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INFLUENCE OF MINERAL FERTILIZERS ON THE YIELD OF WINTER BARLEY IN CONDITIONS OF ALMATY REGION

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Abstract. The paper presents a comparative analysis of the application of different types of mineral fertilizers in cultivation of winter barley on ordinary grey soil, grown in conditions of low concentration of nitrogen. The use of mineral fertilizers improves soil nutrition regime, has a positive effect on growth, development (r = 0.948), and winter barley yield and provides conventionally net income. The application of phosphorus fertilizers containing sulfur improves plants growth and development (r = 0.943), increases productivity of winter barley.

Key words: common grey soil, sulfur-containing fertilizers, mass of seeds, yield, economic efficiency.

INTRODUCTION

Barley - is a crop which is used for different purposes. Its grain is used for making cereals and other food products. This is a valuable raw material for brewing industry. The main amount of gross harvest is used for fodder (about 70 %). The barley grain is rich in nutrients, mainly starch and protein (11-15 %). It contains the entire set of essential amino acids, including those especially deficient, such as lysine and tryptophan [1].

The demand for barley grain grows very rapidly, which is explained by many reasons, in particular, by the fact that in Kazakhstan there is a rapid growth of livestock production [2].

Barley is the second most important grain crop after wheat. The area under barley in the world is 82 mln ha including 2.5 % in Kazakhstan. In the republic, barley areas previously occupied more than 7 mln ha. Currently barley occupies the largest area of fodder-grain crops in the country that is up to 2 million hectares. On average, in five years (2011-2015), the gross grain harvest amounted to 2342 thousand tons in average barley yield 13.1 c/ha, and in 2016 the increase in grain yield to 17.3 c/ha has been observed [3].

In southern Kazakhstan, as well as in Central Asia as a whole, barley is mainly grown during the autumn planting season. Further movement of it to the northern regions is largely due to the progress in breeding of frost resistant varieties, and it is necessary to justify and develop a concept for the synthesis of qualitatively new genotypes of winter barley and develop varieties that can significantly expand the range of cultivation of this crop in Kazakhstan [4].

Winter barley is mainly cultivated in the south and southeast of Kazakhstan. Among winter cereals, it has the shortest vegetation period, since it is sown after rye and wheat, and in the summer it ripens about two weeks faster.

Fertilizer is one of the main factors of maintaining and improving soil fertility, obtaining consistently high yields of good quality agricultural crops. Plants grow better and develop on soils where all necessary nutrition elements and favorable climatic conditions are available. Meanwhile, in the soil, nutrient reserves are not endless and can decline as they are used by the harvest [5-6].

For the full growth and development of plants, the following macronutrients are necessary: N, P, K, Mg, Ca, Fe. Sulfur is also one of the necessary and irreplaceable elements of mineral nutrition of cereals.

Sulfur is an essential nutrient element to improve the quality and growth of crop yields [7]. Sulfur deficiency results in decrease of the yields and quality of agricultural crops and consequently the decrease of economic indicator. In addition, sulfur enhances the growth and absorption of the root system, as well as increases absorption and accumulation of plant essential elements [8]. The use of sulfur-containing fertilizers is very important in different soil and climatic zones for the increase of the yield and quality of crops.

Sulfur also enhances better use of nitrogen and phosphorus by plants, increases the resistance of plants to drought and diseases. This causes the need for the research aimed at studying the use of sulfur-containing fertilizers in cultivation of cereals, legumes and fodder crops [9]. The use of sulfur-containing fertilizers becomes relevant as a result of increasing crop yields, changing crop rotation structure, reducing the volume of organic fertilizer application, and reducing the use of fertilizers containing sulfur.

The novelty of the research lies in the study of the effectiveness of application of fertilizers containing micronized sulfur (ammophos, P_2O_5 – 42 %, N – 11 %, S – 10 %, sulfur particle size from 5 to 200 microns) for cereals (winter wheat, winter barley) in the south and southeast of Kazakhstan. According to the test results, micronization of Kazakhstani element sulfur with ammophos at the domestic enterprise KazFosfat LLP is possible for wide application in agricultural production. The obtained data allow to draw a conclusion about high responsiveness of winter barley to various levels of mineral nutrition, the effect of fertilizers application on the yield.

