FEATURES OF THE FUNCTIONING OF THE ASSIMILATION APPARATUS OF LUPINUS ALBUS DEPENDING ON THE USE OF ECO-BIOLOGICAL PREPARATIONS

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ABSTRACT

The high efficiency and justified necessity of using biopreparations for pre-sowing seed treatment and foliar fertilization has been proven. The results of studies on the effectiveness of the application of pre-sowing treatment and foliar feeding of white lupine plants in the conditions of the right-bank forest-steppe of Ukraine are presented. The optimal leaf surface area and photosynthetic potential were determined. A positive effect of pre-sowing seed treatment with the bacterial preparation Rhyzogumin and the growth stimulator Emistym C in combination with two foliar feedings Emistym C on the content of chlorophyll in the leaves of white lupine varieties Veresnevyi and Makarivskyi was established. Pre-sowing treatment of white lupine seeds of the Veresnevyi and Makarivskyi varieties in combination with foliar feeding contributed to the increase of the leaf surface area and the formation of the photosynthetic apparatus of plants. The effect of the investigated biological preparations on the formation of the assimilation surface and the synthesis of chlorophyll in the leaves of white lupine in the conditions of the right-bank forest-steppe of Ukraine has been proven. It was determined that the greatest stimulatory effect was obtained in the variant where the pre-sowing treatment of seeds involved the interaction of the biological preparations Rhyzogumin and Emistym C in combination with two foliar feedings of Emistym C. The three-year research results also indicate a significant impact of the researched technological methods of cultivation on grain yield.

Keywords: white lupine, variety, pre-sowing seed treatment, foliar feeding, assimilation apparatus, leaf area, photosynthetic potential, chlorophyll.

INTRODUCTION

Lupine is a culture of universal possibilities. Along with providing valuable feed raw materials, lupins are of great importance in increasing soil fertility, phytomelioration, improving the phytosanitary condition of agrocenoses, and reducing energy consumption in crop production (Mazur et al., 2019; Pancy`reva, 2016; Kaletnik & Lutkovska, 2020). White lupine, compared to other types of fodder lupine, is characterized by fast growth rates, early maturity and high fodder and grain productivity. Cultivation of lupine provides an increase in soil fertility, replenishment of the soil nitrogen balance due to its biological fixation, and contributes to the strengthening of the financial condition of farmers. In terms of chemical composition and nutritional value, lupine protein is closest to animal protein. The high content of valuable protein in the plant and a complex of other economically valuable features make lupine an irreplaceable fodder crop. Currently, in the countries where white lupine is grown, numerous scientific studies are being conducted, which are aimed at a detailed study of the chemical composition of this plant. At the same time, the results of studies of white lupine must be compared with soybeans in order to prove their competitiveness and study the possibility of an alternative replacement. In terms of seed quality, lupine is not inferior to this crop, so it is called the second northern soybean (Didur et al., 2020). Formation of grain productivity and fodder value of agricultural crops largely depends on the intensity of photosynthesis, synthesis and transport of metabolites in leaves. Therefore, it is possible to increase the realization of the potential of plants due to the activation of these processes, in particular, the process of photosynthesis. Formation of productivity as a result of photosynthetic activity of plants in crops is determined by the functioning of the assimilation apparatus (Zhu et al., 2019; Ahmadi et al., 2010). Scientifically based bases of technologies for growing leguminous crops, including white lupine, determining the accumulation of chlorophyll in plant leaves is important, since their content affects the intensity of photosynthesis and other physiological processes. The research is aimed at establishing the peculiarities of the functioning of the photosynthetic apparatus, the peculiarities of the formation of the assimilation apparatus in the processes of growth and development of plants are of primary importance when assessing the impact of technological techniques on grain productivity and feed value of plants. In this regard, conducting relevant research is important in modern agricultural production

MATERIALS AND METHODS

Field experiments were conducted in the conditions of the research farm «Agronomichne» of the Vinnytsia National Agrarian University in 2018-2020. The experimental sites are located in the right-bank forest-steppe zone of Ukraine. The soil cover is represented by gray forest soils with a humus content in the soil layer of 0-30 cm at the level of 2.09. The climate in the research area is temperate-continental with an annual precipitation of 418 mm and average monthly temperatures during the growing season of chickpeas in the range of 15.5-22.8 ºC. During the years of the experimental experiments, the growing season was characterized by higher (by 0.9-4.3 ºC) temperatures and a deficit of precipitation compared to the long-term norm, which was 56 mm less.

