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The influence of bio-stimulants on productivity of coriander in the non-chernozem zone of Russia

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Abstract

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The article presents investigations about the possibility of coriander growing in the non-chernozem zone of Russia. Varieties Yantar and Alexeevsky 190 were objects of the experiments. Coriander varieties response to bio-stimulants Nagro, Agat-25K and Extrasol was determined. Coriander varieties Yantar and Alexeevsky 190 showed high response to the use of growth promoting and bacterial preparations. Preparation Nagro applied at concentration of 1 l/ha was most efficient. The yield of Alexeevsky 190 was on average 0.10-0.11 t/ha higher than that of Yantar. The increase of Yantar productivity when using bio-stimulants was on average 0.22 t/ha higher and that of Alexeevsky 190 was 0.23 t/ha higher than the control for 2013-2016.

Keywords: coriander; growth bio-stimulators; yield; essential oil

Introduction

Coriander (*Coriandrum sativum* L.) is annually sown in Russia on more than a hundred thousand hectares of arable land. A fruit, fresh and dried leaves and roots of the plant are used. The main direction of growing this crop is getting fruits, which are used in the food industry and for the production of coriander oil (Diederichsen, 1996; Diederichsen and Rugayah, 1999; Datta and Sengupta, 2003; Khromtsev and Vinogradov, 2016).

The interest to growing this crop has increased recently due to high demand for essential oils and products of their processing in the world and Russian markets. The main suppliers of essential oil raw materials to the domestic market of the country are the Central Chernozem region and Southern region of the Russian Federation (Vinogradov, 2009; Khromtsev and Vinogradov, 2013).

The possibility of non-chernozem zone of Russia has been little used. Although the arable area with essential oil crops expands from year to year, the yields remain very low equal to 0.7 t/ha. In order to meet domestic needs and make growing these crops efficient, it is necessary to increase the yield to 1.5 t/ha or more. Prospects for the development of this direction in the non-chernozem zone of Russia are great (Moshnenko et al., 2009). The work of many scientists proves possibility of successful coriander growing to get seeds in the Central region of Russia.

Studying the adaptive potential of plants is an important prerequisite for successful introduction and further cultivation of essential oil crops in the non-chernozem region. The increased interest in essential oils, first coriander, in the non-chernozem zone is caused by high economic efficiency of its production, good adaptation to temperate climate, high seed yield, and the creation of an ideal background for subsequent crops in crop rotation. Agro-climatic conditions of Ryazan region are favourable for growing oilseeds and essential oil crops. This determined the relevance and direction of the investigation (Vinogradov et al., 2012).

One of the promising and quite new directions in the technology of different crops growing is the use of growth-stimulating preparations, which can be used both as a pre-plant treatment agent and during vegetation (Ilieva and Vasileva, 2013; Vasileva, 2015). Biological preparations are widely used as safest for plants, soil and human. Agat-25K, Extrasol and Nagro are permitted preparations to be used in agriculture on the territory of the Russian Federation.

Agat-25K is a bacterial preparation derived from Pseudomonas aureofaciens ground bacteria, as well as products of their vital activity. The main purpose of the preparation is protection of plants, stimulation of seeds and vegetative plants, and increasing immunity. The composition of preparation Agat-25K is as follows: the culture liquid of inactivated bacteria (titre 6-8x10^{10} in millilitres, before inactivation), optimal initial doses of macro- and microelements, bioactive substances from plant sprouts, natural flavonoids, and active fractions of spruce extract. The interaction of these elements in a single preparation allows efficient action in a wide range in various directions - as a fungicide and immune modulator of plants against various diseases (especially fungal ones) and as a biological growth stimulant (Ershova, 1985).

