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Agroecological assessment of technologies for growing legumes

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ABSTRACT

The conducted research is devoted to the selection of the optimal assortment for certain growing conditions and preparations for seed treatment before sowing during the growing season, which is one of the important tasks not only for increasing the level of yield and productivity elements, but also for carrying out an agroecological assessment of the technology of growing leguminous crops using the example of soybeans. chickpeas and white lupine. It was established that the use of biological preparations for pre-sowing treatment of seeds, namely inoculants and retardants during the growing season, makes it possible to reasonably approach the planning of agrotechnical measures of cultivation on the basis of soil conservation in conditions of climatic changes. The main goal of the study is to carry out a comprehensive agroecological assessment depending on the varietal composition, seed inoculation and retardant concentration. A three-factor experiment was established in the conditions of the Vinnytsia region (Right-Bank Forest-Steppe of Ukraine) during 2018–2022. The material of the researches were varieties of domestic breeding: soybeans – Azimuth and Golubka, chickpeas – Skarb and Pegasus, white lupine – Veresnevyi and Chabanskyi, which were studied according to the following experimental scheme: control (without treatment), seed inoculation (treatment of seed material with a biological preparation), concentration retardant (without treatment, 0.5%, 0.75% and 1% solution). Variants of the experiment were placed by a randomized method in four repetitions. Field and laboratory studies were conducted on the following indicators: the formation of by-products, the content and volumes of accumulation of main nutrients in by-products, removal of nutrients from the soil and with the crop, as well as the balance of main nutrients according to generally accepted methods. Based on the manifestation of the studied signs, the option with seed treatment with the drug and two-time treatment of crops with the chlormequat-chloride retardant was selected: the first – in the phase of the 3rd trifoliate leaf, the second – in the budding phase. The best variants of the experiment with high indicators of the evaluation of technologies for the cultivation of leguminous crops are recommended. It was established that the most economical use of mineral nitrogen and phosphorus among the studied types of leguminous crops has chickpeas, and the greatest consumption is soybean. Soybeans has the most positive effect on the balance of mineral potassium in the soil, and chickpeas have the most negative effect. Of all the options, only Pegasus chickpea cultivation with pre-sowing seed treatment without retardant ensures a positive nitrogen balance in the soil – plus 3.56 kg/ha.

Keywords: legumes, variety, pre-sowing seed treatment, retardant, soil conservation.

INTRODUCTION

In the modern conditions of agricultural production, pulse crops are increasingly attracting attention as a source of ecologically safe food products. These plants are able to accumulate a large amount of spare protein substances in the seeds, which is provided by the symbiosis of the plant roots with soil nitrogen-fixing nodule bacteria belonging to the genus Rhizobium (Bakhmat et al., 2023; Didur et al., 2020).

Therefore, leguminous crops are promising in terms of agro-ecology, compared to other field crops (Pohrishchuk et al., 2023; Ivanyshyn et al., 2021; Lutkovska, 2020). The essential advantages of leguminous crops are their symbiotic nitrogen fixation, which allows the accumulation of up to 120 kg/ha of mineral nitrogen in the soil, most of which the leguminous crops use for their needs, which significantly reduces the application of mineral nitrogen fertilizers, and these crops leave part of the accumulated mineral nitrogen in the soil for the following crops (Didur et al., 2019; Khaietska et al., 2023; Pantsyreva et al., 2023; Pryshliak et al., 2023).

Also, the by-products of leguminous crops in the form of plant residues, stems, leaves, and roots have a more favorable ratio between carbon and nitrogen, which allows them to decompose in the soil without additional consumption of mineral nitrogen from the soil, in contrast to cereal crops, during the decomposition of which it is necessary to add 15 kg of mineral nitrogen for each hectare of arable land (Mazur et al., 2023; Pantsyreva, 2021).

