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РЕСПУБЛИКИ КАЗАХСТАН

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AGRARIAN UNIVERSITY

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INNOVATIVE TECHNOLOGIES OF SOYBEAN CULTIVATION

Abstract. The effectiveness of innovative soybean technology solutions in solving ecological problems of the agroecosystem is reduced, which reduces the environmental burden on the environment in the scale of the cultivated crop. The ecological aspects of the application of mineral fertilizers in combination with the inoculation of soybean seeds, taking into account their biological characteristics, are described as one of the techniques of resource-saving technology aimed at maintaining the stability of the agroecosystem and increasing the productivity of soy. The possibility of replacing the main dump cultivation with fine planing (Mini-till), which provides a reliable restoration and preservation of the fertility of the soil resource, has been revealed. The obtained results indicate that mineral fertilizers contribute directly to the maximum height of soybean standing and the accumulation of dry matter. The introduction of mineral fertilizers in a dose of $P_{60}K_{30}$ provides an increase in linear growth of plants by 11-16% and with an increase in the dose to $N_{30}R_{60}K_{30}$ – by 21%. Rational use of the bioenergetic resource and biological potential of the culture studied, due to the ability of nitrogen fixation to bind atmospheric nitrogen, as a result of which the dose of nitrogen fertilizers used decreases, the norm of nitrogen fertilizer can be reduced, which contributes to the protection of the environment and the resource saving of the agroecosystem.

Keywords: agroecosystem, soybean, innovative technology, inoculation, Mini-till, recovery, productivity.

Introduction. In certain ecosystems its interaction with environment causes many negative consequences, changes in parameters, non-balancing of biogeochemical cycles, elements and level of soil fertility [1]. This refers to the agrarian sphere since agriculture takes a special place in ensuring balanced conditions for ecosystem's normal existence [2, 3]. According to Rattan Lal (2007), world agriculture has never met with such serious problems as in the first decades of the 21st century [4, 5]. These problems are caused by 7.6 billion population in 2017 and its expected increase from 9.6 to 13.2 billion by 2050 [6].

The constant and unceasing growth of the world's population creates an increasing need for food. To meet this demand, agrarians need to develop and implement more advanced and sophisticated innovative farming technologies that allow to obtain more yields per unit of area [7]. The role of agricultural production in providing the country with food, increasing employment and economic development of the republic unambiguously dominates [8, 9].

Therefore, agro-industrial complex faces an important current agroecological problem, connected with achieving goal of the industrial program for development of agro-industrial complex (AIC) of the Republic of Kazakhstan until 2020 [10, 11]. The tasks should be aimed at increasing the yield, acreage, introduction of techniques for intensive crop cultivation. But, at the moment, as a result of increasing frequency and re-occurrence of droughts and increasing aridity on territories of a number of agricultural zones of the republic, productivity of this production will probably decrease sharply. In regard to this, new innovative technologies in agriculture and diversification of crop production are needed to solve these problems.

It should be noted that development of innovative environmental technologies is one of the key conditions for sustainable economic growth, ensuring the competitiveness of its products on world markets. Also it's one of the most pressing issues currently being discussed in the world community. With innovative new technology, production costs are reduced, it is possible to achieve great success in obtaining economic profit [12, 13]. That is why scientists are so interested in issues of continuous modernization and introduction of new perspective and innovative technologies. In context of our study, under environmentalization of agroecosystem's environment, the priority of scientific research is towards ensuring sustainable production of high-quality biological products, effective use of natural bioenergetic potential of cultivated crop and restoration of soil and energy resources.

According to the results of our research, this technology reduces ecological burden on the environment within the scope of cultivated crop, which is especially beneficial (from the economic point of view) for the agricultural enterprises themselves. The less fuel, energy, fertilizers, seeds, man-hours and other resources are expended on the production of a single unit, the lower its cost and the higher the profit from its sale.

Therefore, when developing techniques of innovative soybean technology, resource-saving optimal parameters for application of mineral fertilizers were identified, taking into account the biological characteristics of soybean. We studied the influence of $P_{60}K_{30}$ and $N_{30}P_{60}K_{30}$ aimed at improving environmental situation, maintaining the stability of agroecosystem and increasing productivity of soy.

This article highlights the effectiveness of innovative soybean technology - use of mineral fertilizers in combination with soybean seeds inoculation taking into account their biological characteristics. The possibility of replacing the main dump moldboard tillage with fine flat-cut tillage (Mini-till) can provide: firstly, the restoration of agrophysical indices of soil fertility, and secondly cost reduction of total energy (fuel consumption) by 21.8-28.4%, and production cost when applying resource-saving techniques of innovative technology in foothill zone conditions of southeast of Kazakhstan.

