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Research paper

Efficiency of Innovative Technologies in Addressing Environmental Problems in the Agroecosystem of Soya in the Conditions of Southeastern Kazakhstan

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Abstract:

This article describes the resource-saving innovative technology efficiency in addressing environmental problems of the agroecosystem of soya in the conditions of Southeastern Kazakhstan that have inhibiting effect on the environment at the scale of the cultivated crop. The optimal parameters of the rate of introducing mineral fertilizers in combination with inoculation of soya seeds have been determined, with consideration of their biological features, as one of the methods of resource-saving technology aimed at improving the ecological situation, maintaining stability of the agroecosystem and increasing soya productivity. The rational use of the bioenergy resource and the biological potential of the studied crop have been proven, due to its ability of nitrogen bonding to bond atmospheric nitrogen, thereby reducing the dosage of used nitrogen fertilizers, which contributes to environment protection and resource saving in the agroecosystem. The possibility of replacing the primary dumped tillage with mini-till processing has been found, which provides reliable recovery and preservation of soil fertility. Reducing the mechanical stress during mini-till processing ensures improved water stability of soil aggregates, increases coefficient, and maintains soil structure. The recovered parameters of the agrophysical indicators of soil fertility and reduced total energy costs (fuel consumption) by 21.8-28.4%, as well as the cost of the product with the use of alternative methods technologies in the conditions of the submontane zone of the Southeastern Kazakhstan have been determined.

Keywords: soya, agroecosystem, ecological problems, minimization, resource saving, innovation, technology, nitrogen bonding.

1 Introduction

Today, the perspective of the vision of the natural sciences is in the polarity of development of the production technology and preservation of the ecological potential of the environment. Unfortunately, modern advanced achievements in the science and the technology are in almost full confrontation with the environment and have destructive impact on the ecological balance [1].

Especially in the agricultural sector, numerous negative effects of crop cultivation, changes in the balance of ecosystem biogeochemical cycles, and in the level of soil fertility are systematically observed [2, 3]. According to Rattan Lal (2007), the problems of the world agriculture considerably intensified in the first decade of the 21st century [4]. These problems are caused by the population of 7.6 billion in 2017, and by the expected increase to 9.6-13.2 billion people by 2050 [5].

Constant and ongoing growth of the world's population generates the increasing demand for food products. To meet this demand, farmers have to develop and implement more sophisticated and complex innovative agricultural technologies, which allow obtaining more yield per area unit [6, 7, 8].

The role of the agricultural production in ensuring food supply of the country, growth of employment and economic development of the Republic is clearly dominating. Therefore, the agroindustrial complex is facing a very urgent problem associated with the implementation of the objective of sectoral program of developing the agroindustrial complex (AIC) of Kazakhstan up to 2020 [9, 10]. Its tasks are aimed at significant increasing of productivity, acreage, and introduction of new technologies of agricultural crops' cultivation. However, at the moment, as a result of the increased frequency of droughts and increased aridity, productivity is likely to be dramatically reduced in several agricultural zones of the Republic. Therefore, resolving these problems requires innovative technologies in agriculture and diversification of crop production.

It should be noted that development of innovative environmental technologies is one of the key prerequisites for the long-term and sustainable economic growth, ensuring competitiveness of its products in the world, and one of the most urgent subjects discussed in the world community. Exploitation of natural resources in traditional ways inevitably creates a number of risks – increasing the negative impact on the environment and depletion of nonrenewable natural resources. In the framework of upholding the State policy in the area of rational management of natural resources and environmental safety, developing innovative environmental and resource-saving technologies is a priority.

Innovative technology reduces production costs and allows achieving success in gaining profit. That's why it is very important for the scientists to ensure continuous development and introduction of new and advanced innovative technologies. In the conditions of the study, with ecologization of the environment in the agroecosystems, ensuring sustainable production of quality biological products, efficient use of natural bioenergy potential of agroecosystems and conservation, restoring natural resources are priorities in the scientific research.

Resolving this problem at the present stage of agricultural development, one may be guided by the following main types of innovative technologies of crop production: simple (traditional) technologies, intensive technologies of production, high-intensity and resource-saving technologies of cultivating agricultural crops. The techniques used in the innovative technology of cultivating agricultural crops should be aimed at studying efficiency of elements of resource-saving technologies, identifying efficiency of biological active substances, selecting the most productive energy-intensive crops, introducing results of energy-saving technology elements' development in specific soil and climatic conditions of the agroecosystem.

The authors believe that the use of highly effective resource-saving technologies of crop cultivation is a priority here. The results of the research, the techniques used in this technology reduce the anthropogenic load on the environment at the scale of the crop cultivated, and are particularly advantageous (from the economic point of view) for farms. The less fuel, energy, fertilizers, seeds, man-hours and other resources are used per product unit, the lower its cost is, and the higher the profit from its sale is.

When addressing such highly relevant problems in cultivating studied legume, soya, the authors relied, on the one hand, on the high nitrogen-bonding ability, and on the other hand, on the efficiency of the resource-saving methods of cultivation.

Soya is the most valuable universal legume and oil crop. Soya oil is semidrying; it features high content of physiologically active essential fatty acids. Soya is characterized by irregular consumption of large amounts of nutrients across development phases. Creating significant vegetative mass and forming seeds with high content of fat and protein, soya requires intensive mineral nutrition. According to the researchers, for formation of 1 hw. of soybeans, 8-10 kg of nitrogen, 2.0 to 3.5 kg of phosphorus and 3-4 kg of potassium are used on the average [11]. During the first growth period from germination to branching, soya requires phosphorus, which plays an important role in setting up generative organs. In terms of nitrogen, the critical period is between the budding and the flowering phases, when progressive growth of the vegetative mass occurs. Until the beginning of the flowering phase, soya plants consume 1.5 times more potassium than nitrogen, and 1.8 times more potassium than phosphorus. However, the plant uses the largest amount of potassium in the phase of bean formation and ripening [12].