In the conditions of Ukraine, excessive saturation of crop rotations with high-energy crops such as sunflower and rapeseed has led to a significant decrease in the content of organic matter in the soil, which, in turn, negatively affects the water-holding capacity of the soil (Kaletnik and Lutkovska, 2020). The cheapest way to improve this situation can be the introduction into agricultural production of scientifically based crop rotations, which will be based on the goals of sustainable development and the principles of soil conservation (Petrychenko et al., 2020). It is scientifically based rotation of agricultural crops that will help to break certain chains of harmful microorganisms that were formed in the process of growing crops that are close in terms of biological characteristics (Mazur et al., 2020). And if we consider the rational organization of crop rotation, it primarily concerns leguminous crops (Pantsyreva et al., 2020; Didur, et al., 2021; Razanov et al., 2023).

In the conditions of martial law, the soils of Ukraine have suffered a significant destructive impact, significant soil degradation and erosion is observed (Kaletnik et al., 2020; Mazur et al., 2021). Legumes can be grown in post-war reconstruction on infertile lands, they are resistant to the effects of drought, and the harvest is well preserved for a long period (Mazur et al., 2020). Legumes are an effective source of vegetable protein, which significantly increases their nutritional value (Petrichenko et al., 2017). All this makes them valuable crops capable of improving the food security situation in the world and in Ukraine (Razanov et al., 2020). Therefore, for FAO, legumes are not only a cheap alternative to animal protein, but also a path to sustainable agriculture (Kaletnik and Yaropud, 2023; Mazur et al., 2021; Razanov et al., 2018). For Ukraine, the limiting factor of production is the low yield of legumes compared to cereal crops (Okrushko, 2022). This makes their industrial cultivation less efficient (Honcharuk et al., 2022; Tkachuk and Verhelis). The realization of the genetic potential of productivity is related to climatic, technological, breeding and seed and organizational factorial features (Hnatiuk et al., 2019; Mazur et al., 2019). It is necessary to improve agrotechnological methods of growing legumes and develop specialized equipment (Puyu et al., 2021). Thus, increasing the production of legumes allows solving several tasks at once, which can be divided into three groups: environmental, social and economic aspects (Mazur et al., 2021; Tkachuk, 2021).

MATERIALS AND METHODS

The research was conducted in 2018–2022 at the research field of the Vinnytsia National Agrarian University. The soil of the experimental field is gray forest medium loam. The predecessor was winter wheat. The following varieties were sown: soybeans – Azimuth and Golubka, common chickpea – Skarb and Pegasus, white lupine – Veresnevyi and Chabanskyi in a wide-row method with a row width of 45 cm, with a sowing rate of 500.000 per 1 ha. Agricultural machinery in the experiment was generally accepted for the region. Field experiments were laid out in four repetitions, randomized, the accounting area of the plots was 25 m^2. The scheme of the field experiment was as follows: control (no treatment), seed inoculation (treatment of seed material with a biological preparation), retardant concentration (no treatment, 0.5%, 0.75% and 1% solution).

On the day of sowing, chickpea seeds were treated with a bacterial preparation. During the growing season (budding phase), the retardant – chlormequat chloride, v.r. (750 g/l) f. BASF CE, Germany, in various concentrations (working solution rate 200 l/ha), belonging to the group of quaternary ammonium compounds.

The agroecological assessment of technologies for growing leguminous crops was carried out according to the balance of nutrients in the soil, as the difference between the amount of nutrients used by plants from the soil for crop formation, to the amount of nutrients returned to the soil with by-products of crops (straw, stems, leaves, stubble residues) and symbiotic nitrogen fixation (Kaminsky, 2013)

The volume of by-product formation of leguminous crops was determined experimentally by the method of weighing the total biomass during threshing after separating the seed mass or as the established ratio between the seed yield and the volume of by-product.

The content of the main nutrients in the by-products of leguminous plants was determined on the basis of reference data (Monarkh and Pantsyreva, 2019). The amount of accumulation of the main nutrients in the soil during plowing of plant residues of the by-products of grain and leguminous crops was determined by the calculation method, taking into account the moisture content of the by-products (14%). The amounts of mineral nitrogen accumulation in the soil of symbiotic nitrogen fixation of leguminous crops were determined on the basis of our own research. Removal of nutrients from the soil by 1 ton of leguminous seeds was established on the basis of reference data. The removal of the main nutrients with the harvest of leguminous crops was calculated on the basis of the actual crop yield levels.

