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Influence of the assimilation apparatus and productivity of white lupine plants

V.A. Mazur, H.V. Pantsyreva*, K.V. Mazur and I.M. Didur

Vinnytsia National Agrarian University, Soniachna street 3, UA21008 Vinnytsia, Ukraine,
*Correspondence: pantsyreva@vsau.vin.ua

Abstract. Artificial regulation of the growth and development of cultivated plants aimed to increase biological productivity and improve the quality of eco-frienfly products is an important goal of modern agricultural production. Application of the natural growth stimulators and bacterial agents is quite relevant and effective. The field research was conducted on the basis of the research farm 'Agronomichne' of Vinnytsia National Agrarian University, village Agronomichne, Vinnytsa district, Vinnytsia region, Ukraine. Features of the growth and development of white lupine *(Lupinus albus L.)* plants are examined. There has been established a positive effect of the combination of inoculation with the bacterial agent and growth stimulator on the productivity of white lupine, which is important for the formation of high and stable yields. The papers presents the results of studies on the effect of pre-sowing seed treatment and foliar nutrion under conditions of the right-bank Forest-Steppe of Ukraine on the assimilation apparatus of white lupine plants. It has been established that bacterial agents and growth stimulators increase white lupine productivity due to optimization of the studied technological methods of cultivation. The optimal leaf surface area that provided maximum grain yield has been determined. The research has established a positive effect of pre-sowing seed treatment with the bacterial agent Rhizohumin and the growth stimulator Emistym C and foliar nutrition with Emistym C on the chlorophyll content in the white lupine leaves. The influence of the investigated technological methods on the formation of the assimilation surface area and chlorophyll synthesis in the leaves of white lupine has been proved. The preparations studied induce intensive development of the photosynthetic apparatus, yield increase, improvement of the yield structure and they improve grain quality under conditions of right-bank Forest-Steppe of Ukraine. The issue of seed bacterization and application of growth stimulators requires a more detailed study. Theefore, such researches are relevant and significance in terms of both practical and scientific value.

Key words: white lupine, assimilation apparatus, chlorophyll, variety, productivity, growth stimulator, seed bacterization.

INTRODUCTION

The most important goals of modern agrarian science include the search for new ways and techniques aimed to increase crop productivity as well as to improve the product quality (Rogach, 2009; Mazur & Pantsyreva, 2017). Significant achievements in this area can be achieved through optimization of the level of fulfilment of the genetic potential of plants and simultaneous minimization of the effect of negative environmental factors in the process of their ontogenesis (Muhammad & Muhammad, 2013; Rai et al., 2017).

Climate resources are important for maximizing the biological potential of agricultural crops. The vegetative period in agricultural crops is related to the amount of precipitation and the presence of heat. Among allocated in Ukraine natural agricultural zones include: Woodland, Forest Steppe and Steppe zones. The Forest Steppe zone occupies 34.9% of the territory of Ukraine (20,291,1 thousand hectares). Right Bank Forest Steppe is characterized by moderatelycontinental climate and belongs to the zone of sufficient moisture. The absence of high altitude increases the free movement of air of various origins, which causes a significant variability of weather processes in separate seasons (Furseth, 2012; Madzikane-Mlungwana et al., 2017; Mazur & Pantsyreva, 2017).

Physiologically active substances cause restructuring of the assimilation apparatus of plants, changes in morphometric parameters, ratio of the masses of its organs, emergence of additional attractive centers, and the strengthening or weakening of the functioning of existing ones that indicates changes in the nature of donor-acceptor relationships in the plant (Kuryata et al., 2017). The effect of the growth stimulantors is associated with the acceleration of the processes of division, stretching and differentiation with the simultaneous increase in plant habitus (Madzikane-Mlungwana et al., 2017; Rai et al., 2017), the area of assimilation surface (Polyvanyj & Kuryata, 2015; Ren et al., 2017), an increase in the chlorophyll concentration (Luo et al., 2017; Ren et al., 2017) and, as a consequence, the activation of photosynthetic processes (Mohammad & Mohammad, 2013; Rai et al., 2017; Ren et al., 2017), and the growth of crop productivity (Polyvanyj & Kuryata, 2015; Gonzatto et al., 2016; Khalid et al., 2016; Alexopoulos et al., 2017; Pantsyreva, 2017; Rai et al., 2017).