Extrasol is a preparation created on the basis of rhizosphere bacteria *Bacillus subtilis* CH-13, obtained from the rhizosphere of plants. These bacteria have many important functions such as plant protection and stimulation of growth processes. *Bacillus subtilis* CH-13 can suppress the development of pathogenic fungi and bacteria due to the synthesis of special substances, as well as the synthesis of compounds improving the growth and development of plants. With the development of bacteria *Bacillus subtilis* CH-13 there is an active growth of root hairs, which contributes to the increase of absorption properties. As a result, there is an improved assimilation of basic nutrients from fertilizers and soil. At the same time, it becomes possible to reduce the amount of fertilizers to 40% without losing the quality and quantity of the crop, and even increasing it. With the active development of bacteria on the roots, the immune properties of plants increase, which helps to resist adverse environmental factors (frost and lack of moisture) (Chislova and Samofal, 2004; Khromtsev and Vinogradov, 2013).

Nagro is a unique bio-organic complex, combining a number of useful properties. It acts as a fertilizer, insecticide, and fungicide immune modulator. Bio preparation Nagro is a result of bio- and nanotechnologies having a highly concentrated component composition. This preparation has the properties of a fungicide and a bio pesticide, as well as growth- and immune-stimulating ability. It includes micro-, macro- and mesoelement, micro humates, various vitamins, fulvic and amino acids, hormones, bio solvents, silicon compounds and bio calcium, as well as antioxidants and nitrogen-fixatives.

In 2013-2016 the first complex investigations of coriander varieties Yantar and Alexeevsky 190 took place in the southern part of the non-chernozem zone of Russia. They included studying peculiarities of growth, development, crop formation and biochemical composition of seeds, depending on the use of protective-stimulating and bacterial preparations. Some differences in productivity elements, the yield and its quality, depending on the techniques of cultivation technology, are revealed.

The crop growing technology adapted to the region was developed on the basis of studying the biological features of plants growth and development, their response to the studied agro technical methods, as well as the analysis of economic and bio-energetic efficiency.

The purpose of investigations is studying peculiarities of the formation of coriander varieties yield depending on the action of protective-stimulating preparations and determining the optimal conditions for this crop growing in the southern part of the non-chernozem zone of Russia.

Material and Methods

Investigations took place at the agro technological experimental station of FSBEI HE RSATU, in Ryazan district of Ryazan province in 2013-2016, in conditions of the southern part of the non-chernozem zone of Russia.

The climate is moderately continental, with moderately cold winter, warm summers and well-defined spring and autumn. The vegetation period is 175-185 days with the temperature above +5°C and 135-145 days with the temperature above +10°C. The effective heat sum is 2200-2400°C. The mean annual rainfall is 510 mm. Weather conditions for vegetation periods of 2013 and 2016 were characterized by normal moisture and slightly increased temperature regime (HTI - 1.0), those of 2014 were very dry and rather hot (HTI < 0.8) and those of 2015 were cool and rather wet (HTI - 1.2).

The objects of the investigation were coriander varieties Yantar and Alekseevsky 190.

Variety Yantar is characterized as mid ripening and having the vegetative period of 95-105 days. The stem is round, hollow, bare and branched at the top. Flowers are small, pink, arranged in an umbel. It blossoms depending on the region from July to August. Variety Yantar is plastic and adapted to different soil and climatic conditions. It is tolerant to lodging, fruit falling, splitting and coriander seed weevil. The variety is included in the State Register of the Russian Federation.

Variety Alekseevsky 190 is highly productive, medium-late ripening and adapted to various soil and climatic conditions. The bush is half-closed with the height of 56-102 cm. The stem is straight, branched and 3.5-6.5 cm thick. The height of lower branches is 25-30 cm from the ground. There are 11 limbs. The surface of the leaves is smooth. The leaves have no anthocyanin colour. The leaves are alternate. The inflorescence has an umbel shape. The flower is pale pink. Seeds are light brown and globe. The variety practically does not lodge and shed. The variety is lightly affected by the blight, like the standard, and is affected by ramularia more rarely than the standard. The variety is included in the State Register of the Russian Federation.