OBJECTS AND METHODS

Field research was carried out in Karasai district of Almaty region. Soil is ordinary grey soil. Crop - winter barley, variety "Bereke 54".

Variety of winter barley "Bereke 54", mid-ripening, vegetation period 160-200 days in conditions of the south of Kazakhstan. Resistant to lodging, drought resistance is high, it does not crumble. The potential yield is 50 c/ha., it is zoned for cultivation in Almaty, Zhambyl and South Kazakhstan regions. Authors Baytuganov S., Urazaliev R.A., Abdullaev K., Baytemirova J. South-Kazakhstan region, Saryagash district, village Kyzylsarkyrama, LLP "Krasnovodopad breeding experimental station".

Common grey soils occupy the strip, adjusted to the middle part of the slightly inclined plains of the Karatau Range, Kirghiz, Zailiisky and Dzungar Alatau, within the absolute heights from 600 to 800 m. The relief is hilly and straggly. Soil-forming rocks are represented by loess and loess-like loam, to a lesser extent boulder-pebble sediments. Vegetation is mainly represented by wormwood.

In the upper horizon of grey soils, humus concentration varies from 1.5 to 2 %, nitrogen from 0.11 to 0.13 %.

Irrigated common grey soils are characterized by a lower concentration of humus and total nitrogen, which is explained not only by small amount of organic matter entering the soil, but also by their rapid mineralization, caused by high activity of microbiological processes under irrigation conditions.

By concentration of hydrolyzable nitrogen, ordinary grey soils belong to the sufficient soils, the nitrogen concentration decreases in irrigation. The concentration of mobile phosphorus in the plow layer of ordinary grey soils varies from 20 to 40 mg/kg and when irrigation is less than 15 mg/kg. Ordinary grey soils are well supplied with mobile potassium, its concentration reaches 270-470 mg/kg in the plow layer and more than 270 in the subsoil.

The climate of the region is sharply continental. The average temperature in

January is -6-9°C, in July 22-24°C. The annual amount of precipitation is 300-500 mm, of which 244 mm during the growing season. The average relative air humidity is 56 %. The sum of temperatures above 10ºC is 3359. In winter, in some years, frosts reach -42ºC, and in summer an absolute maximum is 44ºC. The average monthly temperature indicators in January (+0,8°C) and in July (+23,9°C). The last frost on soil is on May 5, and the first frost on October 10. The frost-free period lasts 156 days.

Field experiment was conducted according to the following scheme: 1) Control (without fertilizers); 2) $P_{(1)-60}$; 3)$P_{(2)-60}$; 4)$N_{60}K_{30}$; 5)$N_{60}P_{(1)-60}K_{30}$; 6)$N_{60}P_{(2)-60}K_{30}$. (1 - ammophos, 2 - ammophos + S).

The area of registration plot is 50 m^2. The repetition is 3-fold, the total area of the experiment is 900 m^2. In the experiments the following mineral fertilizers were used: ammonium nitrate (N-34 %), ammophos (P-46 %, N-11 %) and ammophos containing micronized sulfur (P-40 %, N-11 %, S-10 %) and Potassium chloride (K-60 %). According to the experiment scheme, the following mineral fertilizers were applied: phosphate and potash fertilizers in the autumn before sowing, nitrogen fertilizers in the spring. During the vegetation period, soil samples were selected on layers 0-20; 20-40; 40-60 cm.

Research works were conducted in accordance with generally accepted methods of soil and agrochemical research, where all existing norms and rules of technological and environmental safety were observed, in accordance with the requirements of State standards.