It is known that the hormonal system plays an extremely important role in the regulation of the processes of plant morphogenesis, and the physiological effect depends both on the features of varieties and technological methods of cultivation. Application of the preparations based on the strains of nodule bacteria and extracts from epiphyte fungi affect the yield and quality of agricultural products. The use of growth regulators and bacterial agents provides the prospects of artificial redistribution of the flows of assimilants from vegetative growth processes to the formation and growth of grain, and, as a result, it can become an effective factor for increasing crop yields (Davis, Tim, 2017; Rai et al., 2017; Bollman &, Vessey, 2006, Merkushyna, AS, 2013; Xing et al., 2016).

In the research papers, there is enough information available on the use of natural growth stimulators and bacterial agents aimed to activate the production process through morphometric changes in the legumes (Xing et al., 2016; Pantsyreva, 2016), cereals (Muhammad & Muhammad, 2013; Luo et al. , 2017; Zhao et al., 2017), oilseeds (Khodanitska & Kuryata, 2011; Fu et al., 2014; Froschle et al., 2017), vegetables (Tubiis et al., 2016; Palamarchuk, 2017, Alexopoulos et al., 2017), industrial crops (Khhodanitska & Kuryata, 2011; Mohammad & Mohammad, 2013; Rai et al., 2017), fruit crops (Ahmed et al., 2012; Cru-Castilloa et al., 2014), medicinal and decorative crops (Gouveia et al., 2012; Aremu et al., 2017; Madzikane-Mlungwana et al., 2017). Bacterial agents and growth stimulators also increase crop resistance to adverse environmental and biotic factors due to the changes in hormonal status and the activation of antioxidant plant sustems (Javid et al., 2011; Muhammad & Muhammad, 2013; Piotrowska-Niczyporuk et al., 2014; Tubi's et al., 2016; Xing et al., 2016).

Domestic and foreign authors indicate that the biological yield depends on the content of pigments, primarily chlorophylls in the assimilating organs of plants, time and intensity of their work. Chlorophyll content in the leaves affects the intensity of photosynthesis, dry matter accumulation, and, finally, their productivity. The need for research in this area is caused by the fact that the total mass of green pigment and its concentration in the leaf mesophyll as well as the assimilation surface area are considered to be the basis of the potential of photosynthetic activity of the plant organism as a whole (Pantsyreva, 2017; Rai et al., 2017).

The difference in the chlorophyll content, as a rule, is an indicator of the level of compliance with the growing conditions and it varies depending on the variety genotype. The increase in crop yield depends on both the factors affecting photosynthesis and the complex of physiological processes associated with it (water exchange, nutrition, growth). The formation of a well-developed photosynthetic apparatus that is optimal in volume, dynamics and intensity of functioning is the key to the production of organic matter, biological and commodity yield (Pantsyreva, 2017).

Scientifically substantiated foundations of the technologies for growing legume crops, including white lupine, determination of the chlorophyll accumulation in plant leaves are important as their content affects the intensity of photosynthesis and other physiological processes. The researches aimed at establishing the features of the photosynthetic apparatus, peculiarities of formation of the assimilation apparatus during plant growth and development are of primary importance for assessing the influence of the technological methods on the productivity and quality of the plant grain. Therefore, such researches are of great importance for modern agricultural production (Rogach, 2009; Mazur & Pantsyreva, 2017). Thus, the purpose of this research is to establish the specifics of the assimilation apparatus formation by white lupine crops depending on the technological methods under conditions of the right-bank Forest-Steppe.

MATERIALS AND METHODS

The field research (for 2013–2018 years) was conducted on the experimental field ‘Agronomichne’ of Vinnytsia National Agrarian University that was sown with white lupine, village Agronomichne, Vinnitsa district, Vinnytsia region. White lupine variety Veresnevyi was selected as the material for the study.

In the experiment, the effect and interaction of three factors were studied: A – variety, B – pre - sowing seed treatment, C - foliar fertilization. On the day of sowing, white lupine seeds were treated with bacterial Risogumin (600 g per hectare seed) and growth promoter Emistim C (10 mL per 1 t seed) using PKC-20 Super. Growth stimulator Emistim C with a rate of use of 15 mL ha^{-1} was used in the non-root nutrition. The first foliar nutrition of Emistim C was carried out in the budding phase, and the second in the phase of seeding. For control, an option is adopted without pre-planting and without extra-root crops. On the day of sowing, white lupine seeds were treated with water in a control.

Risogumin is used to bacterialize lupine seeds in order to improve nitrogen nutrition of plants, increase productivity of culture. Stimulator of growth of plants Emistim C a wide spectrum of action - a product of biotechnological cultivation of mushroom-epiphytes from the root system of medicinal plants. Transparent, colorless, water-alcohol solution. Contains a balanced set of phytohormones of auxin, cytokinin nature, amino acids, carbohydrates, fatty acids, trace elements.

