DOI 10.5281/ZENODO.10297886
EDN GKIFKA
UDC 579.64: 582.675.1: 581.192

Chaikovskaya L. A., Nemtinov V. I., Baranskaya M. I., Pashtetsky V. S., Pekhova O. A., Timasheva L. A., Radchenko L. A., Yakusheva N. N., Belova I. V.

EFFECT OF MICROBIAL PREPARATIONS ON THE CONTENT OF CHLOROPHYLLS, BIOCHEMICAL INDICATORS AND PRODUCTIVITY OF *NIGELLA DAMASCENA* L.

FSBSI "Research Institute of Agriculture of Crimea"

Summary. *Use of microbial preparations is one of the elements of modern agricultural technologies. Such preparations are produced on the basis of effective bacterial strains with a wide range of useful properties: nitrogen fixation, phosphate mobilization, production of phytohormones and other physiologically active substances. Objects of research: Nigella damascena L.; microbial preparations Azostim^{agro} (A), Phosphostim^{agro} (P), Bioprofid^{agro} (B) and Microbiocom^{agro} (M) created at the Department of Agricultural Microbiology – structural unit of Research Institute of Agriculture of Crimea. The aim of our research was to determine the effect of microbial preparations (pre-sowing seed inoculation) on chlorophyll content, seed yield, as well as productivity and biochemical composition of phytomass of Nigella damascene L. (variety 'Yalita') under conditions of micro-field experiments. The studies were carried out from 2012 to 2022. Pre-sowing seed bacterization had a positive effect on the content of ascorbic acid and sugars in the phytomass of N. damascena L. On average for two years, in variants with Azostim^{agro} and Phosphostim^{agro} application, we observed the greatest increase in accumulation of ascorbic acid (by 13 %), as well as total sugars, mono- and disaccharides (by 8 %, 5 % and 12 %, respectively). Pre-sowing seed inoculation with microbial preparations increased the content of chlorophylls a and b in the leaves of N. damascena L. (on average by 19-24% compared to control values), which in turn allowed to obtain a reliable increase in phytomass (average, dry weight of one plant grown from bacterized seeds was 1.8 times higher than the control figures: 0.94 g vs. 0.54 g, respectively); Microbiocom^{agro} application also improved seed yield (by 1.8 times or 13 % compared to control). These studies show that pre-sowing seed bacterization with microbial preparations, as an element of nigella cultivation technology, is quite promising.*

Keywords: *Nigella damascena L., microbial preparations, photosynthetic pigments, ascorbic acid, sugars, productivity.*

Для цитирования: *Чайковская Л. А., Немтинов В. И., Баранская М. И., Паштецкий В. С., Пехова О. А., Тимашева Л. А., Радченко Л. А., Якушева Н. Н., Белова И. В. Оценка влияния микробных препаратов на содержание хлорофиллов, продуктивность и биохимические показатели Nigella damascena L. // Таврический вестник аграрной науки. 2023. № 4 (36). С. 190–202. EDN: GKIFKA. DOI: 10.5281/zenodo.10297886.*

For citation: *Chaikovskaya L. A., Nemtinov V. I., Baranskaya M. I., Pashtetsky V. S., Pekhova O. A., Timasheva L. A., Radchenko L. A., Yakusheva N. N., Belova I. V. Effect of microbial preparations on the content of chlorophylls, biochemical indicators and productivity of Nigella damascena L. // Taurida Herald of the Agrarian Sciences. 2023. No. 4(36). P. 190–202. EDN: GKIFKA. DOI: 10.5281/zenodo.10297886.*

Introduction

Currently, the key goal for agriculture is its greening, transition to organic farming, environmentally friendly technologies and resource conservation, i.e. rational use of soil potential to preserve and increase its fertility [1, 2]. A significant role in this direction is given to soil microbiota, which determines soil biological activity, as well as microbiological processes direction (nitrogen fixation, phosphate mobilization, transformation of substances, mineralization, humification, etc.) in ecosystems. Microbiota is an integral component of biogeocenoses; it takes an active part in the geochemical cycles of biogenic elements. In the rhizosphere of plants, root exudates create selective conditions for the formation of a specific community of microorganisms. These microorganisms provide plant with available elements of mineral nutrition and synthesize physiologically active substances, which subsequently affect the plant's productivity and immunity [3, 4].

Rhizospheric bacteria have a complex of beneficial properties, one of which is nitrogen fixation. Thanks to the functioning of nitrogen-fixing microorganisms (diazotrophs), both plant nitrogen requirements are met and N is reserved in the soil in the form of nitrogen-containing compounds [5, 6]. Studies aimed at improving the productivity of agrophytocenoses, taking into account diazotrophs as a factor contributing to an increase in the degree of realization of the genetic potential of agricultural crops and their resistance to biotic and abiotic stresses, are topical fundamental and applied issues in agrobiotechnology. Associative microorganisms are an integral part of plant life, contributing to nutrition improvement, growth stimulation and protection against phytopathogens.

A promising direction for improving plant nutrition, in particular phosphorus nutrition, is biological phosphate mobilization, which is carried out by soil microorganisms (micromycetes, bacteria) that are recognized as powerful phosphate solubilizers or converters of poorly soluble phosphorus compounds into forms available for plants [7–9]. The main factors of this conversion (transformation) in soil are the products of microbial metabolism. There are two main strategies for increasing P availability in soil through the action of phosphate-mobilizing microorganisms: 1) enhanced dissolution of mineral phosphates due to acidification of soil solution and release of the metal complexing agents (mainly anions of organic acids); 2) enzymatic degradation of organic phosphates [10, 11].

Thus, management of biological processes in agrocenoses is possible through the introduction of agronomically useful strains of microorganisms. Therefore, use of microbial preparations based on active strains of rhizobacteria is an important technique in agriculture, as well as one of the promising ways to improve mineral nutrition of crops and increase their productivity [12]. Microbial preparations also contribute to an increase in the adaptive potential of winter wheat plants to stress factors (in particular, to heavy metals), which is manifested in oxidative stress reduction [13] and chlorophyll content (in leaves) increment [14]. In literature sources, there are data on the effect of *Bacillus thuriengiensis* on the pigment complex of potato and oregano leaves: *B. thuriengiensis* strains contain β-exotoxin and, therefore, reduce the amount of chlorophylls in potato leaves during different phases of vegetation, e.g. germination, budding, flowering [15]. Effect of *B. thuriengiensis var. darmstadiensis* 0271 and *B. thuriengiensis* 888 on the content of chlorophyll in the leaves of various oregano cultivars depended on the component composition of the synthesized bactericidal secondary metabolites – carvacrol, γ-terpinene, and p-cymene [16, 17]. Based on the foregoing, the development of environmentally friendly biological methods of growing plants using microbial preparations to increase plant productivity and improve the product quality is an urgent task.

