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Formation of the leaf surface and productivity of the chickling vetch (*Lathyrus sativus* L.) depending on the amounts of mineral fertilizers and pre-sowing inoculation of seeds

Kształtowanie się powierzchni liści i produkcyjność lędźwianu siewnego (*Lathyrus sativus* L.) w zależności od dawki nawozów mineralnych i przedsiewnej inokulacji nasion

Summary. The aim of the study was to analyze the effect of different amounts of mineral fertilization and inoculation of seeds on the leaf surface area formation and the chickling vetch (*Lathyrus sativus* L.) productivity. The study engaged two factors. Factor A – fertilization: no fertilizers (control), $N_{15}P_{15}K_{15}$, $N_{30}P_{30}K_{30}$, $N_{15}P_{30}K_{30}$ + N_{15} (top dressing), $N_{45}P_{45}K_{45}$ and $N_{30}P_{45}K_{45}$ + N_{15} (top dressing). Factor B – seed treatment: pre-sowing seed treatment with water, seed inoc-ulation with microbiological preparation Rhizogumin. The experiment was conducted in a rand-omized complete block design in a split-plot arrangement with three replications. The maximum leaf surface area (60.8 thousand m^2 ha^{-1}) was in the phase of grain filling in the variant with seed inoculation with microbiological preparation Rhizogumin and application of mineral fertilizers at the rate $N_{30}P_{45}K_{45}$ + N_{15} (top dressing). In the absence of inoculation at this level of fertilizer application the leaf area decreased by 4.1 thousand m^2 ha^{-1}. The highest crop yield of the chickling vetch (2.77 t ha^{-1}) was obtained in the variant with pre-sowing seed inoculation with the microbiological preparation Rhizogumin and mineral fertilizer rate $N_{30}P_{45}K_{45}$ + N_{15} (top dressing). The crop yield in this variant increased in comparison with the control by 0.46 t ha^{-1} which is 19.9%. In the variant with the application of the minimum rate of fertilizers $N_{15}P_{15}K_{15}$ the grain yield of *Lathyrus sativus* increased compared with the control by 0.17–0.21 t ha^{-1} which is 7.7–9.1%. With an average fertilizer rate of $N_{30}P_{30}K_{30}$, a significant increase in the yield of *Lathyrus sativus* was noted both in comparison with the control (by 0.27–0.31 t ha^{-1} or 12.2–13.4%) and the minimum fertilizer rate (by 0.1 t ha^{-1} or 4.0–4.2%). It was found that the increase in crop grain yield from seed inoculation before sowing with the microbiological preparation Rhizogumin in variants of the minimum fertilization rate was 5.9%, and with the maximum – 6.2%.

Key words: yield, leaf area, *Lathyrus sativus*, fertilizers, seed inoculation, number of seedpods, weight of 1000 seeds

INTRODUCTION

In solving the problem of overcoming the deficiency of vegetable protein and increasing soil fertility due to the transition to ecologization and biologization of modern agriculture, leguminous crops play a key role [Mlyneková et al. 2014, Kouris-Blazos and Belski 2016].

One of the most promising and valuable crops in the legume family is *Lathyrus sativus*. Its seed contains 18–34% protein, 0.9% fat, 5.4% fiber, 48.3% nitrogen-free extractives, 2.8% ash, 16% water. By the content of the most important amino acids – tryptophan, lysine, arginine, histidine and others, *Lathyrus sativus* is not inferior to *Pisum sativum*, *Lens culinaris* and *Phaseolus vulgaris*, although some amino acids are absent in its structure [Grela et al. 2012, Almeida et al. 2015]. *Lathyrus sativus* is widely used as a nutritious animal feed, raw material for industry, and as a food product in Asia and Africa [Khandare et al. 2014].

The main biological properties of this culture are its cold resistance, heat and drought resistance, resistance to salinity and short-term flooding. In years with a pronounced drought, *Lathyrus sativus* crop exceeds many types of leguminous crops, and it is inferior only to *Cicer arietinum* by these characteristics [Vaz Patto et al. 2006, Silvestre et al. 2014].

