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The effect of pre-sowing treatment of seeds with molybdenum and boron on the yield of Zhansaya soybean in the conditions of the Almaty region

The expansion of the planting acreage and increasing the productivity of such crops as soybeans are a priority trend of the agro-industrial complex of Kazakhstan. In the field of biological safety, there are two ways to solve the problem of increasing the yield: selection-genetic and technological. Using new technologies is the leading approach to develop and provide optimal conditions for the full realization of their genetic potential. Managing the growing season of new varieties of plants through the use of scientifically based crop rotation, as well as using micro-fertilizers and growth stimulants, allows achieving the highest profitability of crop production. Undoubtedly, there is the fact of correlation dependence between the development of cell bacteria and the intensity of photosynthesis. There have been studied the effect of pre-sowing treatment of soybean seeds with solutions of Mo and Co microelements on productivity. All the types of treatment have had a positive effect on productivity. Even the introduction of microelements without inoculation increased the yield in comparison with the control by 2.3 kg/ha. The biggest deviation from the control was given by the joint treatment of seeds with nitrogen-fixing bacteria and microelements: 8.4 centers/ha. The quality indicators (protein and fat content) were only slightly affected by the types of treatment. When treated only with a nitrogen-fixing drug and its combined use with microelements, the amount of protein in the seeds increased by 0.6 and 0.7 %, respectively, compared with the control.

Keywords: soybeans, microelements, molybdenum, boron, characteristics of productivity, crop yield.

Introduction

One of the priority aspects of developing the agro-industrial complex of Kazakhstan is the fodder base. A significant place is occupied with such a high-protein and oilseed crop as soybean. The sown area is increasing not only in the countries-leaders by its production but also in our country. Over the past 10 years, the area of soybean cultivation in the Republic was increased 2.5 times — from 53 thousand hectares in 2008 to 138.9 thousand hectares in 2019. Most part of the area is occupied by irrigated lands of the Almaty region (up to 90 %) [1].

The average crop yield in our country is 21,22 kg/ha. Thus, there is a growing need to increase the yield of this crop on a production scale, since in the experimental and demonstration plots it reaches 40–45 centers/ha with traditional irrigation, and up to 60–65 centers/ha after using drip irrigation.

In the field of biological safety, there are two ways to solve the problem of increasing productivity: i) selection-genetic; and ii) technological. In the process of selection-genetic work, new varieties were developed with potentially high biological and economic productivity, resistant to stress factors [2]. New technologies play the leading role in forming and ensuring the optimal conditions for the full realization of their genetic potential.

Managing the vegetation of new breeds of plants includes using micronutrient fertilizers and growth stimulants to allow achieving the highest profitability of crop production [3].

With “successful nitrogen fixation” soybeans can accumulate up to 400 kg/ha of nitrogen, although the most part is used by the plant itself. However, according to various investigators, after harvesting soybeans, 60 to 150 kg of nitrogen remains in the soil for subsequent crops in the composition of nodules, root and crop residues. The fact that trace elements have if not a direct but an indirect effect on nitrogen fixation is written in any textbook on plant physiology. Some of them are, for example, a part of nitrogen-fixing enzymes, while others form conditions for strengthening the processes.

There is a correlation between the development of nodule bacteria and the intensity of photosynthesis, in particular, the synthesis and transport of sugars. This is due to the fact that nitrogen-fixing microorganisms need a sufficient supply of sugars and other carbohydrates. Magnesium, manganese, copper, iron contribute to the enhancement of photosynthesis and, therefore, the accumulation of carbohydrates and boron enhances the movement of sugars from the leaves to the root system. Moreover, numerous experiments of both domestic and foreign researchers indicate that the combined use of molybdenum and boron gives a better result than their separate use.

Cobalt in turn increases the content of hemoglobin in nodules, the content of which determines the intensity of their respiration. In the presence of cobalt, the nitrogen fixation process is active. At the early stages of plant development, molybdenum can promote the growth of the root system, accelerate and stimulate the development of the nodule bacteria activity [4].

