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STUDY ON THE EFFECT OF SOME PRODUCTS FOR FOLIAR APPLICATION ON THE PRODUCTIVITY AND ESSENTIAL OIL CONTENT IN CORIANDER SEEDS (*CORIANDRUM SATIVUM* L.)

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Abstract

The field trial was carried out in the period 2015-2017 on alluvial-meadow soil type on the territory of the village of Voivodinovo – Central-South Bulgaria. The experiment was carried out with coriander of Yantar cultivar. The following foliar fertilizers were included in the study at the respective rates: Variant 1 – Humustim – 1 l/ha; Variant 2 – Maxgrow – 5 l/ha; Variant 3 – Tecamine vigor – 1.5 l/ha; Variant 4 – Yara Tera kristalon blue – 2.5 kg/ha; Variant 5 – Poly Plant – 1 kg/ha. In order to follow out the effect of those products on the elements of productivity, seed yield and essential oil content, the variants were compared to an untreated control (Variant 6). The results show: the structural elements of the yield, i.e. the number of umbels per plant, the number of seeds per plant, the seed weight per plant and the 1000 seed weight in the treated variants exceeded the untreated control by 4-15%, 5-15.2%, 3.2-15.4% and 6.5-12.5%, respectively. The highest seed yield was produced under the treatment of coriander with leaf fertilizer Yara Tera kristalon blue in dose of 2.5 kg/ha. An increase in the essential oil content from 2.8 to 9.4% was established after treatment with the foliar applied products compared to the untreated control.

Key words: *coriander, fertilizer, productivity, seed yield, essential oil.*

INTRODUCTION

Coriander is one of the major essential oil crops grown in Bulgaria. The application of suitable agrotechnical practices in its cultivation is a prerequisite for the realization of the productive potential of plants (Manhart & Delibaltova, 2022; Delibaltova, 2020; Mishra et al., 2017; Panda et al., 2007; Kehayov et al., 2005). The use of growth regulators stimulating plant growth and development is of great importance for increasing the seed yield and essential oil content, as well as the ability of the crop to overcome some abiotic stress factors (Kuri et al., 2017; Vinogradov et al., 2017). Those products have an impact by enhancing metabolism, by promoting nutrient uptake and helping to redistribute them in the body (Meena et al., 2015). They stimulate or suppress the physiological processes essential for plant growth and development. Unlike other nutrients, they are not feeding the plants but they have an effect on life processes, on growth rates and development, they coordinate the activities of the separate organs (Yugandhar et al., 2016). A number of studies show that the application of foliar fertilizers and growth regulators in coriander is an appropriate method to stimulate the biological potential of plants. As a result, higher values of the elements of productivity, seed yield and essential and ordinary oil content were reported compared to the control (Singh et al., 2017; Yugandhar et al., 2017; Haokip et al., 2016; Kolev et al., 2005). The results of those studies confirmed that coriander reacts positively to the applied growth regulators and foliar fertilizers, thus motivating further investigations on the crop.

The aim of the present study was to investigate the effect of some foliar fertilizers on the elements of productivity, seed yield and the essential oil content in Yantar coriander cultivar.

MATERIALS AND METHODS

The field trial was carried out in the period 2015-2017 on alluvial-meadow soil type on the territory of the village of Voivodinovo – Central-South Bulgaria. The experiment was set by the block-plot design method in four

replications with a plot size of 15 m^2, after wheat as a predecessor. The experiment was carried out with coriander of Yantar cultivar.

The following foliar fertilizers and growth regulators were included in the study at the respective rates: Variant 1 – Humustim – 1 l/ha; Variant 2 – Maxgrow – 5 l/ha; Variant 3 – Tecamine vigor – 1.5 l/ha; Variant 4 – Yara Tera kristalon blue – 2.5 kg/ha; Variant 5 – Poly Plant – 1 kg/ha. They were applied at the end of buttoning and the beginning of flowering stage. In order to follow out the effect of those products on the elements of productivity, seed yield and essential oil content, the variants were compared to an untreated control (Variant 6).

The experiment was carried out following the adopted cultivation technology. The structural elements of the yield were determined after analysing 50 plants from one square meter.

Soil cultivation included ploughing in of the stubble in July and plowing at a depth of 20-22 cm in September, twice pre-sowing cultivation with harrowing, the last being at a depth of 5-6 cm. The phosphorus fertilizer was introduced before plowing at a rate of 80 kg/ha and the nitrogen fertilizer – with the last pre-sowing soil cultivation at a rate of 10 kg/ha. Every year sowing was carried out in the period 10-20 February at spacing between the rows 12-15 cm and a seed rate of 250 germinating seeds per m^2 at a depth of 3-4 cm. Weed control was achieved by treatment with the herbicide Linurex 45 SC – 2 l/ha, applied after sowing, pre-emergence of the crop. All the steps of the adopted coriander cultivation technology were respected.