Compared to other legumes, *Lathyrus sativus* plants are highly resistant to crop pests, in particular the pea weevil (*Bruchus pisorum*), the pea aphid (*Acyrthosiphon pisum*), the pea thrips (*Kakothrips robustus*), and a variety of pathogens: powdery mildew (*Erys pisi*), rust (*Uromyces fabae*), downy mildew (*Peronospora lathyri-palustris*) [Campbell 1997].

Lathyrus sativus, like other legumes, has a unique ability to enter into symbiotic relationships with nodule bacteria and, in the process of symbiotic fixation, assimilate up to 124 kg ha^{-1} of molecular nitrogen per year. After harvesting, up to 60 kg ha^{-1} of nitrogen enters the soil with crop residues [Schulz et al. 1999]. These characteristics allowed *Lathyrus sativus* to be grown in conditions unsuitable for other crops, especially in poor soils areas and with insufficient moisture supply [Silvestre et al. 2014].

A significant reserve for improving the conditions for the formation of the productivity of *Lathyrus sativus* is to provide plants with a sufficient amount of mineral nutrition elements necessary for their vital activity, taking into account their presence in the soil [Ali et al. 2008]. It is generally known that mineral nitrogen has a negative effect on legume-rhizobial symbiosis. However, at the initial stages of development, legume plants need initial nitrogen fertilization and a full dose of mineral phosphorus, which contributes to the formation of a well-developed root system and the formation of legume-rhizobial symbiosis [Huda et al. 2007, Saturno et al. 2017].

Phosphorus is the most important macronutrient that takes part in most of the processes associated with the growth and development of culture. Improving the availability of phosphorus to plants had a positive effect on the formation of elements of individual plant productivity.

The applying of mineral phosphorus contributed to the development of the root system and the formation of a powerful assimilation apparatus, which ensured an increase in the level of fixation of molecular nitrogen from the air and its accumulation in *Lathyrus sativus* plants [Singh et al. 2011].

Potassium activates of more than 60 enzymes that play a key role in most of the biochemical and physiological processes of plant growth and development. It stimulates photosynthetic activity of plants and the movement of photosynthates from leaves to storage organs (seeds, tubers, roots), plays an important role in the synthesis and renewal of proteins in plants, energy transfer and cation-anion balance, in regulating stomatal opening and, therefore, in the internal water relations of plants and provides resistance against a number of pests, diseases and stresses (frost and drought) [Roy et al. 2006, Wang et al. 2008].

Taking into account mentioned above, the research was made to analyze the influence of various amounts of mineral fertilization and bacterization of seeds on the formation of leaf area and productivity of *Lathyrus sativus*.

MATERIALS AND METHODS

The research was made in 2015–2017 in the laboratory of agriculture and technologies in the Poltava State Agricultural Experiment Station named after Nikolai Vavilov. The geographic location of the research site is 49°55'N and 34°78'E. Height above sea level is 175 m on average.

The soil in the experimental field is typical low-humus heavy loamy Chernozem with a humus content in the 0–20 cm layer of 5.15%, easily hydrolyzable nitrogen 162 mg kg^{-1}, mobile phosphorus and potassium respectively 150 mg kg^{-1} of soil and 208 mg kg^{-1} of soil. The pH of the saline solution is 5.8.

The average annual precipitation for the study period was 608 mm, including 287 mm for the growing season (47% of the annual amount). However, the distribution of precipitation during the growing season of *Lathyrus sativus* was uneven. In 2015, for the period April–July, the amount of precipitation was 210.3 mm, which is 11.7 mm or 5.3% less than the average from the long-term period (Fig. 1). The growing season of the crop