The experiment took place on a dark grey forest soil with the following agrochemical parameters: humus content - 1.6-1.9%; high soil acidification, pH 5.2 on average for 0-40 cm layer; labile phosphorus (P_2O_5) - 240-255 mg/kg of soil; the average exchange potassium (K_2O) - 240 mg/kg of soil.

Humus content was determined by Tyurin, pH sol, total exchange bases by Capano - Wilkowice and hydrolytic acidity by Kappen. P_2O_5 (by Kirsanov) and K_2O (with a flame photometer) were determined in soil samples according to GOST R 54650-2011. Soil moisture was determined by the thermostat-weight method.

The content of essential oil is determined by the Kalinkina and Isaykina (2008) method of quantitative determination of essential oil in medicinal plant raw materials.

Bioenergetic evaluation of coriander production and energy coefficient was carried out according to Bazarov (1983).

The experiment is two-factor: factor A is represented by coriander varieties Yantar and Alekseevsky 190; factor B is represented by bio stimulants Agat-25K (40 g/ha), Nagro (1 l/ha) and Extrasol (1 l/ha). The coriander varieties were sown in the first decade of May, the seeding rate was 1.4 million pcs/ha, the fertilizer (background) was N90 (as ammonium nitrate) added before pre-plant tilling. Bio stimulants were added twice in a tank mixture: emulsion concentrate with herbicide Gezagard in a phase of 2-3 true leaves and emulsion concentrate with insecticide Fastak in a shooting phase before flowering. The working fluid consumption was 250 l/ha. The replication was fourfold.

Agro technical measures on coriander growing were carried out in accordance with existing recommendations. Winter wheat was the preceding crop. Soil tillage happened in the following way: 24-26 cm autumn fall tillage, early spring harrowing with harrow ZBZSS-1.0, 12-14 cm cultivating with KPS-4 and pre-plant cultivating with KPE-3.8 to the depth of sowing.

Sowing in experiments was carried out at a depth of 2-2.5 cm, in a continuous ordinary way, with the “Eurodrill Lemken” planter in the MTZ-1221 unit. After sowing, rolling with 3ksh-6 took place. After sowing, before emergence and during the vegetation period of the crop in the 2-4 leaves phase, the crops were processed according to the schemes in order to control the weeds and study the action of herbicide and its doses, as well as protective and stimulating agents. The treatment was done with OPSH-15-01 and Kvazar-12. The consumption rate of the process fluid was 250 l/ha.

The crop was harvested by Tarion-2010 and Palesse GS-12 when 60-70% browning of coriander seeds and the seed moisture in the range of 15-20%. The height of the cut was 15-20 cm.

All observations, surveys and tests were conducted according to standard techniques and GOSTs of Russia. Phenological observations and considering the density of planting, yield and its structure were carried out by the method of State Cultivar Testing of Crops. Weed estimation was done by a quantitative weight method in accordance with Spiridonov and Larina (2009). All agrotechnical methods, laboratory and field surveys and analyses were carried out at the optimum time.

Mathematical processing of data was carried out by the method of dispersion analysis using MS Excel (ANOVA LSD at P = 0.5.).

Results and Discussion

The level of soil moisture before planting and in the period of seeding-seedling was important for field germination. So, in 2015, the level of precipitation and soil moisture exceeded the average values, which contributed to the emergence of more amicable shoots in variants with two varieties, and 2-3 days earlier than in 2013, 2014 and 2016. On average, the field germination rate was 78.5-82.4% for variety Yantar and 78.0-84.1% for variety Alekseevsky 190.

The use of growth bio stimulators during coriander vegetation was an important influencing factor. Their use in different ways contributed to an increase in the activity of growth processes, influenced the safety and survival of plants. The best results were obtained on variants with Nagro and Extrasol with both varieties. With the use of these preparations, one could notice accelerated growth of the herbage and increase of the root, which contributed to some increase in light and water availability (Figure 1).

A high survival rate of plants was noted. The best result of variety Yantar was obtained on the variant with the use of Nagro (92.0%), and that of variety Alekseevsky 190 on the variant with Extrasol (89.1%).

