	2,35	39,7	28,9	601	524
Manure 60t/ha+ NPK	2,69	2,45	52,3	45,4	765	717
Initial, 1961	2,60	2,50	24,0	19,5	525	470

The reserves of humus in soil in the variant without application of fertilizers decreased by the end of the fifth rotation by 6,9 t/ha in the upper layer and by 1,7 t/ha in the lower layer. In using full mineral fertilizer, by the end of the fifth rotation the reserves have stabilized at the level of the initial values, in the lower layer they increased by 3,1 t/ha. In joint application of mineral fertilizers and manure, extensive reproduction of humus in soil has been achieved. Its reserves increased versus the initial values by 4,8 t/ha in the upper and 5,7 t/ha in the lower layer.

The results of research carried out in a multifactor experiment made it possi-

ble to calculate the equation of the dependence of humus concentration in irrigated light chestnut soil in systematic application of increasing fertilizer rates for 25 years. It has been determined that humus concentration increases with the increase of the rate of introduced manure (H), and has a rectilinear character and is described with a sufficient degree of probability by the regression equation: $Y = 2,47 + 0,06H$ at $R = 0,594$. The introduction of increasing rates of manure for three rotations of the eight-field crop rotation provides an increase in humus concentration by 0,06-0,24 % (figure 4).

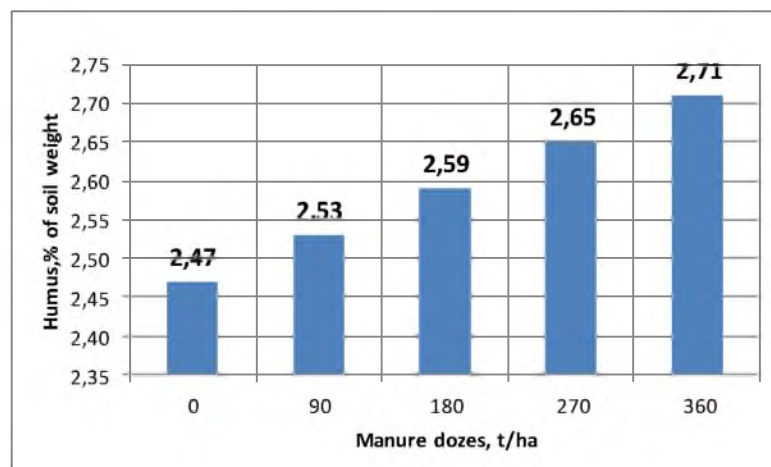


Figure 4 - Effect of periodic application of manure on humus concentration in the 0-30 cm layer of light chestnut soil during 25 year period (1991-2016).

Phosphorus is an important element of plant nutrition. Its lack in soil adversely affects the growth, development and formation of crop yields. The low level of provision of soils of the south-east of the republic with mobile phosphorus in many respects limits the increase in the productivity of field crops. Long-term investigations of K.I. Imangaziev [7], A.T. Ponomareva [9], B.S. Basibekov [10], R.E. Yeleshev [11], conducted in the south-east of the republic, determined the formation of soil phosphate regime of the region, optimal values of the level of provision of soil with mobile phosphorus for the main field crops, the values of removal and the coefficients of the use of soil phosphorus and fertilizers were calculated. Scientific recommendations on the effective use of phosphorus fertilizers have been developed.

In a long-term stationary experiment, the initial concentration of mobile phosphorus in the upper soil layer was at the level of 24,0 mg/kg. When cultivating crops in crop rotation in five rotations

without the use of fertilizers, the concentration of mobile phosphorus decreased by 7,1 mg/ kg in the upper soil layer and 5,5 mg /kg in the lower soil layer versus the baseline values (table 3).

In systematic application of a full mineral fertilizer, the concentration of mobile phosphorus in soil by the end of the fifth rotation on fertilized variants in the upper layer was at the optimal level, in combined use of mineral and organic fertilizers at a high level. It is important to note that when using fertilizers, the availability of mobile phosphorus in lower soil layers has also significantly improved (table 3).