The purpose of the research is to establish the specifics of the formation of the assimilation apparatus by plants of white lupine (*Lupinus albus* L.) depending on biological preparations. The material for the research was white lupine (*Lupinus albus* L.) Veresnevyi and Makarivskyi varieties.

The technology of growing white lupine varieties is generally accepted for the forest-steppe zone of Ukraine and included pre-sowing treatment of seeds with the bacterial preparation Rhyzogumin in combination with the growth stimulator Emistym C and foliar feeding Emistym C. On the day of sowing, white lupine seeds were treated with the bacterial preparation Rhyzogumin (600 g per hectare rate of seeds) and growth stimulator Emistim C (10 ml per 1 ton of seeds) using PKS-20 Super. In foliar top dressing, the growth stimulator Emistim C was used at a rate of 15 ml/ha. The first foliar top dressing of Emistym C was carried out in the budding phase, the second - in the phase of the beginning of pouring seeds. The area of the accounting plot is 25 m^2. Repetition - five times. Placement of options is systematic in two tiers.

Evaluation of the photosynthetic activity of plants was carried out according to the following methods: the area of the leaf surface was measured by the «cuts» method, the photosynthetic potential was determined according to the method of A. A. Nychiporovich (1996); the amount of chlorophyll was determined by the method of alcohol weighing on a conditioned electrophotocolorimeter (KFK-2) (Nychyporovych et al, 1961).

RESULTS AND DISCUSSION

Chlorophyll content in leaves is an indicator characterizing the potential level of photosynthetic productivity of plants. The informativeness of this parameter is determined by a set of features that do not allow using the leaf surface area as an absolute indicator of their photosynthetic productivity.First of all, it is the thickness of the leaf plate and the total concentration of pigments in the cells. The last indicator can vary significantly depending on the species and even the variety. As a rule, species that spread from south to north are characterized by an increase in leaf surface area with a decrease in total chlorophyll concentration. Conversely, in species whose range expansion goes in the opposite direction – from north to south – a decrease in the area of individual leaves is observed while maintaining or increasing the concentration pigments (Chynchyk, 2013; Langewisch, 2017).

Domestic and foreign authors indicate that the biological harvest depends on the content of pigments, primarily chlorophylls in the assimilating organs of plants, time and intensity of their work. The content of chlorophyll in leaves affects the intensity of photosynthesis, the accumulation of dry matter, and ultimately their productivity. The need for research in this direction is due to the fact that the total mass of green pigment and its concentration in the mesophyll of the leaf, together with the dimensions of the assimilation surface, are considered as the basis of the potential of the photosynthetic activity of the plant organism as a whole (Vdovenko, 2018; Kantolic, 2013).

The difference in chlorophyll content, as a rule, is an indicator of the level of compliance with vegetation conditions and varies depending on the genotype of the variety. Increasing the yield of agricultural crops depends both on factors affecting photosynthesis and on the complex of physiological processes associated with it (water exchange, nutrition, growth). The formation of a well-developed photosynthetic apparatus, optimal in terms of volume, dynamics and intensity of functioning, is the key to the creation of organic matter, biological and marketable crops (Mazur et al., 2021; Kaletnik et al., 2020; Puyu et al., 2021).

Research has established that for the formation of a crop as a photosynthetic system, many factors should be taken into account, among which the variety, its ecology and biology, and technological methods of cultivation are of great importance (Rai et al., 2017; Bandura et al., 2019).

During the years of research, the dependence between the process of formation of the leaf surface of lupine and the elements of growing technology was observed. The results of the conducted research showed that the choice of varieties that are not damaged by pests and diseases, the phases of vegetation and technological methods were of great importance for the functioning of the leaf surface.