There was applied the technology of growing white lupine varieties that was conventional for the Forest-Steppe zone of Ukraine and involved pre-sowing seed treatment with the bacterial agent Rhizohumin combined with the growth stimulator Emistym C and foliar nutrition with Emistym C. The registered area was 25 m^2. Replication was five-time. The variants were located systematically in two layers.

Evaluation of photosynthetic activity of plants was carried out in accordance with the following techniques: leaf area was measured by the method of 'carving', photosynthetic potential was determined by the method of A.A. Nichiporovich (1996); chlorophyll content was determined by the method of alcohol batch using a certified electrophotocololymer (KFK-2).

Statistical analysis of the experimental data was carried out using the computer program STATICA - 6. Validity of the difference of the experimental data regarding the control was determined using Student's t-criterion. The tables and figures show the average data over the years of research.

The revealed dependencies (Fig. 4) between the formation of indicators of individual productivity and grain yield of white lupine varieties can be expressed by the following regression equations:

$$У = 7.881678 + 0.066816x_1 + 0.196308x_2 – 0.026010x_3 \quad (1)$$

where У – grain yield, t ha^{-1}; x_1 – number of beans per plant, pcs/plant; x_2 – number of grains per plant, pcs; x_3 – mass of 1,000 seeds, g.

In this case, the coefficients of the multiple linear correlation in white lupine were $R = 0.904254$ and $R = 0.896057$, respectively. The pair correlation coefficients (r) between the grain yield and the number of beans, the number of seeds per plant, and the mass of 1,000 seeds were 0.145801, 0.045127, 0.09706. These indicators show a close relationship between the basic indicators of individual plant productivity and the level of grain yield of white lupine.

RESULTS AND DISCUSSION

It is known that white lupine is characterized by slow and uneven growth in the initial phase of development; however its growth rate increases in the future. White lupine grows especially intensely after the beginning of bloom. The growth rate during this period depends mainly on the environment and characteristics of the variety.

It is noted that depending on the factors studied the height of white lupine plants before the phase of budding did not change significantly, but since the beginning of the stage of full bloom the difference in height between the variants considerably increased.

The researches (Rogach, 2009; Mazur & Pantsyreva, 2017) have revealed the dependence of white lupine plant height on the effect and interaction of bacterial agent and growth stimulators that were studied (Fig. 1).

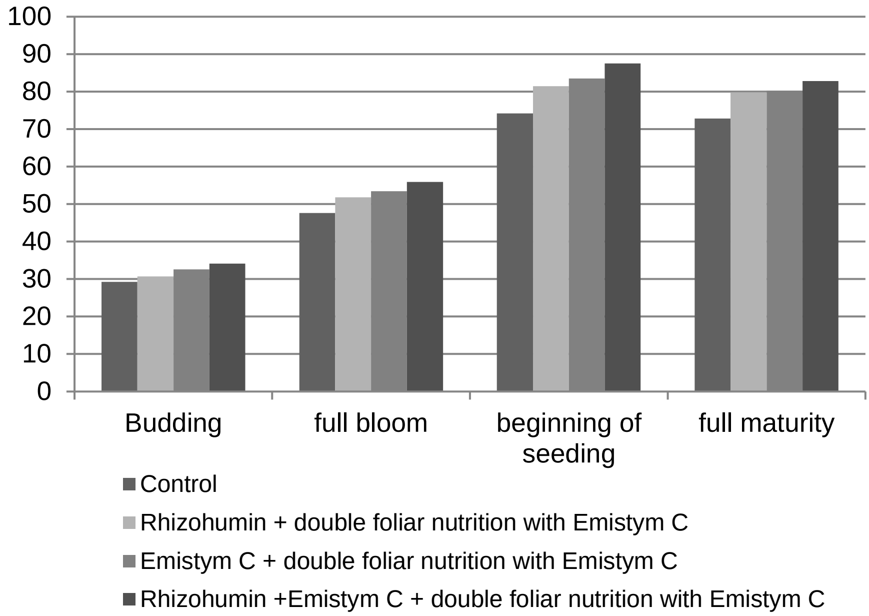

Figure 1. Dynamics of while lupine plant height in Veresnevyi variety depending on pre-sowing seed treatment and foliar nutrition, cm (average of 2013–2017).

The highest height of this variety was recorded at the beginning of the grain pouring and was 87.5 cm in the version where pre-sowing seed treatment with an inoculum Risogumin with an Emistim C growth stimulator was carried out in conjunction with two non-root nutrients. This indicator exceeded the control version without the use of pre-seed treatment on average 13.3 cm.