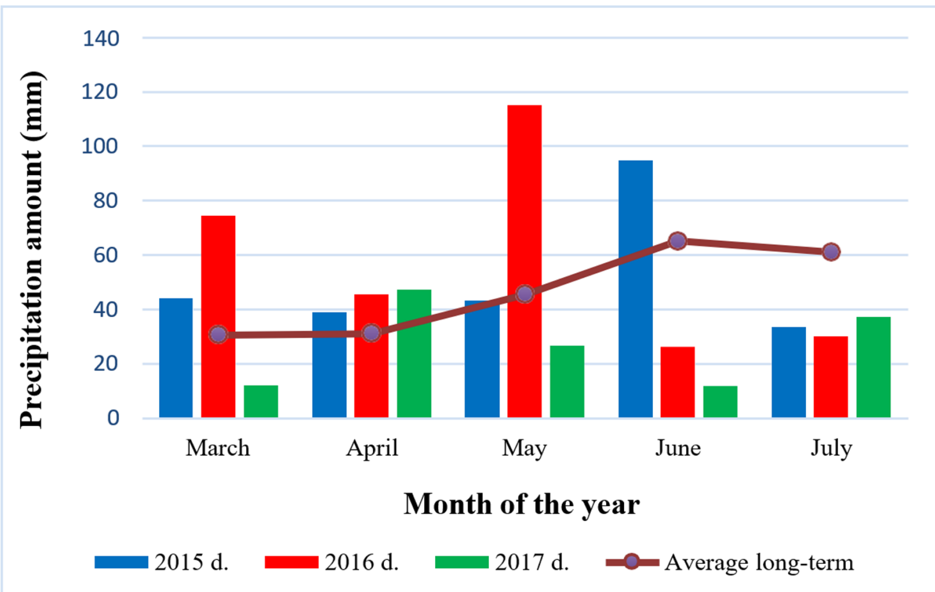

Fig. 1. Rainfall during the growing seasons of *Lathyrus sativus*, according to the meteorological post of the Poltava State Agricultural Experiment Station named after Nikolai Vavilov

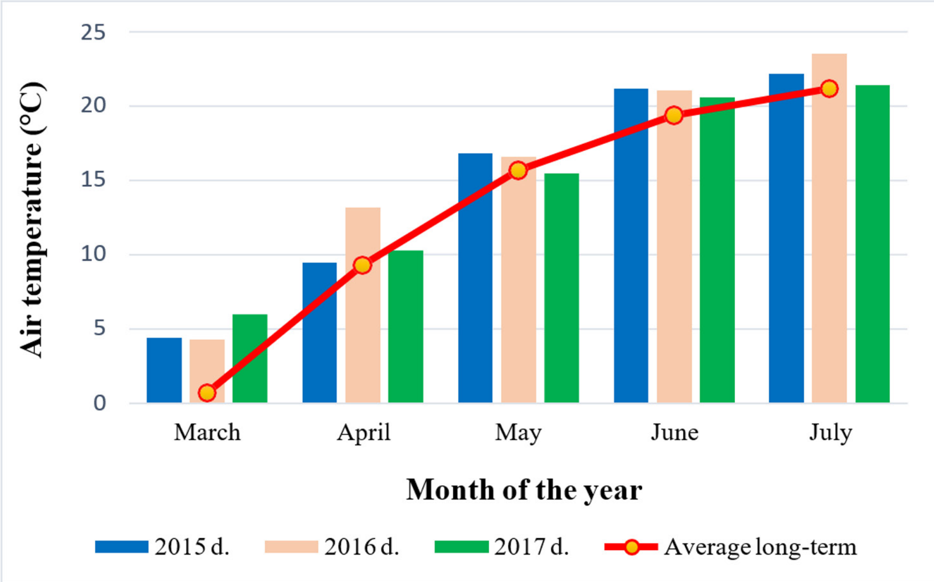

Fig. 2. Air temperature during the growing season of *Lathyrus sativus*, according to the meteorological post of the Poltava State Agricultural Experiment Station named after Nikolai Vavilov

in 2016, was practically equal to the averages from the long-term period of precipitation. However, in June and July the shortfall in precipitation was 33.9 and 40.9 mm, or 56.5 and 57.6%, respectively. The growing season of 2017 was characterized by a significant deficit of precipitation, which compared to the norm was 99.2 mm or 44.7%. It should be noted that the average monthly air temperature of the growing season of *Lathyrus sativus* in 2015, 2016 and 2017 exceeded the long-term average indicator (15.8°C) by 1.6, 2.8 and 1.2°C, respectively (Fig. 2). The average annual air temperature was +8.5°C. Average daily temperature indicators of the warmest month (June) reach +20.5°C, and the coldest month – January, exceed –7°C.

The transition of air temperature through 0°C in autumn occurs on November 21, and in the spring – on March 21. At the same time, the duration of the frost-free period is 174 days, and on the soil surface – 156 days.

Thus, the weather conditions during the years of research were heterogeneous, which made it possible to study the factors under study comprehensively.