It was noted that the area of the leaf surface of white lupine increases gradually, reaching the maximum value in the phase of the beginning of seed pouring. After this phase, a decrease in leaf area was observed, which is determined by the biological characteristics of the culture. Thus, the redistribution and increased outflow of plastic substances from vegetative organs to seeds causes the death of leaves during the ripening of white lupine plants. A similar trend of the effect of the researched technological methods on the leaf surface area was also found in the plots of the Makarivskyi white lupine variety. However, the indicators of the dynamics of the leaf surface area were somewhat lower than in the Veresnevyi variety. This is explained by a genetically determined feature.

The formation of the size of the leaf area in different phases of growth and development of white lupine was influenced by the pre-sowing treatment of seeds with nodule bacteria and a growth stimulator in combination with foliar fertilization (Fig. 1).

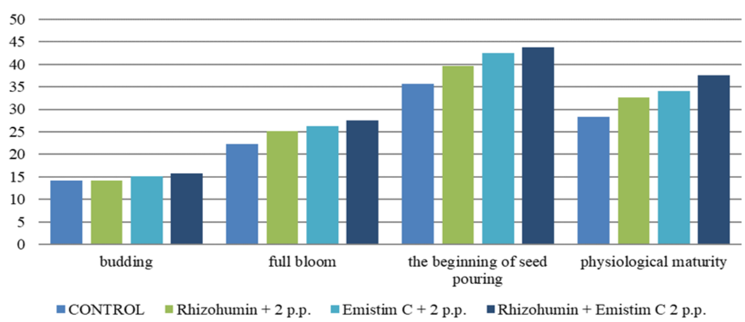

Figura 1. Dynamics of the leaf surface area of white Lupine plants of the Veresnevyi variety depending on biological preparations, thousand m^2/ha (2018-2020)

Thus, in the phases of branching and budding, the influence of the investigated technological techniques on the parameters of the leaf surface area was insignificant. On the plots of the Veresnevyi variety, during budding, the leaf area index, depending on the pre-sowing treatment of seeds and foliar fertilization, was in the range of 14.2-15.7 thousand m^2/ha, and during the period of full flowering - from 22.3 to 27.6 thousand m^2/ha.The formation of the photosynthetic surface of the crop is influenced by both biotic and abiotic factors. Optimizing thermal, water, air, and nutrient regimes is of great importance for the productive work of sowing as a photosynthetic system.

Photosynthesis is the main complex and multi-stage process of plant nutrition, therefore, other processes are effective only to the extent that they improve and stimulate photosynthetic activity and create conditions for the synthesis of assimilants and their best use for the processes of growth, development and crop formation. Organic substances formed in the process of photosynthesis make up about 95% of the dry mass of plants. Therefore, formation by the process of photosynthesis, increasing its productivity is one of the effective methods of influencing the productivity of plants, and for agricultural crops it is an important means of increasing the yield (Mazur et al., 2019; Honcharuk et al, 2020; Kaletnik, 2010; Mazur et al., 2020; Didur et al., 2020; Bulgakov et al., 2014).
The records conducted during the research period showed that the pre-sowing treatment of lupine seeds with the bacterial preparation Rhizogumin in combination with the growth stimulator Emistym C with two foliar feedings Emistym C has a positive effect on the formation of the photosynthetic apparatus of white lupine plants (Table 1).

Table 1. The formation of the photosynthetic potential of white lupine varieties depends from biological preparations, million m2/ha (average for 2018-2020).