In the case of seedless pre-seed treatment, plant height was the lowest in all phases of growth and development of white lupine plants. The greatest value of this indicator on the control version without foliar feeding at the beginning of the pouring of grain was 74.2 cm.

In the version with the use of bacterial preparation Rizogumin without endocrine infusions in the phase of the onset of grain, the height of the plant reached 78.9 cm, which is 4.7 cm less for this variant. In the variant with pre-sowing treatment with growth stimulator Emistim C with two extra-root nutrients, the height of 83.5 cm was fixed, which is 9.3 cm less than the control variant.

The process of formation of fruit elements in white lupine plants depending on pre-sowing seed treatment and foliar nutrition is of great scientific and practical value for maximum fulfilment of the genetic potential of the variety under conditions of the right-bank Forest-Steppe. Observations of the nature of formation of fruit elements in white lupine showed that their number depends on the effect of the biological agents that were studied (Table 1).

Table 1. Formation of fruit elements in white lupine depending on pre-sowing seed treatment and foliar nutrition (average of 2013–2015)

Factors		Average number per plant, pcs.			% of mature beans	
Pre-sowing seed treatment	Foliar nutrition with Emistym C	Flowers	Beans after setting	Beans at the period of ripening	from the number of flowers	From the formed beans
Without pre-sowing seed treatment	without nutrition	25.1	7.7	5.0	19.9	64.9
	single nutrition	25.4	7.8	5.1	20.1	65.4
	double nutrition	25.8	7.9	5.2	20.2	65.8
Rhizohumin	without nutrition	25.5	8.3	5.6	22.5	67.5
	single nutrition	25.7	8.7	5.9	23.0	67.8
	double nutrition	25.9	8.9	6.0	23.2	67.4
Emistym C	without nutrition	26.3	8.8	6.1	23.2	69.3
	single nutrition	27.1	9.0	6.4	23.6	71.1
	double nutrition	27.9	9.2	6.6	23.7	71.7
Rhizohumin + Emistym C	without nutrition	28.4	9.3	6.7	23.6	72.0
	single nutrition	29.4	9.5	7.0	23.8	73.7
	double nutrition	29.7	9.6	7.1	23.9	74.0

$LSD_{0.5}$: A-0.04; B-0.8; C-0.07; AB-0.10; AC-0.11; BC-0.15; ABC-0.20
2013 $LSD_{0.5}$ t ha^{-1}: A-0.03; B-0.04; C-0.03; AB-0.07; AC-0.06; BC-0.7; ABC-0.10
2014 $LSD_{0.5}$ t ha^{-1}: A-0.04; B-0.05; C-0.04; AB-0.09; AC-0.08; BC-0.10; ABC-0.14
2015 $LSD_{0.5}$ t ha^{-1}: A-0.05; B-0.05; C-0.05; AB-0.08; AC-0.07; BC-0.10; ABC-0.13.

It was established that the largest number of flowers per plant in white lupine was formed in the variant where pre-sowing seed treatment involved the bacterial agent Rhizohumin and the growth stimulator Emistym C in combination with double foliar nutrition with Emistym C in the budding phase. Thus, the number of flowers per plant in Veresnevyi variety was 29.7 flowers per plant, which exceeded the control variant by 4.6 flowers per plant. The variants without pre-sowing seed treatment and foliar nutrition had the lowest figures, which were 25.1 flowers per plant in Veresnevyi variety.

Thus, the effect of the studied preparations on the figures of the leaf surface area was insignificant in the phases of branching and budding. On the site where Veresnevyi variety was grown, the leaf area index, depending on the pre-sowing seed treatment and foliar nutrition, was within 14.2–15.7 thousand m^2 pe ha in the budding phase, and it ranged within 22.3–27.6 thousand m^2 per ha in the phase of full bloom.

It was established that the highest index of the area of the leaf surface per hectare of lupine of the white variety of the Veresnevyi – 43.7 thousand m^2 ha^{-1} was formed in the phase of the beginning of the filling of grain in the variant with the use of the bacterial preparation Risogumin in combination with growth stimulator Emistim C with two extracorporeal feedings Emistim C. This indicator was greater than control at 8.1 thousand m^2 ha^{-1} (Fig. 2).