The authors of the article are executors of applied research on the topic “Development of scientific and technological support for increasing soil fertility and rational use of the potential of biological resources”.

RESULTS

Accounting for the by-products of soybean varieties depending on the pre-sowing treatment of seeds and the use of retardant showed that the most plant residues were formed on the variants of pre-sowing treatment of seeds of the Golubka variety, both with the introduction of a retardant and without it – 3.20 t/ha each. This was 11.6% more than the by-products formed by soybean plants of the Azimut variety with pre-sowing seed treatment, but without the use of a retardant, where the volume of by-products formed was the smallest of all soybean variants and amounted to 2.83 t/ha (Table 1).

Between the productivity of soybean seeds and the volume of its by-products, the ratio is 1: (1.2–1.4) with the advantage of by-products. The largest share of soybean by-products was formed in the control option without pre-sowing treatment of seeds and without the introduction of a retardant – 1: 1.4, and the smallest - in the option of pre-sowing treatment of seeds and the introduction of a retardant – 1: 1.2. This is explained by the fact that preparations for pre-sowing treatment of seeds and retardants are aimed at the redistribution of parts of the formed biomass of plants with an emphasis on the formation of a larger share of seeds due to a decrease in the share of vegetative mass.

Taking this factor into account, the lowest volume of soybean by-products had the variant where the seed yield was 5.5% higher than the control variant with the lowest yield. And the largest volume of byproducts was obtained on two options, one of which had a 7.9% lower seed yield.

When growing chickpeas, the largest volume of by-products was formed by the option of pre-sowing seed treatment and the use of a retardant on the Pegasus variety – 3.32 t/ha. This was 16.3% more than the formed biomass of by-products of chickpea variety Skarb in the control variant without pre-sowing seed treatment and without application of retardant, as well as in variants with pre-sowing seed treatment both with and without application of retardant. On these variants, the amount of by-products formed was the smallest and amounted to 2.78 t/ha.

The ratio of the main production of chickpeas to the secondary production in different variants was 1: (1.1–1.3). The same trend was maintained as in the versions with soy. We did not find a clear direct-proportional relationship between the yield of chickpea seeds and the amount of by-products formed. In particular, in the variants with pre-sowing treatment of the seeds of the Skarb variety with and without the retardant, the seed yield was 7.8% and 15.4% higher, respectively, than in the control variant, where the lowest seed yield was recorded.

The largest volume of formation of lupine by-products was provided by the option of pre-sowing seed treatment of the Chabansky variety with the introduction of a retardant – 5.47 t/ha. This was 17.0% more than the by-products formed on the option of pre-sowing seed treatment of the Veresnevy variety without the introduction of a retardant, where the volume of by-products was the smallest and amounted to 4.54 t/ha.

The yield of seeds and yield of by-products in lupine are correlated as 1: (1.7–2.0) and have

Table 1. Formation of by-products of leguminous crops depending on pre-sowing seed treatment and retardant application, average for 2018–2022

