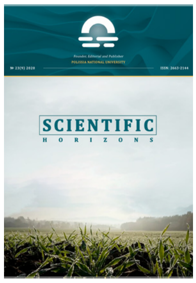
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua

Scientific Horizons, 24(2), 77-83



UDC 633.559.533:34:63.582(477)

DOI: 10.48077/scihor.24(2).2021.77-83

SOYBEAN PRODUCTIVITY DEPENDING ON THE ELEMENTS OF ORGANIC CULTIVATION TECHNOLOGY IN THE SHORT-TERM CROP ROTATION OF UKRAINIAN POLISSIA

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Article's History:

Received: 05.02.2021

Revised: 28.04.2021

Accepted: 24.05.2021

Suggested Citation:

Didora, V., & Kluchevych, M. (2021). Soybean productivity depending on the elements of organic cultivation technology in the short-term crop rotation of Ukrainian Polissia. *Scientific Horizons*, 24(2), 77-83

Abstract. Over the past decades, intensive farming has operated under conditions of progressive degradation of the soil cover, maintaining production levels only at the expense of inadequate expenditure of non-renewable energy resources. The soils have acquired irreversible excessive compaction in the sub-arable part of the profile, and the dehumification has acquired a threatening status. The humus content in the soils of Ukraine decreased by almost 25%, and the average annual losses amount to 0.6-0.7 t/ha. Therefore, the search for ways to guarantee the reproduction of soil organic matter, reliable control and restoration of the optimal humus status is extremely relevant. The purpose of the study is to activate natural nitrogen-fixing systems using a mix of green manure and by-products of agricultural crops of short-term leguminous crop rotation. Field experiments were conducted on light grey soils during 2018-2020 in the experimental field of Polissia National University in a leguminous short-term rotation system. This study uses general scientific methods to establish the area of research, plan and lay experiments, conduct observations and analysis; visual – during the implementation of phenological observations; field – to study the relationship with abiotic factors; physiological – to determine the symbiotic effectiveness of preparations of biological origin. The technology of growing agricultural crops in leguminous crop rotation, which ensures the supply of raw materials of organic origin and the accumulation of air nitrogen by root nodule bacteria, has been theoretically substantiated and improved. It is established that one hectare of crop rotation area receives 6.8 tonnes of dry organic raw materials, which corresponds to 78.3 kg/ha of biological nitrogen. It is found out that inoculation of soybean seeds with a preparation of biological origin – Optimise 400, and treatment of soybean crops at BBCH microstages 60-63 with a complex microfertiliser on a chelated basis Nanovit Super+Magnesium Sulphate contributes to the active development of nodule bacteria, the number and weight of which is 81-89 pcs per plant and 510-572 kg/ha. Thus, the active symbiotic potential was 34.2-38.9 thousand kg/day. It is proved that during the growing season soybeans generate 357-400 kg/ha of biological nitrogen in the air, which provides a seed yield of 2.96-2.64 t/ha and leaves 117-160 kg/ha of nitrogen in the soil. The practical value of this study lies in the possibility of enriching the soil with organic matter and the biological form of nitrogen

Keywords: soil fertility, crop rotation, seed inoculation, foliar dressing, soybean yield

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INTRODUCTION

Natural soil fertility deteriorates due to violations of scientifically based farming systems. The humus content in the soils of Ukraine decreased by almost 25%, and the average annual losses amount to 0.6-0.7 t/ha. The main reason for the loss of humus and nutrients is a catastrophic decrease in the application of organic fertilisers. The volume of production and application of organic fertilisers decreased by almost 15 times. If in 1990 the rate of application was about 10 t/ha per 1 ha, then in 2010 it was only 0.55 t/ha [1].