The cultivated area of the plot was 100 m^2, and the accounting area was 80 m^2. The experiment was repeated three times. The experiment was conducted in a randomized complete block design in a split-plot arrangement with three replications. In the experiment, the variety *Lathyrus sativus* Spodivanka was sown (7 April 2015, 11 April 2016, 4 April 2017) at a density of 120 seeds per 1 m^2 with a distance of rows of 15 cm with seed depth 6–8 cm. The forecrop of *Lathyrus sativus* in the experiment was grain maize (*Zea mays* L.).

The experimental design involved the study of two factors. Factor A – fertilization: no fertilizers (control option), $N_{15}P_{15}K_{15}$, $N_{30}P_{30}K_{30}$, $N_{15}P_{30}K_{30}$ + N_{15} (top dressing), $N_{45}P_{45}K_{45}$

and $N_{30}P_{45}K_{45} + N_{15}$ (top dressing). Nitrogen fertilizers in the form of ammonium nitrate (34.5%), phosphorus in the form of ammophos (nitrogen content – 12%, phosphorus – 52%) and potassium in the form of potassium chloride (potassium content 60%), were applied in autumn for the main treatment soil. Plant feeding with nitrogen fertilizers was carried out at the beginning of branching (22–23 stage according to the BBCH scale) by root method using a seeder for continuous sowing. Factor B – seed treatment: pre-sowing seed treatment with water (chickling vetch seeds were washed with water in a dose 10 l t^{-1} of seeds), pre-sowing seed treatment with the microbiological preparation Rhizogumin, which contains a suspension of nodule bacteria *Rhizobium leguminosarum 31* and physiologically active substances of biological origin (auxins, cytokinins, amino acids, humic acids), minor-nutrient elements in chelated form and macronutrient elements in starting concentrations. Seed treatment was carried out at the rate of 300 ml of the preparation per 1 ha of seed rate (280 kg).

The leaf surface area was determined by the cutting method [Nichiporovich et al. 1961] (in the phase of the first triple leaf (BBCH 51–59), budding (BBCH 60–65), flowering (BBCH 71–74), grain filling (BBCH 75–79), which includes the selection of 15 plants where the leaves are quickly cut, weighed and their wet weight determined. After that, cuts are made with a probe of a known diameter, 5 pcs from every leaf. The mass of all cuts was determined. The leaf area from one plant was determined by the formula:

$$S = \frac{P \times S_1 \times n}{P_1}$$

where, S – total leaf area (cm^2); S_1 – area of one cut (cm^2); P – is the total mass of leaves (g); n – is the number of cuts; P_1 – is the mass of the cuttings (g).

After determining the surface area of the leaves of each plant, the average plant area was calculated for each variant of the experiment. The average leaf surface area was multiplied by the number of plants per square meter, and the result was multiplied by 10000 to convert it to the average leaf surface area per hectare.

At full maturity stage of chickling vetch plants, 15 random plants from each plot were used to determine plant height, the number of pods per 1 plant and seeds in seedpod, the number of seeds per 1 plant, mass of 1000 seeds [Hrytsayenko et al. 2003].

The statistical processing of the results of field studies was carried out by the method of dispersion analysis using the PIK Agrostat computer application and MS Office Excel. The treatment differences were approximated by LSD-test of significance.

RESULTS AND DISCUSSION

The process of plant growth and development is a complex of quantitative and qualitative changes associated with an increase in the linear dimensions of plants, growth of cells and organs, and the intensity of physiological and biochemical processes, the most important of which is photosynthesis [Kefely 1994]. The main organ of photosynthesis in a plant is a leaf, which is more adapted for capturing sunlight because of its shape [Skliar 2015]. The total number of leaves on a plant forms the leaf surface of a certain area, which in turn determines the intensity of photosynthetic activity, during which plants absorb water and nutrients from the substrate and, with the help of solar energy, convert them into high-energy organic compounds for further use in metabolic processes and, as a result, on the formation of the yield [Nichiporovich 1982].

During analyzing the results of the studies, the dependence of the size of the leaf surface on the seed inoculation and fertilizer amounts was revealed. The most intense formation of the leaf surface area occurred in the period from budding to the pod formation.