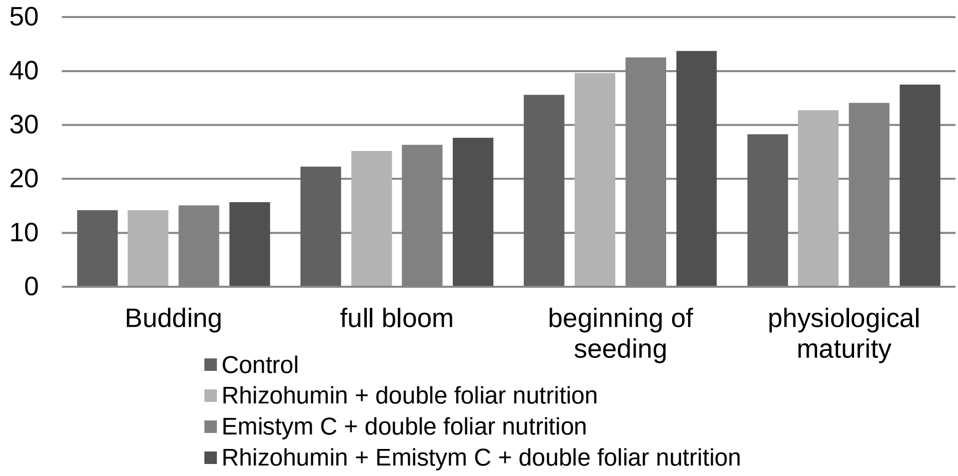

Figure 2. Dynamics of the leaf surface area of white lupine plants of Veresnevyi variety depending on technological methods, thousand m^2 per ha (2013–2015).

The records taken during the trial have showed that pre-sowing seed treatment of white lupine with the bacterial agent Rhizohumin in combination with the growth stimulator Emistym C with double foliar nutrition with Emistym C have a positive effect on the formation of photosynthetic apparatus of plants and on chlorophyll content in the leaves of white lupine (Table 2).

Table 2. Formation of the photosynthetic potential of white lupine of Veresnevyi variety depending on pre-sowing seed treatment and foliar nutrition, million m^2 per ha (average for 2013–2017)

Factors		Periods of vegetation of plants			
Pre-sowing seed treatment	Foliar nutrition with Emistym C	Full germination - budding	Full germination - full bloom	Full germination Beginning of seeding	Full germination - physiological maturity
Without pre-sowing seed treatment	without nutrition	0.321	0.601	0.989	1.505
	single nutrition	0.321	0.606	1.005	1.529
	double nutrition	0.321	0.606	1.006	1.559
Rhizohumin	without nutrition	0.326	0.616	1.050	1.588
	single nutrition	0.326	0.622	1.075	1.638
	double nutrition	0.336	0.622	1.076	1.689
Emistym C	without nutrition	0.337	0.637	1.125	1.766
	single nutrition	0.337	0.648	1.150	1.819
	double nutrition	0.337	0.648	1.151	1.860
Rhizohumin + Emistym C	without nutrition	0.354	0.675	1.125	1.941
	single nutrition	0.354	0.689	1.260	1.982
	double nutrition	0,354	0.689	1.262	2.061

$LSD_{0.5}$ million m^2 per ha: A-0.05; B-0.6; C-0.07; AB-0.12; AC-0.11; BC-0.14; ABC-0.09
2013 $LSD_{0.5}$ t ha^{-1}: A-0.04; B-0.05; C-0.04; AB-0.06; AC-0.06; BC-0.07; ABC-0.10
2014 $LSD_{0.5}$ t ha^{-1}: A-0.05; B-0.06; C-0.05; AB-0.08; AC-0.07; BC-0.08; ABC-0.14
2015 $LSD_{0.5}$ t ha^{-1}: A-0.06; B-0.07; C-0.05; AB-0.08; AC-0.07; BC-0.10; ABC-0.13.

It is proved that the effectiveness of application during pre-sowing seed treatment of the bacterial agent Rhizohumin and the growth stimulator Emistym C and foliar nutrition with the growth stimulator Emistym C is marked in the phase of physiological maturation. Thus, the highest figures of formation of photosynthetic potential of white lupine plants were observed in the period of full germination – physiological maturity in the variants where pre-sowing seed treatment involved a bacterial agent and a growth stimulator in combination with with double foliar nutrition and amounted to 2.061, which exceeded the control variant by 27.0%.

The increase in crop yield depends on both the factors affecting photosynthesis and the complex of physiological processes associated with it (water exchange, nutrition, growth). The formation of a well-developed photosynthetic apparatus that is optimal in volume, dynamics and intensity of functioning is the key to formation of organic matter, biological and commodity yields.