Soybeans, like other legumes, have an increased yield of boron and molybdenum [5]. In this regard, scientists face the task of improving and optimizing methods of using micronutrient fertilizers in soybean cultivation. The analysis of scientific literature shows that in terms of the possibility of increasing crop yields through the use of foliar dressing when growing grain legumes, soybean has been most studied [6]. It was established that the dosages recommended in the scientific literature are not optimal and require adjustment [7].

Introducing boron and other microelements must be carried out on acidic ($pH < 5.5$) and alkaline ($pH > 7.5$) soils through their complicated availability to plants. Boron plays an important role in cell division and cell wall formation, so it is important throughout the growing season. It affects the number of flowers and fruits, ensures seed ripening.

The nitrogenous enzyme involved in the nitrogenification process also contains molybdenum. Soybean responds well to fertilization with molybdenum. Traditionally, it is used for pre-sowing seed treatment (for 1 centner of soybean seeds 30–50 g of molybdenum-acid ammonium (50 % Mo). With foliar dressing during the budding period–the beginning of flowering, the application rate is up to 200 g/ha. Cobalt is directly involved in the processes of nitrogen assimilation from the air since it is concentrated in the very nodules, where it promotes the reproduction of nodule bacteria. It is used for foliar feeding and introducing directly into the soil [8, 9].

It is possible to enrich soybean seeds to the required concentration both by foliar application and by seed treatment. Yu.N. Kazachkov's study [10] showed that in cases of using increased doses of molybdenum (50 and more g/ha), the coefficient of its assimilation was higher when wetting seeds and after spraying of plants.

It was noted that the use of molybdenum by the method of wetting seeds was not always effective. For example, in one of the experiments carried out by Yu.N. Kazachkov on meadow chernozem soil, the use of molybdenum in a dry year by wetting seeds with the dose of 100 g/ha, reduced the crop yield of soybean grain on 2–6 centner/ha [10]. In the Far East in recent years the high efficiency of sulfur and molybdenum fertilizers was noted in the cultivation of soybeans. The treatment of soybean seeds with molybdenum was considered a mandatory method in the existing zonal farming systems.

The minimum dose of molybdenum fertilizers for applying on wetting seeds is 50 g/ha, and for plant spraying — 200 g/ha. Preliminary enrichment of soybean seeds with molybdenum allows avoiding its antagonism with sulfur when fertilizers containing these elements are applied together and achieving an additional increase in the crop yield of soybean grain. The content of molybdenum in seeds, as shown in our long-term observations, was the most objective and the most acceptable diagnostic indicator of the need for soybean crops in molybdenum fertilizers [11].

Experimental

In our studies, we used the best soybean variety Zhansaya approved for production in the Almaty region. The originator of variety is the Kazakh Research Institute of Agriculture and Plant Growing. Zhansaya belongs to the group of mid-ripening, the growing season in the Almaty region is 125–127 days. The plant height is 95–105 cm, the growth type is determinant. The mass of 1000 seeds is 165–170 g. The average yield is 4.5–4.7 tons/ha; the protein content in the grain is 40, 41 %; the oil content is 19 %. The variety has been approved for use in the Almaty region since the 2012 year.

The studies were carried out in 2019 at the field stations of the Kazakh Research Institute of Agriculture and Plant Growing, which is located in the Almaty region at the altitude of 740 meters above sea level, N 43°15', E 76°54′. The zone is characterized by continental climatic conditions: mild and cool winters, cold springs, hot and dry summers, warm and dry autumns. The average duration of the frost-free period is 170–180 days with temperature fluctuations. However, the often recurring late spring and early autumn frosts often reduce the frost-free period to 140–150 days, which leads to frost damage in late-ripening soybean breeds.

Summer thermal resources in the region are high. The average sum of positive temperatures is 3500–4000°. This thermal model allows growing a lot of heat-loving crops here, including soybeans.