Methods and objects of research. The object of research is a unique leguminous crop – soybean (Eureka variety), short-rotational crop tillage. The traditional technology of soybean cultivation was used as a control in experiments, in accordance with recommendations of the System of Agriculture of Almaty oblast [14]. The classical techniques of field observations and experiments have been used [15, 16]. Field experiments were made in training and experimental farm "Agrouniversitet" in foothill zone conditions of southeast of Kazakhstan.

The experimental field's soil is resembled as onion-chestnut type of heavy mechanical composition. The humus content in the plow horizon is 4.3%, which gradually decreases with depth. The content of total nitrogen and total phosphorus is high - 0.258 and 0.211%, respectively [17]. The climate of the region is characterized as sharply continental with low humidity, plenty of sunlight, short, but cold winter.

Results of the research and discussions. The effectiveness of innovative methods of soybean technology, such as use of mineral fertilizers in combination with soybean seeds inoculation has been studied taking into account their biological characteristics. Various methods of cultivation technology such as the timing of sowing, depth and methods of seeding, inoculation of seeds, basic and presowing soil formation, etc. have a tremendous impact on activity of microorganisms, soil aeration and crop quality. And this, in turn, affects speed of nitrogen fixation.

During the study of resource-saving techniques of innovative technology, we tested two options for application of mineral fertilizers - $P_{60}K_{30}$ and - $N_{30}P_{60}K_{30}$ when treating seeds with nitragin and without treatment. To determine the influence and dosage of the studied variants and mineral fertilizers and study inoculation on activity of nodule formation and determining the optimum seeding rate, we studied 3 seeding rates of 400, 600 and 800 thousand pcs / ha with a row spacing of 30 cm.

In order to make a comparative evaluation of the studied norms of mineral fertilizers, inoculation and the rate of seeding we took as control - St soybean seeding without fertilizers with traditional technology.

To determine the influence of studied variants of mineral fertilizers' norms and inoculation on the activity of forming nodules, we studied 3 seeding rates of 400, 600 and 800 thousand pieces / ha. Studied variants of techniques have impact on growth and development of soybeans along with the aboveground part and the underground part of the culture. The main indicator of the effectiveness of symbiosis of plants and nodule bacteria is their number and mass.

Observations and calculations of the amount of formed nodules and their mass under traditional technology in studied seeding rate variants without inoculation showed that very few nodules of 9.7- 12.4 pieces per plant were formed on the roots of soy. Their number increases in case of seed inoculation with nitragin. In variants with nitragin inoculation but without fertilizers, the number of nodules increases depending on the seeding rate from 16.2 pcs. up to 21.0 pieces on one plant. When $N_{60}P_{180}K_{90}$ mineral fertilizers were applied in recommended dose on the control variant of traditional technology, the formation of nitrogen-fixing nodules increases up to 27.7 and 29.5 pc/plant, while the weight of dry nodules is 124.6-137.1 mg/plant.

Under resource-saving technology seed inoculation with nitragin has a significant positive effect on formation of nodules where the number of nodules increases to 24.5-29.1 pcs/plant, depending on the seed sowing rate. When applying $P_{60}K_{30}$ – 35.1-38.0, when applying $N_{30}P_{60}K_{30}$ fertilizers this pattern of dependence of nodule formation is maintained and makes 39.4-47.6 pcs/plant (in case of resource-saving Mini-tillage on depth of 16-18 cm). And, the mass of nodules increases in the same sequence as the number of nodules in the variants. The increase of these indicators proves the rational use of bioenergetic resource and the biological potential of studied culture, due to the ability of nitrogen fixation to bind atmospheric nitrogen, which decreases the dose of used nitrogen fertilizers (thereby reducing the nitrogen fertilizer rate by 25-50%), which contributes to environmental protection and resource saving agro-ecosystem.

In interpreting obtained experimental data, we noted that advantages of resource-saving methods of innovative technologies are: - a reduction in the number of technological operations for soil processing, - restoring, maintaining and increasing soil fertility, - improving the ecology of the ecosystem and reducing current costs.

In existing traditional system, which is adopted for the control variant, a number of tillage methods are performed in a certain sequence. As a result, environmental problems arise, such as excessive soil spraying and drying, deterioration of soil resources indicators, increase in financial and energy costs. The share of tillage accounts for 30-40 percent of all costs. Therefore, it is necessary to focus on effective and environmentally friendly innovative methods of cultivation technologies, such as minimal tillage.