O.I. Furdychko [1] claims that the reduction of sown areas of legumes and perennial grasses, and a significant restriction on the application of organic fertilisers has led to the withdrawal from the cycle of almost 550 thousand tonnes of nitrogen. Due to the growth of the area under cultivation of energy crops, the intensive use of synthetic mineral fertilisers, the production of chemical plant protection products, the threat of chemical soil degradation and pollution of crop production increases. Threats of chemisation have led to the fact that the soil became "thin". The problem of intensive chemisation of soils was considered by many experts, in particular I.E. Ovsinskyi, one of the first to develop a system of agriculture that protects the soil from chemisation and allows obtaining environmentally friendly products [2].

The most important feature of ecological agriculture is the activation of natural nitrogen-fixing systems that accumulate biological nitrogen using leguminous crops [3]. In this regard, there is a need to find affordable and low-cost and economically justified measures to preserve and restore soil fertility, one of which is the mix of green manure with by-products of agricultural crops, especially straw, crop and root residues.

Straw contains macro- and microelements and becomes a source of plant nutrition after mineralisation in the soil. Approximately 180 kg of humus is synthesised from 1 tonne of straw. In addition, the straw of grain crops contains a large amount of nitrogen-free substances, which delays the biological processes of straw decomposition. For the mineralisation of straw, it is necessary to add 10-15 kg of mineral nitrogen or biogenic decomposers for each tonne [4].

Green fertiliser and bacterial preparations are the cheapest and best way to comprehensively restore soil fertility [5]. The use of green manure in combination with crushed straw, peat and partially with manure increases humus content in the soil by 0.10-0.12%, total nitrogen by 0.011%, mobile forms of phosphorus and potassium by 5-6 mg/100 g of soil [6]. The combined use of by-products of the predecessor and post-harvest crops of the cabbage green manure contributes to an increase in the humus content by 0.09% [7].

The potential of crop production can be fulfilled only through high soil fertility and improvement of its functional properties. Reproduction of soil fertility is one of the main levers for increasing the yield of various crops and the productivity of agricultural systems as a whole [8]. Symbiosis of legumes with nodule bacteria is one of the most effective systems of biological nitrogen fixation, which is of great ecological and practical importance. In rhizobium-legume symbiosis, a combination of global biological processes – nitrogen fixation and photosynthesis – is achieved, which normalises the nitrogen-carbohydrate balance of the plant organism [9; 10]. It is proved that nitrogen fixation occurs slowly at the initial stages, but by the phase of full flowering, the activity and raw weight of root nodules reaches maximum [11]. Under optimal conditions of symbiotic nitrogen fixation, soybean plants can absorb up to 200 kg of biological nitrogen per ha [12-14], the absorbed nitrogen is used to form the soybean crop and 25-40% remains in the soil with organic residues, increases the content of humus and nitrogen in it.

The purpose of the study – to investigate the elements of organic technology, providing the soil with organic raw materials of short-term crop rotation and the symbiotic efficiency of nodule bacteria and the intake of biological nitrogen from the atmosphere.

MATERIALS AND METHODS

The study was carried out in accordance with the methodology of scientific research in agronomy [15]. Weather conditions, especially in 2019-2020, were dry, during the period of bean formation, the hydrothermal coefficient ranged from 0.1-0.9, which negatively affected the yield of field crops in rotation.

Productivity of short-term crop rotation was studied according to the following scheme:

1. Clover.
2. Winter wheat with the use of by-products and post-harvest green fertiliser.
3. Soy with the use of stem mass for fertiliser.
4. Barley with clover undersowing.

Studies on the effect of nitrogen-fixing, phosphorus-mobilising and complex microfertilisers in the form of EDTA chelate on the symbiotic productivity of soybeans are presented in the scheme:

1. Control – free of mineral fertilisers and pesticides.
2. Inoculation of seeds with Optimise 400.
3. Inoculation of seeds with phosphoroenterin.
4. Foliar dressing with a complex chelated fertiliser – Nanovit Super + magnesium sulphate.
5. Inoculation of seeds with Optimise 400 + phosphoroenterin.
6. Seed inoculation with Optimise 400 + foliar dressing (Nanovit Super + magnesium sulphate).
7. Inoculation of seeds with Optimise 400 + phosphoroenterin + foliar dressing;

The sown area is 33.6 (3.6x11) m^2, the accounting area is 25 (2.5x10) m^2, four-time replication.