The distribution of atmospheric precipitation in the dry steppe zone is not the same. So, according to the meteorological station, the average long-term amount of atmospheric precipitation is 414.6 mm with the following distribution over the seasons: in winter 70.8 mm; in spring 166.9 mm; in summer 101.8 mm and in autumn 75.1 mm. In summer, the main amount of precipitation falls in June and is 53.9 mm.

The soil cover is represented by light chestnut, loamy, less often sandy loam soils.

According to the data of the Kazakh Research Institute of Agriculture and Plant Growing meteorological station, the meteorological conditions of the research period in 2019 in the research area significantly differed from the average long-term values. The temperature background from May to October was higher than the average long-term indicators by 0.5–3.2 ^{0}C (Tab. 1). High temperatures, both day and night, led to air droughts during the reproductive periods of soybeans.

Table 1

Average monthly air temperature and precipitation in the vegetation period, 2019

Month	Temperature, ºC			Precipitation, mm		
	actual	average long-term	deviation	actual	average long-term	deviation
April	+12.4	+ 10.4	+2.0	183.0	56.5	+126.5
May	+16.9	+16.4	+0.5	39.3	61.6	–22.3
June	+22.3	+21.2	+1.1	72.7	53.9	+18.8
July	+26.9	+24.1	+2.8	25.7	26.6	–0.9
August	+24.9	+22.1	+2.8	67.7	21.3	+46.4
September	+18.5	+16.0	+2.5	67.2	15.9	+51.3
October	+11.5	+8.3	+3.2	44.7	29.1	+15.6

The excess of the average annual precipitation in April by 3.5 times had a favorable effect on the moisture recharge and subsequent seedlings. May, June, July, and the first half of August were characterized by an unstable distribution of precipitation.

Pre-sowing treatment of seed materials. Two weeks before sowing, the soybean seeds were treated with a solution of ammonium molybdenum acid (in doze 40 g/100 kg of seeds, 4 L of water) and cobalt (II) sulfate (in doze 4 g/100 kg of seeds, 7 L of water). Before sowing, the seeds were treated with a preparation containing Histick nitrogen-fixing bacteria (in doze 400 g/100 kg of seeds).

The experiment is based on the following scheme:

i) control — without treatment;

ii) 1st experiment: seed treatment with Mo and Co;

iii) 2nd experiment: seed treatment with Histick;

iv) 3rd experiment: seed treatment with Histick; Mo and Co.

Sowing was carried out on May 1. The accounting plot was 25 square meters, the seeding rate was 500 thousand seeds/ha, row spacing was 30 cm, seeding depth was 4 cm; randomized seeding was in triplicate.

All agrotechnological measures to prepare for sowing, watering, loosening row spacing, destroying weeds, harvesting were conducted according to the methodology of B.A. Dospekhov [12] and the method of State Breed Testing of agricultural crops [13]. Gravity vegetation irrigation on the irrigated plot was carried out three times on June 25, July 15, and August 7 with an irrigation rate of 1200 (m^3/ha).

Phenological observations of the main phases of development were as follows: sowing, seedlings (VE), the appearance of the trigeminal leaf (V1), flowering (R2), bean formation (R4), the filling of beans (R6), ripening (R8) [14].

Statistical data processing was performed in the software environment R version 3.6.1 (2019–07–05) “Action of the Toes”). A two-sample Welch’s t-test from the built-in package {stats} was carried out.

Results and Discussion

Studying the phenological phases of development did not reveal the effect of pre-sowing treatment on their duration. Regardless of the pre-sowing treatment and without treatment, the phenological phases of development proceeded synchronously, and the growing season in all variants was 127 days (Tab. 2).