The results of soil fertility monitoring in studying the effect of minimal soil cultivation on soil resources (soil fertility) made it possible to give a comparative assessment of the arable layer and soil composition and structure comparing to traditional and resource-saving technologies. In traditional technologies system of dump moldboard tillage processing, the arable layer is characterized by a more loose composition with a high total porosity and degree of aeration, which is not desirable.

According to many researches the density leaves an imprint on the whole complex of soil's physical conditions, on its hydro, aerial, thermal regimes and, consequently, on conditions of agroecosystem's biological activity. When soy is cultivated, optimal aeration of the upper soil layer is very important, in which the root system of plants and nodule nitrogen-fixing bacteria normally function. Therefore, at present, both domestic and foreign scientists study the soil treatment system in terms of regulating soil density.

Under the conditions of our research, composition of arable layer of soil has been studied in dynamics over the phases of soybean development. During the initial period of plant development, soil density under traditional cultivation technology is much lower. In period of soybean sowing associated with the preparation of soil for sowing, the bulk mass of the soil is within the limits of 0.89 and 0.95 g/cm^3. The arable layer has a loose constitution with a large porosity, which causes an accelerated physical evaporation of soil moisture, after that the water regime of the root-forming layer of nodule formation decreases.

In this variant of traditional technology, the bulk mass of the soil increases in the developmental phases from 0.95 to 1.19 g/cm^3. The average density of soil during the vegetation period of soy is 1.06 g/cm^3.

With application of minimal tillage variants, the soil density becomes 1.14-1.15 g/cm^3. During the vegetative period, the regularity in structure of arable layer of soil is characterized by minimal tillage variant of study. During the periods of growth and development of soybean, the density of the soil is characterized by the bulk increase of mass with flat-cut soil tillage for the depth of 16-18 cm from 1.16 g/cm^3 (sprouting phase) to 1.24 g/cm^3 (ripening), where average density in vegetation is 1.20 g/cm^3.

In case of a minimal flat-cut tillage for the depth of 12-14 cm, composition of arable layer has a more dense build-up, the bulk mass of the soil increases from 1.17 g/cm^3 (sprouting phase) to 1.27 g/cm^3 (ripening), where the average density for vegetation is 1.22 g/cm^3.

It should be noted that under resource-saving technology, minimization of soil cultivation has resulted in a reliable preservation and restoration of soil fertility indicators due to changes of arable soil layer's composition. In variants with minimal (Mini-Till) technology of tillage, the soil density is optimized in comparison with the traditional treatment, the volume mass of the arable layer increases by 0.14-0.16 g/cm^3, optimal density approaches the equilibrium of 1.20-1.22 g/cm^3 of soil, where develop favorable environmental conditions for growth and development of soybean plants (table 1).

Table 1 – 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/cm^3							Macro-structuredness, %	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 depth of 16-18 cm without ploughing	1.14	1.16	1.19	1.20	1.22	1.24	1.20	43.2	38.1	0.84
	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

Along with optimization of arable soil layer's structure the techniques of resource-saving technology have a significant effect on aggregate composition and structure of soil. As can be seen from the table, in comparison to traditional technology with dump plowing, the sum of macroaggregates of the arable layer of soil is 32.1%, and the sum of water-resistant aggregates is 23.5%, with a structural coefficient only 0.63. The results of agrophysical indices of this technology characterize the deterioration of the soil structure. Decrease in these indicators greatly reduces the most important processes occurring in the soil, primarily aerial, hydro and thermo regimes, and this leads to a decrease in growth and development of soy. It is especially important to ensure optimum parameters of soil porosity during the flowering phase - the bean formation, when the symbiotic soybean apparatus reaches its maximum development and the lack of air during this period can lead to low nitrogen uptake and, as a consequence, shortage of harvest. Minimal tillage of the soil resulted in a reliable preservation and increase of agrophysical indicators of soil fertility. Comparing to resource-saving technology, flat-cut minimal-tillage (Mini-Till) showed that the sum of soil macroaggregates rises from 32.1% to 43.2 - 51.7%, and the sum of water-resistant aggregates from 23.5%, to 38.1 – 39.2% and the structural coefficient from 0.63 to 0.84 - 0.89.