Factors			Vegetation periods of plants			
variety	pre-sowing seed processing	foliar feeding*	full stairs - budding	full adder-full bloom	full stairs - start of pouring	full stairs - physiological maturity
Veresnevyi	Without pre-sowing seed treatment**	without supplements**	0,321	0,601	0,989	1,505
		one feeding	0,321	0,606	1,005	1,529
		two feedings	0,321	0,606	1,006	1,559
	Rhizohumin	without supplements	0,326	0,616	1,050	1,588
		one feeding	0,326	0,622	1,075	1,638
		two feedings	0,336	0,622	1,076	1,689
	Emistym C	without supplements	0,337	0,637	1,125	1,766
		one feeding	0,337	0,648	1,150	1,819
		two feedings	0,337	0,648	1,151	1,860
	Rhizohumin + Emystim C	without supplements	0,354	0,675	1,125	1,941
		one feeding	0,354	0,689	1,260	1,982
		two feedings	0,354	0,689	1,262	2,061
Makarovskyi	Without pre-sowing seed treatment	without supplements	0,281	0,495	0,861	1,301
		one feeding	0,281	0,501	0,878	1,333
		two feedings	0,281	0,501	0,879	1,351
	Rhizohumin	without supplements	0,290	0,516	0,921	1,389
		one feeding	0,290	0,525	0,939	1,420
		two feedings	0,290	0,525	0,940	1,452
	Emistym C	without supplements	0,301	0,552	1,009	1,522
		one feeding	0,301	0,566	1,036	1,577
		two feedings	0,301	0,566	1,037	1,615
	Rhizohumin + Emystim C	without supplements	0,316	0,574	1,073	1,650
		one feeding	0,316	0,589	1,093	1,678
		two feedings	0,316	0,589	1,095	1,720

*Notes: * – Emistym C; **- CONTROL.*

However, the effectiveness of the application of pre-sowing treatment of seeds and foliar fertilization is noticeable in the phase of physiological maturity. Thus, the highest indicators of photosynthetic potential of white lupine varieties Veresnevyi and Makarivskyi were observed in the period of full germination - physiological maturity in the variants with the use of a bacterial drug and a growth stimulator in the pre-sowing treatment of seeds in combination with two foliar feedings and were, respectively, 2.061 and 1.720. These indicators of white lupine plants of Veresnevyi and Makarivskyi varieties exceeded the control variant by 27.0% and 21.5%, respectively.
The presence of a positive effect of pre-sowing seed treatment and foliar fertilization on the content of chlorophyll in white lupine leaves was established (Table 2).

Table 2. Chlorophyll content of white lupine varieties depending on biological preparations (average for 2018-2020)

Factors			Chlorophyll content in leaves, mg/g raw mass	Chlorophyll content in leaves, mg/m²
variety	pre-sowing seed processing	foliar feeding*		
Veresnevyi	Without pre-sowing seed treatment **	without supplements **	2,03	2101,28
		one feeding	2,03	2101,28
		two feedings	2,07	2560,29
	Rhizohumin	without supplements	2,16	2699,44
		one feeding	2,23	2707,68
		two feedings	2,33	3246,51
	Emistym C	without supplements	2,16	2699,44
		one feeding	2,23	2707,68
		two feedings	2,48	3679,94
	Rhizohumin + Emystim C	without supplements	2,48	3679,94
		one feeding	2,69	4083,31
		two feedings	2,87	4802,12
Makarovskyi	Without pre-sowing seed treatment **	without supplements	1,52	695,92
		one feeding	1,52	695,92
		two feedings	1,67	916,98
	Rhizohumin	without supplements	1,73	1012,70
		one feeding	1,75	1110,50
		two feedings	2,04	1541,55
	Emistym C	without supplements	1,67	916,98
		one feeding	1,73	1012,70
		two feedings	2,11	1594,45
	Rhizohumin + Emystim C	without supplements	2,16	1491,36
		one feeding	2,22	1761,59
		two feedings	2,35	1829,73

Notes: * – Emistym C; **- CONTROL.

The use of the biological preparation Rizogumin with the use of two foliar feedings of Emistym C contributed to an increase in the chlorophyll content in lupine of the Veresnevy white variety by 0.3 mg/g, and in the Makarivsky variety by 0.59 mg/g compared to the control. On both varieties of white lupine, pre-sowing treatment of seeds with a complex of drugs Rhyzogumin and Emistym C followed by foliar feeding of plants with Emistym C provided the highest pigment content in the experiment, both in terms of raw weight and in terms of unit area. In plants of the Veresnevyi variety, these indicators were 2.87 mg/g and 4802.12 mg/m^2, in the Makarivskyi variety - 2.35 mg/g and 1829.73 mg/m^2. It was noted that the intensity of dry matter accumulation during the growing season of white lupine varieties depended on the studied factors, namely pre-sowing seed treatment and foliar fertilization. Observations of the dynamics of dry matter accumulation in white lupine varieties showed that the maximum yield is formed in the phase of physiological maturity (Table 3).