Observations of the formation of the leaf area by *Lathyrus sativus* plants revealed that in the phase of the first true leaf, the crops of *Lathyrus sativus* formed a leaf surface with an area of 0.98 to 1.62 thousand m^2 ha^{-1} (Tab. 1). The smallest indicator was observed in the variant without fertilization and without seed inoculation. Seed treatment with Rhizogumin contributed to an increase in leaf area by 0.16 thousand m^2 ha^{-1} which is 16.3%. The application of the minimum fertilization amount $N_{15}P_{15}K_{15}$ provided an increase in the leaf area by 0.17–0.26 thousand m^2 ha^{-1} compared to the control. The largest area of the leaf apparatus of *Lathyrus sativus* (1.38–1.65 thousand m^2 ha^{-1}) in this phase was recorded for variants with fertilization of 45 kg ha^{-1} NPK, applied both at the same time and fractionally in top dressing. Moreover, the largest leaf area was with top dressing and exceeded the absolute control by 0.40–0.51 thousand m^2 ha^{-1} which is 40.8–44.7%. The advantage of high amounts of fertilizers during the formation of the leaf surface remained throughout the entire observation period.

During the budding period, the leaf area of *Lathyrus sativus* ranged from 12.5 to 18.5 thousand m ha^{-1}. Also during this period, a beneficial effect of seed inoculation on the leaf area was revealed. The largest difference between the indicators, depending on the conduct of this agro-activity was on the control without fertilizers (7.2%), and the smallest (1.81%) with fertilizing with the amount of $N_{15}P_{30}K_{30} + N_{15}$.

Lathyrus sativus formed the maximum leaf area during the growing season in the grain filling phase. The leading role in the preservation of the leaf apparatus and the continuation of the period of its functioning was played by nitrogen fertilizers, especially variants with feeding. The maximum leaf area (60.8 thousand m^2 ha^{-1}) during this period was when $N_{30}P_{45}K_{45} + N_{15}$ was added to top dressing and seed treatment with Rizogumin. In the absence of inoculation, the leaf area was 4.1 thousand m^2 ha^{-1} less.

In the conditions of the experiment, the indicators mentioned above also changed under the influence of the factors under study. The tallest plants of *Lathyrus sativus* were observed in variants with $N_{45}P_{45}K_{45}$ application, both in the main fertilizer and fractionally, during seed inoculation (Tab. 2). In these variants, the indicators were practically the same and were, respectively, 111 and 110 cm with the control level 99–100 cm. In general, the plant height increased under the influence of mineral fertilizers, particularly nitrogen fertilizers.

The number of seedpods on a plant also changed under the influence of fertilization. If on the absolute control there were 12.3 pcs $plant^{-1}$, then inoculation of seeds contributed to an increasing of their amount by 2.1 pcs $plant^{-1}$. When $N_{15}P_{15}K_{15}$ was applied, the plants produced 12.5–16.3% more seedpods than control. An increase in the dose of nitrogen, phosphorus and potassium fertilizers up to 30 kg ha^{-1} did not have a significant effect on this indicator, and when seeds were inoculated, even a slight decrease was observed in comparison with $N_{15}P_{15}K_{15}$. The maximum amount of seedpods was on plants when fertilized with $N_{45}P_{45}K_{45}$ in combination with inoculation (18.0 pcs $plant^{-1}$).

On average, over the years of research in one seedpod of *Lathyrus sativus* was formed from 1.22 to 1.59 seed, and the maximum indicator was on absolute control. The increase in the fertilizer dose caused a decrease in the amount of seeds in the pod, especially during the inoculation of the seeds. In our research, in contrast to Khokhoeva et al. [2018], the application of fertilizers enhanced vegetative development and increased the number of seedpods on the plant, but the seed formation was less well.