It should be noted that the use of microbial preparations is advisable not only for growing traditional crops, but also in the cultivation of medicinal and essential oil crops, in particular *N. damascena* L. Thanks to its spicy-aromatic properties, nigella can be widely used in perfumery, baking and food industries, as well as in folk medicine. The content of essential oil in the seeds of different types of nigella (0.92%) determines their high aromaticity and consumer properties [18]. *Nigella damascena* seeds are used as medicinal raw material (VFS 42-1691-87) for the preparation "Nigedaza", which is used for the treatment of chronic gastrointestinal tract diseases; is especially useful for older and elderly people [19]. However, the issues of improving the efficiency of nigella production have not been studied sufficiently, namely the relationship between the biological characteristics of the plant and microbial preparations [20].

The aim of our research was to determine the effect of microbial preparations (pre-sowing seed inoculation) on the content of photosynthetic pigments (chlorophyll *a* and *b*), productivity and biochemical parameters of *N. damascena* L. (variety 'Yalita').

Materials and methods

Materials of research: microbial preparations and their complex; plants of *N. damascena* L. variety 'Yalita' [21]. Field experiments were carried out at the trial plots of the Department of Plant Breeding and Seed Production of Vegetable and Melon Crops – structural unit of the Research Institute of Agriculture of Crimea in 2021–2022. Soil of the experimental plot – chernozem southern calcareous; granulometric composition can be defined as heavy weak-structural loam. The content of humus in the arable layer – 4.3 %, nitrogen – 3.2 mg/100 g, phosphorus – 8.9 mg/100 g, potassium – 64.8 mg/100 g of soil, pH – 8.3 units. Irrigation of the plot – drip irrigation (we maintained 70% soil water holding capacity).

For pre-sowing inoculation, we used microbial preparations Azostim^{agro}, Phosphostim^{agro} [22], Bioprofid^{agro} and Microbiocom^{agro} [23] created at the Department of Agricultural Microbiology – structural unit of the Research Institute of Agriculture of Crimea. Azostim^{agro} (based on *Rhizobium radiobacter* 204) improves nitrogen nutrition in crop plants and stimulates plant growth and development; Phosphostim^{agro} (based on *Lelliottia nimipressuralis* CCM 32-3) is a strain that produces phytohormones and converts hard soluble phosphorus compounds into forms available for plants; Bioprofid^{agro} (based on *Paenibacillus polymyxa* P) synthesizes chitinase and antifungal components; Microbiocom^{agro} is a universal multystrain microbial preparation composed of the three aforementioned strains. All these strains are registered in the Crimean Collection of Microorganisms (CCM) – unique scientific facility created by the scientists of the Research Institute of Agriculture of Crimea (http://www.ckp-rf.ru, No. 507484). Control – moistening seeds with water.

Micro-field experimental design included the following options: 1. Control (without inoculation); 2. Phosphostim^{agro} (P); 3. Azostim^{agro} (A); 4. Bioprofid^{agro} (B); 5. Microbiocom^{agro} (M). Square of the experimental plots – 2.0 m^2; position of the plots – randomized, fourfold replication (IST (industry standard) 46 71-78, 1979). Morphometric studies of plants were carried out in three replications on accounting plots with an area of 1.8 m^2 in the budding phase according to the "Method of testing for distinctness, uniformity and stability" [24].

Differential extraction of photosynthetic pigments (chlorophylls *a* + *b*) was carried out with 96% ethyl alcohol; their quantitative determination was carried out by the colorimetric method [25]. Biochemical analysis was carried out in the Laboratory of Processing and Standardization of Essential Oils – structural unit of the Research Institute of Agriculture of Crimea in full compliance with generally accepted methods of chemical analyses. The content of dry matter was determined by the thermogravimetric method (GOST 28561-90, 2011). The content of total ash in plant material was determined by the method based on the determination of the incombustible residue of inorganic substances after burning and calcination of raw materials [26]. The content of sugars in nigella plant material was determined by the Bertran photocolorimetric method [27]. The content of vitamin C (ascorbic acid) in the plant material of nigella was determined by the titrimetric method using Tillmans dye [27].

Field experiments were carried out according to generally accepted methods [28]; data obtained were processed by statistical methods using S_O_2 and Statistica 7 software package.

Results and discussion

Effect of pre-sowing inoculation on the content of photosynthetic pigments in N. damascena leaves. We studied the content of photosynthetic pigments (chlorophylls *a + b)* in nigella leaves as it is one of the main indicators of the physiological state of the photosynthetic apparatus. Analysis of the obtained results showed that the use of microbial preparations for pre-sowing inoculation of *N. damascena* seeds contributed to an increase in the content of photosynthetic pigments in leaves (Table 1). So, in the first year of research, the content of the sum of chlorophylls *a* + *b* in the leaves of plants grown from bacterized seeds varied within 11.3–12.3 mg/g, which significantly exceeded the control indicators by 31–43 % (8.6 mg/g). But in the second year of research situation was different: a reliable increase in the content of photosynthetic pigments in nigella leaves (compared to control) was only in variant with P and M application – by 11 % and 6 %, respectively.

Table 1 – Content of chlorophylls *a+b* in *N. damascena* leaves, budding phase

Variant	2021		2022	
	mg/g	%	mg/g	%
Control	8.6	100	8.4	100
Phosphostim^{agro}	*11.6	134	*9.5	111
Azostim^{agro}	*12.3	143	8.8	105
Bioprofid^{agro}	*11.6	134	8.5	101
Microbiocom^{agro}	*11.3	131	*8.9	106
LSD_{05}	0.31		0.40	

Note. ** – Variants have differences at 5 % significance level.*

On average, for two years of research, the sum of chlorophylls *a* + *b* in the control variant was 8.5 mg/g of the raw weight (Figure 1). At the same time, in the leaves of *N. damascena* L. grown from bacterized seeds, the content of photosynthetic pigments increased to 10.6 mg/g (P, A) and 10.1 mg/g (B, M), which exceeded the control figures by 24 % and 19 %, respectively. These results confirm our previous studies, in which a positive effect of microbial preparations on the content of photosynthetic pigments in winter wheat leaves was established under conditions of both vegetative and field experiments [29].