Legume culture	Variety	Pre-sowing treatment of seeds	Retardant concentration, %	Seed yield, t/ha	Volume of by-product formation, t/ha	Ratio of seed yield to by-products
Soybeans	Azimut	Without treatment	Without treatment	2.06	2.88	1 : 1.4
			0.75	2.24	2.91	1 : 1.3
		Rhizohumin	Without treatment	2.18	2.83	1 : 1.3
			0.75	2.39	2.87	1 : 1.2
	Golubka	Without treatment	Without treatment	2.21	3.09	1 : 1.4
			0.75	2.31	3.00	1 : 1.3
		Rhizohumin	Without treatment	2.46	3.20	1 : 1.3
			0.75	2.67	3.20	1 : 1.2
Chickpeas	Skarb	Without treatment	Without treatment	2.14	2.78	1 : 1.3
			0.75	2.33	2.80	1 : 1.2
		Rhizohumin-Plus	Without treatment	2.32	2.78	1 : 1.2
			0.75	2.53	2.78	1 : 1.1
	Pegasus	Without treatment	Without treatment	2.28	2.96	1 : 1.3
			0.75	2.56	3.07	1 : 1.2
		Rhizohumin-Plus	Without treatment	2.54	3.05	1 : 1.2
			0.75	3.02	3.32	1 : 1.1
Lupine white	Veresnevyi	Without treatment	Without treatment	2.44	4.88	1 : 2.0
			0.75	2.65	5.04	1 : 1.9
		Rhizohumin-Plus	Without treatment	2.52	4.54	1 : 1.8
			0.75	2.73	4.64	1 : 1.7
	Chabanskyi	Without treatment	Without treatment	2.58	5.16	1 : 2.0
			0.75	2.86	5.43	1 : 1.9
		Rhizohumin-Plus	Without treatment	2.84	5.11	1 : 1.8
			0.75	3.22	5.47	1 : 1.7

the same dependence as in soybeans. At the same time, the smallest volume of lupine by-products was formed in the variant where the level of seed yield was 3.2% higher than in the worst variant according to this indicator.

A comparison of all studied types of leguminous crops showed that the largest volume of by-products was provided by lupine crops – 5.47 t/ha, and the smallest – by chickpea crops – 2.78 t/ha, which was 49.2% less. Lupine also had the highest ratio between seed yield and by-product yield, which was 35% greater than chickpea crops. Therefore, it is lupine crops that have the greatest positive agro-ecological value in terms of returning organic matter to the soil.

The chemical composition of the by-products of the studied types of leguminous crops is approximately the same and is: nitrogen – 10.6–12.0 kg/t, phosphorus – 3.3–3.6 kg/t, potassium – 4.5–5.0 kg/t. Soybeans has the highest content of nutrients in by-products (Table 2).

When growing soybeans, 29.2–33.0 kg/ha of mineral nitrogen, 8.8–9.9 kg/ha of mineral phosphorus and 12.2–13.8 kg/ha of mineral potassium. The most mineral nitrogen, phosphorus and potassium accumulates in the option of growing soybeans of the Golubka variety with pre-sowing treatment of seeds with and without the use of a retardant, which was 11.5% more than in the option with the least accumulation of mineral nitrogen, phosphorus and potassium – for the cultivation of the variety Azimuth soybeans with pre-sowing seed treatment and without the use of a retardant (Table 3).

Table 2. Content of main nutrients in by-products of leguminous plants, kg/t

Leguminous crops	N	P	K
Soybeans	12.0	3.6	5.0
Chickpeas	10.6	3.5	4.7
Lupine white	11.0	3.3	4.5

Table 3. Accumulation volumes of the main nutrients in the soil during plowing of plant residues of by-products of grain and leguminous crops depending on pre-sowing treatment of seeds and application of retardant, average for 2018–2022, kg/ha

Legume culture	Variety	Pre-sowing treatment of seeds	Retardant concentration, %	N	P	K
Soybeans	Azimut	Without treatment	Without treatment	29.7	8.9	12.4
			0.75	30.0	9.0	12.5
		Rhizohumin	Without treatment	29.2	8.8	12.2
			0.75	29.6	8.9	12.3
	Golubka	Without treatment	Without treatment	31.9	9.6	13.3
			0.75	31.0	9.3	12.9
		Rhizohumin	Without treatment	33.0	9.9	13.8
			0.75	33.0	9.9	13.8
Chickpeas	Skarb	Without treatment	Without treatment	25.3	8.4	11.3
			0.75	25.5	8.4	11.3
		Rhizohumin-Plus	Without treatment	25.3	8.4	11.3
			0.75	25.3	8.4	11.3
	Pegasus	Without treatment	Without treatment	27.0	8.9	11.9
			0.75	28.0	9.2	12.4
		Rhizohumin-Plus	Without treatment	27.8	9.2	12.3
			0.75	30.3	10.0	13.4
Lupine white	Veresnevyi	Without treatment	Without treatment	46.2	13.8	18.9
			0.75	47.7	14.3	19.5
		Rhizohumin-Plus	Without treatment	42.9	12.9	17.6
			0.75	43.9	13.2	18.0
	Chabanskyi	Without treatment	Without treatment	48.8	14.6	20.0
			0.75	51.4	15.4	21.0
		Rhizohumin-Plus	Without treatment	48.3	14.5	19.8
			0.75	51.7	15.5	21.2