The following characteristics were reported: number of umbels per plant, number of seeds per plant, seed weight per plant, 1000 seed weight, test weight, seed yield and essential oil content in seeds.

Data obtained for the values of the structural elements, the yield and the essential oil content were statistically processed by the method of dispersion and correlation analyses.

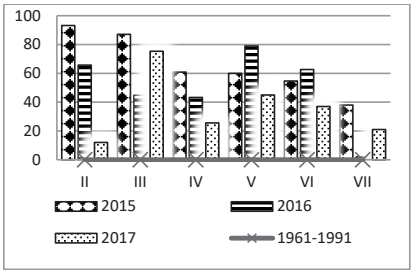

Figure 1. Rainfall, mm

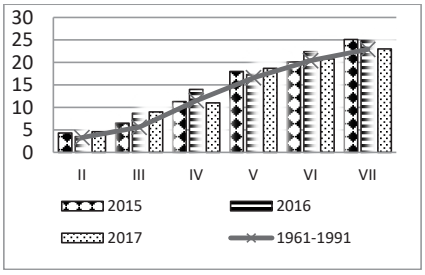

Figure 2. Average monthly air temperature, ^0C

Meteorological conditions during vegetation had an effect on the growth, development and productivity of coriander. Figures 1 and 2 present data about the amount of rainfall and the average monthly air temperature in the period February 2015 till July 2017. The results show that the air temperatures were close to or slightly higher than those established for a multiple-year period, with no significant deviations from the crop requirements. The differences between the three years of the study were established in the amount of rainfall during vegetation. The lowest amount of precipitation was reported in 2017 economic year – 215 mm versus 276.0 mm for a multiple-year period. That year was characterized by uneven distribution of rainfall, which was not enough to meet the plant requirements for water at the critical stages. In April, May and June at the stages of buttoning, flowering and fruit setting, the amount of rainfall was 107.6 mm versus 156 mm for a multiple-year period, i.e. about 31% less. That determined the third experimental year as less favorable for the productivity of coriander compared to the others.

The first year of the study (2015) was characterized by the greatest amount of rainfall during vegetation (383.9 mm). The reported amount was 107.9 mm above the climatic norm. Precipitation was evenly distributed during vegetation and in a combination with the reported temperature values, it was considered to be the most favorable for coriander cultivation of the three experimental years. In

2016, the total amount of rainfall was 295.7 mm and exceeded the values for the period 1961-1991 by 19.7 mm, however it was not very well distributed. At the beginning of vegetation (February-March) the rainfall was 33.5 mm above the norm, during the buttoning and flowering stages it was 24.5 mm more than the reported over a multiple-year period, and, during the ripening stage (July) rainfall was almost missing. This had a good effect on the seed yield and on the essential oil content.

Out of the three years of study, the most favourable for the coriander seed yield was 2015 and referring to the essential oil content, 2016 proved to be the best.

RESULTS AND DISCUSSIONS

The more favorable climatic factors in 2015 preconditioned the formation of a larger number of umbels per plant than in the other two experimental years (Figure 3). All the treated variants exceeded the untreated control by 2.1% to 12.4%. The largest number of umbels was reported in Variant 4 – 31.5, followed by Variant 2 – 30.0 and the smallest number was established in Variant 1 – 28.6. In the second experimental year, the number of umbels per plant was by 10% lower on average, compared to 2015 and the applied foliar fertilization increased the values of that characteristic to 13.5%.

The smallest number of umbels per plant was reported in the third year of the study (2017), ranging from 19.0 in the control to 25.0 in Variant 4. The treated variants exceeded the untreated control by 7.1 to 19.0%.

On average for the three-year period, the plants treated with Yara Tera kristalon blue at a rate of 2.5 l/ha formed the largest number of umbels – 28.4, followed by those treated with Maxdrow at a rate of 5 l/ha – 27.1 and the smallest number of umbels was established in the control variant – 24.7. The applied growth regulators increased the values of that indicator from 4.0 to 15%.