Soil chemical analyzes were carried out according to the following methods. Determination of organic matter according to GOST 26213-91; Mobile compounds of phosphorus and potassium by method of Machigin in modification of CINAO GOST 26205-91; Easily hydrolyzable nitrogen according to Tyurin-Kononova; Granulometric composition of soil by solution of sodium pyrophosphate; pH by potentiometric method; CO_2 by calcimeter using the Golubev method, GOST 26490-85; concentration of gross sulfur in accordance with GOST 32599.2-2013, determination of mobile sulfur by extracting a solution of potassium chloride from soil according to GOST 26490-85 according to CINAO method [10].

For statistical processing of the obtained data, dispersion and correlation analyzes were carried out with the help of Excel and SPSS Statistics V23 programs.

RESULTS AND DISCUSSION

According to agrochemical data, soil is characterized by the following indicators: it has high mobile forms of phosphorus (66-74 mg/kg) and potassium (357-383 mg/kg) and has low - easily hydrolyzable nitrogen (30.8-33.6 mg/kg). The total humus concentration in the upper 0-20 cm soil layer is low (1.81 %), and decreased to 1.23 % in depth (table 1). The concentration of mobile sulfur is low, in the range of 4.0-4.5 mg/kg soil. The investigated soils are medium loamy, low-carbonate (1.33-2.12 %), medium alkaline (8.42-8.44).

Table 1 – Average indices of initial grey soils status

Depth, cm	Humus, %	Mobile forms, mg/kg			Sulfur		CO_2	pH
		Nhydro.	P_2O_5	K_2O	Gross, %	Mobile, mg/kg		
0-20	1,81	33,6	74	383	0,026	4,5	1,33	8,42
20-40	1,50	30,8	66	357	0,016	4,3	1,42	8,44
40-60	1,23	28,0	65	277	0,015	4,0	2,12	8,50

Barley responds well to mineral fertilizers application. Nitrogen fertilizers have the greatest influence on grain yield volume and quality. Provision of plants with phosphorus enhances root system development, the formation of a large ear, better accumulation of starch in grain, increase in its extractivity. Application of potassium in winter barley is also important, as plants are intensively supplied with potassium from the first days of growth to the very flowering period. It strengthens the stems, reduces damage from diseases, increases grain fullness [11].

Plant productivity is one of the main aggregate features, which consists of many elements of crop structure and their optimal combination. Some elements of the structure are conditioned by variety and specific features, have a small variability (length of the ear, number of grains in the ear) and are closely dependent on external conditions.

According to our research, mineral fertilizers have a significant effect on main elements of the winter barley yield structure. Thus, the height of barley plants in the control variant (without fertilizers) was 74.0 ± 1.02 cm. The use of phosphorus fertilizers, ammophos and sulfur-enriched ammophos (variants 2 and 3) increases the height of barley plants to 79.9 ± 1.48 (r = 0.958) -81.6 ± 1.57 (r = 0.393) cm (Table 2). In option 4 - the application of nitrogen and potassium fertilizers increases the plants height to 94.0 ± 1.0 cm (r = 0.969). The joint application of nitrogen, phosphorus and potassium fertilizers (variants 5-6) increases this indicator to 99.3 ± 1.95 -100.9 ± 1.32 cm (r = 0.948, 0.943).

The number of barley stems also depends on application of mineral fertilizers and increases from 3.0 ± 0.33 to 3.8 ± 0.36 pieces in comparison with the control variant (2.8 ± 0.27 pieces).

The quantity of grains in the ear is very important. The quantity of grains of the ear of winter barley varies depending on the use of mineral fertilizers. Thus, the quantity of grains in the ear in the control variant is 20.0 ± 2.13 pcs. The application of fertilizers increases this index from 25.2 ± 1.5 to 36.8 ± 1.91 pcs. The application of fertilizers as a whole had a weak positive effect on the increase in the quantity of grains in the spike (in comparison with the control), except for the variant with application of $N_{60}P_{60}K_{30}$, where the differences were significant (r = 0.519; p = 0.084).