Many authors indicate that the biological yield depends on the content of pigments, primarily chlorophylls in the assimilating organs of plants, the time and intensity of their work. The content of chlorophyll in the leaves affects the intensity of photosynthesis, accumulation of dry matter, and, finally, their productivity. The need for research in this area is caused by the fact that the total mass of the green pigment and its concentration in leaf mesophillous and the size of the assimilation surface are considered as a basis for the potential of photosynthetic activity of the plant organism as a whole.

Availability of the positive effect of pre-sowing seed treatment and foliar nutrition on the chlorophyll content in white lupine leaves was established (Table 3).

Table 3. Chlorophyll content in while lupine depending on pre-sowing seed treatment and foliar nutrition (average of 2013–2017)

Factors		Chlorophyll content in the leaves,	
Pre-sowing seed treatment	Foliar nutrition with Emistym C	mg g^{-1} of crude mass	mg m^{-2}
without pre-sowing seed treatment	without nutrition	2.03	2,101.28
	single nutrition	2.03	2,101.28
	double nutrition	2.07	2,560.29
Rhizohumin	without nutrition	2.16	2,699.44
	single nutrition	2.23	2,707.68
	double nutrition	2.33	3,246.51
Emistym C	without nutrition	2.16	2,699.44
	single nutrition	2.23	2,707.68
	double nutrition	2.48	3,679.94
Rhizohumin Emistym C	without nutrition	2.48	3,679.94
	single nutrition	2.69	4,083.31
	double nutrition	2.87	4,802.12

Pre-sowing seed treatment of white lupine plants both with Rhizohumin and Emistym C with subsequent foliar nutrition of plants with Emistym C provided the highest pigment content in the experiment, both in terms of crude mass and per unit of area. Thus, this indicator in the plants of Varesvenyi variety was 2.87 mg g^{-1} and 4,802.12 mg m^{-2}, respectively.

Observation of the dynamics of dry matter accumulation in white lupine plants showed that the maximum output was formed in the phase of physiological maturity (Fig. 3).

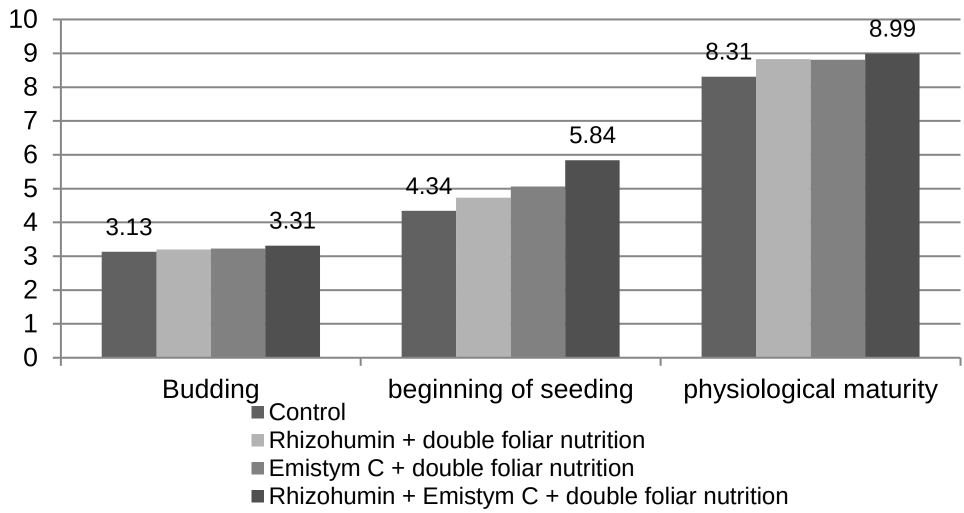

Figure 3. Dynamics of dry matter accumulation in while lupine of Veresnevyi variety depending on pre-sowing seed treatment and foliar nutrition, t ha^{-1} (average of 2013–2017).

It was noted that the intensity of dry matter accumulation during the growing season of white lupine varieties depended on the factors studied, namely, pre-sowing seed treatment and foliar nutrition. Application of the bacterial agent in combination with double foliar nutrition contributed to obtaining the largest output of dry matter of white lupine.

According to our research, individual productivity of while lupine plants depended on the features of the variety and the factors studied (Table 4).

Thus, the maximum individual productivity of white lupine plants of Veresnevyi variety was observed in the variant with pre-sowing seed treatment with a bacterial agent and a growth stimulator combined with the double foliar nutrition. In this case, the indicators of individual productivity were as follows: the number of beans per plant was 6.5 pcs, the number of grains per plant was 20.3 pcs, the mass of 1,000 grains was 335.1 g, the mass of grains per plant was 6.8 g. On the control trial sites, where no pre-sowing seed treatment and no foliar nutrition was applied, indicators of the individual productivity were the lowest, and they were as follows: the number of beans per plant was 4.9 pcs, the number of seeds per plant was 15.5 pcs, the mass of 1,000 grains was 317.2 g, the mass of grains per plant was 4.9 g.