In a multifactor stationery experiment, a direct relationship between the rate of application of fertilizers, the duration of their application, and the provision of soil with mobile phosphorus was determined. Based on the results of the studies, a regression model has been developed that highly describes the effect of phosphorus fertilizers and manure on the concentration of mobile phosphorus in soil:

$$Y = 24,7 + 9,1P + 15,7PH \text{ at } R = 0,930.$$

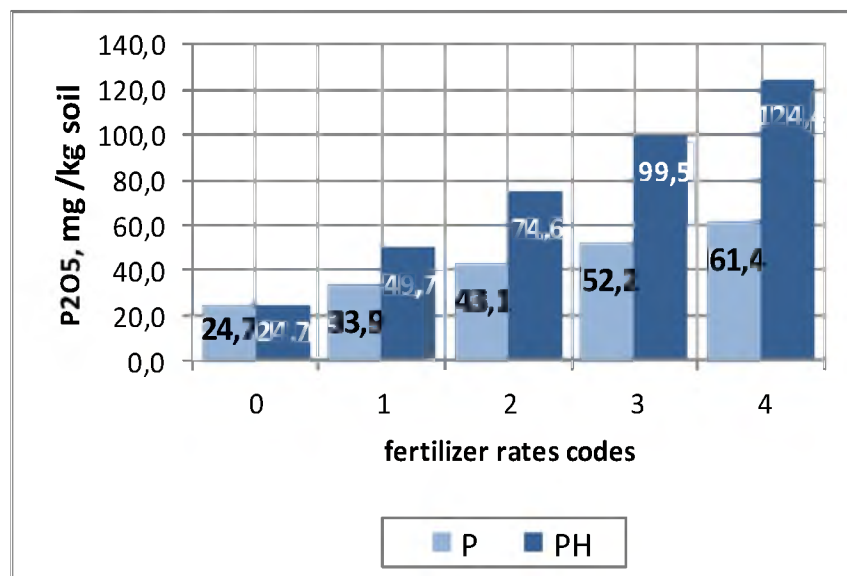


Figure 5 - Effect of long-term use of fertilizers on the content of mobile phosphorus in a 0-30 cm layer of irrigated light chestnut soil (1991-2016)

Separate application of manure did not lead to a significant increase in the concentration of mobile phosphorus in soil, while the combined application of manure and phosphorus fertilizers provided a fivefold increase in comparison with the variant without fertilizers.

In a long-term stationary experiment, the systematic application of fertilizers ensured an improvement in potassium regime of irrigated light chestnut soils (table 3). Soils of Kazakhstan are well provided with exchangeable potassium. However, long-term cultivation of crops without fertilizers resulted in a significant reduction in the concentration of exchangeable potassium in soil. Thus, by the end of the fifth rotation, the concentration of exchangeable potassium decreased by 76 mg/kg in the upper and 52,0 mg/kg - in

the lower soil layer. At the same time, the level of provision of soil with exchangeable potassium continued to be high. On variants with application of only mineral fertilizers, by the end of the fifth rotation, the concentration of exchangeable potassium in soil increased by 76 mg/kg in the upper and 54 mg/kg in the lower layers. In combined use of mineral fertilizers and manure, this increase was 240 and 247 mg/kg of soil, respectively.

In a multifactor stationary experiment it was determined that the efficiency of manure and potassium fertilizers on replenishing the reserves of exchange potassium in soil is almost the same, which is well described by the regression equation: $Y=343+29,9K+29,8H$; $R=0,810$; and is illustrated in Figure 6.