When forming the harvest, soya brigs out a lot of available nitrogen from soil, however, significant share of it (approximately two thirds) is absorbed from the air in the process of nitrogen bonding provided nodule bacteria on the roots are well developed. This is explained by the symbiosis of soya with the nodule bacteria, which can provide 50% to 75% of the required nitrogen. The process of nitrogen bonding requires the presence of corresponding bacteria in the soil (Rhyzobium japonicum) or introduction of these bacteria with seed. Currently, the most efficient bacterial preparation for soya is Rizovit-AKS or nitragin. The results of studying the nutrient status by scientists show the need for a differentiated approach to the norms of introducing mineral fertilizers with regard to the biological characteristics of the crop [13]. In this regard, studying the environmental problems of using mineral fertilizers in cultivation of this crop at present in a particular agroecosystem is a very important issue.

Therefore, along with developing the methods of innovative resource-saving technology of soya cultivation, it is necessary to identify the optimal parameters for the norm of introducing mineral fertilizers with regard to the biological characteristics of soya. The authors have studied the effect of $P_{60}K_{30}$ and $N_{30}P_{60}K_{30}$ as a method of the resource-saving technology aimed at improving the ecological state, maintaining stability of the agroecosystem and increasing soya productivity.

This article describes the efficiency of the resource-saving innovative technology in addressing environmental problems of the agroecosystem of soya in the conditions of Southeastern Kazakhstan that have inhibiting effect on the environment at the scale of the cultivated crop.

2 Materials and Methods

The experimental research was performed at the Agro-University Scientific Experimental Station of the Kazakh National Agrarian University situated on a plain on the Northern slope of the Zailiyskiy Alatau (550-700 m above the sea level). The terrain is characterized by the extreme continental climate, with short yet cold winter, long period of high air temperatures, intense sunlight during warm months, intensive evaporation, low humidity with the complete absence of precipitation (Alisheva, 2006) [14]. The experiment was performed on the heavy-textured meadow-chestnut soils, which are characteristic for the foothill zones of the Tien Shan Mountains.

The object of the study is the unique grain-leguminous crop - soybeans (variety Eureka), with short crop rotation period. The reference in the experiments was the traditional technology of soya cultivation in accordance with the recommendations of the System of Farming in the Almaty region [15]. Field experiments and experimental research were performed according to the traditional classic methods: experiment and observation. All methodological requirements to the method of laying field experiments have been met, and the experiments were performed according to B. A. Dospekhov [16], and according to the recommendations of Boyko A. T. and Karyagina Y. G., OJSC Vita [17].

Biometric and phenological observations were performed according to the recommendations of the Institute of Field Farming and Vegetable Farming, methods of the State Grade Testing of cereals, legumes and oil crops [18, 19]. The obtained experimental data were processed using the statistical method [16].

Agrochemical studies aimed at determining soil nutrient status (GOST 17.4.4.02.) included several mandatory procedures: sampling, samples' preparation for analysis, and determining the content of mobile forms of nitrogen and phosphorus [20].

The content of heavy metals in the soil was determined using atomic-absorption spectrophotometer Shimadzu AA7000 with hollow cathode bulbs made of the elements Cr, Zn, Cu, Pb, Cd. Samples were prepared for the study using method RD 52.18.286-91 [21].

The content of mobile forms of N- NO_3 and P_2O_5, mg/kg in the soil was determined using a photoelectric colorimeter. The method is based on extracting mobile phosphorus compounds from the soil with the solution of acetic acid at the soil to solution concentration of 1:25 mol dm and subsequent determination of phosphorus in the form of blue phosphorous-molybdenum complex at the photoelectric colorimeter (Spirina & Solovieva, 2014) [22].

3 Results

Within the framework of the research, the authors used the methods of resource-saving technology with two variants of introducing mineral fertilizers - $P_{60}K_{30}$ and - $N_{30}P_{60}K_{30}$ - and the influence of soybean seeds' treatment with Rizovit-AKS - nitragin against the background. To establish the influence of the studied variants of mineral fertilizers' norms and inoculation on the activity of nodules' formation, and to determine the optimal seeding rate, the authors studied 3 seeding rates - 400, 600 and 800 thousand seeds/ha, with the interrow width of 30 cm.

In comparative assessment of the studied norms of mineral fertilizers' introduction, inoculation and seeding rate, the reference – St shall be sowing soya by the traditional technology without fertilizers. To establish the effect of the studied variants of norms of mineral fertilizers and inoculation on the activity of nodules' formation, the authors studied 3 seeding rates - 400, 600 and 800 thousand seeds/ha. The studied variants of the methods have effect on the growth and development of not only the aboveground portion, but also the underground part of the crop. Depending on the prevailing abiotic factors, nodules develop in the roots of the plant. The main indicator of the efficiency of plants and nodule bacteria symbiosis is their number and weight (Table 1).

Table 1: The effect of mineral fertilizers with inoculation and the seeding rate on the number and the weight of nodules of nitrogen-bonding bacteria in the roots of soya (average for the years of research)

Technology	Variants of using the fertilizer	Number of nodules per plant			Weight of nodules, mg/plant		
		400 thousand per ha	600 thousand per ha	800 thousand per ha	400 thousand per ha	600 thousand per ha	800 thousand per ha
Traditional	Without fert.	9.7	12.4	11.6	42.0	57.7	55.1
	Nitragin	16.2	21.0	19.7	72.9	97.9	93.6
	$N_{60}P_{180}K_{90}$	27.7	29.5	27.4	124.6	137.1	130.1
Resource-saving Mini-till (16-18 cm)	Nitragin	24.5	29.1	26.7	110.2	135.3	125.5
	$P_{60}K_{30}$	35.1	38.0	36.3	152.5	175.8	170.6
	$N_{30}P_{60}K_{30}$	39.4	47.6	45.9	177.3	221.3	252.0
Resource-saving Mini-till (12-14 cm)	Nitragin	28.2	30.5	24.9	126.9	151.9	118.8
	$P_{60}K_{30}$	33.9	37.8	30.3	157.9	176.4	143.3
	$N_{30}P_{60}K_{30}$	35.8	39.1	32.5	161.0	181.8	152.7

The observation and counting the number of formed nodules and their weight have shown that in case of the traditional technology, in the studied variants of seeding rates without inoculation, very few nodules - 9.7 to 12.4 per plant - formed on the soya roots.