Table 3. Dynamics of accumulation of dry matter of white lupine varieties depending on biological preparations, g/plant (average for 2018-2020).

Factors			Air-dry mass of the aerial part of the plant, g/plant		
variety	pre-sowing seed processing	foliar feeding*	budding	full bloom	full ripeness
Veresnevyi	Without pre-sowing seed treatment **	without supplements **	3,13	4,34	8,61
		one feeding	3,15	4,45	8,64
		two feedings	3,17	4,56	8,67

	Rhizohumin	without supplements	3,16	4,51	8,70
		one feeding	3,18	4,62	8,74
		two feedings	3,20	4,73	8,83
	Emistym C	without supplements	3,19	4,84	8,71
		one feeding	3,21	4,95	8,76
		two feedings	3,23	5,06	8,81
	Rhizohumin + Emystim C	without supplements	3,25	5,07	8,80
		one feeding	3,28	5,41	8,84
		two feedings	3,31	5,84	8,99
Makarovskyi	Without pre-sowing seed treatment **	without supplements	2,84	3,86	8,26
		one feeding	2,86	3,95	8,30
		two feedings	2,88	4,04	8,34
	Rhizohumin	without supplements	2,87	4,13	8,40
		one feeding	2,89	4,22	8,46
		two feedings	2,91	4,31	8,50
	Emistym C	without supplements	2,90	4,25	8,32
		one feeding	2,92	4,34	8,37
		two feedings	2,94	4,43	8,41
	Rhizohumin + Emystim C	without supplements	2,96	4,52	8,50
		one feeding	2,99	4,61	8,53
		two feedings	3,02	4,70	8,61

Notes: * – Emistym C; **- CONTROL.

Thus, in the variants where the biopreparations Ryzogumin and Emistym C were applied in combination with two foliar top dressings Emistym C, the amount of dry matter was 8.99 t/ha in the Veresnevy variety, and 8.61 t/ha in the Makarivsky variety, which was 0.28 and by 0.35 t/ha more than in the variants without application of pre-sowing treatment and without foliar fertilization. Productivity is a complex complex feature that manifests itself on the basis of the functional activity of various plant organs that make up their morphological and physiological structure. Each organ (root, stem, leaf, seed) is formed at a certain stage of ontogenesis. Their vital activities are limited to different time periods and are regulated by the genetic apparatus of organisms in complex interaction with environmental conditions (Roggatz et al., 1999; Soltani et al., 2001; Ahmadi et al., 2010). In an average of 3 years, the research results indicate a significant impact of the researched technological methods of growing on the yield (Table 4).

Table 4. Grain yield of white lupine varieties depending on biological preparations, t/ha (average for 2018-2020).

Factors			Years			Average
variety	pre-sowing seed processing	foliar feeding*	2018	2019	2020	
Veresnevyi	Without pre-sowing seed treatment **	without supplements **	3,08	3,24	2,55	2,96
		one feeding	3,13	3,35	2,59	3,02
		two feedings	3,18	3,42	2,62	3,17
	Rhizohumin	without supplements	3,15	3,71	2,90	3,25
		one feeding	3,31	3,88	2,94	3,38
		two feedings	3,40	3,90	3,05	3,45
	Emistym C	without supplements	3,10	3,68	2,82	3,20
		one feeding	3,20	3,74	2,86	3,27
		two feedings	3,31	3,81	2,93	3,35
	Rhizohumin + Emystim C	without supplements	3,08	3,62	2,88	3,19
		one feeding	3,12	3,85	3,01	3,32
		two feedings	3,58	4,10	3,15	3,61
Makarovskyi	Without pre-sowing seed treatment **	without supplements	2,69	2,74	2,46	2,63
		one feeding	2,78	2,81	2,54	2,71
		two feedings	2,90	2,93	2,62	2,81
	Rhizohumin	without supplements	3,00	3,13	2,51	2,88
		one feeding	3,14	3,31	2,72	3,05
		two feedings	3,20	3,45	2,80	3,15
	Emistym C	without supplements	2,68	2,78	2,28	2,58
		one feeding	2,71	2,85	2,32	2,62
		two feedings	2,80	2,90	2,50	2,73