The formation of nodules during the growing season was determined by the method of G. S. Posypanov (number and weight of nodules, nitrogen content and fixation) [16]. Elements of the technology of growing agricultural crops in a short-term crop rotation are generally accepted for the zone of sufficient moisture (Ukrainian Polissia).

Nanovit Super is a highly effective multicomponent preparation with a high NPK content of magnesium, sulphur, boron, copper, manganese, molybdenum, zinc soluble in water, based on EDTA chelate and organic components. Magnesium sulphite promotes growth and development, increases yields, the number of beans and seeds, increases resistance to drought, diseases, and pests, reduces the nitrate content. Mg – increases the chlorophyll content.

Optimise 400 is created based on the LCOPromote technologies, it contains the following components: an active component containing a pure culture of nitrogen-fixing bacteria (Bradyrhizobium japonicum); liquid components that extend the survival time of bacteria on seeds. The Optimise 400 promotes the colonisation of the soybean root system with nitrogen-fixing bacteria, the formation of nodules on the roots, regardless of environmental conditions, improves germination, root system development, increases yield and protein content in soybean seeds. This preparation can be used in a tank mixture with some seed protectants.

Nodules are formed 10 days earlier than when using other preparations, early closing of plants in the row spacing, increases competitiveness in relation to weeds, improves the resistance of soybeans to harmful organisms. Phosphoroenterin is designed to improve phosphorus nutrition from the soil. The strain of bacteria that make up the drug is able to decompose hard-to-dissolve organic phosphates. The consumption rate is 100 mg/ha. The drug is compatible with growth stimulants, microorganisms.

RESULTS AND DISCUSSION

Intensive use of mineral fertilisers contributes to an increase in yield, but is accompanied by a deterioration in the biological, physico-chemical and phytosanitary properties of the soil. Excess nitrogen leads to a decrease in the synthesising activity of microorganisms and, in particular, nitrogen-fixing bacteria and to an increase in the content of nitrates and nitrites. Therefore, modern crop rotations provide for the saturation with legumes to attract air nitrogen to the biological cycle and use them for green fodder and fertiliser. For this purpose, it is recommended to use local organic fertilisers, raw materials of crop residues, and green manure crops.

According to the results of the study conducted in 2018-2020, it was found out that the grinding and wrapping of by-products in combination with an intermediate form of green fertiliser, the introduction into the short-term crop rotation of perennial legumes (clover), legumes (soybeans), per 1 ha of crop rotation area receives 6.8 tonnes of dry weight, of which 5.3 tonnes of by-products (straw, crop and root residues), which in terms of mineral nitrogen is 78.3 kg/ha. The main share of organic raw materials falls on the embedding in the soil of by-products of winter wheat and post-harvest use of oilseed radish for green manure (Fig. 1).