Their number increases in case of seeds' inoculation with nitragin. In the variants with inoculation without fertilizers, the number of nodules increases, and, depending on the seeding rate, is 16.2 to 21.0 nodules per plant. And against the background of the traditional technology and the recommended dosage of $N_{60}P_{180}K_{90}$ mineral fertilizer [15], they have significant effect on the number of formed nitrogen-fixing nodules, which is 27.7 to 29.5 nodules per plant, and dry weight of nodules is 124.6 to 137.1 mg/plant.

In case of the resource-saving technology, inoculation of seeds with nitragin has significant positive effect on nodules' formation, where the number of nodules increases to 24.5-29.1 nodules per plant, depending on the seeding rate. After the introduction of $P_{60}K_{30}$ the number of nodules increases to 35.1-38.0 nodules per plant, and after the introduction of the $N_{30}P_{60}K_{30}$ fertilizer, this regularity in nodule formation persists and amounts to 39.4-47.6 nodules per plant (against the background of the resource-saving Mini-till at the depth of 16-18 cm). And the weight of nodules increases the same way as the number of nodules in the variants.

The introduction of mineral fertilizers at the dosage of $P_{60}K_{30}$ was the main and the optimal background for using the inoculant, therefore the possibility of nodules' formation on the roots of soya plants *increased* 1.31-1.43 times, and after introduction of $N_{30}P_{60}K_{30}$ the possibility of nodules' formation on the roots of soya plants *increased* 1.08-1.33 times. On the average over the 3 years, the greatest number of nodules on soya plants was formed in case of seeding with the interrow width of 30 cm with the seeding rate of 600 thousand seeds per ha – 47.6 nodules per plant, and their weight increased to 221.3 mg/plant.

The results of monitoring soil fertility in studying the effect of minimum tillage on soil resources (soil fertility) provided comparative assessment by the composition of the arable layer and soil structure against the background of traditional and resource-saving technologies. In the system of dump processing according to the traditional technology, the topsoil is characterized by loose composition with high general porosity and degree of aeration, which is not desirable.

According to many authors, density affects the entire complex of physical soil conditions, its water, air and temperature state, and, therefore, the conditions of the biological activity of the agroecosystem. In cultivating soya, optimal aeration of the upper layer of the soil is very important, since it ensures normal functioning of the root system of the plants and nitrogen-bonding nodule bacteria. Therefore, both domestic and foreign scientists have studied the tillage system in terms of regulating soil density.

During the research, the structure of the arable layer of soil was studied in the dynamics over the phases of soya development. In the initial period of plant development, soil density in case of the traditional cultivation technology was much lower. In the period of sowing soya associated with soil preparation for sowing, soil bulk density was in the range between 0.89 and 0.95 g/cm^3. The topsoil had loose structure with high porosity, which caused accelerated physical evaporation of soil moisture, which subsequently decreased the water condition of the root layer where nodules were formed.

In this variant with the traditional technology, bulk density of soil increased over phases of development from 0.95 g/cm^3 to 1.19 g/cm^3. The average density of the soil during soya vegetation season was 1.06 g/cm^3.

After using the mini-till variants, the density of soil ranged between 1.14 and 1.15 g/cm^3. During the vegetation period, the regularity of changes in the structure of the arable soil layer was characteristic of the studied variants with minimum tillage. In the periods of soya growth and development, in case of tilling the soil to the depth of 16-18 cm without ploughing, soil density – bulk weight - increased from 1.16 g/cm^3 (germination phase) to 1.24 g/cm^3 (ripening phase), where the average density over the growing season was 1.20 g/cm^3 (Table 2).

Table 2: The influence of the mini-till technology on the structure of the arable layer and the structural properties of soil in terms of density, g/cm^3 (average over 2015-2017)

Technology	Variants of mini-tillage	Structural properties of the arable (0-20 cm) soil layer									
		Soil density over the phases of soya development, g/cm3							Macrostructuredness, %	Σ of water stable soil aggregates, %	Coefficient of structuredness
		Sowing	Shooting	Branching	Flowering	Bean formation	Ripening	Average			
Traditional	Plowing to the depth of 20-22 cm	0.89	0.95	1.02	1.08	1.12	1.19	1.06	32.1	23.5	0.63
Resource-saving	Tilling the soil to the	1.14	1.16	1.19	1.20	1.22	1.24	1.20	43.2	38.1	0.84

	depth of 16-18 cm without ploughing										
	Tilling the soil to the depth of 12-14 cm without ploughing	1.15	1.17	1.20	1.21	1.25	1.27	1.22	51.7	39.2	0.89

With the minimum tillage to the depth of 12-14 cm without ploughing, the structure of the arable layer was denser, soil bulk density increased to 1.17 g/cm^3 (in the phase of shoots) and to 1.27 g/cm^3 (ripening), and the average density over the vegetation period was 1.22 g/cm^3.

It should be noted that when resource-saving technologies are used, minimizing tillage results in significant saving and restoration of soil fertility due to changes in the structure of the arable layer of the soil. Variants of the mini-till soil processing technology optimize soil density compared to traditional soil treatment, the bulk density of the arable layer increases by 0.14-0.16 g/cm^3 approaching the equilibrium optimal soil density of 1.20-1.22 g/cm^3, where favorable environmental conditions are reached for growth and development of soya plants.