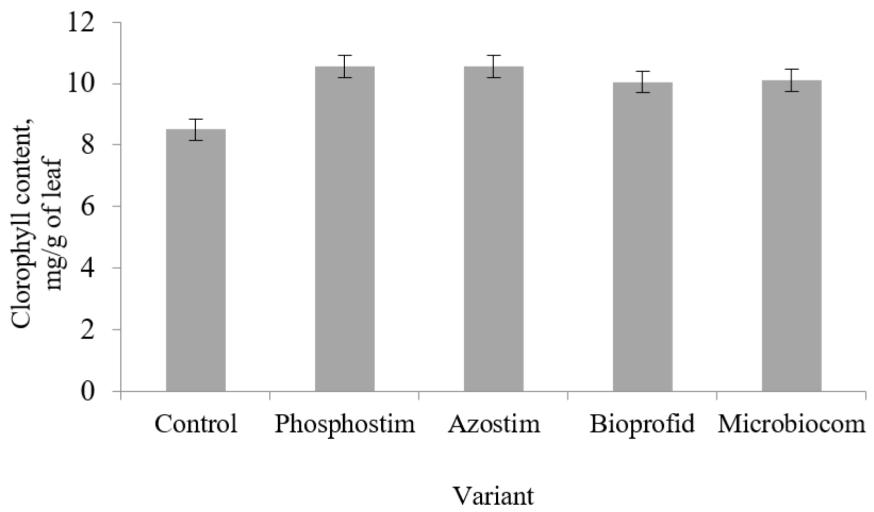

Figure 1 – Content of chlorophylls *a+b* in *N. damascena* leaves, budding phase (average for 2 years)

Photosynthesis plays an important role in plant productivity. This process occurs in leaves and provides emerging seeds with necessary assimilants. In literature sources, there is information that chlorophyll, which is the main component of plant photosystems, can affect productivity, but its content in leaves can be both high and low. A number of studies showed that high content of this pigment in leaves has a positive effect on the yield of cereals. For instance, as reported by Priadkina et al., yield increase of modern winter wheat variety

'Favoritka' was associated with a rise of content and gross amount of chlorophyll and a prolongation of functioning of crop photosynthetic apparatus during the reproductive period [30]. It was proved that an increase in chlorophyll concentration in leaves of the high-yielding winter wheat variety played a major role in obtaining higher productivity [31]. Research results of Gu et al. [32] indicate that low concentration of chlorophyll in the leaves of rice had a negative impact on grain productivity. At the same time, there was no significant relationship between the content of chlorophyll in the leaves of 30 spring wheat genotypes and their productivity under different irrigation regimes [33].

Effect of pre-sowing inoculation on the productivity of N. damascena. The use of microbial preparations for pre-sowing seed bacterization also contributed to the increase in phytomass compared to control: by 71–105 % in 2021 and 31–92 % in 2022 (Table 2). Reliable results were noted in 2021 when A, B and M were applied, as well as in 2022 after bacterization with P: absolutely dry weight of one plant exceeded control figures by almost twice and by 92 %, respectively. On average, for two years of research, dry weight of one plant grown from bacterized seeds varied within 0.91–0.97 g, which was 1.8 times higher than the control figures that reach only 0.54 g.

Table 2 – Effect of microbial preparations on *N. damascena* productivity

Variant	Weight of one plant, absolutely dry				Seed yield			
	2021		2022		2021		2022	
	g	%	g	%	kg/m^2	%	kg/m^2	%
Control	0.59	100	0.49	100	0.13	100	0.26	100
Phosphostim^{agro}	1.01	171	0.94*	192	0.10	77	0.27	104
Azostim^{agro}	1.17*	198	0.74	151	0.11	85	0.27	104
Bioprofid^{agro}	1.21*	205	0.72	147	0.13	100	0.22	85
Microbiocom^{agro}	1.18*	200	0.64	131	0.15*	115	0.31*	119
LSD_{05}	0.470		0.300		0.010		0.028	

Note. ** – Variants have differences at 5% significance level.*

Seed yield of *N. damascena* L. in variants with the use of microbial preparations varied within 0.10–0.15 kg/m^2 in 2021 and 0.22–0.31 kg/m^2 in 2022; control figures – 0.13 and 0.26 kg/m^2, respectively. A significant increase in the yield of nigella seeds in 2021 and 2022 compared to control (by 15 % and 19 %, respectively) was detected only in case of pre-sowing seed bacterization with M. In our opinion, the differences in nigella seed yield over the years of research can be explained by the difference in weather conditions (temperature and air humidity).

On average, for two years, seed productivity of bacterized plants varied within 0.17–0.23 kg/m^2 compared to 0.20 kg/m^2 in the control variant; significant increase (by 13 %) was in variant with M application (Figure 2).

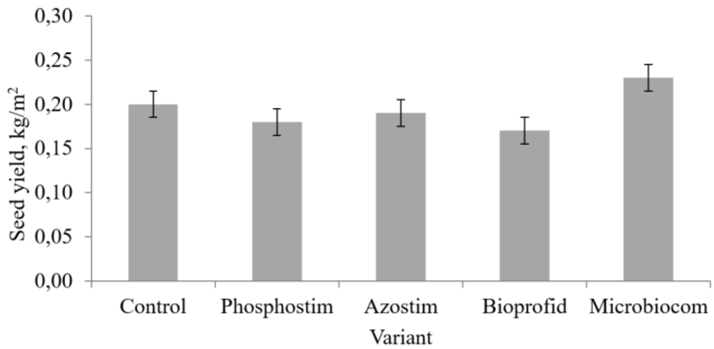

Figure 2 – Effect of microbial preparations on *N. damascena* seed yield (average for 2 years)

According to the results of our studies, pre-sowing seed bacterization with P, A, B and M significantly increased the content of chlorophylls *a + b* in *N. damascena* leaves: up to 19-24 % compared to control. This circumstance can be considered as one of the main aspects that allowed to obtain a reliable increase in phytomass, e.g. in our research, on average for two years, that of in bacterized plants exceeded control by 1.8 times. Furthermore, it should be noted that M application for pre-sowing seed treatment significantly increased nigella seed yield.

Effect of pre-sowing inoculation on N. damascena plant height and morphometric parameters. It is well known that many effective strains of bacteria, which are the basis of microbial preparations, have the ability to produce growth-stimulating substances. In the experiments carried out in 2021, a positive effect of the tested preparations on the height of nigella was established: it exceeded the control plants by 19–32 % (Table 3). Thus, pre-sowing seed bacterization with P, A, B and M contributed to an increase in plant height compared to the control values by 19 %, 32 %, 26 % and 29 %, respectively. It should be noted that reliable results were obtained in variants with A, B and M. However, in 2022, no significant effect of the studied microbial preparations was revealed. On average, for two years of research, a trend towards an increase in the height of bacterized plants compared to the control ones was revealed.

Evaluation of the effect of microbial preparations on the morphometric parameters of nigella indicates that seed inoculation did not have a significant effect either on the length of leaves or on their number per one plant (Table 3).