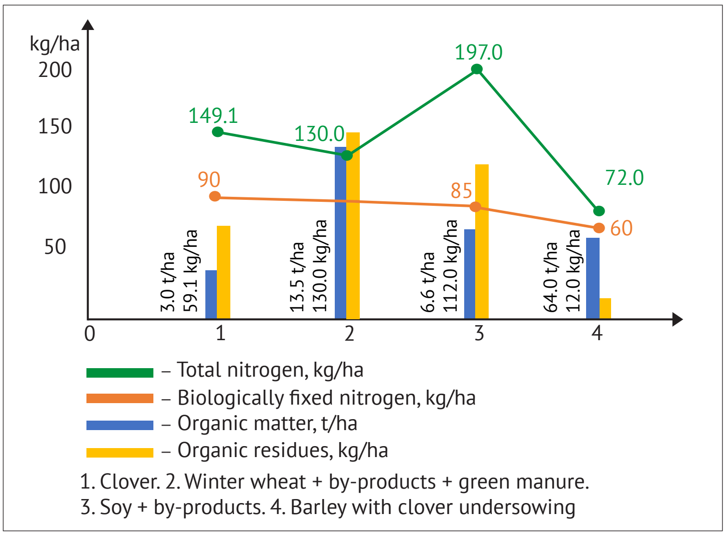


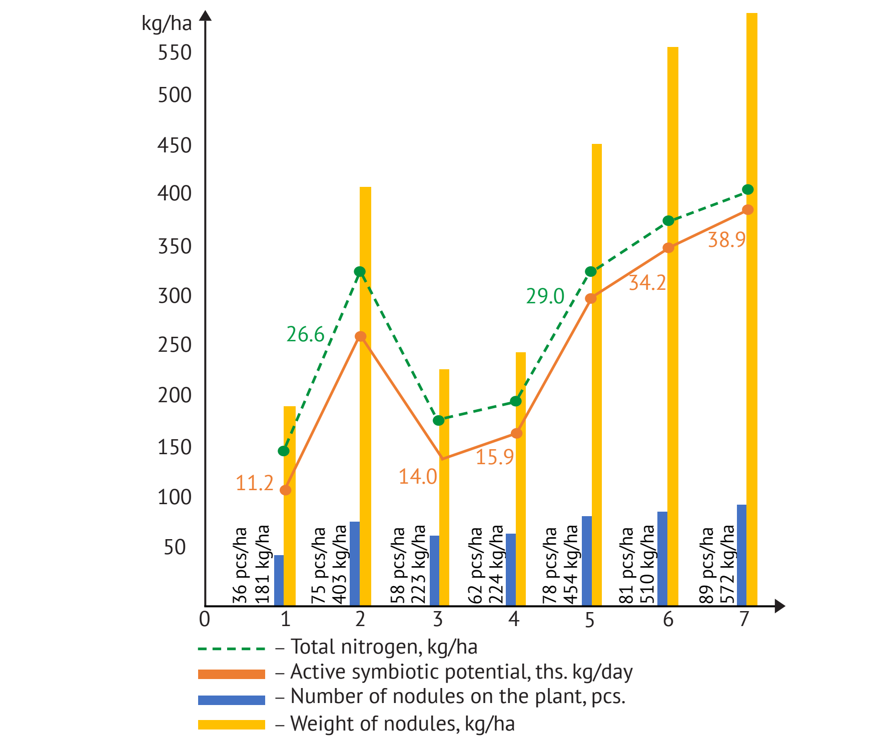
***Figure 1**. Intake of dry organic substance by weight and nitrogen in short term organic crop rotation*

The largest part of the supply of dry organic raw materials is obtained from by-products of straw, stubble and root residues and post-harvest sowing of oilseed radish for green fertiliser and is 13.5 t/ha and leafy soybean products, the share of which is 6.6 t/ha, that is, almost twice as much as clover and half as much as by-products of winter wheat with post-harvest green manure sowing. Calculations of nitrogen intake from by-products of winter wheat and green manure amount to 130 kg/ha, from soybeans – 112 kg/ha, and on average, 78.3 kg/ha is received per 1 ha of crop rotation area in 4-field crop rotation.

Biological fixation of air nitrogen by perennial legumes on average for 2018-2020 is 90 kg, and nodule bacteria fix 85 kg/ha. Figure 1 shows that the total nitrogen intake per 1 ha of crop rotation area is 137 kg/ha, which is equivalent to 410 kg of ammonium nitrate. To form a soybean yield of 3.0 t/ha, 240 kg of nitrogen is needed, therefore, 170 kg of biological nitrogen remains in the soil with by-products for the next crop in the rotation.