When growing chickpeas, 25.3–30.3 kg/ha of mineral nitrogen, 8.4–9.2 kg/ha of mineral phosphorus and 11.3–13.4 kg/ha of mineral potassium accumulate in the soil with plant residues. The most mineral nitrogen, phosphorus and potassium will come from the variant of pre-sowing treatment of Pegasus honeycomb seeds and with the introduction of a retardant. This was 16.5% more than the amount of mineral nitrogen from the options for growing the Skarb chickpea variety without pre-sowing seed treatment and without the introduction of a retardant, as well as with pre-sowing seed treatment with and without the introduction of a retardant.

When growing lupine, 42.9–51.7 kg/ha of mineral nitrogen, 12.9–15.5 kg/ha of mineral phosphorus and 17.6–21.2 kg/ha of mineral potassium will reach the soil with by-products. The largest yield is provided by the Chabanskyi variety with pre-sowing seed treatment and the introduction of a retardant, which is 17.0% more than the Veresnevyi variety with pre-sowing seed treatment without the use of a retardant.

Thus, our research established that the highest efficiency of the application of pre-sowing treatment of seeds, retardants and the successful selection of varieties regarding the accumulation of mineral nitrogen, phosphorus and potassium with by-products in the cultivation of leguminous crops is typical for lupine – 17.0%, and the lowest – in the cultivation of soybeans – 11.5%. It is the lupine crops that provide the largest amount of return of mineral nitrogen with by-products to the soil – 51.7 kg/ha, which was 41.4% more than the accumulated mineral nitrogen with by-products by chickpea crops; mineral phosphorus – 15.5 kg/ha, which was 45.8% more than after growing chickpeas, and mineral potassium – 21.2 kg/ha, which was 46.7% more.

When growing soybeans, the most mineral nitrogen, taking into account symbiotic nitrogen fixation and by-products of crop production, will

Table 4. Volumes of accumulation of mineral nitrogen in the soil during plowing of plant residues of by-products and taking into account symbiotic nitrogen fixation of leguminous crops, depending on pre-sowing treatment of seeds and introduction of retardant, average for 2018–2022, kg/ha

Legume culture	Variety	Pre-sowing treatment of seeds	Retardant concentration, %	Symbiotic nitrogen fixation, kg/ha	Accumulated nitrogen with by-products, kg/ha	Total accumulated mineral nitrogen, kg/ha
Soybeans	Azimut	Without treatment	Without treatment	40.41	29.7	70.11
			0.75	42.15	30.0	72.15
		Rhizohumin	Without treatment	74.32	29.2	103.52
			0.75	76.31	29.6	105.91
	Golubka	Without treatment	Without treatment	77.38	31.9	109.28
			0.75	79.06	31.0	110.06
		Rhizohumin	Without treatment	117.54	33.0	150.54
			0.75	124.56	33.0	157.56
Chickpeas	Skarb	Without treatment	Without treatment	41.22	25.3	66.52
			0.75	41.32	25.5	66.82
		Rhizohumin-Plus	Without treatment	65.02	25.3	90.32
			0.75	68.76	25.3	94.06
	Pegasus	Without treatment	Without treatment	64.33	27.0	91.33
			0.75	65.96	28.0	93.96
		Rhizohumin-Plus	Without treatment	110.76	27.8	138.56
			0.75	118.09	30.3	148.39
Lupine white	Veresnevyi	Without treatment	Without treatment	33.02	46.2	79.22
			0.75	33.32	47.7	81.02
		Rhizohumin-Plus	Without treatment	55.72	42.9	98.62
			0.75	58.69	43.9	102.59
	Chabanskyi	Without treatment	Without treatment	44.05	48.8	92.85
			0.75	44.48	51.4	95.88
		Rhizohumin-Plus	Without treatment	87.76	48.3	136.06
			0.75	96.09	51.7	147.79