Table 3 – Effect of microbial preparations on *N. damascena* plant height and morphometric parameters

Variant	Plant height, cm			Number of leaves on one plant, pcs	Leaf length, cm
	2021	2022	average	average for two years	average for two years
Control	22.3	20.2	21.3	9.7 ± 1.24	8.1 ± 1.79
Phosphostim^{agro}	26.5	20.1	23.3	8.8 ± 0.22	8.1 ± 0.82
Azostim^{agro}	29.5*	21.4	25.5	8.6 ± 0.10	8.4 ± 0.77
Bioprofid^{agro}	28.2*	21.5	24.9	10.1 ± 0.77	7.7 ± 1.05
Microbiocom^{agro}	28.8*	21.9	25.4	7.5 ± 0.51	8.2 ± 1.00
LSD_{05}	4.38	4.40			

Note. ** – Variants have differences at 5 % significance level; ± mean error at 5 % significance level.*

Effect of pre-sowing inoculation on the biochemical parameters in fresh raw materials of N. damascena. A study of the biochemical composition of nigella phytomass showed that in the budding phase the content of dry matter in fresh raw materials varied within 17.9–18.5 % in the first and second years of the experiments (Table 4). There was no clear effect of microbial preparations on this indicator. However, in 2022, reliable results were noted in variants with P and A – dry matter content in inoculated plants increased by 2.2–2.5% compared to control. On average, for two years of research, a trend towards an increase in dry matter in the phytomass of nigella was revealed.

Table 4 – Dry matter and total ash contents in fresh raw materials of *N. damascena* (budding phase)

Variant	Dry matter content, %			Total ash content, %		
	2021	2022	average	2021	2022	average
Control	18.2	18.0	18.1	11.5	10.6	11.1
Phosphostim^{agro}	18.0	18.4*	18.2	10.2	11.2*	10.7
Azostim^{agro}	17.9	18.5*	18.3	11.7	12.1*	11.9
Bioprofid^{agro}	18.1	18.2	18.2	11.9	11.6*	11.7
Microbiocom^{agro}	18.4	17.9	18.3	10.0*	11.2*	10.6
LSD_{05}	0.34	0.33		1.35	0.45	

Note. ** – Variants have differences at 5% significance level.*

The content of total ash in the phytomass of *N. damascena* over the years of research varied within 10.0–12.1 % (Table 4) or was 6 to15 times higher than typical indicator of the most studied green crops [34]. Results obtained in 2018 testify to the ambiguous effect of bacterization on the content of total ash in plants: there were both positive (A, B) and negative (P, M) effects compared to control. However, reliable data were noted only in variants with M application: 9.5 % vs. 11.5 % in the control. A significant effect of inoculation on the content of total ash in the aboveground mass of nigella in 2022 was noted: the use of microbial preparations contributed to an increase by 5 % (P, M), 10 % (B) and 15 % (A) compared to control figures.

Carbohydrates make up 75–80 % of organic matter in plants and are the main product of photosynthesis, as well as the main respiratory material. A significant part of sugars is used for polymerization and formation of polysaccharides – starch and cellulose. Results of our studies showed that the content of total sugars in the phytomass of nigella on average over two years of research varied within 11.1–12.8 %, monosaccharides – 5.5–6.2 %, disaccharides – 5.1–6.6 % (Table 5). An ambiguous effect of microbial preparations on the accumulation of sugars in fresh raw materials of *N. damascena* should be noted: it was both positive and negative. Thus, pre-sowing seed bacterization with P and A contributed to a significant increase in the content of total, mono- and disaccharides in the plant phytomass, B – led to its significant decrease compared to control. Results obtained in the variant with M revealed a trend towards a decrease in the content of monosaccharides, but the amount of disaccharides was at the level of control figures.

Table 5 – Sugars and ascorbic acid content in fresh raw materials of *N. damascena* (budding phase), average for two years

Variant	Sugars content, %			Ascorbic acid content, mg/100 g
	total	monosaccharides	disaccharides	
Control	11.8	5.9	5.9	178.2
Phosphostim^{agro}	12.8*	6.2*	6.6*	201.3*
Azostim^{agro}	12.4*	6.2*	6.2	201.7*
Bioprofid^{agro}	11.1*	6.0	5.1*	183.8
Microbiocom^{agro}	11.4	5.5*	5.9	187.3
LSD_{05}	0.56	0,25	0.34	11.14

Note. ** – Variants have differences at 5 % significance level.*

Ascorbic acid is a unique polyfunctional plant compound that can be reversibly oxidized and reduced. It takes part in the energy processes in the plant cell and is a recognized antioxidant. According to our research results, the content of ascorbic acid in the phytomass of nigella varied within 178.2–201.7 mg/100 g. The use of microbial preparations for seed inoculation also contributed to an increase in the content of ascorbic acid in fresh raw materials of *N. damascena*: up to 201.7 mg/100 g vs. 178.3 mg/100 g in control. However, it should be noted that significant differences were revealed only in case of pre-sowing seed treatment with P and A, but in variants with B and M, results were within the experimental error.

Correlation analysis showed a significant inverse average relationship (r = -0.62) between the content of chlorophylls in leaves and the yield of nigella seeds. This indicates that a decrease in the content of chlorophylls leads to a drop in seed yield (Table 6). Thus, our results indicate that microbial preparations increase the content of chlorophylls *a* + *b* in nigella leaves, which in turn contributes to the phytomass productivity and seed yield improvement.

Between the content of total sugars and monosaccharides, as well as total sugars and disaccharides in the phytomass of nigella, a significant direct medium and strong relationship has been established (correlation coefficients – 0.61 and 0.81, respectively). At the same time, a significant direct average relationship was noted between the content of total sugars and ascorbic acid, as well as monosaccharides and ascorbic acid in *N. damascena* plants: correlation coefficients – 0.65 and 0.54, respectively.

Table 6 – Correlations between indicators of nigella under the influence of bacterization (2021–2022)

Indicator	Content in leaves					Seed yield, kg/m^2
	chlorophylls, mg/g	total sugars, %	monosac-charides, %	disaccha-rides, %	ascorbic acid, mg/100 g	
Chlorophylls, mg/g of leaves	1.00	-0.06	-0.33	0.16	-0,13	-0.62
Total sugars, %	**-0.06**	1.00	0.61	0.81	0.65	0.24
Monosaccharides, %	**-0.33**	**0.61***	1.00	0.03	0.54	0.53
Disaccharides, %	**0.16**	**0.81***	**0.03**	1.00	0.42	-0.09
Ascorbic acid, mg/100 g	**-0.13**	**0.65***	**0.54***	**0.42***	1.00	0.30
Seed yield, kg/m^2	**-0.62***	**0.24**	**0.53***	**-0.09**	**0.30**	1.00

Note. ** – Marked correlations are significant at $p < 0.05000$.*

A significant direct average relationship (r = 0.53) between the content of monosaccharides in the phytomass and the yield of nigella seeds was also revealed. The increase in the content of disaccharides in the leaves of nigella had a significant impact on the increase in the amount of ascorbic acid in plants: relationship was direct average (r = 0.42).