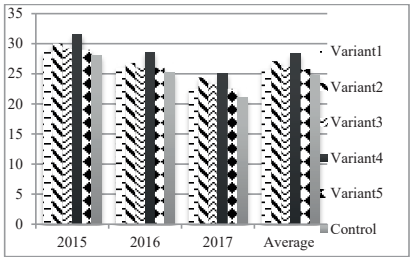

Figure 3. Effect of leaf fertilizers and growth regulators on number umbels per plant

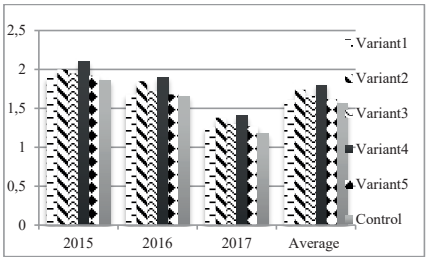

Figure 4: Effect of leaf fertilizers and growth regulators on seed weight per plant, g

The analysis of variance shows a strong statistically significant impact of both the studied variants and the years with their specific climatic conditions (Table 1). An interaction between Variant and Year was observed.

Table 1. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant**	126.4863	5	25.29725	43.01508	<0.001	2.38607
Year**	533.7325	2	266.8663	453.7756	<0.001	3.168246
Interactions**	23.0625	10	2.30625	3.921515	<0.001	2.011181
Within	31.7575	54	0.588102			

*F - test significant at P<0.05; **F - test significant at P<0.01; ns - non significant.

Table 2 presents data about the number of seeds per plant. The results confirm that the foliar applied products increased the values of that characteristic up to 14% in 2015, up to 13.3% and 18.4% in 2016 and 2017, respectively, compared to the untreated control.

On average for the years of study, the largest number of seeds per plant was formed in the variant of plant treatment with Yara Tera kristalon blue at a rate of 2.5 l/ha – 296 versus 257.0 in the control. All the treated variants exceeded the control by 13 to 39 seeds.

Table 3 presents the results of the analysis for the number of seeds per plant. Both the variants and the conditions during the year had the strongest effect on the variation of the characteristic. The interaction between the two factors was less expressed.

Table 2. Number of seeds per plant

	Years of study			Average for the period
	2015	2016	2017	
Variant 1	335 [b]	265 [b]	209 [b]	270
Variant 2	352 [d]	277 [d]	230 [d]	286
Variant 3	346 [c]	270 [c]	219 [c]	278
Variant 4	365 [e]	290 [e]	232 [d]	296
Variant 5	340 [b]	270 [b]	211 [b]	274
Variant 6	320 [a]	256 [a]	196 [a]	257

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test.

Table 3. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant**	13883.24	5	2776.647	99.05133	0.00	2.38607
Year**	194335.4	2	97167.68	3466.262	0.00	3.168246
Interactions*	571.9722	10	57.19722	2.040396	0.05	2.011181
Within	1513.75	54	28.03241			

*F - test significant at P<0.05; ** F - test significant at P<0.01; ns - non significant.

An important characteristic determining the coriander seed yield is the seed weight per plant. The different climatic conditions during the years of the experiment, as well as the applied foliar products resulted in the formation of seed yield of different weight (Figure 4). The lowest values of that indicator were reported in the control – 1.09 g in 2017 when the climatic conditions were less favorable for the growth and development of coriander compared to 2015 and 2016. In 2017 the variants, in which the plants were treated with growth regulators, exceeded the untreated control variant by 6.8 to 19.5%.

Table 4. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant**	2.68844	5	0.537688	50.1709	<0.001	2.38607
Year**	13.087	2	6.543501	610.5647	<0.001	3.168246
Interactions**	2.465431	10	0.246543	23.00458	<0.001	2.011181
Within	0.578725	54	0.010717			

*F - test significant at P<0.05; **F - test significant at P<0.01; ns - non significant.

During the first and third experimental years, the weight of the seeds of the plant in the treated variants exhibited a higher value in comparison to those of the control. Specifically, there was an observed rise in seed weight from 2.2% to 12.9% in 2015, and from 1.8% to 15.1% in 2017. On average for the period 2015-2017, the highest seed weight per plant was obtained in Variant 4 – 1.80 g (Yara Tera kristalon blue at a rate of 2.5 l/ha) and in Variant 2 – 1.74 (Maxgrow – 5 l/ha) versus 1.56 g in Variant 6 (control). The rest of the treated variants exceeded the control by 3.2 to 6.4%.

The results of the analysis of variance (ANOVA) about the effect of the factors and their interaction on seed weight per plant show a clear statistical significance in the changes of the characteristic and the interaction between the two factors was statistically significant (Table 4).

The 1000 seed weight in the first experimental year (2015) varied from 7.3 to 7.7 g in the treated variants versus 6.9 g in the control. Treatment with foliar fertilizers exceeded the untreated control by 8.7% on average (Figure 5).