enter the soil from the option of pre-sowing treatment of seeds of the Golubka variety and with retardant treatment – 157.56 kg/ha. This same variant had the largest share of symbiotically fixed nitrogen from the total amount of mineral nitrogen accumulation – 79.1%. The least amount of nitrogen was accumulated on the control version of the Azimut variety without pre-sowing seed treatment and without retardant – 70.11 kg/ha, which was 2.2 times less. The same variant had the smallest share of symbiotically fixed nitrogen from the total amount of mineral nitrogen accumulation – 57.6% (Table 4).

When growing chickpeas, the most mineral nitrogen, taking into account symbiotic nitrogen fixation and by-products of crop production, will enter the soil from the variant of pre-sowing treatment of seeds of the Pegasus variety and with retardant treatment – 148.39 kg/ha. This same variant had the largest share of symbiotically fixed nitrogen from the total volume of mineral nitrogen accumulation – 79.6%. The least accumulated nitrogen was found on the control version of the Skárb variety without pre-sowing seed treatment and without retardant – 66.52 kg/ha, which was 2.2 times less. The same option had the smallest share of symbiotically fixed nitrogen from the total volume of mineral nitrogen accumulation – 62.0%.

When growing lupine, the most mineral nitrogen, taking into account symbiotic nitrogen fixation and crop production by-products, will enter the soil from the variant of pre-sowing seed treatment of the Chabansky variety and with retardant treatment – 147.79 kg/ha. This same variant had the largest share of symbiotically fixed nitrogen from the total amount of mineral nitrogen accumulation – 65.0%. The least amount of nitrogen was accumulated on the control version of the Veresnevy variety without pre-sowing seed treatment and without retardant – 79.22 kg/ha, which was 1.9 times less. The same option had the smallest share of symbiotically fixed nitrogen from the total volume of mineral nitrogen accumulation – 47.4%.

Thus, it was established that the largest total amount of mineral nitrogen accumulation during the cultivation of leguminous crops was observed in soybean crops – 157.56 kg/ha, which was 5.8% more than in chickpea crops and 6.2% more than in lupine crops.

Therefore, our research has established that the largest amount of return of by-products to the soil in the form of above-ground residues has lupine crops – 5.47 t/ha, and the smallest – chickpea crops – 2.78 t/ha, which was 49.2% less. It is with complete plowing of plant residues of lupine that the greatest probability of increasing the humus content in the soil is possible. Also, lupine crops provide the largest return of mineral nitrogen with by-products to the soil – 51.7 kg/ha, which was 41.4% more than the accumulated mineral nitrogen with by-products of chickpea crops; mineral phosphorus – 15.5 kg/ha, which was 45.8% more than after growing chickpeas, and mineral potassium – 21.2 kg/ha, which was 46.7% more. The largest total volume of mineral nitrogen accumulation, taking into account symbiotic nitrogen fixation during the cultivation of leguminous crops, is observed on soybean crops – 157.56 kg/ha, which was 5.8% more than on chickpea crops and 6.2% more than on crops lupine.

Nutrient uptake by leguminous crops for the formation of 1 ton of seeds showed that soybean needs the most nitrogen – 100 kg/t, and chickpeas the least – 53 kg/t. Soy also needs the most phosphorus – 31 kg/t, while chickpeas – only 18 kg/t. Chickpeas need potassium the most – 75 kg/t, and soybeans the least – 36 kg/t (Table 5).