The weight of nodules on the root system of soybeans, without the use of agrochemicals, pesticides, and preparations of biological origin, is only 0.56 g, in terms of 1 ha – 181 kg/ha. Inoculation of soybean seeds with the Optimise 400 nitrogen-fixing drug provides an increase in the weight of nodules on the root system twice and reaches 403 kg/ha, forming 302 kg of air nitrogen. Treatment of soybean crops in the flowering phase with a complex chelated EDTA microfertiliser against the background of sowing inoculated seeds, the number of nodules on the root system increases by 45-53 pcs, and their weight amounts to 510-572 kg/ha. The symbiotic active potential is 34.2-38.9 ths kg/day and the resulting nitrogen of biological origin is 357-400 kg, which is 230-273 kg more than the control variant. That is, nature provided 1.0-1.19 tonnes of nitrogen worth UAH 9-10 thousand.

The active symbiotic potential and total nitrogen depending on preparations of biological origin are shown in Figure 2.



1. Control. 2. Inoculation – Optimise 400. 3. Inoculation – phosphoroenterin.
4. Foliar dressing. 5. Optimise 400 + phosphoroenterin. 6. Optimise 400 + foliar dressing.
7. Optimise 400 + phosphoroenterin + foliar dressing

***Figure 2**. Symbiotic potential depending on preparations of biological origin*

Taking into account the fixation of air nitrogen by nodule bacteria: clover – 90 kg/ha; soybeans – 85 kg/ha, on average, 137.0 kg/ha of nitrogen is received per 1 ha of crop rotation area, which is equivalent to 410 kg/ha of ammonium nitrate worth about 4,000 UAH (Table 1).

***Table 1**. Productivity of short-term leguminous crop rotation (average for 2018-2020)*

Biological crop rotation	Yield of dry organic raw materials, t/ha				Biological nitrogen intake, kg/ha			
	Seeds	Straw, crop and root residues	Green manure	Organic matter	Organic residues	Biologically fixed nitrogen	Total nitrogen	Ammonium nitrate equivalent
1. Clover	–	3.0	–	3.0	59.1	90.0	149.1	446
2. Winter wheat + by-products + green manure	6.8	7.5	6.0	13.5	130.0	–	130.0	130
3. Soybean + by-products	2.3	6.6	–	6.6	112.0	85.0	197.0	590
4. Barley with clover undersowing	4.6	4.0	–	4.0	12.0	60.0	72.0	240
Total	–	21.1	6.0	27.1	313.1	235.0	548.1	1640
per 1 ha of crop rotation area, kg	–	5.3	1.5	6.80	78.3	58.7	137.0	410

The use of straw in combination with intermediate forms of green fertiliser is of great ecological importance. Straw, together with the green mass of manure, decomposes without polluting the soil with high concentrations of nitrate nitrogen and eliminates the leaching of trace elements into water bodies. The use of green manure contributes to the development of soil fauna, in particular, increases the vital activity of bacteria, earthworms and other soil organisms.

Spraying of soybean crops with complex fertilisers Nanovit Super + magnesium sulphate was carried out at BBCH microstages 60-65 (emergence of the first flower buds) before opening 50% of the flowers. According to the study results, it was found that preparations of biological origin have positively affected the activity of the process of forming a symbiotic apparatus.

Studying the action and interaction of nitrogen-fixing, phosphorus-mobilising preparations and complex microfertilisers on a chelated basis, it was found that nodule bacteria began to appear on the roots of soybean plants at BBCH microstages 12-13, which was not observed in the control group. Not all nodule bacteria formed on the roots are nitrogen-fixing, that is, active. If they have a pink colour, then they can be classified as active. Conversely, if the nodules are greenish or grey in colour, then nitrogen fixation does not occur in them.