Along with the arable layer structure optimization, methods of the resource-saving technology have significant effect on the aggregate composition and structural properties of the soil. As can be seen in the table, against the background of the traditional technology with moldboard plowing, the total of macroaggregates in the topsoil is 32.1%, and the total of water stable aggregates is 23.5% with the coefficient of structuredness of only 0.63 (Fig.1).

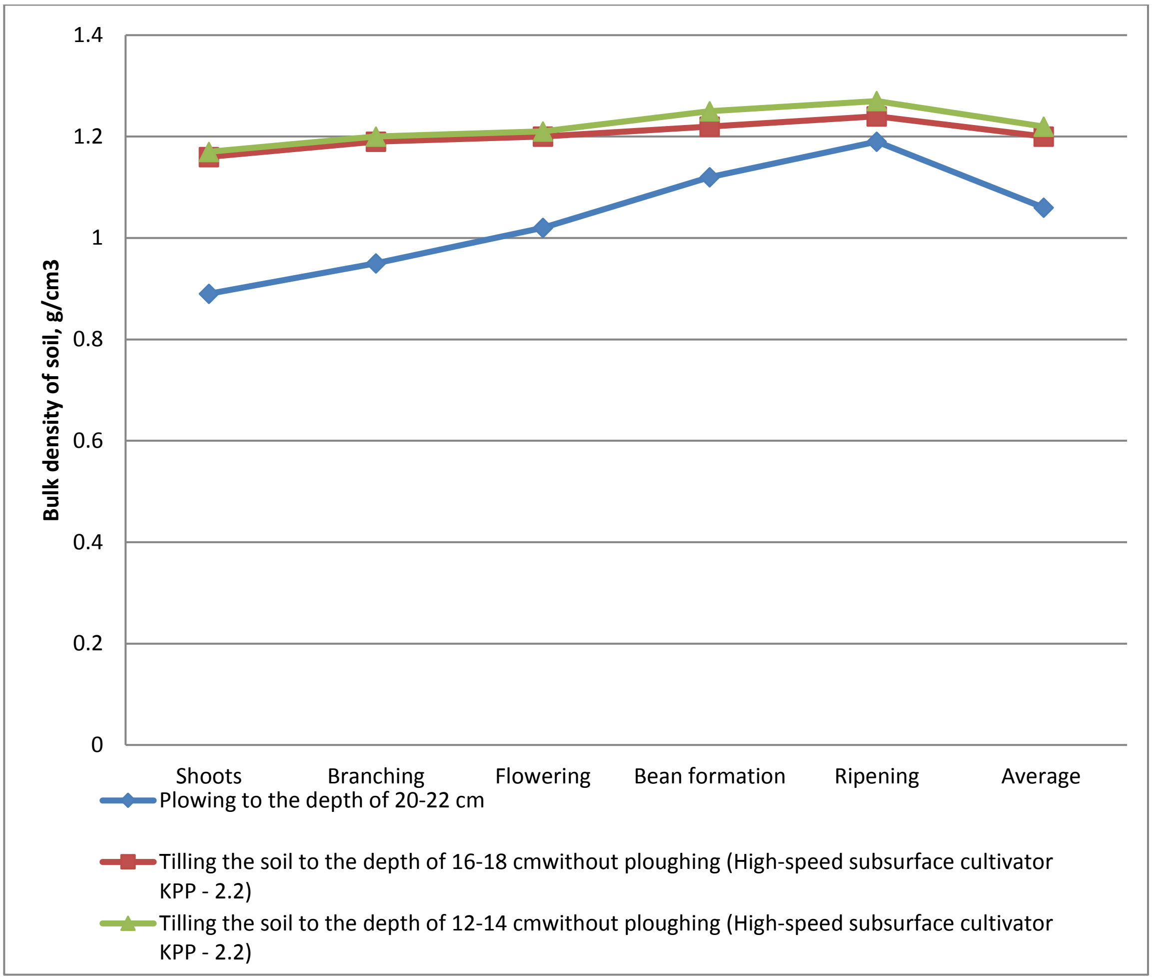

Fig.1 : Structure of the arable layer (by density, g/cm^3) depending on the minimum (Mini-Till) technology of soil treatment

Agrophysical indicators of this technology characterize deterioration of soil structuredness. Deterioration of these indicators seriously affects the most important processes that occur in the soil, primarily air, water and temperature states, and this deteriorates soya growth and development. It is particularly important to ensure the optimal parameters of soil porosity in the flowering phase - bean formation, when the symbiotic apparatus of soya reaches its maximum development and lack of air in this period may result in low nitrogen assimilation and, consequently, loss of the yield.

With the resource-saving technology, minimizing soil tillage resulted in the maximum preservation and improvement of soil fertility. In case of mini-tillage, arable soil layer was optimized, compared to traditional treatment.

Against the background of resource-saving minimal tillage (Mini-Till) technology without ploughing, the total of macroaggregates in the soil increased from 32.1% to 43.2-51.7%, and the total of water stable aggregates - from 23.5% to 38.1-39.2%, and the coefficient of structuredness - from 0.63 to 0.84-0.89.

Reducing the number of mechanical stresses during mini-tillage enhances water stability of soil aggregates, which is especially important in cultivation soya in the conditions of irrigation. Since the symbiotrophic process is aerobic, optimization of the air state in the active root layer becomes particularly important. In locations where the most nodules of nitrogen-bonding bacteria are formed on soya roots, the aggregate composition and soil structure are improved, and the air state of the agroecosystems is optimized (Fig.2).