Table 1. Dynamics of the leaf surface formation area by crops of *Lathyrus sativus* depending on fertilization and seed inoculation, on average in 2015–2017 (thousand $m^2 ha^{-1}$)

Fertilizer combination	Period of growth and development									
	first true leaf (BBCH 11)		budding (BBCH 51–59)		flowering (BBCH 60–65)		pod formation (BBCH 71–74)		grain filling (BBCH 75–79)	
	I*	II*	I	II	I	II	I	II	I	II
Without fertilizer (control)	0.98	1.14	12.5	13.4	22.6	24.2	34.2	39.1	34.2	36.9
$N_{15}P_{15}K_{15}$	1.15	1.40	14.8	15.2	26.7	27.3	41.6	45.6	43.9	46.7
$N_{30}P_{30}K_{30}$	1.24	1.49	15.6	16.4	28.1	29.6	44.5	50.1	48.2	50.9
$N_{15}P_{30}K_{30} + N_{15}$	1.28	1.56	16.3	16.6	29.2	29.9	45.7	50.9	49.4	51.9
$N_{45}P_{45}K_{45}$	1.36	1.62	17.4	18.2	31.4	32.8	51.2	54.3	52.4	58.2
$N_{30}P_{45}K_{45} + N_{15}$	1.38	1.65	17.6	18.5	31.8	33.4	52.1	56.3	54.7	60.8
$LSD_{0.95}$ *A*B**	0.23		0.67		0.88		1.22		1.46	
mean for fertilizer combination										
Without fertilizer (control)	1.06		12.9		23.4		36.6		35.5	
$N_{15}P_{15}K_{15}$	1.27		15.0		27.0		43.6		45.3	
$N_{30}P_{30}K_{30}$	1.36		16.0		28.8		47.3		49.5	
$N_{15}P_{30}K_{30} + N_{15}$	1.42		16.4		29.5		48.3		50.6	
$N_{45}P_{45}K_{45}$	1.49		17.8		32.1		52.7		55.3	
$N_{30}P_{45}K_{45} + N_{15}$	1.52		18.0		32.6		54.2		57.7	
$LSD_{0.95}$ A	0.09		0.27		0.36		0.50		0.59	
mean for seed treatment										
I	1.23		15.7		28.3		44.9		47.1	
II	1.48		16.4		29.5		49.4		50.9	
$LSD_{0.95}$ B	0.16		0.47		0.63		0.87		1.03	

* I – pre-sowing seed treatment with water; II – pre-sowing seed treatment with the microbiological preparation Rhizogumin

** *A* – fertilizer combination, *B* – seed treatment methods, *AB* – factors interaction

Table 2. Indicators of the *Lathyrus sativus* crop structure depending on fertilization and seed inoculation on average for 2015–2017 years

Fertilizer combination	Plant height (cm)	Number of seedpods (pcs/plant)	Number of seeds		Mass of 1000 seeds (g)
			in a seedpod, pcs/seedpod	Per 1 plant, pcs/plant	
pre-sowing seed treatment with water					
Without fertilizer (control)	99	12.3	1.59	19.5	138
$N_{15}P_{15}K_{15}$	102	14.3	1.41	20.1	141
$N_{30}P_{30}K_{30}$	107	14.6	1.41	20.6	141
$N_{15}P_{30}K_{30} + N_{15}$	105	15.1	1.37	20.7	142
$N_{45}P_{45}K_{45}$	107	16.4	1.32	21.6	141
$N_{30}P_{45}K_{45} + N_{15}$	105	16.5	1.33	21.9	143
Mean	104	14.9	1.41	20.7	141
pre-sowing seed treatment with the microbiological preparation Rhizogumin					
Without fertilizer (control)	100	14.4	1.46	21.0	139
$N_{15}P_{15}K_{15}$	102	16.2	1.30	21.0	141
$N_{30}P_{30}K_{30}$	110	15.6	1.33	20.8	141
$N_{15}P_{30}K_{30} + N_{15}$	109	15.4	1.39	21.4	142
$N_{45}P_{45}K_{45}$	111	18.0	1.22	21.9	145
$N_{30}P_{45}K_{45} + N_{15}$	110	17.9	1.25	22.3	146
Mean	107	16.3	1.33	21.4	142
$LSD_{0.95}$ B* $LSD_{0.95}$ AB	0.68 1.67	0.31 0.77	0.02 0.04	0.39 0.96	0.85 2.09
mean					
Without fertilizer (control)	99	13.3	1.53	20.2	138
$N_{15}P_{15}K_{15}$	102	15.2	1.36	21.0	141
$N_{30}P_{30}K_{30}$	108	15.1	1.37	20,7	141
$N_{15}P_{30}K_{30} + N_{15}$	107	15.2	1.38	21.0	142
$N_{45}P_{45}K_{45}$	109	17.2	1.27	21.7	143
$N_{30}P_{45}K_{45} + N_{15}$	107	17.2	1.29	22.1	144
$LSD_{0.95}$ A	1.18	0.54	0.03	0.68	1.45