The studied varieties of coriander had different features of development, the degree of adaptation to soil and climate, different genetic potentials, which explained the difference

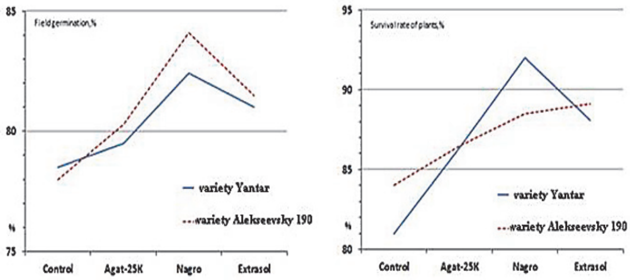

Fig. 1. Field germination and survival of coriander plants, depending on the treatment option, on average

in the parameters of the crop yield structure influenced by the same investigated factors.

The duration of vegetation of two varieties did not differ significantly. Both varieties were mid ripening, and the vegetation period varied from 105 to 121 days, depending on meteorological conditions of the investigation year. In 2015, there was abundant rainfall exceeding the norm and increased water availability contributed to lengthening the vegetation period. The year of 2013, on the contrary, was hot and arid, which reduced the vegetative period to the minimum (101-104 days).

The maximum results of the elements of the crop yield structure were obtained using variants with Extrarosol for variety Yantar and preparation Nagro for variety Alekseevsky 190. The coriander was most responsive to these preparations for all years of the study (Table 1).

Depending on the type of bio stimulants used, the activation of growth processes and the increase in linear growth of plants took place to a different extent. The maximum linear growth was noted in varieties on variants with the use of preparation Nagro: Yantar variety (88.4 cm) and Alekseevsky 190 variety (96.0 cm). The low indicator was noted on the control option (without treatment). Plants of Alekseevsky 190 were on average of 8-10 cm higher than those of Yantar, which is due, above all, to the variety characteristics of the plants under study.

The mass of 1000 seeds is a variety characteristic of different crops. So, variety Alekseevsky 190 was distinguished by larger fruits and on the average this index was 7.35-7.50 g. The seeds of variety Yantar were smaller, with a significant number of small and frail seeds (7.00-7.20 g).

Table 1. Elements of the crop yield structure depending on the use of growth-stimulating preparations, average for 2013-2016

Treatments		Weight of seeds from one plant	Number of seeds per plant	Mass of 1000 seeds	Linear growth of plants before harvest
		g	pcs.	g	cm
			Yantar		
Control		1.32	176.1	7.00	79.5
Agat-25K		1.40	179.3	7.15	81.3
Nagro		1.39	175.0	7.20	88.4
Extrasol		1.44	178.4	7.10	85.5
			Alekseevsky 190		
Control		1.44	185.1	7.35	86.9
Agat-25K		1.57	194.5	7.50	91.0
Nagro		1.60	193.0	7.50	96.0
Extrasol		1.58	199.0	7.45	95.1
LSD_{05} factor A (variety)	2013	0.03	4.26	0.06	2.64
	2014	0.04	5.59	0.06	3.12
	2015	0.05	7.97	0.04	2.55
	2016	0.03	3.17	0.04	2.12
LSD_{05} factor B (treatment)	2013	0.04	6.03	0.08	3.73
	2014	0.05	7.91	0.09	4.41
	2015	0.07	11.27	0.06	3.61
	2016	0.04	5.12	0.06	3.24
LSD_{05} interaction AB	2013	0.06	8.52	0.12	5.28
	2014	0.08	11.18	0.13	6.24
	2015	0.09	15.94	0.09	5.11
	2016	0.06	7.60	0.09	5.01

During the years of investigations the yield of variety Yantar averaged from 1.20 to 1.43 t/ha and that of variety Alekseevsky 190 was 1.31-1.56 t/ha (Table 2).