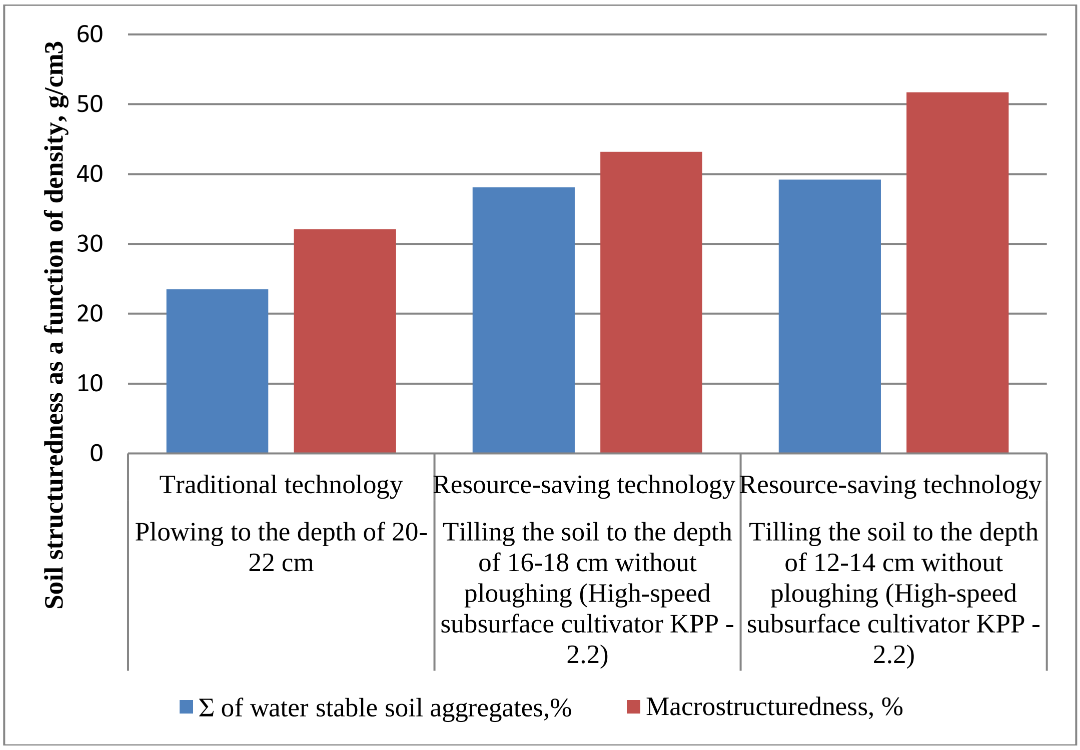

Fig.2: The effect of soil mini-tillage on soil structuredness, % (average over 2015-2017)

The results prove that the use of the mini-till technology increases stability of soil ecological state, stabilizes the structure of the arable soil layer for optimal soya growth and development in the conditions of Southeastern Kazakhstan.

The results show that mineral fertilizers directly contribute to reaching the highest soya stand, and accumulation of dry matter. The introduction of mineral fertilizers at the dosage of $P_{60}K_{30}$ increased the linear growth of plants by 11-16%, and after increasing the dosage to $N_{30}P_{60}K_{30}$ – by 21%, and the accumulation of dry matter increased at the appropriate dosages within 9% and 12% due to better nutrients' supply. Over the years, plant height fluctuated between 47.3 and 70.7. It increased with increasing in seeding rate.

In case of soya row sowing with the width of 30 cm, the lowest plant height was observed in the variants with the lowest seeding rate – 40.3 cm, and after increasing the seeding rate to 800 thousand seeds/ha, it reached 63.5 cm. This was due to the improved light state, which stimulated the increase in the plant height. The height of lower beans' attachment directly depended on plant height, and changed along with it. The average number of grains in soybeans, over the years, ranged between 1.6 and 2.5, weight of 1,000 seeds ranged between 104.8 and 142.4 g.

According to the results of structural bundle analysis, soya productivity in case of the traditional technology without fertilizers is only 19.8 hw/ha. Against this background, treating soybeans with nitragin increases soya yield by 2.8 hw/ha.

The use of nitragin influences the symbiotic activity, increases the number and weight of nodules on the roots of soya plants that improve nitrogen nutrition of crops with subsequent increase in the soya yield (Table 3).

Table 3: Soya productivity depending on the use of mineral fertilizer with inoculation during the years of the study, kg/ha

Technology	Variants of using the fertilizer	Yield over the years of the research, hw/ha			Average yield, hw/ha	Increase in	
		2015	2016	2017		hw/ha	%
Traditional	Without fertilizers	18.1	20.0	21.2	19.8	St	-
	Nitragin	18.9	23.1	23.8	21.9	2.1	10.6
	$N_{60}P_{180}K_{90}$	23.0	26.8	28.2	26.0	6.2	31.3
Resource-saving tilling the soil to the depth of 16-18 cm without ploughing	Nitragin	22.0	22.4	23.7	22.7	2.9	14.6
	$P_{60}K_{30}$	22.7	27.7	26.1	25.5	5.7	28.7
	$N_{30}P_{60}K_{30}$	24.3	28.9	27.5	26.9	7.1	35.8
Resource-saving tilling the soil to the depth of 12-14 cm without ploughing	Nitragin	23.5	24.6	23.9	24.0	4.2	21.2
	$P_{60}K_{30}$	25.8	25.1	26.2	25.7	5.9	29.7
	$N_{30}P_{60}K_{30}$	27.2	24.3	27.4	26.3	6.5	32.8
LSD_{05}, hw/ha =		1.85	2.15	2.3			
S_x, % =		2.75	3.06	3.87			

In case of using the resource-saving technologies against the background of phosphorus-potassium fertilizer ($P_{60}K_{30}$), soya yield increases to 25.5 hw/ha, i.e. by 28.7%, ensuring the yield increase by 5.7 hw/ha; and in case of complete introduction of fertilizer ($N_{30}P_{60}K_{30}$), the soya yield increases to 26.9 hw/ha (35.8%), which ensures additional yield of up to 7.1 hw/ha. The comparative assessment of soya responsiveness to the level of mineral nutrition has shown that due to its physiological characteristics soya clearly responds to changes in the nutrient status of the soil. The introduction of phosphorus and potassium fertilizers against the background of treating seeds with nitragin increases soya yield up to 25.7 hw/ha ($P_{60}K_{30}$) and 26.3hw/ha ($N_{30}P_{60}K_{30}$).