During 2018-2020, at the BBCH microstages 61-71, the total number of nodules on the control variant was 36 pcs/ plant, of which active – 16 pcs/ plant (Table 2).

Table 2. *Formation of the symbiotic potential of soybeans depending on biological preparations (bean filling phase (average for 2018-2020)*

Options	Seed yield, t/ha	Formation of nodules on the plant: Quantity, pcs	Formation of nodules on the plant: Weight of nodules on the plant, g	Formation of nodules on the plant: Nodule weight, kg/ha	Duration of active symbiosis, days	Symbiotic potential, thousand kg/day: Total	Symbiotic potential, thousand kg/day: Active	Air nitrogen formation, kg/ha
Control	1.61	36	0.56	181	62	17.3	11.2	127
Inoculation – Optimise 400	1.99	75	1.12	403	66	30.8	26.6	302
Inoculation – phosphoroenterin	1.80	58	0.62	223	63	22.4	14.0	156
Foliar dressing	1.68	62	0.66	244	65	20.6	15.9	192
Optimise 400 + phosphoroenterin	2.21	78	1.18	454	64	33.2	29.0	318
Optimise 400 + foliar dressing	2.96	81	1.22	510	67	34.1	34.2	357
Optimise 400 + phospho-roenterin + foliar dressing	2.64	89	1.26	572	68	41.8	38.9	400
$LSD_{0.5}$	2018 – 0.07 t/ha; 2019 – 0.05 t/ha; 2020 – 0.10 t/ha							

Data in Table 2 shows that in the control group, the formation of nodules was the smallest, and their weight was only 0.56 g per plant. Taking into account the density of the stem before harvesting and the weight of nodules of one plant, it was determined that for the duration of 62 days, their total weight was 181 kg/ha, and the formation of symbiotic nitrogen from the air was 127 kg/ha, for the seed yield of 3.0 t/ha, it assimilates 240 kg. The weight of nodules on the root system is doubled and amounts to 1.12 g, with the duration of active symbiosis, the assimilation of biological nitrogen is 302 kg, of which 240 kg is used to form crops and 62 kg remains in the soil. Carrying out inoculation of soybean seeds with phosphoroenterin does not contribute to the activation of the development of nodule bacteria, since the strains of bacteria that make up the preparation are able to decompose hard-to-dissolve organic phosphates only in soils rich in organic matter.

During growth and development, soy unevenly consumes nutrients, from flowering to seed filling, it uses 78.5% nitrogen, and during this interphase period, nodule bacteria die. Thus, it is necessary to carry out foliar dressing with a multicomponent composition of macro- and microcomponents based on EDTA chelate. With the help of reduced nodule bacteria, soy is able to fix the biological nitrogen of the air, which ensures the yield of 4.0 t/ha.

The average yield of soybean grain in optimal weather conditions in 2018 was 2.73 t/ha, in arid conditions in 2019-2020, the yield indicators decreased by 0.88-1.17 t/ha. Treatment of soybean seeds with Optimise 400 inoculant provides an average yield increase of 0.38 t/ha for 2018-2020, spraying of crops at BBCH microstages of 61-71 with a complex chelated EDTA microfertiliser Nanovit Super + magnesium sulphate against the background of seed inoculation, the yield was 2.96 t/ha, which is 1.35 t/ha more compared to the control.

CONCLUSIONS

The results of studies conducted on light grey soils, seed treatment with inoculants, and foliar dressing with a multi-complex preparation Nanovit Super in a tank mixture with magnesium sulphate ensure a yield of environmentally friendly soybean products up to 3 t/ha. Short-term 4-field grain-legume crop rotation during the growing season forms the yield of dry organic matter per 1 ha of crop rotation area – 6.8 tonnes, the share of winter wheat straw and post-harvest crops of green fertiliser and soybean stem mass amount to 72%.