We have found that there is a close relationship between individual productivity of plants and the level of crop yield, including white lupine.

The maximum value of the white lupine grain yield of Veresvenyi variety was obtained in the trial variants with pre-sowing seed treatment with the inoculant Rhizohumin and growth stimulator Emistym C in combination with double foliar nutrition with Emistym C (Table 5). At the same time, the grain yield was 3.61 t ha^{-1}, and it exceeded the control variant by 0.65 t ha^{-1} or 18%, respectively.

Table 4. Individual productivity of white lupine plants depending on pre-sowing seed treatment and foliar nutrition (average of 2013–2015)

Factors Pre-sowing seed treatment	Foliar nutrition	Number of beans per plant, pcs.	Number of grains per plant, pcs.	Mass of 1,000 seeds, pcs.	Mass of grains per plant, g
Without pre-sowing seed treatment	without nutrition	4.9	15.5	317.2	4.9
	single nutrition with Emistym C	5.0	16.0	318.1	5.1
	double nutrition with Emistym C	5.0	16.3	319.4	5.2
Rhizohumin	without nutrition	5.1	16.2	314.9	5.1
	single nutrition with Emistym C	5.2	17.3	317.0	5.5
	double nutrition with Emistym C	5.5	17.5	319.4	5.6
Emistym C	without nutrition	5.2	16.3	317.6	5.2
	single nutrition with Emistym C	5.4	17.6	320.1	5.6
	double nutrition with Emistym C	5.8	17.9	323.7	5.8
Rhizohumin + Emistym C	without nutrition	5.4	16.6	321.6	5.3
	single nutrition with Emistym C	6.1	18.1	325.9	5.9
	double nutrition with Emistym C	6.5	20.3	335.1	6.8

Table 5. Grain yield of while lupine depending on pre-sowing seed treatment and foliar nutrition, t ha^{-1} (average of 2013–2015)

Factors		Years			
Pre-sowing seed treatment	Foliar nutrition with Emistym C	2013	2014	2015	Average
Without pre-sowing seed treatment	without nutrition	3.08	3.24	2.55	2.96
	single nutrition	3.13	3.35	2.59	3.02
	double nutrition	3.18	3.42	2.62	3.17
Rhizohumin	without nutrition	3.15	3.71	2.90	3.25
	single nutrition	3.31	3.88	2.94	3.38
	double nutrition	3.40	3.90	3.05	3.45
Emistym C	without nutrition	3.10	3.68	2.82	3.20
	single nutrition	3.20	3.74	2.86	3.27
	double nutrition	3.31	3.81	2.93	3.35
Rhizohumin + Emistym C	without nutrition	3.08	3.62	2.88	3.19
	single nutrition	3.12	3.85	3.01	3.32
	double nutrition	3.58	4.10	3.15	3.61

$LSD_{0.5}$ t ha^{-1}: A-0.07; B-0.10; C-0.08; AB-0.14; AC-0.12; BC-0.17; ABC-0.24
2013 $LSD_{0.5}$ t ha^{-1}: A-0.04; B-0.05; C-0.04; AB-0.07; AC-0.06; BC-008; ABC-0.12
2014 $LSD_{0.5}$ t ha^{-1}: A-0.05; B-0.06; C-0.06; AB-0.09; AC-0.08; BC-0.11; ABC-0.16
2015 $LSD_{0.5}$ t ha^{-1}: A-0.04; B-0.06; C-0.05; AB-0.08; AC-0.07; BC-0.10; ABC-0.14.

It has been established that foliar nutrition with Emistym C provided an increase in the grain yield of white lupine. However, the increase in grain yield depended on the pre-sowing seed treatment, which involved foliar nutrition. Double foliar nutrition on the trial sites without pre-sowing seed treatment resulted in the yield increase of 0.21 t ha^{-1}.

While the application of double foilar nutrition with the growth stimulator Emistym C combined with pre-sowing seed treatment with the inoculant Rhizohumin and growth stimulator Emistim C provided a maximum grain yield increase of 0.65 t ha^{-1}. In the variants where pre-sowing seed treatment was conducted by the bactericidal agent Rhizohumin separately from the growth stimulator Emistym C , the application of double foliar nutrition resulted in somewhat lower yield increase of 0.49 t ha^{-1} and 0.39 t ha^{-1} or 14.2% and 12.0%, respectively. Consequently, there was revealed a significant effect of foliar nutrition with Emistym C combined with pre-sowing seed treatment with the bacterial agent Rhizohumin and growth stimulator Emistym C.