* A – fertilizer combination; B – seed treatment methods; AB – factors interaction

Table 3. The influence of the cultivation technology elements on the yield of *Lathyrus sativus* on average in 2015–2017 (t ha^{-1})

Fertilizer combination	Pre-sowing seed treatment with water	Seed treatment with biopreparation Rhizogumin	Mean
Without fertilizing (control)	2.21	2.31	2.26
$N_{15}P_{15}K_{15}$	2.38	2.52	2.45
$N_{30}P_{30}K_{30}$	2.48	2.62	2.55
$N_{15}P_{30}K_{30} + N_{15}$ (top dressing)	2.50	2.68	2.59
$N_{45}P_{45}K_{45}$	2.58	2.74	2.66
$N_{30}P_{45}K_{45} + N_{15}$ (top dressing)	2.64	2.77	2.71
Mean	2.47	2.61	-
$LSD_{0.95}$ factor A (fertilizer combination)			0.04
$LSD_{0.95}$ factor B (seed treatment methods)*			0.04
$LSD_{0.95}$ AB factors interaction*			0.09

The mass of 1000 grains is one of the main indicators of the structure of the crop, which determines both the size of the seeds and its fulfilment. In our studies, a significant difference in the weight of 1000 grains was observed only on variants with contrasting fertilization. So, on the control without fertilization when sowing with non-inoculated seeds, the weight of 1000 grains of *Lathyrus sativus* was 138 g. Seed inoculation did not significantly affect this indicator. The application of mineral fertilizers in the norm from $N_{15}P_{15}K_{15}$ to $N_{45}P_{45}K_{45}$ caused the increasing the weight of 1000 grains by only 3–5 g against the background without inoculation and by 2–7 g with inoculating seeds, reaching a maximum indicator when applying $N_{30}P_{45}K_{45} + N_{15}$.

The yield of a cultivated plant is a derivative of its genetically determined productivity potential and the degree of satisfying the plant's biological needs by a set of environmental and agrotechnical factors. In legumes, as in other agricultural crops, it is formed under the influence of a number of factors that are present in certain environmental conditions throughout the entire period of ontogenesis, from sowing to harvesting the crop. Under the environmental factors, in the context of research, first of all, one should see the weather conditions of the growing season, elements of cultivation technology and biological characteristics of crops.

To improve the technology of *Lathyrus sativus* cultivation in our case we had to optimize the conditions for the mineral nutrition of plants for the longest period of their life cycle under various weather conditions that have developed during the years of the experiment.

Studies carried out during 2015–2017 showed the dependence of the yield level of *Lathyrus sativus* on the pre-sowing seed treatment and fertilizer doses (Tab. 3).

The highest crop yield of *Lathyrus sativus* grain was formed on the variant with the application of the maximum amount of fertilizers $N_{30}P_{45}K_{45} + N_{15}$ (top dressing) and seed inoculation with the microbiological preparation Rhizogumin and amounted to 2.77 t ha^{-1}. The yield increase in comparison with the control was equal to 0.46 t ha^{-1} or 19.9%. It should be noted that when applying above the specified amount of mineral fertilizers at a time (variant 5), the yield of the crop was lower compared to the fractional use of nitrogen, only by 0.03 t ha^{-1}. When adding the minimum amount of fertilizers $N_{15}P_{15}K_{15}$, the yield of *Lathyrus sativus* increased compared to the control by 0.17–0.21 t ha^{-1} or 7.7–9.1%. At an average amount of $N_{30}P_{30}K_{30}$ fertilizers, a significant increase in the yield of *Lathyrus sativus* was noted both in comparison with the control (by 0.27–0.31 t ha^{-1} or 12.2–13.4%) and the minimum amount (by 0.1 t ha^{-1} or 4.0–4.2%). The research results indicate that when part of the nitrogen dose is transferred to top dressing in the branching phase, a significant increase in crop grain yield has not been achieved, although the trend is positive.