Table 2

Phenological phases of developing the Zhansaya soybean breed depending on the pre-sowing seed treatment (2019)

Experiment option	Seeding down	Seedlings	Flowering	Bean formation	Bean filling	Ripening
Control without treatment	1.05	13.05	10.06	28.07	25.08	17.09
Mo + Co	1.05	13.05	10.06	28.07	25.08	17.09
Histick	1.05	13.05	10.06	28.07	25.08	17.09
Histick + Mo+ Co	1.05	13.05	10.06	28.07	25.08	17.09

The productivity traits reflect the picture of productivity determined by a positive correlation with each of them. The main indicators of productivity in soybeans are considered to be the height, the number of side branches, the number of productive nodes, the number of beans per plant, the weight of seeds per plant, the weight of 1000 seeds.

In the analysis of productivity, the effect of pre-sowing treatment with microelements on the elements of soybean productivity was revealed (Tab. 3).

Table 3

Productivity traits of the Zhansya soybean breed depending on pre-sowing seed treatment (2019)

Experiment option	Height, cm	Height of the lower beans attachment, cm	Number of branches, pcs	Number of productive nodes, pcs	Number of beans per plant, pcs	Weight of the seeds per plant, g	Weight of 1000 seeds
Control without treatment	67.9	5.5	1.6	15.7	37.0	26.2	165
Mo + Co	67.8	6.7	2.3	20.8	56.7	27.3	159
Histick	67.9	5.3	1.9	18.5	59.4	38.1	165
Histick + Mo+ Co	67.7	5.8	2.1	21.1	65.2	44.1	165

It is interesting to note that all the types of treatment did not affect the plant growth and the attachment height of the lower beans. That is, in general, the architectonics of the plant was preserved. Seed treatment had a great effect on increasing the flower setting, which was reflected in increasing the number of beans per plant from 37.0 without treatment to 65.2 pieces when treated with Histick preparation and microelements. Without increasing the mass of 1000 seeds for all the types of treatment, the mass of seeds per plant increased due to increasing the total number of seeds. The greatest difference in comparison with the control was shown in the experiment with joint treatment with a nitrogen-fixing drug and microelements.

When analyzing productivity, the effect of pre-sowing treatment with microelements on the crop yield of soybeans was also revealed (Tab. 4). All the types of treatment had a positive impact on the yield. Even the introduction of microelements without inoculation increased the yield by 2.3 kg/ha in comparison with the control.

Table 4

Crop yield and quality of the Zhansaya soybean breed with different types of treatment (2019)

Experiment option	Bulk yield from the plot, kg				Crop yield, c/ha	Deviation from the control, c/ha	Protein, %	Fat, %
	1 repeatability	2 repeatability	3 repeatability	average				
Control without treatment	8.7	7.9	8.5	8.4	34.9	0.0	39.1	22.7
Mo+ Co	7.0	9.1	10.7	8.9	37.2	+2.3	38.7	22.6
Histick	9.7	9.9	9.5	9.7	40.4	+5.5	39.7	22.0
Histick + Mo+ Co	10.0	10.0	11.2	10.4	43.3	+8.4	39.8	22.2
HCP						1,5		

The largest deviation from the control was given by the joint treatment of seeds with nitrogen-fixing bacteria and microelements: 8.4 c/ha.

The quality indicators (protein and fat content) were slightly affected by the types of treatment. When treated only with a nitrogen-fixing drug and its combined use with microelements, the amount of protein in the seeds increased by 0.6 and 0.7 %, respectively, compared with the control.

Conclusions

Expansion of the cultivated areas and the increase in the productivity of such a crop as soybean are a priority aspect of the agro-industrial complex of Kazakhstan. Pre-sowing of soybean seeds with solutions of microelements Mo and Co had a positive effect on the crop yield. Since these elements are involved in nitrogen fixation, the largest deviation from the control (8.4 centners/ha) was given by the joint treatment of seeds with nitrogen-fixing bacteria (Histick) and microelements. The crop yield increased due to the increase in the number of beans and seeds per plant. However, they all are united by the same properties: stimulating the growth and development of plants, increasing field germination, resistance to pests, diseases, and unfavorable environmental factors.