Conclusions

In the course of the research, we studied the effect of microbial preparations (A, P, B, M) on the chlorophyll content, phytomass productivity and seed yield, as well as on the morphometric parameters and biochemical composition of the aboveground mass of *N. damascena* under conditions of micro-field experiments. The use of microbial preparations contributed to an increase in the content of chlorophylls *a* + *b* in the leaves (by 19–24 % vs. control), which had a positive effect on the phytomass productivity. Positive effect of P and A on the improvement of the biochemical composition of *N. damascena* green mass was also established: the content of sugars (12.8 %) and ascorbic acid (201.7 mg/100 g) significantly exceeded control values by 1 % and 23.5 mg/100 g, respectively. The use of M significantly increased *N. damascena* L. seed yield: by 13% compared to control. Correlation analysis showed that under the influence of bacterization, on average for two years, the most significant impact on seed yield was caused by a change in the content of chlorophylls (r = -0.62) and monosaccharides (r = 0.53) in leaves. These studies show that pre-sowing seed bacterization with microbial preparations, as an element of nigella cultivation technology, is quite promising.

References

1. Zavalin A. A., Almetov N. S., Berdnikov V. V., Blagoveshchenskaya G.G. Efficiency of biopreparations in a crop rotation // Agrohimia. 2010. Vol. 6. P. 28–37.
2. Zavalin A. A., Sokolov O. A., Shmyreva N. Ya. Nitrogen flows in agrophytocenosis on soddy-podzolic soil (research with 15N) // Vestnik of the Russian agricultural science. 2018. Vol. 5. P. 17–21. DOI: 10.30850/vrsn/2018/5/17-21.
3. Tikhonovich I. A., Andronov E. E., Provorov N. A. Microevolutionary processes in plant-microbe symbiosis // In book: Genetics, Evolution and Radiation. Crossing Borders, The Interdisciplinary Legacy of Nikolay W. Timofeeff-Ressovsky. Cham: Springer, 2016. P. 441–454. DOI: 10.1007/978-3-319-48838-7_36.
4. Provorov N. A., Tikchonovich I. A. Agricultural мicrobiology and symbiogenetics: synthesis of classical ideas and construction of highly productive agrocenoses (review) // Sel'skokhozyaistvennaya Biologiya [Agricultural Biology]. 2022. Vol. 57. No. 5. P. 821–831. DOI: 10.15389/agrobiology.2022.5.821eng.
5. Zavalin A. A., Kozhemyakov A. P., Andreev O. A., Laktionov Y. V., Popova T. A. [et al.]. New technologies of promotion and application of biopreparations with complex impact. Saint-Petersburg: Khimizdat, 2010. 64 p.

6. Kots S. Ya., Morgun V. V., Patyka V. F., Datsenko V. K., Krugova E. D., Kirichenko E. V., Melnikova N. N., Mikhalkiv L. M. Biological nitrogen fixation: bean-rhizobial symbiosis: Monograph in 4 volumes. Vol. 1. Kyiv: Logos, 2010. 508 p.

7. Khan M. S., Zaidi A., Musarrat J. Phosphate solubilizing microorganisms: principles and application of microphos technology. Cham: Springer, 2014. 307 p. DOI: 10.1007/978-3-319-08216-5.

8. Satyaprakash M., Nikitha T., Reddi E.U.B., Sadhana B., Satya Vani S. Phosphorous and phosphate solubilising bacteria and their role in plant nutrition // International Journal of Current Microbiology and Applied Sciences. 2017. Vol. 6. No. 4. P. 2133–2144. DOI: 10.20546/ijcmas.2017.604.251.

9. Chaikovskaya L. A., Ovsienko O. L. Phosphate-mobilizing microorganisms: 1. Biodiversity, influence on plants mineral nutrition and productivity // Taurida Herald of the Agrarian Sciences. 2021. No. 4 (28). P. 159–182. DOI: 10.33952/2542-0720-2021-4-28-159-182.

10. Jain P., Khichi D. S. Phosphate solubilizing microorganism (PSM): an ecofriendly biofertilizer and pollution manager // Journal of Dynamics in Agricultural Research. 2014. Vol. 1 (4). P. 23–28.

11. Jones D. L., Oburger E. Solubilization of phosphorus by soil microorganisms // In Book: Phosphorus in Action. Biological Processes in Soil Phosphorus Cycling. Berlin, Heidelberg: Springer, 2011. P. 169–198. DOI: 10.1007/978-3-642-15271-9_7.

12. Tikhonovich I. A., Zavalin A. A. Application potential of nitrogen-fixing and phytostimulating microorganisms for increasing the efficiency of the agroindustrial complex and improving the agroecological situation in Russian Federation // Plodorodie. 2016. No. 5 (92). P. 28–32.

13. Ovsienko O. L., Chaikovskaya L. A. The effect of a microbial preparation on the lipid-pigment complex of *Triticum aestivum* L. when soil is contaminated by heavy metals // Scientific Notes of V.I. Vernadsky Crimean Federal University. Biology. Chemistry. 2022. Vol. 8(74). No. 4. P. 166–177.

14. Chaikovskaya L. A., Baranskaya M. I., Ovsienko O. L., Klimenko N. N. Effect of microbial preparations on the adaptive potential of winter wheat under the influence of heavy metals // Taurida Herald of the Agrarian Sciences. 2019. No. 4(20). P. 123–132. DOI: 10.33952/2542-0720-2019-4-20-123-132.

15. Kryzhko A. V., Kuznetsova L. N. Effect of bioinsecticides based on *Bacillus thuringiensis* on the pigment complex and the activity of oxidases in potato leaves // Vestnik of the North-Eastern Federal University. 2018. No. 4(66). P. 5–13. DOI: 10.25587/SVFU.2018.66.16113.

16. Kryzhko A. V., Budzhurova U. M. Effects of *Bacillus thuringiensis* 0271 on individual indicators of nonspecific resistance of *Origanum vulgare* L. to stressful conditions // Proceedings of Universities. Applied Chemistry and Biotechnology. 2020. No. 10(4). P. 647–656. DOI: 10.21285/2227-2925-2020-10-4-647-656.

17. Kryzhko A. V. Plants and entomopathogenic bacteria *Bacillus thuringiensis* interaction in the agrocenosis of *Origanum vulgare* L. // Proceedings of the Kuban State Agrarian University. 2021. No. 91. P. 174–180. DOI: 10.21515/1999-1703-91-174-180.

18. Nemtinov V. I. *Nigella sativa* in the Crimea // Potato and Vegetables. 2016. No. 10. P. 22–23.

19. Orlovskaya T. V., Mashirova S. Yu. Morphoanatomic study seeds *Nigella sativa* L. and *Nigella damascena* L. // Traditional medicine. 2012. Vol. 3(30). P. 54–57.

20. Baranskaya M. I., Chaikovskaya L. A., Nemtinov V. I. Effect of biological agents of microbial preparations (*Rhizobium radiobacter* 204, *Lelliottia nimipressuralis* CCM 32-3, *Paenibacillus polymyxa* P) on the seeds of *Nigella damascena* L. // Taurida Herald of the Agrarian Sciences. 2020. No. 3(23). P. 18–25. DOI: 10.33952/2542-0720-2020-3-23-18-25.