It was found that the increase in crop grain yield from pre-sowing seed inoculating with the microbiological preparation Rizogumin in the variant with the lowest fertilizer dose ($N_{15}P_{15}K_{15}$) was 5.9%, and in the variant with the maximum fertilization rate ($N_{30}P_{45}K_{45} + N_{15}$) – 6.2%.

According to the research results, the advantage of a balanced system of plant fertilization was revealed, in which the presence and availability of nutrients during critical periods of growth and development plays a predominant role. This is evidenced by the high productivity indices of *Lathyrus sativus* on variants with seed treatment and fractional nitrogen application, when the supply of the nutrient is as close as possible to the period of critical need for it.

The effectiveness of low rates of mineral fertilizers has been confirmed by a number of other scientific studies. Thus, the use of nitrogen-phosphorus fertilizers had a positive effect on the accumulation of absolutely dry biomass by plants of leguminous crops and their productivity. The highest yields of dry biomass and grain were obtained with the application of $N_{20}P_{20}$, which was associated with an improvement in the conditions for the formation of the root system at early stages of plant development, an increase in the intensity and productivity of photosynthetic activity, and the accumulation of aboveground organic biomass [Mesfin et al. 2020]. Other studies [Agha et al. 2004, Ronnera et al. 2016] showed that the combined use of nitrogen and phosphorus mineral fertilizers significantly increases the yield of legumes by satisfaction of their need for nitrogen during the fixing it from the atmosphere.

The research results showed that high indices of length, mass and nitrogen content in the aerial parts of *Lathyrus sativus* plants were found when mineral nitrogen was applied at the amount of N_{60} kg ha^{-1}, while the largest number of nodules, their weight and N content were recorded in the variant of reducing nitrogen doses by half (N_{30} kg ha^{-1}) [Mrkovački et al. 2008].

With the applying of P_{50}, the number of pods on the plants was 13.83 pcs, at the same time, against the background of P_{40} and P_{30}, there was a tendency to decreasing of this indicator, by 0.4 and 2.5%, respectively. The increasing the level of individual productivity of plants contributed to a corresponding increase in the productivity of *Lathyrus sativus* grain. Its highest values were noted in the variant with application of P_{50} (825.01 kg ha^{-1}). With a decreasing the level of phosphorus application to P_{20}, the yield of *Lathyrus sativus* grain was 18.6% lower in comparison with the best option [Nandini Devi et al. 2018].

The number of seedpods and seeds formed on plants varied depending on the genotype of *Lathyrus sativus* and was determined by the level of potassium supply during the growing season. High values of these indicators (32.2 pcs, and 4.7 pcs, respectively) were noted in the option of applying K_{20}. With a decrease in the dose of applied potassium to 10 kg of active substance per 1 ha, 28.2 seedpods formed on the plants, with the number of seeds in them 4.2 pcs [Mohammadjanloo et al. 2009].

The maximum crop yield of *Lathyrus sativus* (2589 kg ha^{-1}) was obtained in the variant with the applying of potash fertilizers with the amount of the active ingredient K_{20}. A decrease in the level of potash fertilizer led to a corresponding decrease in grain yield by 286 kg ha^{-1} [Ashraf et al. 2011].

CONCLUSIONS

1. In the course of the field experiment, it was found that the dynamics of the growth of the leaf surface area, the formation of biometric indicators and the yield of the chickling vetch (*Lathyrus sativus*) varied significantly depending on the factors studied.
2. It was found that the use of different norms of mineral fertilizers contributed to an increase in the leaf surface area of the chickling vetch by 28.4–59.9%, and fertilizers and pre-sowing treatment of seeds with a microbiological preparation – by 36.5–77.8%.
3. The largest surface area of the chickling vetch leaves (60.8 thousand m^2 ha^{-1}) was in the phase of grain filling when $N_{30}P_{45}K_{45}$ + N_{15} was added to the top dressing and seed treatment with Rizogumin.
4. The maximum grain yield of chickling vetch in the experiment was formed with fertilizing combination of $N_{30}P_{45}K_{45}$ + N_{15} (top dressing) and seed inoculation with a microbiological preparation and amounted to 2.77 t ha^{-1}. The yield increase in comparison with the control was 19.9%.

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