Accounting for soya yield has shown that the highest increase in the yield due to the use of mineral fertilizers with inoculation was 6.5-7.1 hw/ha, compared to the yield of 19.8 t/ha in the reference group.

In case of traditional technology, inoculation of seeds provides an increase in the yield by 2.1 hw/ha, while against the background of resource-saving technology, this difference is from 5.7 to 5.9 hw/ha (with the use of $P_{60}K_{30}$) and from 6.5 to 7.1 hw/ha (with the use of $N_{30}P_{60}K_{30}$). The combined use of mineral fertilizers and inoculation with the resource-saving technology creates favorable conditions for biomass synthesis and accumulation; variants without fertilizers and with mineral fertilizers $P_{60}K_{30}$ had the higher effect of inoculation.

4 Discussion

In discussing the results, it should be noted that due to the set of valuable properties of soya plants and seeds, as well as the universality of its use, the modern crop breeding in the world classifies soya (Glycine max (L.) Merr.) as the most valuable protein and oil seed crop. According to FAO (2009), 36.6 million tons of oil was made of soya, which indicated its dominant share among other oilseeds. The importance of this crop in the global economy is increasing, which is determined by high content of protein (40-45%) and oil (20-25%) in the seeds [23].

Soya has been cultivated in various parts of the world in various periods of history (the USA, Brazil, Argentina and China) and for various purposes. Used first as a green manure, over time, soya started being used as fodder and nitrogen-bonding crop due to its ability to bond significant amounts of atmospheric nitrogen by nodule (Bradyrhizobiom) bacteria [24].

In recent years, attention to soybean, being the most important crop of the third millennium, has been growing due to its environmental friendliness. Soy is of interest in agroecosystems due to its ability to bond atmospheric nitrogen. Soya itself reduces the introduced dosages of nitrogen fertilizers, and purifies the environment in the agroecosystems.

Due to its specific biological features, soya is a crop of diversified use; being a nitrogen bonding crop, it enriches the soil with nitrogen and improves its structure. In favorable conditions, soya can leave up to 50-80 kg/ha of nitrogen in the soil. Unlike mineral nitrogen, soya nitrogen does not pollute the environment, and is easily absorbed by other plants. In addition, cultivation of soy can dramatically reduce the cost of nitrogen fertilizer, solving the problem of resource saving. And in the industrial environment, the use of unsubstantiated dosages of mineral fertilizers causes considerable damage to the environment of agroecosystems.

High protein content in the vegetative mass and grain of soya determines its high need for nitrogen, which is increasingly satisfied by its consumption from the atmosphere through symbiotic nitrogen bonding (Milto, 1982). By efficiency of inoculation, soya is superior to peas, lupine, clover and alfalfa [25].

Bonding of molecular nitrogen of the air occurs as a result of plants' symbiosis with a specific group of nodule bacteria – Rhizobium japonicum (Kirchner) Buchanan. Cells infected with nodule bacteria and the neighboring uninfected cells of the root cortex start dividing, which results in the formation of a nodule swelling. The number of nodules per plant of soya may vary considerably from single to several hundreds, depending (Emtsev, Mishustin, 2005) on the conditions of the coenotic community functioning [26].

Biological nitrogen bonding is good for the environment [27] and is an important source of nitrogen in agriculture. The potential of this phenomenon requires additional disclosure with the use of agronomic measures and microbiological means, as well as plant breeding [28]. However, soya cultivation has not been considered successful in terms of soya's ability to bond atmospheric nitrogen [29].

Soya can bond large quantities of atmospheric nitrogen. And though today the implementation of biological nitrogen bonding has not been studied sufficiently, there are prospects for improving it. In course of various examinations and national competitions in the United States, very high yields (6,000-8,600 kg/ha) of soya seeds have been noted [30]. And since soya seeds are rich in protein, it is expected that obtaining such high yields will require high level of nitrogen nutrition. To some extent this need may be satisfied at the expense of soil nitrogen and nitrogen fertilizers. However, the role of biological nitrogen bonding becomes increasingly important due to the high costs of using nitrogen fertilizers, along with other environmental considerations in their production and usage.

Moreover, the authors note that when soya is cultivated in new areas, nitrogen-bonding bacteria appear on the roots and form nodules only after several years of planting, since in the soil they are found in inactive form and in insufficient quantities. Therefore, before sowing soya seeds should be treated with Rizovit-AKS or nitragin for soya. This method – inoculation - has been adopted as the studied resource-saving method of increasing potential productivity of the crop, and is one of the methods to significantly increase soil fertility.

Inoculation of soya seeds with Bradyrhizobium bacteria significantly increases the yield of the crop. The effect is even stronger in case of combining Bradyrhizobium inoculation with the introduction of phosphorus at the dosage of 26 kg/ha [31]. Formation of larger number of nodules and increase in the seed yield and nitrogen content in the seeds are only possible with efficient seed inoculation with an adequate number of nodule bacteria [32]. Significant reduction of microorganisms viability (94.0-99.9**%**) may occur between inoculation and sowing [28], therefore, the inoculation methods should minimize or eliminate the loss of nodule bacteria. To date, it has been clearly established that the ability of different strains of Bradyrhizobium to affect biological nitrogen bonding varies significantly.

To improve nitrogen bonding, zero tillage should be encouraged. For example, in the pampas of Argentine, cultivation of soya on the largest share of the acreage (about 90%) is performed with zero tillage [33]. In Brazil, this type of tillage is used on almost 50% of soya-based crop rotation, and the yield is similar to the yield obtained from the soil treated traditionally [34**].** With moderate levels of nitrates in the soil, the number and the dry weight of nodules, the amount of bonded nitrogen, the share of bonded nitrogen and nitrogen balance provided by soya are higher with zero treatment [35].