21. Patent RF No. 11207. *Nigella damascena* L. 'Yalita' // Authors: Glumova V. I., Nemtinov V. I., Patent holder: FSBSI "Research Institute of Agriculture of Crimea". 2020.

22. Patent RF No. 2676926. "Phosphate-mobilizing strains of soil bacteria *Lelliottia nimipressuralis* CCM 32-3 and biopreparation on its basis for the optimization of mineral nutrition of plants, stimulates their growth and increase yields application" // Authors: Chaikovskaya L. A., Melnichuk T. N., Kameneva I. A., Baranskaya M. I., Ovsienko O.L. Patent holder: FSBSI "Research Institute of Agriculture of Crimea". 2019.

23. Patent RF No. 2777194. "Complex biopreparation for optimizing mineral nutrition of plants, protection from phytopathogens, increasing productivity and a method for obtaining this biopreparation" // Authors: Kameneva I. A., Melnichuk T. N., Yakubovskaya A. I., Chaikovskaya L. A., Pashtetsky V. S., Gritchin M. V., Konopleva G. N. Patent holder: FSBSI "Research Institute of Agriculture of Crimea". 2022.

24. Methodology of testing for distinctness, uniformity and stability. *Nigella* L. // Official Bulletin of Federal State Budgetary Institution "State Commission of the Russian Federation for Testing and Protection of Breeding Achievements". 2019. Section 8. No. 9(249). P. 674–682.

25. Gavrilenko V. F., Ladygina M. E., Khandobina L. M. Big practicum on plant physiology: training manual. Moscow: Vysshaya shkola, 1975. 392 p.

26. OFS 1.2.2.2.0013.15 Total ash. [Electronic resource]. Access point: https://pharmacopoeia.ru/ofs-1-2-2-2-0013-15-zola-obshhaya (reference's date 04.07.2023).

27. Ermakov A. I., Arasimovich V. V., Yarosh N. P., Peruansky Yu.V., Lukovnikova G. A., Ikonnikova M. I. Methods of biochemical research of plants. Leningrad: Agropromizdat, 1987. 430 p.

28. Dospekhov B. A. Methods of field research. Moscow: Kniga po trebovaniyu, 2012. 351 p.

29. Chaikovskaya L. A., Ovsienko O. L., Baranskaya M. I., Klyuchenko V. V., Lipieva N. N. The impact of microbial preparations on the content of water soluble forms of copper in the rhizosphere of winter wheat and grain quality // Taurida Herald of the Agrarian Sciences. 2018. No. 2(14). P. 46–53. DOI: 10.25637/TVAN. 2018.02.04.

30. Priadkina G. A. Pigments, efficiency of photosynthesis and winter wheat productivity // Plant varieties studying and protection. 2018. Vol. 14. No. 1. P. 97–108. DOI: 10.21498/2518-1017.14.1.2018.126524.

31. Sui N., Li M., Meng Q.-W., Tian J.-Ch., Zhao Sh.-J. Photosynthetic characteristics of a super high yield cultivar of winter wheat during late grown period // Agricultural Science in China. 2010. Vol. 9(3). P. 346–354. DOI: 10.1016/S1671-2927(09)60103-6.

32. Gu J., Yin X., Stomph E.J., Struik P.C. Can exploiting natural genetic variation in leaf photosynthesis contribute to increase rice productivity? A simulation analysis // Plant, Cell and Environment. 2014. Vol. 37(1). P. 22–34. DOI: 10.1111/pce.12173.

33. Li P., Wu P., Chen J. Evaluation of flag leaf chlorophyll content index in 30 spring wheat genotypes under three irrigation regimes // Australian Journal of Crop Science. 2012. Vol. 6(6). P. 1123–1130.

34. Ash content in greens, herbs, leaves and salads. [Electronic resource]. Access point: https:// fitaudit.ru/categories/lvs/ash / (reference’s date 04.07.2023).

Литература

1. Завалин А. А., Алметов Н. С., Бердников В. В., Благовещенская Г. Г. Эффективность применения биопрепаратов в севообороте // Агрохимия. 2010. № 6. С. 28–37.

2. Завалин А. А., Соколов О. А., Шмырева Н. Я. Потоки азота в агрофитоценозе на дерново-подзолистой почве // Вестник Российской сельскохозяйственной науки. 2018. № 5. С. 17–21. DOI: 10.30850/vrsn/2018/5/17-21.

3. Tikhonovich I. A., Andronov E. E., Provorov N. A. Microevolutionary processes in plant-microbe symbiosis // In book: Genetics, Evolution and Radiation. Crossing Borders, The Interdisciplinary Legacy of Nikolay W. Timofeeff-Ressovsky. Cham: Springer, 2016. P. 441–454. DOI: 10.1007/978-3-319-48838-7_36.

4. Проворов Н. А., Тихонович И. А. Сельскохозяйственная микробиология и симбиогенетика: синтез классических идей и конструирование высокопродуктивных агроценозов (обзор) // Сельскохозяйственная биология. 2022. Vol. 57. No. 5. С. 821–831. DOI: 10.15389/agrobiology.2022.5.821rus.

5. Завалин А. А., Кожемяков А. П., Андреев О. А., Лактионов Ю. В., Попова Т. А. [и др.]. Новые технологии производства и применения биопрепаратов комплексного действия. Санкт-Петербург: Химиздат, 2010. 64 с.

6. Коць С. Я., Моргун В. В., Патыка В.Ф., Даценко В. К., Круглова Е. Д., Кириченко Е. В., Мельникова Н. Н., Михалкив Л. М. Биологическая фиксация азота: Монография в 4-х т. Т.1. К.: Логос, 2010. 508 с.

7. Khan M. S., Zaidi A., Musarrat J. Phosphate solubilizing microorganisms: principles and application of microphos technology. Cham: Springer, 2014. 307 p. DOI: 10.1007/978-3-319-08216-5.

8. Satyaprakash M., Nikitha T., Reddi E.U.B., Sadhana B., Satya Vani S. Phosphorous and phosphate solubilising bacteria and their role in plant nutrition // International Journal of Current Microbiology and Applied Sciences. 2017. Vol. 6. No. 4. P. 2133–2144. DOI:10.20546/ijcmas.2017.604.251.

9. Чайковская Л. А., Овсиенко О. Л. Фосфатмобилизующие микроорганизмы: 1. Биоразнообразие, влияние на минеральное питание растений и их продуктивность // Таврический вестник аграрной науки. 2021. №. 4 (28). С. 159–182. DOI: 10.33952/2542-0720-2021-4-28-159-182.

10. Jain P., Khichi D.S. Phosphate solubilizing microorganism (PSM): an ecofriendly biofertilizer and pollution manager // Journal of Dynamics in Agricultural Research. 2014. Vol .1 (4). P. 23–28.