Table 5. Removal of nutrients from the soil by 1 ton of leguminous seeds, kg/t

Leguminous crops	N	P	K
Soybeans	100	31	36
Chickpeas	53	18	75
Lupine white	75	23	40

Table 6. Removal of the main nutrients from the crop of legumes depending on the pre-sowing treatment of the seeds and the application of the retardant, average for 2018–2022, kg/ha

Legume culture	Variety	Pre-sowing treatment of seeds	Retardant concentration, %	N	P	K
Soybeans	Azimut	Without treatment	Without treatment	206	64	74
			0.75	224	69	81
		Rhizohumin	Without treatment	218	68	79
			0.75	239	74	86
	Golubka	Without treatment	Without treatment	221	69	80
			0.75	231	72	83
		Rhizohumin	Without treatment	246	76	89
			0.75	267	83	96
Chickpeas	Skarb	Without treatment	Without treatment	113	39	161
			0.75	124	42	175
		Rhizohumin-Plus	Without treatment	123	42	174
			0.75	134	46	190
	Pegasus	Without treatment	Without treatment	121	41	171
			0.75	136	46	192
		Rhizohumin-Plus	Without treatment	135	46	191
			0.75	160	55	227
Lupine white	Veresnevyi	Without treatment	Without treatment	183	56	98
			0.75	199	61	106
		Rhizohumin-Plus	Without treatment	189	58	101
			0.75	205	63	109
	Chabanskyi	Without treatment	Without treatment	194	59	103
			0.75	215	66	114
		Rhizohumin-Plus	Without treatment	213	65	114
			0.75	242	74	129

The removal of mineral nitrogen with the soybean crop is 206–267 kg/ha and is proportional to the level of seed productivity. With a chickpea crop, 113–160 kg/ha of nitrogen is removed from the soil, and with a lupine crop – 183–242 kg/ha. Thus, it was established that among the investigated types of leguminous crops, the largest removal of mineral nitrogen with the crop is carried out by soybeans, and the smallest by chickpeas (Table 6).

Soybeans with a crop remove 64–83 kg/ha of phosphorus from the soil. For chickpeas, this indicator is 39–55 kg/ha, and for lupine – 56–74 kg/ha. That is, among the studied leguminous crops, soybean consumes the most phosphorus from the soil, and chickpea consumes the least.

Soybeans take mineral potassium from the soil with a yield of 74–96 kg/ha, chickpeas – 161–227 kg/ha, and lupine – 98–129 kg/ha. So, among the studied types of leguminous crops, chickpeas yield the most from the soil, and soybeans the least.

The balance of nutrients during the cultivation of leguminous crops, as the difference between the amount of substances (N, P, K) used to form the crop and the amount of substances returned to the soil as a result of plowing plant residues and symbiotic nitrogen fixation, showed that in almost all options it was negative. In particular, the balance of nitrogen on soybean crops was minus 95.46 – minus 151.85 kg/ha. The smallest negative nitrogen balance had the option of pre-sowing seed treatment of the Golubka variety without the use of a retardant, and the most negative balance was the option without pre-sowing seed treatment of the Azimut variety with a retardant (Table 7).

When growing chickpeas, the balance of mineral nitrogen was minus 57.18 – plus 3.56 kg/ha. The positive nitrogen balance had the option of pre-sowing treatment of seeds of the Pegasus variety without the use of a retardant, and the most negative – without pre-sowing treatment of the seeds of the Skarb variety with a retardant.