Inoculation of seeds with nodule bacteria increases the ability of soya plants to autotrophic nitrogen nutrition, where 30-65 kg/ha of nitrogen are absorbed from the air and over 50 kg/ha of nitrogen are left in the soil (due to organic residues after soya harvesting). Thereby, the resource-saving technology improves the environment of the agroecosystem by increasing the share of autotrophic nitrogen nutrition of soya, and can reduce the amount of nitrogen fertilizer from 50 to 80%.

In the variants without fertilizers with seeds' inoculation, in case of insufficient amount of mineral nitrogen in the soil, plants themselves stimulate the processes of nodule bacteria symbiosis through nitrogen bonding, and get the missing share of nitrogen nutrition. In the production, such technology ensures resource-saving by reducing the amount of nitrogen fertilizers.

Currently, the need for introducing innovative environmentally safe technologies of farming is dictated by the environmental state, and by the need for reducing direct production costs for obtaining the final yield. In interpreting the experimental material, it should be noted that the advantages of the resource-saving technologies are the following: reducing the number of tillage operations; rehabilitation, preservation and improvement of soil fertility;

reduction of soil vulnerability to erosion; improving the ecological state of the ecosystem; and reducing operating costs.

In the existing traditional system, a sequence of many methods of tillage is performed. This causes environmental problems, such as excessive soil dispersion and drying, deterioration of the agrophysical and agrochemical indicators of soil fertility, increase in the financial, energy and labor costs. The share of tillage accounts for 30-40 per cent of the cost associated with cultivation of this crop. It is therefore necessary to focus on efficient and environmentally friendly methods of cultivation, such as minimum tillage and inoculation of soya seeds.

The obtained data show that in the conditions of South-Eastern Kazakhstan the main scientifically substantiated methods of improving soil fertility and the yield of soya are the use of optimal dosages of mineral fertilizers and inoculation of soya seeds with the use of alternative methods and innovative technologies, which allow to promptly monitor the environmental situation in agroecosystems, are the main methods for stabilizing soil and biological resources, and for ensuring energy and resource saving in the agroecosystems.

5. Conclusion

An optimal amount of mineral fertilizers combined with inoculation of soya seeds with regard to the biological features has been determined as one of the methods of the resource-saving technology aimed at improving the ecological situation, maintaining stability of the agroecosystem (restoring macrostructures and water stable aggregates), and improving productivity (obtaining extra yield of up to 7.1 hw/ha) of soya.

The rational use of the bioenergy resource and the biological potential of the most studied crop has been proven, due to its ability of nitrogen bonding to bond atmospheric nitrogen, thereby reducing the dosage of used nitrogen fertilizers (which allows to reduce the amount of nitrogen fertilizer by 25-50%), which contributes to environment protection and resource saving in the agroecosystem.

The possibility of replacing the primary dumped tillage with mini-till processing has been found, which provides reliable recovery and preservation of soil fertility. Reducing the mechanical stress during mini-till processing ensures improved water stability of soil aggregates, increases coefficient, and maintains soil structure.

The recovered parameters of the agrophysical indicators of soil fertility and reduced total energy costs (fuel consumption) by 21.8-28.4%, as well as the cost of the product with the use of alternative methods technologies in the conditions of the submontane zone of the Southeastern Kazakhstan have been determined.

References

[1] A.P. Kaledin, E.G. Abdullah-Zadeh, V.V. Dezhkin, Ekologo-ekonomicheskie problemi APK, Ekologo-ekonomicheskie aspekti sovremennogo prirodopolzovaniya [Ecological-economic problems of the AIC, Ecological and economic aspects of modern environmental management], Moscow: MGOOiR, 2011; 157-166.

[2] V.A. Gazdanov, Itogi raboti NII agroekologii Gorskogo GaU [Results of the Agroecology Research Institute of the Gorsky SAU], International scientific-practical conference "Environmentally Friendly Technologies in the Agricultural Production of the XXI Century", Vladikavkaz: Publishing House of the Gorsky State Agrarian University, 2000; 3-7.

[3] B.M. Mirkin, L.G. Naumova, Besedi ob ustoichivosti ekosistem [Conversations about ecosystems sustainability], Ecology and Life 2 (2005) 33-37.

[4] P.V. Smekalov, N.Y. Omarova, Globalnie tendentsii i prioritetnie napravleniya razvitiya selskogo hozyaistva v nachale XXI veka [Global trends and priorities in development of the agriculture at the beginning of the XXI century], Economy of the Region 1 (2011) 11-21.

[5] E.M. Shcherbakova, Naselenie mira po otsenkam OON peresmotra 2017 goda [The World's Population According to UN Estimates, 2017 revision], Demoscope Weekly 735-736 (2017). http://demoscope.ru/weekly/2017/0735/barom01.php. Accessed August 9, 2018.

[6] J. Beddington, The Future of Food and Farming: Goals and Alternatives to global Sustainable Development, Foresight: The Future of Food and Farming, London: The Government Office for Science, 2011.

[7] S.B. Kenenbayev, Strategicheskaya tsel – innovatsionnie resheniya [Strategic goal is innovation], Agricultural Bulletin of Kazakhstan 6 (2011) 7-9.

[8] N. Suleimenova, M. Filipova, E.M. Kuandykova, S. Zharaspayeva, Innovative technology in the sphere of environmental safety today, 16th International Scientific Geo Conference, Albene, 28 June-7 July, 2016; 501-507.

[9] S.I. Gilevich, Nauchnie osnovi sberegayuschego zemledeliya stepnih raionov Kazahstana. [Scientific bases for efficient farming in the steppe regions of Kazakhstan], Agricultural Bulletin of Kazakhstan 1 (2011) 35-37.

[10] Ministry of Agriculture of RK, The new branch-related Program for development of the agroindustrial complex in 2013-2020 "Agribusiness-2020" of AIC of RK.