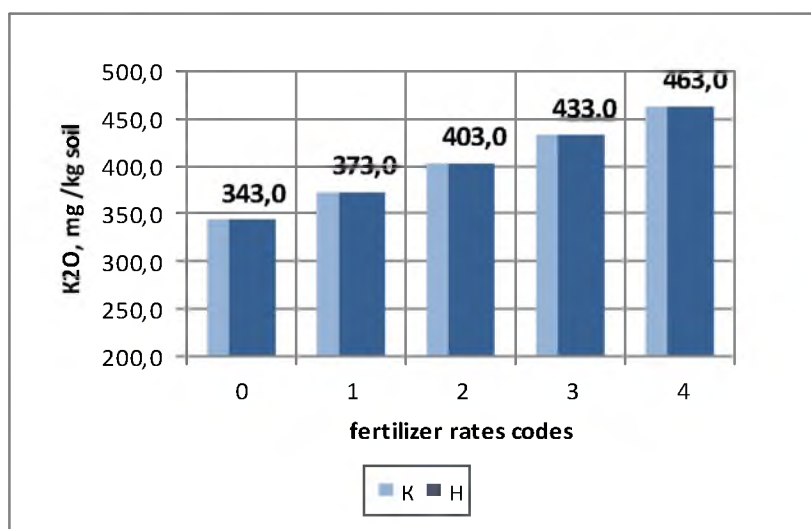


Figure 6 - Effect of long-term use of fertilizers on concentration of exchange potassium in 0-30 cm layer of irrigated light chestnut soil (1991-2016)

Fertilizers, having a positive effect on the nutrient regime of irrigated light chestnut soils, contributed to the increased productivity of crops in sugar beet crop rotation (Table 4).

As noted above, in long-term cultivation of crops in crop rotation without application of fertilizers, deterioration of

the main agrochemical indicators of irrigated light chestnut soil was observed, which caused a sharp decrease in yield and product quality. Thus, the yield of sugar beet in the fifth rotation with the use of fertilizers increased more than twice, in comparison with the control variant, winter wheat grain - more than three times,

maize of medium-ripen hybrids - 1,4 and alfalfa hay - almost 1,5 times. At the same time, the product quality has improved significantly - sugar content of root crops has increased by 2,7-2,8 %, the content of

raw protein in wheat grain by 1,8-2,3 %, and in corn grain 1,8 %. High yields of good quality were obtained in systematic joint application of mineral and organic fertilizers.

Table 4 - Impact of long-term systematic application of fertilizers on the yield and quality of crops in sugar beet crop rotation in the fifth rotation.

Variant	Sugar beets		Winter wheat		Corn	Alfalfa
	Yield capacity, c/ha	Sugar content, %	Yield capacity, c/ha	protein, %	Yield capacity, c/ha	Yield capacity, c/ha
Without fertilizers	152	13,1	23,9	12,2	70,1	110,6
NPK	459	15,9	49,0	14,0	99,4	152,5
Manure 60t/	431	15,8	48,4	14,5	101,9	157,8

CONCLUSION

Thus, the practical experience of long-term chemicalization of land cultivation and the results of the research indicate a low level of use of fertilizers in farming of the republic. The use of fertilizers in such volumes does not significantly

affect soil fertility, the yield volume and product quality. At the same time, fertilizers are a powerful factor of impact on plants and their scientifically based, timely application ensures sustainable good quality yields, preservation and improvement of soil fertility.

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ТҮЙІН.

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ЕГІНШІЛІГІНДЕ МИНЕРАЛДЫ
ТЫҢАЙТҚЫШТАРДЫ ҚОЛДАНУ

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Тыңайтқыштарды ұзақ мерзімді жүйелі қолданудың суармалы ашық қара-қоңыр топырақтар құнарлылығының негізгі көрсеткіштеріне және ауыл шаруашылығы дақылдарының өнімділігіне әсері көрсетілді. Тыңайтқыштарды үдемелі қолданудың топырақтың агрохимиялық көрсеткіштері, өнімділігі және өнім сапасы арасындағы жоғары дәрежелі тығыз болымды өзара қатынасын көрсететін регрессиялық теңдеулер есептелді.

Түйінді сөздер: тыңайтқыш, қара шірінді, қоректік элементтер, өнімділік, тиімділік

РЕЗЮМЕ

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ПРИМЕНЕНИЕ МИНЕРАЛЬНЫХ УДОБРЕНИЙ В ЗЕМЛЕДЕЛИИ
РЕСПУБЛИКИ КАЗАХСТАН

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Показано влияние длительного систематического применения удобрений на основные показатели плодородия орошаемых светло-каштановых почв и продуктивность сельскохозяйственных культур. Рассчитаны уравнения регрессии, описывающие с высокой степенью вероятности тесную положительную взаимосвязь между интенсивностью применения удобрений, агрохимическими показателями почвы, урожайностью и качеством продукции.

Ключевые слова: удобрения, гумус, элементы питания, продуктивность, эффективность.