One of the main indicators of stable and high yield is the mass of 1000 grains. On the control variant without fertilizer application, the mass of 1000 grains was 28.2 grams. The greatest value of the mass of 1000 grains was observed in variants 5 and 6, where the mass of 1000 grains was higher by 2.3-2.5 grams.

Table 2 - Indicators of the winter barley yield structure

Variants	Height, cm	Number of stems, pieces	Quantity of grain in the ear, pieces.	Weight of 1000 grains	
				gram	Deviation from control, g
Control	74,0 ± 1,02	2,8 ± 0,27	20,0 ± 2,13	28,2	-
$P_{(1)-60}$	81,6 ± 1,57	3,0 ± 0,33	25,2 ± 1,50	29,0	+0,8
$P_{(2)-60}$	79,9 ± 1,48	3,1 ± 0,33	27,1 ± 2,78	29,3	+1,1
$N_{60}K_{30}$	94,0 ± 1,00	3,0 ± 0,41	28,2 ± 1,73	30,0	+1,8
$N_{60}P_{(1)-60}K_{30}$	100,9 ± 1,32	3,5 ± 0,36	33,3 ± 1,92	30,5	+2,3
$N_{60}P_{(2)-60}K_{30}$	99,3 ± 1,95	3,8 ± 0,36	36,8 ± 1,91	30,7	+2,5
Note: 1 – ammophos, 2 –ammophos + S					

Despite the high concentration of mobile phosphorus (66-74 mg/kg) and exchange potassium (357-383 mg/kg) in soil, the effectiveness of mineral fertilizers is observed during the growth of winter barley. Thus, the use of ammophos (P_{60}) provided an increase in grain by 2.1 c/ha (12.3 %) compared to the control - without the use of fertilizers (Table 3). In variant with addition of ammophos (P_{60}) containing 10 % micronized sulfur, the gain increased to 3.5 c/ha, i.e. The use of sulfur only increases the additional yield of winter barley grain by 1.4 c/ha.

The joint application of ammophos with nitrogen-potassium fertilizers ($N_{60}P_{60}K_{30}$) provides grain increase to 6.4 c/ha, while the use of ammophos with sulfur (version 6) on the background of nitrogen-potassium fertilizers slightly increases this index to 7.2 c/ha. The variant with application of nitrogen-potassium fertilizers ($N_{60}K_{30}$) ensured the increase in grain - 4.7 c/ha in comparison with the control, which is slightly higher than with application of ammophos and less in comparison with the full dose of mineral fertilizers ($N_{60}P_{60}K_{30}$).

Table 3 – Winter barley yield, c/ha

№	Variants	Grain yield, c/ha	Increase	
			c/ha	%
1	Control	17,1	-	-
2	$P_{(1)\text{-}60}$	19,2	2,1	12,3
3	$P_{(2)\text{-}60}$	20,6	3,5	20,5
4	$N_{60}K_{30}$	21,8	4,7	27,5
5	$N_{60}P_{(1)\text{-}60}K_{30}$	23,5	6,4	37,4
6	$N_{60}P_{(2)\text{-}60}K_{30}$	24,3	7,2	42,1
	HCP_{095} -1,9 c/ha, P - 3,97			
Note: 1 – ammophos, 2 –ammophos + S				

As it can be seen from the data obtained, winter barley responds well to the application of sulfur with sufficient concentration of macronutrients into the soil and systematic application of nitrogen-phosphorus-potassium fertilizers. Similar results in other soil-climatic conditions are also achieved in terms of balanced nutrition of plants with nitrogen, phosphorus, sulfur and zinc [12].

The calculation of economic efficiency of mineral fertilizers makes it possible to estimate their payback, taking into account all costs. Table 4 shows economic efficiency of the application of mineral fertilizers in winter barley. In 2016, the cost of 1 ton of winter barley grain is 48,000 tenge. The conventionally net income from joint application of different types of mineral fertilizers ranges from 10.4 to 14.3 thousand tenge per hectare. The conditionally net income from the use of ammophos and sulfur amounted to 5.05 thousand tenge, which is significantly higher in comparison with ammophos.