Decreasing the number of mechanical influences by 2 times with the minimum (Mini-Till) technology of soil cultivation provides an increase of aggregates' water resistance which is especially important in soybeans cultivation in irrigation conditions. Since the symbiotrophic process is aerobic, the optimization of air regime in the active root layer has particular importance

The aggregate composition improves, soil structure restores and air regime of agroecosystem becomes optimized in cases where large nodules of nitrogen-fixing bacteria are formed on soybean roots.

Based on the results obtained, it is proved that the application of minimal (Mini-Till) soil cultivation increases the stability of soil's ecological condition, ensures stabilization of arable soil structure for optimal growth and development of soybean in southeast of Kazakhstan.

The obtained results indicate that mineral fertilizers contribute directly to the maximum height of soybean standing and accumulation of dry matter. The introduction of mineral fertilizers in a dose of $P_{60}K_{30}$ provide an increase in linear growth of plants by 11-16%, and dose increase to $N_{30}R_{60}K_{30}$ - by 21% and accumulation of solids increases at appropriate doses within 9% and 12%, which is associated with improved supply of food elements with nutrients. The height of plants during the years of research varied between 47.3 and 70.7. It grew with increasing seeding rate.

In regular soybean sowing with a width of 30 cm, the smallest plant height of 40.3 cm was noted in the variants with the lowest seeding rate, and with an increase of up to 800 thousand pieces/ha, it reached 63.5 cm. This is due to the fact that light regime improvement stimulates an increase in plant height. The height of lower beans' attachment directly depended on the height of the plants and changed with it. The average number of grains in soya beans varied from 1.6 to 2.5 per year, the weight of 1000 seeds varied from 104.8 to 142.4 g.

The use of nitragin has a symbiotic effect, increases the number and weight of nodules on the roots of soybean plants, which improve the nitrogen nutrition of crops, with the subsequent increase in the productivity of the crop (table 2).

Table 2 – Productivity of soybean depending on use of mineral fertilizers with inoculation during the years of research, centner/ha

Technology	Variants of using fertilizers	Yield during years of research, c/ha			Average yield, c/ha	Increase in	
		2015	2016	2017		c/ha	%
Traditional	W/t 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
Resourse- saving flat-cut tillage for depth of 16-18 cm	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
Resourse- saving flat-cut tillage for depth of 12-14 cm	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
HCP_{05}, centners/ha =		1.85	2.15	2.3			
S_x, % =		2.75	3.06	3.87			

Under resource-saving technology on the background of phosphate-potassium fertilizer ($P_{60}K_{30}$), the yield of soybeans rises to 25.5 c/ha, which is 28.7%, providing an increase in yield of 5.7 c/ha and full fertilization ($N_{30}R_{60}K_{30}$) provides 26.9 c/ha (35.8%) and an additional yield of up to 7.1 c/ha.

A comparative assessment of soybean responsiveness to the level of mineral nutrition showed that, due to its physiological characteristics, the soybean reacts distinctly to changes in the nutrient regime of soil. Introduction of phosphorus and potassium fertilizers against the background of seed treatment with nitragin increases the yield of soybeans to 25.7 c/ha ($P_{60}K_{30}$) and to 26.3 c/ha ($N_{30}R_{60}K_{30}$).

The yield of soybean grain showed a higher yield increase from using mineral fertilizers with inoculation: 6.5 - 7.1 c/ha compared to the control harvest.

Under traditional technology, seed inoculation provides a yield increase of 2.1 c/ha, while in case of resource-saving technology this difference is 5.7-5.9 c/ha (at a dose of $P_{60}K_{30}$) and 6.5-7.1 c/ha (at a dose of $N_{30}R_{60}K_{30}$). Joint application of mineral fertilizers and inoculation with resource-saving technology creates favorable conditions for the synthesis and accumulation of biomass. Moreover, a higher effect of inoculation was observed in variants without fertilizers and with application of mineral fertilizers $P_{60}K_{30}$.

Thus, it was revealed that in conditions of southeast of Kazakhstan primary scientifically justified methods of increasing soil fertility and soybean yield are the application of optimal dose of mineral fertilizers and inoculation of soybean seeds with use of resource-saving techniques of innovative technologies that allow to quickly monitor agroecosystem's ecological situation. Thus, they are among the main methods for stabilizing soil, biological resources, providing energy and maintaining agroecosystem's resource saving.

Conclusion. The norms for introduction of mineral fertilizers ($P_{60}K_{30}$) in combination with inoculation of soybean seeds, by taking into account biological characteristics, are optimal, as one of the methods of resource-saving technology and are aimed toards improving ecological situation, maintaining stability of agroecosystem (soil structure and water resistance of the aggregates are restored) and increasing productivity (additional yield up to 7.1 centner/ha.) of soybeans.