Table 7. The balance of the main nutrients for the cultivation of leguminous crops depending on the pre-sowing treatment of seeds and the introduction of retardant, average for 2018–2022, kg/ha

Legume culture	Variety	Pre-sowing treatment of seeds	Retardant concentration, %	N	P	K
Soybeans	Azimut	Without treatment	Without treatment	-135.89	-55.1	-61.6
			0.75	-151.85	-60.0	-68.5
		Rhizohumin	Without treatment	-114.48	-59.2	-66.8
			0.75	-133.09	-65.1	-73.7
	Golubka	Without treatment	Without treatment	-111,72	-59,4	-66,7
			0.75	-120.94	-62.7	-70.1
		Rhizohumin	Without treatment	-95.46	-66.1	-75.2
			0.75	-109.44	-73.1	-82.2
Chickpeas	Skarb	Without treatment	Without treatment	-46.48	-30.6	-149.7
			0.75	-57.18	-33.6	-163.7
		Rhizohumin-Plus	Without treatment	-32.68	-33.6	-162.7
			0.75	-39.94	-37.6	-178.7
	Pegasus	Without treatment	Without treatment	-29.67	-32.1	-159.1
			0.75	-42.04	-36.8	-179.6
		Rhizohumin-Plus	Without treatment	+3.56	-36.8	-178.7
			0.75	-11.61	-45.0	-213.6
Lupine white	Veresnevyi	Without treatment	Without treatment	-103.78	-42.2	-79.1
			0.75	-117.98	-46.7	-86.5
		Rhizohumin-Plus	Without treatment	-90.38	-45.1	-83.4
			0.75	-102.41	-49.8	-91.0
	Chabanskyi	Without treatment	Without treatment	-101.15	-44.4	-83,0
			0.75	-119.12	-50.6	-93,0
		Rhizohumin-Plus	Without treatment	-76.94	-50.5	-94.2
			0.75	-94.21	-58.5	-107.8

Lupine cultivation has a mineral nitrogen balance of minus 119.12 – minus 76.94 kg/ha. The most negative nitrogen balance had the variant without pre-sowing seed treatment of the Chabansky variety with the use of a retardant, and the least negative – the pre-sowing treatment of the Chabansky variety seeds without a retardant. Thus, it was established that chickpea cultivation is the most frugal in terms of nitrogen content, and soybean is the most expendable crop.

The balance of mineral phosphorus and potassium when growing soybeans is negative: minus 73.1 – minus 55.1 kg/ha and minus 82.2 – minus 61.6 kg/ha, respectively. The most negative balance of mineral phosphorus and potassium had the option of pre-sowing seed treatment of the Golubka variety with a retardant, and the least negative – without pre-sowing treatment of the Azimut variety seeds without a retardant.

When growing chickpeas, the balance of mineral phosphorus and potassium is also negative: minus 45.0 – minus 30.6 kg/ha and minus 213.6 – minus 149.7 kg/ha. The most negative balance of mineral phosphorus and potassium had the option of pre-sowing seed treatment of the Pegasus variety with a retardant, and the least negative – without pre-sowing treatment of the seeds of the Skarb variety without a retardant.

Lupine variants also had a negative balance of mineral phosphorus and potassium: minus 58.5 – minus 42.2 kg/ha and minus 107.8 kg/ha – minus 79.1 kg/ha. The most negative balance of mineral phosphorus and potassium had the option of pre-sowing seed treatment of the Chabanskyi variety, and the least negative – without pre-sowing treatment of the Veresnevyi variety seeds without retardant.

CONCLUSIONS

It has been proven that in order to form the maximum yield of leguminous seeds, it is necessary to use a bacterial preparation in the pre-sowing treatment of seeds and to treat the crops twice with the chlormequat – chloride retardant: the first – in the phase of the 3rd trifoliate leaf, the second – in the budding phase. It has been established that during these periods the establishment and development of generative organs takes place in plants. In turn, retardants affect the synthesis or activity of gibberellins, which are responsible for laying flowers and their fertility. As a result, increased outflow of nutrients to generative organs was accompanied by an increase in seed productivity. In this way, it was established that the most economical use of mineral nitrogen and phosphorus among the studied types of leguminous crops has chickpeas, and the most consumption – soybean. Soybean has the most positive effect on the balance of mineral potassium in the soil, and chickpeas have the most negative effect. Of all the options, only Pegasus chickpea cultivation with pre-sowing seed treatment without retardant ensures a positive nitrogen balance in the soil – plus 3.56 kg/ha.

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