11. Jones D. L., Oburger E. Solubilization of phosphorus by soil microorganisms // In Book: Phosphorus in action. Biological Processes in Soil Phosphorus Cycling. Berlin, Heidelberg: Springer, 2011. P. 169–198. DOI: 10.1007/978-3-642-15271-9_7.

12. Тихонович И. А., Завалин А. А. Перспективы использования азотфиксирующих и фитостимулирующих микроорганизмов для повышения эффективности агропромышленного комплекса и улучшения агроэкологической ситуации в РФ // Плодородие. 2016. № 5 (92). Р. 28 –32.

13. Овсиенко О. Л., Чайковская Л. А. Влияние микробного препарата на липидно-пигментный комплекс *Triticum aestivum* L. При загрязнении почвы тяжелыми металлами // Ученые записки Крымского федерального университета им. В. И. Вернадского. Серия «Биология, Химия». 2022. Т. 8. № 4. С. 166–177.

14. Чайковская Л. А., Баранская М. И., Овсиенко О. Л., Клименко Н. Н. Влияние микробных препаратов на адаптивный потенциал озимой пшеницы при воздействии тяжелых металлов // Таврический вестник аграрной науки. 2019. № 4 (20). С. 113–132. DOI 10.33952/2542-0720-2019-4-20-123-132.

15. Крыжко А. В., Кузнецова Л. Н. Влияние биоинсектицидов на основе *Bacillus thuringiensis* на пигментный комплекс и активность оксидаз в листьях картофеля // Вестник Северо-восточного федерального университета. 2018. № 4 (66). С. 5–13. DOI 10.25587/SVFU.2018.66.16113.

16. Крыжко А. В., Буджурова У. М. Особенности влияния *Bacillus thuringiensis* 0271 на отдельные показатели неспецифической резистентности *Origanum vulgare* L. к стрессовым условиям // Известия вузов: Прикладная химия и биотехнология. 2020. № 10 (4). С. 647–656. DOI: 10.21285/2227-2925-2020-10-4-647-656.

17. Крыжко А. В. Взаимодействие растений и энтомопатогенных бактерий *Bacillus thuringiensis* а агроценозе *Origanum vulgare* L. // Труды КубГАУ. 2021. № 91. С. 174 –180. DOI: 10.21515/1999-1703-91-174-180.

18. Немтинов В. И. Нигелла посевная в Крыму // Картофель и овощи. 2016. № 10. С. 22–23.

19. Орловская Т.В., Маширова С.Ю. Морфолого-анатомическое изучение семян чернушки посевной (*Nigella sativa* L.) и чернушки дамасской (*Nigella damascena* L.) // Традиционная медицина. 2012. № 3 (30). С. 54 –57.

20. Баранская М. И., Чайковская Л. А., Немтинов В. И. Воздействие биоагентов микробных препаратов (*Rhizobium radiobacter 204, Lelliottia nimipressuralis* CCM 32-3*, Paenibacillus polymyxa* П) на семена *Nigella damasceana* L. // Таврический вестник аграрной науки. 2020. № 3 (23). С. 18–25. DOI 10.33952/2542-0720-2020-3-23-18-25.

21. Патент России № 11207. «*Nigella damascena* L. сорт Ялита» // Авторы: Глумова В. И., Немтинов В. И. Патентообладатель: ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма». 2020.

22. Патент РФ № 2676926. «Фосфатмобилизующий штамм почвенных бактерий *Lelliottia nimipressuralis* CCM 32-3 и биопрепарат на его основе для оптимизации минерального питания растений, стимуляции их роста и повышения урожайности» // Авторы: Чайковская Л. А., Мельничук Т. Н., Каменева И. А., Баранская М. И., Овсиенко О. Л. Патентообладатель: ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма». 2019.

23. Патент РФ №.2777194. «Комплексный биопрепарат для оптимизации минерального питания растений, защиты от фитопатогенов, повышения продуктивности и способ получения этого биопрепарата» // Авторы: Каменева И. А., Мельничук Т. Н., Якубовская А. И., Чайковская Л. А., Паштецкий В. С., Гритчин М. В., Коноплева Г. Н. Патентообладатель ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма». 2022.

24. Методика проведения испытаний на отличимость, однородность и стабильность», вид Нигелла (*Nigella* L.). // Официальный бюллетень ФГБНУ «Государственная комиссия Российской Федерации по испытанию и охране селекционных достижений». 2019. № 9 (249). Секция 8. С. 674–682.

25. Гавриленко В. Ф., Ладыгина М. Е., Хандобина Л. М. Большой практикум по физиологии растений: учебное пособие. М.: Высшая школа, 1975. 392 с.

26. ОФС 1.2.2.2.0013.15. Зола общая. [Электронный ресурс]. Режим доступа: https://pharmacopoeia.ru/ofs-1-2-2-2-0013-15-zola-obshhaya / (дата обращения 04.07.2023).

27. Ермаков А. И., Арасимович В. В., Ярош Н. П., Перуанский Ю. В., Луковникова Г. А., Иконникова М. И. Методы биохимического исследования растений. Л.: Агропромиздат, 1987. 456 с.

28. Доспехов Б. А. Методы полевых исследований. М.: Книга по требованию, 2012. 351 с.

29. Чайковская Л. А., Овсиенко О. Л., Баранская М. И., Ключенко В. В., Липиева Н. Н. Воздействие микробных препаратов на содержание водорастворимых форм меди в ризосфере озимой пшеницы и качество зерна // Таврический вестник аграрной науки. 2018. № 2 (14). С. 46–53. DOI: 10.25637/TVAN.2018.02.04.

30. Прядкина Г. А. Пигменты, эффективность фотосинтеза и продуктивность пшеницы // Физиология и генетика растений. 2018. Т. 14. № 1. С. 97–108. DOI: 10.21498/2518-1017.14.1.2018.126524.

31. Sui N., Li M., Meng Q.-W., Tian J.-Ch., Zhao Sh.-J. Photosynthetic characteristics of a super high yield cultivar of winter wheat during late grown period // Agricultural Science in China. 2010. Vol. 9(3). P. 346–354. DOI:10.1016/S1671-2927(09)60103-6.

32. Gu J., Yin X., Stomph E. J., Struik P. C. Can exploiting natural genetic variation in leaf photosynthesis contribute to increase rice productivity? A simulation analysis // Plant, Cell and Environment. 2014. Vol. 37(1). P. 22 – 34. DOI: 10.1111/pce.12173.

33. Li P., Wu P., Chen J. Evaluation of flag leaf chlorophyll content index in 30 spring wheat genotypes under three irrigation regimes // Australian Journal of Crop Science. 2012. Vol. 6(6). P. 1123–1130.

34. Ash content in greens, herbs, leaves and salads. [Электронный ресурс]. Режим доступа: https:// fitaudit.ru/categories/lvs/ash / (дата обращения 04.07.2023).