The nitrogen of organic residues – 78.3 kg/ha and the biologically fixed nitrogen of perennial legumes and soybeans per 1 ha of crop rotation area – 58.7 kg, thus, the total amount of nitrogen received – 137 kg/ha. Inoculation of soybean seeds with the nitrogen-fixing preparation Optimise 400 increases the growth of nodules on the root system by almost twice. High fixation of biological nitrogen was obtained by inoculation of seeds and foliar dressing with a complex chelated microfertiliser Nanovit Super + magnesium sulphite + phosphoroenterin, which amounts to 400 kg/ha.

Prospects for further study of the elements of organic soybean cultivation technology consists in analysing innovative biologic compounds based on live soil microorganisms and their metabolites, including Bio Stim-Niva degrader, nitrogen-fixing and phosphorus-mobilising biologics, in order to stabilise and reproduce soil fertility.

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ПРОДУКТИВНІСТЬ СОЇ ЗАЛЕЖНО ВІД ЕЛЕМЕНТІВ ОРГАНІЧНОЇ ТЕХНОЛОГІЇ ВИРОЩУВАННЯ В КОРОТКОРОТАЦІЙНІЙ СІВОЗМІНІ ПОЛІССЯ УКРАЇНИ

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Анотація. Інтенсивне землеробство протягом останніх десятиріч функціонувало в умовах прогресуючої деградації ґрунтового покриву, підтримуючи виробничий рівень лише за рахунок неадекватних витрат невідновлюваних ресурсів енергії. Ґрунти набули незворотнього надмірного ущільнення в підорній частині профілю, а процес дегуміфікації набрав загрозливого статусу. Вміст гумусу в ґрунтах України знизився майже на 25 %, а середньорічні втрати становлять 0,6–0,7 т/га. Тому пошук шляхів гарантованого відтворення органічної речовини ґрунту, надійного контролю та відновлення оптимального гумусового стану є надзвичайно актуальними. Мета наукових досліджень полягає в активізації природних азотфіксуючих систем з використанням зеленої маси сидератів у суміші з побічною продукцією сільськогосподарських культур коротко-ротаційної зернобобової сівозміни. Польові досліди проводилися на ясно-сірих ґрунтах впродовж 2018–2020 рр. на дослідному полі Поліського національного університету у коротко-ротаційній зернобобовій сівозміні. У статті використовуються загальнонаукові методи для встановлення напряму досліджень, планування і закладання дослідів, проведення спостережень та аналізу; візуальний – під час здійснення фенологічних спостережень; польовий – для дослідження взаємозв’язку з абіотичними чинниками; фізіологічний – для визначення симбіотичної ефективності препаратів біологічного походження. Теоретично обґрунтовано та удосконалено технологію вирощування сільськогосподарських культур у зернобобовій сівозміні, яка забезпечує надходження сировини органічного походження та накопичення азоту повітря бульбочковими азотфіксаторами. Встановлено, що на один гектар сівозміної площі надходить 6,8 тонн сухої органічної сировини, що відповідає 78,3 кг/га біологічного азоту. З’ясовано, що проведення інокуляції насіння сої препаратом біологічного походження – азотфіксатором Оптимайз 400 і оброблення посівів сої за мікростадіями BBCH 60-63 комплексним мікродобривом на хелатній основі Нановіт Супер + сульфат магнію сприяє активному розвитку бульбочкових бактерій, кількість і маса яких становить 81–89 шт. на рослину та 510–572 кг/га. Таким чином активний симбіотичний потенціал становив 34,2–38,9 тис. кг/діб. Доведено, що за вегетаційний період соя формує 357–400 кг/га біологічного азоту повітря, що забезпечує урожайність зерна 2,96–2,64 т/га і залишає в ґрунті 117–160 кг/га азоту. Практична цінність наукової роботи полягає в збагаченні ґрунту органічною речовиною та біологічною формою азоту

Ключові слова: родючість ґрунту, сівозміна, інокуляція насіння, позакореневе підживлення, урожайність сої