Plant functioning depends on a significant number of exogenous and endogenous factors, among which the regulation of productivity by the growth stimulator and bacterial agent is quite significant, since the changes in growth, physiological and biochemical processes cause restructuring of the entire plant organism in this way (Kuryata et al., 2017; Poprotska & Kuryata, 2017; Mazur et al., 2018). Stimulation of growth and development processes is associated with the mobilization of the genetic potential of plants and targeting assimilation resources at the enhancement of biological productivity, in contrast to the effects of inhibitors, although the effect of the latter, as it is known, may also be accompanied by the increased yields due to the redistribution of plastic substances between plant organs.

Application of pre-sowing seed treatment and foliar nutrition with the bacterial agent and growth stimulator induces changes in the processes of morphogenesis and intensification of metabolism in white lupine plants.

It is known that the leaf is the main source of assimilates in the plant. Changes in the structure and functioning of the leaf apparatus as a donor of plastic substances are the key ones in the production process. Enhancement of the activity of all types of meristem tissues under the effect of bacterial agent and growth stimulator has contributed to the formation of plants, which are bigger in their size (Mesejo et al., 2012; Aremu et al., 2017; Madzikane-Mlungwana et al., 2017) and form a more powerful leaf apparatus (Rogach, 2009; Polyvanyj & Kuryata, 2015). Setting of a bigger number of leaves, increase in the area and mass of crude matter in the leaves has resulted in the activation of photosynthetic processes and enhanced the donor function of the leaf.

Another kind of effect of the studied preparations is the mesostructure organization of the leaf. Strengthening of mitotic activity under the effect of preparations contributed to the thickening of the leaf blade due to assimilation tissue, which was manifested in increasing the number, size and volume of cells. The investigated influence of growth stimulators on the mesostructure of leaf blade in the white lupine can provide preconditions for increasing the crop photosynthetic productivity.

Assimilates, which were intensively synthesized under the effect of the bacterial preparation and growth stimulator, especially in the initial stages of ontogenesis, actively influenced the growth processes and accelerated the development of white lupine plants. Thus, the analysis of the ratio of masses of vegetative and generative organs shows that at the beginning of formation of grains, i.e. the main acceptors of plastic substances in the plant, their share increased under the effect of preparation studied. At the same time, the mass proportion of donor assimilates, i.e. the leaves in the indicated phase of ontogenesis, practically did not change, while the share of another powerful acceptor of plastic substances, i.e. the stem, significantly decreased. Their application caused changes in the activity and direction of growth processes. The treated sites showed a stronger branching of the stem compared with the control sites. An increase in the habitus of plants was due to effect of preparations.

The use of pre-sowing seed treatment and foliar nutrition contributed to the formation of a powerful photosynthetic apparatus. Under the effect of the growth stimulator, a large number of leaves were formed on the stem, and the duration of their active functioning was prolonged. At the same time, leaf surface area of white lupine plants increased. Under the effect of the preperations studied, the number and size of chloroplasts in the leaves increased, which resulted in the increased index of pure productivity of photosynthesis, increased photosynthetic performance, more intensive growth of the dry matter mass of white lupine plants. Consequently, pre-sowing seed treatment with the bacterial agent Rhizohumin and the growth stimulator Emistym C in combination with double foliar nutrition with the growth stimulator Emistym C contributed to the increase of the gross photosynthetic productivity of white lupine plants, which is an important condition for increasing the grain and fodder productivity of the crop.

Consequently, as the result of such application, enhancement of the growth processes under the effect of bacterial agents and growth stimulators and changes in plant morphometry, including the structure of the leaf apparatus, caused formation of a greater number of plastic substances with their subsequent transfer to the economically valuable organs in white lupine plants, i.e. grains, the number of which is greater under effect of the preparations. This resulted in the increase of biological productivity of the crop as a whole and the grain yield in particular.

CONCLUSIONS

Application of the bacterial agent Rhizohumin and the growth stimulator in combination with the double foliar nutrition with the growth stimulator Emistym C during pre-sowing treatment of white lupine seeds promoted the increase of the leaf area, formation of photosynthetic apparatus of plants and chlorophyll content in the leaves. The highest stimulatory effect was obtained in the variant of pre-sowing seed treatment with Rhizohumin + Emistym C + double foliar nutrition with Emistym C.

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