Table 4 - Economic efficiency of application of mineral fertilizers in winter barley

Experiment variant	Additional yield from fertilizers, kg/ha	Cost of additional yield, tenge/ha	Costs of purchase and application, tenge/ha	Conditionally net income, tenge/ha
$P_{(1)\text{-}60}$	210	10080	9435	645
$P_{(2)\text{-}60}$	350	16800	11750	5050
$N_{60}K_{30}$	470	22560	12112	10448
$N_{60}P_{(1)\text{-}60}K_{30}$	640	30720	17655	13065
$N_{60}P_{(2)\text{-}60}K_{30}$	720	34560	20243	14317

CONCLUSION

By agrochemical data, ordinary grey soils are highly supplied with mobile forms of phosphorus (66-74 mg/kg) and potassium (357-383 mg/kg) and are low-supplied with easy hydrolyzable nitrogen (30.8-33.6 mg/kg). The total humus concentration in the upper 0-20 cm soil layer is low (1.81 %). Soils are poorly provided with gross and mobile forms of sulfur.

The use of mineral fertilizers improves soil nutrition regime. The combined use of nitrogen and potassium fertilizers ($N_{60}K_{30}$) increases the yield of winter barley by 27.5 % compared to the control variant. The introduction of ammophos provides the increase of the yield by 12.3 %. The use of ammophos with sulfuric nitrogen-potassium background ($N_{60}K_{30}$) contributes to the increase to 42.1 %.

Our data indicate that ammophos containing sulfur has a positive effect on growth, development (r = 0.943) and productivity of winter barley. High economic efficiency of various kinds of mineral fertilizers is observed. Conditionally pure income from joint use of mineral fertilizers ranges from 10.4 to 14.3 thousand Tenge per hectare. The application of ammophos with sulfur on a nitrogen-potassium background increases the conditionally net income.

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АЛМАТЫ ОБЛЫСЫНЫҢ ЖАҒДАЙЫНДА КҮЗДІК АРПАНЫҢ ӨНІМІНЕ МИНЕРАЛДЫ ТЫҢАЙТҚЫШТАРДЫҢ ӘСЕРІ

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Мақалада азотпен төмен қамтамасыз етілу жағдайында өсірілетін, кәдімгі боз топырақтарда күздік арпаны өсірген кезде минералды тыңайтқыштардың әр түрлі түрлерін қолданудың салыстырмалы талдауы берілген. Минералды тыңайтқыштар қолдану топырақтың қоректік режимін жақсартады, күздік арпаның өсіп-өнуіне (r = 0.948) және өнімділігіне жағымды әсер етіп, шартты түрде таза табыспен қамтамасыз етеді. Құрамында күкірт бар фосфор тыңайтқыштарын енгізу күздік арпаның өсіп-өнуін жақсартады, (r = 0.943) және өнімділігін арттырады.

Түйінді сөздер: кәдімгі боз топырақ, құрамында күкірт бар тыңайтқыш, тұқымның салмағы, өнімділік, экономикалық тиімділік.

РЕЗЮМЕ

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ВЛИЯНИЕ МИНЕРАЛЬНЫХ УДОБРЕНИЙ НА УРОЖАЙ ОЗИМОГО ЯЧМЕНЯ В УСЛОВИЯХ АЛМАТИНСКОЙ ОБЛАСТИ

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В статье приведен сравнительный анализ применения разных видов минеральных удобрений при возделывании озимого ячменя на обыкновенных сероземах, выращиваемого в условиях низко обеспеченности азотом. Применение минеральных удобрений улучшает пищевой режим почвы, оказывает положительное влияние на рост и развитие (r = 0.948) и урожайность озимого ячменя и обеспечивает условно чистый доход. Внесение фосфорных удобрений, содержащих серу, улучшает рост и развитие растений (r = 0.943), повышает продуктивность озимого ячменя.

Ключевые слова: обыкновенный серозем, серосодержащие удобрения, масса семян, урожайность, экономическая эффективность.