УДК 579.64: 582.675.1: 581.192

Чайковская Л. А., Немтинов В. И., Баранская М. И., Паштецкий В. С., Пехова О. А., Тимашева Л. А., Радченко Л. А., Якушева Н. Н., Белова И. В.

ОЦЕНКА ВЛИЯНИЯ МИКРОБНЫХ ПРЕПАРАТОВ НА СОДЕРЖАНИЕ ХЛОРОФИЛЛОВ, ПРОДУКТИВНОСТЬ И БИОХИМИЧЕСКИЕ ПОКАЗАТЕЛИ *NIGELLA DAMASCENA* L.

Реферат. *Одним из элементов современных агротехнологий выращивания растений является применение микробных препаратов на основе эффективных штаммов бактерий, обладающих широким спектром полезных свойств: азотфиксацией, фосфатмобилизацией, способностью продуцировать фитогормоны и другие физиологически активные вещества. Объекты исследований: нигелла (Nigella damascena L.) и микробные препараты, созданные в отделе сельскохозяйственной микробиологии ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»: Азостим^{агро} (А), Фосфостим^{агро} (Ф), Биопрофид^{агро} (Б) и Микробиоком^{агро} (М.). Цель наших исследований заключалась в определении влияния микробных препаратов (предпосевная инокуляция семян) на содержание хлорофиллов, урожайность семян Nigella damascena L. (сорт Ялита), а также продуктивность и биохимический состав фитомассы в условиях микрополевых экспериментов. Исследования проводили в 2021–2022 гг. Анализ полученных результатов показал позитивное влияние предпосевной бактеризации семян на содержание аскорбиновой кислоты и сахаров в фитомассе N. damascena. Наибольшая прибавка по сравнению с контролем получена в вариантах с применением А и Ф: накопление аскорбиновой кислоты увеличилось на 13 %; общих сахаров, моно- и дисахаров – на 8 %, 5 % и 12 % соответственно (среднее за два года). Установлено, что применение микробных препаратов для предпосевной инокуляции семян N. damascena способствовало повышению содержания хлорофиллов a и b (в среднем на 19–24 % по сравнению с контролем) в её листьях, что в свою очередь позволило получить достоверную прибавку фитомассы (в среднем а.с.м. бактеризованных растений превышала контроль в 1,8 раза: 0,94 г против 0,54 в контроле), а при использовании М – также и урожайности семян (в 1,8 раза и на 13 % против контроля соответственно). Проведенные исследования свидетельствуют о перспективе применения предпосевной бактеризации семян микробными препаратами как элемента агротехнологии при выращивании нигеллы.*

Ключевые слова: *нигелла (Nigella damascena L.), микробные препараты, фотосинтезирующие пигменты, аскорбиновая кислота, сахара, продуктивность.*

Chaikovskaya Ludmila Aleksandrovna, Dr. Sc. (Agr.), senior researcher, Laboratory of physiology and ecology of microorganisms, FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: ludachaika@mail.ru.

Nemtinov Viktor Illarionovich, Dr. Sc. (Agr.), chief researcher, Laboratory of vegetable and melon crops plant breeding, FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: nemtin2@mail.ru.

Baranskaya Marina Ivanovna, Cand. Sc. (Agr.), leading researcher, Laboratory of of physiology and ecology of microorganisms, FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: baranskaya@rambler.ru.

Pashtetsky Vladimir Stepanovich, Dr. Sc. (Agr.), director of the FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: pvs98a@gmail.com.

Pekhova Olga Antonovna, Cand. Sc. (Agr.), leading researcher, Laboratory of processing and standardization of plant raw materials, FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: isocrimea@gmail.com.

Timasheva Lidiya Alekseevna, Cand. Sc. (Agr.), leading researcher, Laboratory of processing and standardization of plant raw materials, FSBSI “Research Institute of Agriculture of Crimea”; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: isocrimea@gmail.com.

Radchenko Lyudmila Anatolyevna, Cand. Sc. (Agr.), deputy director for scientific work, FSBSI "Research Institute of Agriculture of Crimea"; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: radchenkolydmila@yandex.ru.

Yakusheva Nina Nikolaevna, Cand. Sc. (Agr.), senior researcher, Laboratory of physiology and ecology of microorganisms, FSBSI "Research Institute of Agriculture of Crimea"; 150, Kievskaya str., Simferopol, Republic of Crimea, 295453, Russia; e-mail: ninaklymenko@yandex.ru.

Белова Ирина Викторовна, Cand. Sc. (Agr.), researcher, Laboratory of processing and standardization of plant raw materials, FSBSI "Research Institute of Agriculture of Crimea"; 295453, 150 Kievskaya str., Simferopol, Republic of Crimea, Russia; e-mail: isocrimea@gmail.com.

Чайковская Людмила Александровна, доктор сельскохозяйственных наук, старший научный сотрудник лаборатории экологии и физиологии микроорганизмов, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: ludachaika@mail.ru.

Немтинов Виктор Илларионович, доктор сельскохозяйственных наук, главный научный сотрудник отдела селекции и семеноводства овощных и бахчевых культур, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: nemtin2@mail.ru.

Баранская Марина Ивановна, кандидат сельскохозяйственных наук, ведущий научный сотрудник лаборатории растительно-микробного взаимодействия, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: baranskaya@rambler.ru

Паштецкий Владимир Степанович, доктор сельскохозяйственных наук, член-корреспондент РАН, старший научный сотрудник, директор ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: pvs98a@gmail.com.

Пехова Ольга Антоновна, кандидат сельскохозяйственных наук, ведущий научный сотрудник отдела переработки и стандартизации эфиромасличного сырья, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: e-mail: isocrimea@gmail.com.

Тимашева Лидия Алексеевна, кандидат сельскохозяйственных наук, старший научный сотрудник, ведущий научный сотрудник отдела переработки и стандартизации эфиромасличного сырья ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295493, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: isocrimea@gmail.com.

Радченко Людмила Анатольевна, кандидат сельскохозяйственных наук, заместитель директора по научной работе ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295493, Россия, Республика Крым, г. Симферополь, ул. Киевская 150; e-mail: radchenkolydmila@yndex.ru.

Якушева Нина Николаевна, кандидат сельскохозяйственных наук, старший научный сотрудник лаборатории экологии и физиологии микроорганизмов, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295453, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: ninaklymenko@yandex.ru.

Белова Ирина Викторовна, кандидат сельскохозяйственных наук, научный сотрудник отдела переработки и стандартизации эфиромасличного сырья, ФГБУН «Научно-исследовательский институт сельского хозяйства Крыма»; 295493, Россия, Республика Крым, г. Симферополь, ул. Киевская, 150; e-mail: isocrimea@gmail.com.

Дата поступления в редакцию – 28.09.2023
Дата принятия к печати – 18.11.2023