[11] V.N. Gladkov, Vliyanie sistemi osnovnoi obrabotki chernozema vischelochennogo na plotnost' slozheniya, razvitie klubenkovih bakterii i urozhainost soi v nizmenno-zapadinnom agrolandshafte [The influence of the main system of tilling leached black soil for achieving structural density, development of nodule bacteria and soya yields in the lowlands-pitted landscapes], Works of the Kuban State Agrarian University 1(34) (2012) 164-166.

[12] V.P. Vasilko, V.N. Gladkov, Alternativnie tehnologii vozdelivaniya soi na vischelochennom chernozeme tsentralnoi zoni Krasnodarskogo kraya v usloviyah orosheniya [Alternative technologies of cultivating soya on leached black soils of the Central zone of the Krasnodar Krai with irrigation], KubSAU 408(436) (2004) 142-147.

[13] A.K. Sadanov, G.D. Sultanbekova, A.A. Torekhanov, Izuchenie deistviya preparata «RIZOVIT-AKS» na urozhainost soi v krestyanskih hozyaistvah almatinskoi oblasti [Studying the effect of the RIZOVIT-AKS preparation on soya yield at the farms in the Almaty region], News of NAS of RK: Biology (2013) 60 -62.

[14] K. Alisheva, Prirodnie resursi Kazahstana ih ispol'zovanie i ohrana. Pochvennie resursi i ih ohrana [Natural resources of Kazakhstan and their use and protection. Soil resources and their protection], Almaty: NAS, 2006.

[15] Sistema vedeniya selskogo hozyaistva almatinskoi oblasti: Rekomendatsii [The agriculture system in the Almaty region: Recommendations], Almaty: LLP "Nurly Alem", 2005.

[16] B.A. Dospekhov, Metodika polevogo opyta [Field experiment methods], Moscow: Agropromizdat, 1985.

[17] A.T. Boyko, Y.G. Karyagin, Metodicheskie Rekomendatsii. Soya visokobelkovaya kultura [Guidelines. Soya as a high protein crop], Almaty: JSC "Vita", 2004.

[18] Institute of Field Crops and Vegetable Production, Soya: Obschie polozheniya i rekomendatsii po viraschivaniyu [Soya: General regulations and recommendations for cultivation], Novi Sad, 2001.

[19] A.M. Novikova, D.A. Novikov, Metodologiya nauchnogo issledovaniya [Methodology of scientific research], Moscow: Librokom, 2010.

[20] R.E. Eleshev (ed.), Praktikum po agrohimii [Workshop on agricultural chemistry], Almaty, 2014.

[21] State Committee of the USSR for Hydrometeorology, RD 52.18.286-91 Metodika vipolneniya izmerenii massovoi doli vodorastvorimykh form metallov (medi, svintsa, tsinka, nikelya, kadmiya, kobalta, hroma, margantsa) v probah pochvi atomno-absorbtsionnim analizom [Methods of measuring the mass fraction of water-soluble forms of metals (copper, lead, zinc, nickel, cadmium, cobalt, chromium, manganese) in soil samples by atomic absorption analysis], Moscow, 1991.

[22] V.Z. Spirina, T.P. Solovyova, Agrohimicheskie metodi issledovaniya pochv, rasteniy i udobreniy [Agrochemical methods of studying soils, plants and fertilizers], Tomsk: Publishing House of Tomsk State University, 2014.

[23] Directorate of Soybean Research, Director’s Report and Summary Tables of Experiments (2008-2009), Indore: All India Coordinated Research Project on Soybean, 2009.

[24] S. Gurikbal, B. Shivokumar, Rol soi v selskom hozyaistve [The role of soybean in agriculture], SOYA: biology, production, and usage, Kiev: Publishing house "Zerno", 2014; 59-88.

[25] N.I. Milto, Klubenkovye bakterii i produktivnost bobovih rasteniy [Root nodule bacteria and productivity of leguminous plants], Minsk, 1982.
[26] V.S. Emtsev, E.N. Mishustin, Microbiology, Moscow: Drofa, 2005.
[27] M.J. Unkovich, J.S. Pate, An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes, Field Crops Research 65 (2000) 211-228.
[28] J. Brockwell, R.R. Gault, D.F. Herridge, L.J. Morthocpe, R.J. Roughley, Studies on altecnative means of legume inoculants: microbiological and agronomic appraisals of commercial procedures for inoculating soybeans with Bradyrhizobium japonicum, Australian Journal of Agricultural Research 39 (1988) 965-972.
[29] D.F. Herridge, M.B. Peoples, R.M. Boddey, Global inputs of biological nitrogen fixation in agricultural systems, Plant and Soil 311 (2008) 1-18.
[30] R.L. Cooper, A delayed flowering barrier to higher soybean yields, Field Crops Research 82 (2003) 27-35.
[31] P.A. Ndakidemi, F.D. Dakora, E.M. Nkonya, D. Ringo, H. Mansoor, Yield and economic benefits of common bean (Phaseolus vulgaris) and soybean (Glycine max) inoculation in northern Tanzania, Australian Journal of Experimental Agriculture 46 (2006) 571-577.
[32] M. Albureda, D.N. Kodriguez-Navarro, F.J. Temprano, Soybean inoculation: Dose N fertilizer supplementation and rhizobia persistence in soil, Field Crops Research 113 (2009) 352-356.
[33] A.T. Austin, G. Pineiro, M. Gonzales-Polo, More or less: Agricultural impact on the N cycle in Argentina, Biogeochemistry 79 (2006) 45-60.
[34] B.J.R. Alves, R.M. Boddey, S. Urquiaga, The success of BNF in soybean in Brazil, Plant and Soil 252 (2003) 1-9.
[35] D.F. Herridge, J.F. Holland, Production of summer crops in northern New South Wales. I. Effects of tillage and double cropping on growth, grain and N yields of six crops, Australian Journal of Agricultural Research 43 (1992) 105-122.