	Rhizohumin + Emystim C	without supplements	3,11	3,24	2,38	2,91
		one feeding	3,22	3,40	2,41	3,01
		two feedings	3,34	3,65	2,70	3,23
LSD $_{0,5}$ t/ha: A-0,07; B-0,10; C-0,08; AB-0,14; AC-0,12; BC-0,17; ABC-0,24 2018 p. HIP$_{0,5}$ t/ha: A-0,04; B-0,05; C-0,04; AB-0,07; AC-0,06; BC-0,08; ABC-0,12 2019 p. HIP$_{0,5}$ t/ha: A-0,05; B-0,06; C-0,06; AB-0,09; AC-0,08; BC-0,11; ABC-0,16 2020 p. HIP$_{0,5}$ t/ha: A-0,04; B-0,06; C-0,05; AB-0,08; AC-0,07; BC-0,10; ABC-0,14						

*Notes: * – Emistym C; **- CONTROL.*

The maximum value of grain yield of white lupine of the Veresnevy variety was obtained in the variants of the experiment with pre-sowing seed treatment with the inoculant Rhizogumin and the growth stimulator Emistym C in combination with two foliar fertilizing Emistym C. At the same time, the amount of grain yield was 3.61 t/ha, and exceeded the control variant by 0.65 t/ha, and in the percentage ratio, respectively – 18%.

CONCLUSIONS

Vinnytsia National Agrarian University develops the latest technologies for growing legumes, including white lupine, with elements of biologization and implements the results in production, within the framework of the implementation of the state theme, which is carried out at the expense of the state budget on the topic: «Development of methods for improving cultivation technology legumes using biofertilizers, bacterial preparations, foliar feeding and physiologically active substances» (state registration number 0120U102034).
During 2018-2020, on the basis of the research farm Agronomichne" of the Vinnytsia National Agrarian University, field studies were conducted on the effect of treating white lupine with biological preparations. Pre-sowing treatment of seeds with nodule bacteria and a growth stimulator in combination with foliar fertilization influenced the formation of the value of growth and development processes, as well as quantitative and qualitative indicators of white lupine. On the basis of the obtained research results, with the aim of growing high yields of white lupine grain at the level of 3.23-3.61 t/ha, agroforming recommends:
- sowing the intensive variety of white lupine Veresnevy;
- carry out pre-sowing seed treatment with the bacterial preparation Rhyzogumin (600 g per hectare of seed rate) and the growth stimulator Emistym C (10 ml per 1 ton of seeds) in combination with two foliar fertilizing Emistym C in two periods: the first - in the budding phase, the second - in phase of the beginning of grain pouring (15 ml/ha).

REFERENCES

1. Vdovenko, S. et al. (2018). Symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biological products in agrocoenosis of the right-bank forest-steppe of Ukraine. Ukrainian Journal of Ecology, 8 (3), 270–274;
2. Langewisch T. et al. (2017). The development and use of a molecular model for soybean maturity groups. Bmc Plant Biology, 17, 13;
3. Pancy`reva G. V. (2016). Doslidzhennya sortovy`x resursiv lyupy`nu bilogo (Lupinus albus L.) v Ukrayini. Vinny`cya, 4, 88-93;
4. Kaletnik, G., & Lutkovska, S. (2020). Innovative Environmental Strategy for Sustainable Development. European Journal of Sustainable Development, 9(2), 89, https://doi.org/10.14207/ejsd.2020.v9n2p89;
5. Nychyporovych, A.A. et al. (1961). Photosynthetic activity of plants in sowings. Moscow: USSR Academy of Sciences;
6. Chynchyk, O.S. (2013). Influence of fertilization system and methods of basic tillage on the formation of pea plant structure. Feed and feed production: interdepartmental thematic collection of scientific papers, 77, 123–127;
7. Didur I. et al. (2020). Agroecological rationale of technological methods of growing legumes. The scientific heritage, 52. P. 3–14;

8. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020) Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. Ukrainian Journal of Ecology. 10 (5), 54-61;
9. Didur I., Chynchyk O., Pantsyreva H., Olifirovych S., Olifirovych V., Tkachuk O. (2021) Effect of fertilizers for Phaseolus vulgaris L. productivity in Western Forest-Steppe of Ukraine. Ukrainian Journal of Ecology. 11 (1), 419-424;
10. Kantolic A. (2013). Seed number responses to extended photoperiod and shading during reproductive stages in indeterminate soybean. European Journal of Agronomy, 51: 91–100;
11. Mazur, V. et al. (2021). Ecological suitability peas (Pisum sativum) varieties to climate change in Ukraine. Agraarteadus, 32 (2), 276–283, https://doi.org/10.15159/jas.21.26;
12. Honcharuk, I. et al. (2020). Efficiency of growing legumes crops in Ukraine. In :Integration of traditional and innovation processes of development of modern science: ñollective monograph (3rd ed). (Ed. A. Jankovska). Baltija Publishing, Riga, Latvia, 42– 65. DOI: 10.30525/978-9934-26-021- 6-31;
13. Kaletnik, G.M. (2010). Biofuels. Food, Energy and Environmental Security of Ukraine: Monograph. K: High-tech Press, 516;
14. Kaletnik, G. et al. (2020). The The Waste-Free Production Development for the Energy Autonomy Formation of Ukrainian Agricultural Enterprises. Journal of Environmental Management and Tourismthis. 11(3): 513–522;
15. Zhu J.H. et al. (2019). Loss of Function of the E1-Like-b Gene Associates With Early Flowering Under Long-Day Conditions in Soybean. Frontiers in Plant Science, 9, 13;
16. Mazur, V.A. et al. (2019). Influence of the assimilation apparatus and productivity of white lupine plants. Agronomy Research, 17, 206-219;
17. Mazur, V. et al. (2020). Agroecological prospects of using corn hybrids for biogas production. Agronomy Research, 18, 205-219;
18. Puyu, V. et al. (2021). Socialand-Ecological Aspects of Forage Production Reform in Ukraine in the Early 21st Century. European Journal of Sustainable Development, 10(1), 221–228;
19. Roggatz, U. et al. (1999). Effects of nitrogen deprivation on cell division and expansion in leaves of Ricinus communis L. Plant, Cell and Environment, 22(1) : 81–89. DOI:1046/ j.1365-3040.1999.00383.x;
20. Soltani, A. et al. (2001). A simulation study of chickpea crop response to limited irrigation in semiarid environment. Agricultural Water Management, 95: 171–181;
21. Ahmadi, H. et al. (2010). Effect of different levels of nitrogen fertilizer on yield, nitrate, accumulation and several quantitative attributes of five Iranian spinach accessions. AmericanEurasian Journal of Agricultural and Environmental Science, 8(4), 468–473;
22. Bandura, V. et al. (2019). Research on sunflower seeds drying process in a monolayer tray vibration dryer based on infrared radiation. INMATEN. Agricultural Engineering, 57(1), 233–242;
23. Rai R. et al. (2017). Exogenous application of ethrel and gibberellic acid stimulates physiological growth of late planted sugarcane with short growth period in subtropical India. Journal of Plant Growth Regulation, 36(2), 472-486;
24. Bulgakov V. et al. (2014). Mathematical model of vibration digging up of root crops from soil. Agronomy Research, 12 (1), 41-58;
25. Mazur V., Didur I., Tkachuk O., Pantsyreva H., Ovcharuk V. (2021) Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. Scientific Horizons. 24 (1), 54-60;
26. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021) Quality of pea seeds and agroecological condition of soil when using structured water. Scientific Horizons. 24 (7), 53-60;
27. Mazur V., Tkachuk O., Pantsyreva H., Kupchuk I., Mordvaniuk M., Chynchyk O. (2021) Ecological suitability peas (Pisum sativum) varieties to climate change in Ukraine. Agraarteadus. Journal of Agricultural Science. 2 (32), 276-283;
28. Didur, I. et al. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank Forest-Steppe in Ukraine. Ukrainian Journal of Ecology, 10 (5), 54-61;
29. Mazur, V. et al. (2019). Influence of the Photosynthetic Productivity and Seed Productivity of White Lupine Plants. Ukrainian Journal of Ecology, 9(4), 665-670;