The possibility of replacing the basic dump cultivation with fine flat-cut (Mini-till) tillage, where:

- firstly, the aggregate composition improves, the soil structure restores and the air regime of the agroecosystem becomes optimized in case where large nodules of nitrogen-fixing bacteria are formed on soybean roots;

- Secondly, it reduces the costs of aggregate energy (fuel consumption) by 21.8-28.4% and raises yields while using resource-saving techniques of innovative technology in foothill zone of the southeast of Kazakhstan.

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ИННОВАЦИОННЫЕ ТЕХНОЛОГИИ ВОЗДЕЛЫВАНИЯ СОИ

Аннотация. Освящена эффективность приемов инновационной технологии сои в решении экологических проблем агроэкосистемы, которые снижают экологическую нагрузку на окружающую среду в масштабах возделываемой культуры. Изложены экологические аспекты применения минеральных удобрений в сочетании с инокуляцией семян сои с учетом их биологических особенностей, как один из приемов ресурсосберегающей технологии направленные на поддержание стабильности агроэкосистемы и повышение продуктивности сои. Выявлено возможность замены основной отвальной обработки почвы с мелкой плоскорезной обработкой (Mini-till), обеспечивающие достоверное восстановление и сохранение плодородия почвенного ресурса. Полученные результаты свидетельствует о том, что минеральные удобрения непосредственно способствуют достижению наибольшей высоты стояния сои и накоплению сухого вещества. Внесение минеральных удобрений в дозе $P_{60}K_{30}$ обеспечивает увеличение линейного роста растений на 11-16% и при увеличении дозы до $N_{30}P_{60}K_{30}$ – на 21%.

Рациональное использование биоэнергетического ресурса и биологического потенциала самой изучаемой культуры, благодаря способности азотфиксации связывать атмосферный азот, вследствие чего снижается доза применяемых азотных удобрений позволяет уменьшить норму азотного удобрения, что способствует защите окружающей среды и ресурсосбережения агроэкосистемы.

Ключевые слова: агроэкосистема, соя, инновационная технология, инокуляция, Mini-till, восстановление, урожайность.

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МАЙБҰРШАҚ ӨСІРУДІҢ ИННОВАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАРЫ

Аннотация. Мақалада агроэкожүйенің экологиялық мәселелерін шешуде майбұршақ дақылын өсірудің инновациялық технологиясының тиімділігі баяндалады, бұл егістік өнімділігіне және қоршаған ортаға экологиялық жағдайын жақсартуға, ресурстарды үнемдеуге ықпал етеді. Минералды тыңайтқыштарды қолданудың экологиялық аспектілері олардың биологиялық сипаттамалары ескеріліп, майбұршақ дәндерінің егуімен ұштастыра отырып, агроэкожүйенің тұрақтылығын сақтауға және майбұршақ өнімділігін арттыруға бағытталған ресурс үнемдеу технологиясының әдісі ретінде қарастырылады. Топырақты минималды шығынмен сыдыра жырту (Mini-till) әдісімен ауыстырудың маңыздылығын дәлелдеуде, агроэкожүйенің тиімді экологиялық жағдайын қамтамасыз ететін, топырақ ресурстарының құнарлығын қалпына келтіреді және сақтап қалады. Алынған нәтижелер бойынша минералды тыңайтқыштардың әсері майбұршақтың биіктігіне және құрғақ заттардың жинақталуына тікелей әсер ететіні айқындалды. $P_{60}K_{30}$ мөлшерінде минералды тыңайтқыштарды қолдану өсімдіктің өсуін 11-16%-ға және $N_{30}P_{60}K_{30}$ мөлшерде 21%-ға дейін арттыруға мүмкіндік береді. Зерттелініп отырған майбұршақ дақылында агроэкожүйесінің өнімділігін арттыру мақсатында биоэнергетикалық ресурсты және биологиялық потенциалды рациональды пайдалану, азотфиксация қабілетіне байланысты – атмосфералық азотты байланыстырады, соның салдарынан қолданбалы азотты тыңайтқыштардың дозасы азаяды, бұл қоршаған ортаны қорғауға және агроэкожүйенің ресурстық үнемдеуіне ықпал етеді.

Түйін сөздер: агроэкожүйе, майбұршақ, инновациялық технологиялар, инокуляция, Mini-till, қалпына келтіру, өнімділік.

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