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Алматы облысы жағдайында тұқымдарды молибденмен және бормен себу алдындағы өңдеудің Жансая соясының өнімділігіне әсері

Егіс алқаптарын кеңейту және соя тәрізді дақылдың өнімділігін арттыру Қазақстанның агроөнеркәсіптік кешенінің басым бағыты болып табылады. Биологиялық қауіпсіздік саласында өнімділікті арттыру мәселелерін шешудің екі жолы бар — селекциялық–генетикалық және технологиялық. Жаңа технологиялар олардың генетикалық әлеуетін толық іске асыру үшін оңтайлы жағдайларды жасауда және қамтамасыз етуде жетекші орынға ие. Өсімдіктің жаңа сортының өсіп жетілу кезеңін ғылыми негізделген ауыспалы егісті пайдалану арқылы, сондай-ақ, микротыңайтқыштар мен өсу стимуляторларының көмегімен басқару өсімдік шаруашылығының жоғары рентабельділігіне қол жеткізуге мүмкіндік береді. Әлбетте, түйінді бактериялардың дамуы мен фотосинтездің қарқындылығы арасындағы корреляциялық тәуелділік фактісінің болуы сөзсіз. Соя тұқымын себу алдында Мо және Со микроэлементтері ерітінділерімен өңдеу арқылы оның өнімділігіне әсері зерттелген. Өңдеудің барлық түрлері өнімділікке оң әсер етті. Тіпті, иннокуляциясыз микроэлементтерді енгізу бақылаумен салыстырғанда өнімділікті 2,3 кг/га арттырды. Бақылаудағы ең үлкен ауытқу — тұқымдарды азот жинақтаушы бактериялары мен 8,4 кг/га микроэлементтерімен бірлескен өңдеу барысында берді. Өңдеу сапалық көрсеткіштерге (ақуыздар мен майлардың құрамына) аз әсер етті. Тек азотты бекітетін препаратпен өңдеу және оны микроэлементтермен біріктіріп қолдану кезінде тұқымдардағы ақуыз мөлшері бақылаумен салыстырғанда ғана 0,6 және 0,7 %-ға артты.

Кілт сөздер: соя, микроэлементтер, өнімділіктің сипаттамасы, ауыл шаруашылық дақылдарының шығымдылығы.

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Влияние предпосевной обработки семян молибденом и бором на урожайность сои Жансая в условиях Алматинской области

Расширение посевных площадей и увеличение продуктивности такой культуры, как соя является приоритетным направлением агропромышленного комплекса Казахстана. В области биологической безопасности существует два пути решения проблемы повышения урожайности — селекционно-генетический и технологический. Новым технологиям принадлежит ведущее место в созднии и обеспечении оптимальных условий для полной реализации их генетического потенциала. Управление вегетацией растений новых сортов путем использования научно обоснованного севооборота, а также с помощью микроудобрений и стимуляторов роста позволяет добиться высокой рентабельности растениеводства. Несомненным является факт корреляционной зависимости между развитием клубеньковых бактерий и интенсивностью фотосинтеза. Изучено влияние предпосевной обработки семян сои растворами микроэлементов *Mo* и *Co* на ее урожайность. Все виды обработок оказали положительное влияние на урожайность. Даже внесение микроэлементов без иннокуляции повысило урожайность по сравнению с контролем на 2,3 ц/га. Самое большое отклонение от контроля дала совместная обработка семян азотфиксирующими бактериями и микроэлементами — 8,4 ц/га. На качественные показатели (содержание белков и жиров) виды обработок повлияли незначительно. При обработке только азотфиксирующим препаратом и комбинированном применении его с микроэлементами количество белка в семенах увеличивалось на 0,6 и 0,7 %, соответственно, по сравнению с контролем.

Ключевые слова: соя, микроэлементы, характеристика продуктивности, урожайность сельскохозяйственных культур.

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