The yield of coriander depended mainly on the structural parameters, i.e. the crop density, the mass of seeds from a single plant and the number of seeds from a single plant. Thus, the mass of seeds from one plant varied within 1.32-1.44 g for variety Yantar and 1.44-1.60 g for variety Alekseevsky 190. The control variant (without treatment) had the minimum values.

Low yield was obtained in 2013 on the variants with variety Yantar without treatment with stimulants (control) equal to 0.89 t/ha and with variety Alekseevsky 190 without any treatment equal to 1.01 t/ha. The maximum yield in 2016 was on the variant with Nagro - 1.59 t/ha (Yantar) and on the variant with Extrasol - 1.76 t/ha (Alekseevsky 190).

An increase in yields was noted with the use of growth stimulators, on average for 2013-2016, it was 0.23 t/ha for variety Yantar and 0.22 t/ha for Alekseevsky 190.

Thus, coriander varieties Yantar and Alekseevsky 190 showed high responsiveness to the use of growth-stimulating and bacterial preparations. The most effective preparation in studies was Nagro at concentration of 1 l/ha. In experiments, the yield of Alekseevsky 190 was superior to that of Yantar, on average, 0.11-0.19 t/ha. One should note that plants of variety Yantar in studies were more prone to lodging, which, along with general losses, led to yield decrease.

Essential oil of coriander has about 22 different substances. Coriander seeds contain 17-29% fatty oil consisting of oleic (28.0%), linoleic (14%), palmitic (3%), stearic (2%) and other fatty acids (Scherbakov and Lobanov, 2003).

The standard for coriander essential oil in Russia provides the following technical indicators: density of 0.864-0.870, acid number not more than 1.5 mg KOH and linalool content not less than 65% (Scherbakov and Lobanov, 2003).

The content of essential oil in our studies was higher in immature fruits, but because of the sharp and unpleasant odor, it had a low demand. If the fruits of coriander were not dried to the required humidity (13%), this led to their spoilage.

The creation of new varieties of coriander, such as Yantar, and the improvement of the technique of its processing contribute to the increase of essential oil from 0.65-0.85% to 2.5% (Figure 2).

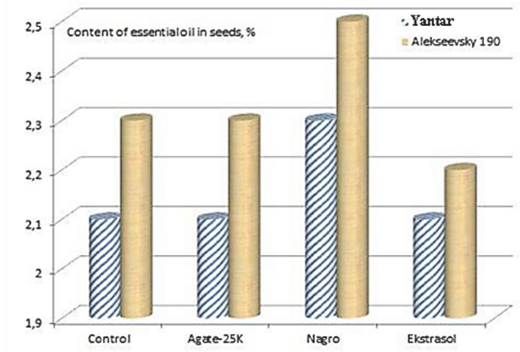

Fig. 2. Content of essential oil in seeds of coriander, %

The content of essential oil in experiments depended on the variety. One can note some increase in the content of essential oil in the variant treated with preparation Na-

Table 2. Yield of coriander depending on the use of growth-stimulating and bacterial preparations, average for 2013-2016

Treatments	Productivity, t/ha				
	2013	2014	2015	2016	average
Yantar					
Control	0.89	1.16	1.12	1.34	1.13
Agat-25K	0.99	1.22	1.28	1.42	1.23
Nagro	1.09	1.35	1.37	1.59	1.35
Extrasol	1.03	1.29	1.31	1.54	1.29
Alekseevsky 190					
Control	1.01	1.23	1.23	1.47	1.24
Agat-25K	1.10	1.37	1.38	1.55	1.35
Nagro	1.19	1.49	1.46	1.74	1.47
Extrasol	1.18	1.45	1.44	1.76	1.46
LSD_{05} factor A (variety)	0.28	0.46	0.32	1.10	
LSD_{05} factor B (treatment)	0.39	0.65	0.46	1.21	
LSD_{05} interaction AB	0.56	0.92	0.64	1.54	

gro, on two studied varieties Yantar and Alekseevsky 190 (0.2-0.3%).

On average, the amount of essential oil reached up to 35 kg/ha on the variant with Nagro treatment.

The main part of the energy was made up of mineral fertilizers: from 30% to 58%. The rest of the energy composed fuels and lubricants, agro technological operations, seeds, live labor.

On average, over the years of investigations, the bio-energetic value of coriander yield was 33,625.0 mJ/ha.

The value of the bio-energetic coefficient averaged 2.1. Low coefficients are associated with high energy costs and relatively low yields. Some increase of the bio-energetic efficiency of coriander growing can be achieved by reducing energy costs for agro technological operations thanks to the use of combined machines, the use of energy and resource-saving technologies, and the use of organic fertilizers.

In calculating the economic efficiency, the data and prices relevant for December 2017 were used. The economic efficiency of coriander growing depends directly on the yield indicators. The higher the yield, the greater the income received, the lower the cost and, correspondingly, the higher profitability of the production is. Economic efficiency depends on manufacturing expenditures to get the production unit.

In experiment 1, the maximum costs were obtained on the variant with Alekseevsky 190 treated with Nagro equal to 275.3 $/ha.

Variety Yantar without treatment with bio stimulants (control) had low costs of 252.1 $/ha. The highest income was received on the variant Alekseevsky 190 with the use of Nagro - 419.7 $ and the profitability of coriander production is 152.4%.

In general, it is necessary to note the high profitability of all experimental variants (over 60%), which indicates the possibility of coriander growing with high economic efficiency in the southern part of the non-chernozem zone of Russia.

It should be noted that studies with biological preparations of Nagro, Agat-25 and Extrasol for growing coriander in the territory of the Russian Federation were not carried out. The experiments with other agricultural crops in the non-chernozem zone of Russia show rather high efficiency from the action of Nagro, Agat-25 and Extrasol. So, the use of Agat-25K for spring wheat in the region made it possible to increase the yield by 7.8-12.5%, simultaneously increasing the protein and gluten content in the grain (Prokofyeva, 1999), increase the yield of oats by 1.27-1.50 t/ha, spring barley by 0.7-0.9 t/ha and spring rapeseed by 1.1 t/ha as compared to the control without any treatment with growth regulator (Shchur et al., 2016).

With regard to varieties Alekseevsky 190 and Yantar used, they were characterized in this region as medium-ripening, with a vegetation period of 105-115 days, which is typical in the European part of Russia. The results of the studies proved the possibility of growing coriander on dark gray forest soils, and the yield of seeds obtained in the non-chernozem zone is comparable to that in the countries that are the main suppliers of the ether-based raw materials, such as India, Morocco, Canada, Ukraine, Bulgaria and Romania (Helmke, 1993; Nazarenko and Bugaenko, 2003; Khromtsev and Vinogradov, 2013).

The possibilities of the non-chernozem zone of Russia in this direction are little used, although the acreage with essential-oil crops is expanding from year to year, so it is so important to introduce the technology of growing coriander varieties Yantar, Alekseevsky 190 with the possibility of obtaining the regional yield of 1.5 tons/ha or more.

Conclusions

The possibility of obtaining a high, stable yield of coriander seed equal to 1.5 tons/ha and more has been proved in soil-climatic conditions of the southern part of the non-chernozem zone of Russia on dark gray forest, medium-cultivated soils.

Coriander varieties Yantar and Alekseevsky 190 showed high responsiveness to the use of growth-stimulating and bacterial preparations. Preparation Nagro at concentration of 1 l/ha was most effective in experiments. The yield of Alekseevsky 190 is on average 0.1-0.11 t/ha higher than that of Yantar. The yield increase when using growth-stimulants, on average for 2013-2016, was 0.22 t/ha for Yantar and 0.23 t/ha for Alekseevsky 190 as compared to the control.

The plants of variety Yantar were more prone to lodging in investigations, which, along with common losses, led to yield decrease.

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