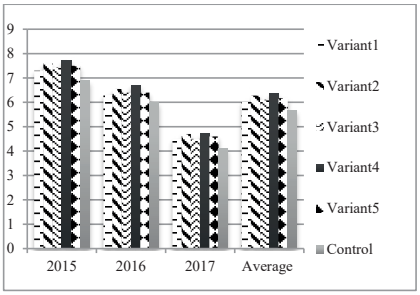

Figure 5. Effect of leaf fertilizers and growth regulators on 1000 seed weight

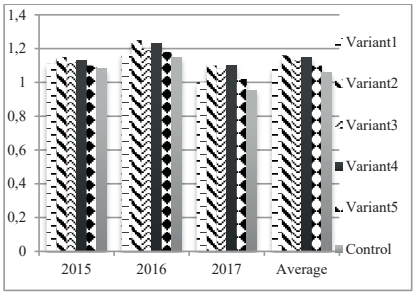

Figure 6. Effect of leaf fertilizers and growth regulators on essential oil content

In 2016, the 1000 seed weight ranged from 6.3 to 6.7 g in the treated variants versus 6.0 g in the control. On average for the study period, the highest 1000 seed weight was reported in the variant, in which the coriander was treated with Yara Tera kristalon blue at a rate of 2.5 kg/ha (6.37 g), followed by Variant 2 (6.28 g) and Variant 5 (6.17 g). An increase of 6.5% to 12.5% was reported in the treated variants compared to the control.

The results of the dispersion analysis about the influence of the factors and their interaction on the 1000 seed weight show clear statistically significant variations and the interaction between the two factors was statistically insignificant (Table 5).

Table 5. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant**	4.88684	5	0.977368	7.27933	0.00	2.38607
Year**	100.4047	2	50.20233	373.9014	0.00	3.168246
Interactions ^{ns}	0.438264	10	0.043826	0.326414	0.97	2.011181
Within	7.250375	54	0.134266			

*F - test significant at P<0.05; **F - test significant at P<0.01; ns - non significant.

The test weight is an indicator of the commercial quality of seeds and it plays an important role in determining the sale price. The results of the data analysis show that the values of that indicator were not affected by the applied foliar fertilizers. The effect of the year on the test weight was statistically significant but the interaction between both factors was insignificant (Table 6).

Table 6. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant ^{ns}	3.924444	5	0.784889	0.484001	0.79	2.38607
Year**	92.01694	2	46.00847	28.3711	0.00	3.168246
Interactions ^{ns}	12.05306	10	1.205306	0.743251	0.68	2.011181
Within	87.57	54	1.621667			

*F - test significant at P<0.05; **F-test significant at P<0.01; ns - non significant.

Data about the effect of the foliar applied products on yield seed depending on the meteorological conditions during the three experimental years, are presented in Table 7.

The results show that both the structural elements and the seed yield increased after the application of foliar fertilizers and growth regulators. The favorable combination of temperature and moisture during the vegetation period of coriander was a precondition for obtaining a higher seed yield in 2015 compared to 2016 and 2017. During the first experimental year, the values of that indicator in the treated variants ranged from 2340 to 2460 kg/ha versus 2190 kg/ha in the control. All the variants, in which the plants were treated with growth regulators, exceeded the untreated control by 6.8 to 12.3%, the difference being statistically

significant. In 2016, the coriander seed yield was about 12% lower than in the previous year and the treated variants exceeded the untreated control by 9.2% on average.

In the last year of the experiment, the seed yield ranged from 1600 to 1685 kg/ha in the treated variants and in the control variant it was 1530 kg/ha.

Table 7. Seed yield, kg/ha

	Years of study			Average for the period
	2015	2016	2017	
Variant 1	2340 [b]	2070 [b]	1600 [b]	2003
Variant 2	2430 [d]	2140 [c]	1685 [e]	2085
Variant 3	2400 [c]	2120 [c]	1664 [c]	2061
Variant 4	2460 [e]	2190 [d]	1680 [e]	2110
Variant 5	2360 [b]	2100 [b]	1672 [d]	2044
Variant 6	2190 [a]	1950 [a]	1530 [a]	1890

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test.

In the last experimental year the seed yield, obtained in the treated variants, was by 4.6 to 9.8% higher compared to the control.

On average for the study period (2015-2017), the highest yield was obtained in Variant 4 with application of Yara Tera kristalon blue at a rate of 2.5 kg/ha (2110 kg/ha); followed by Variant 2 with the application of Maxgrow at the rate of 5 l/ha (2085 kg/ha) and lowest yield of 1890 kg/ha was established in the control. All the variants treated with growth regulators exceeded the untreated control by 6.0 to 11.6%.

The results of the dispersion analysis about the effect of the factors Variant and Year, as well as their interaction, on the indicator seed yield, are presented in Table 8. The results show a statistically significant effect of the studied factors and an insignificant of their interaction.

Table 8. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant*	389423.6	5	77884.72	5.255084	0.00	2.38607
Year**	8072578	2	4036289	272.3389	0.00	3.168246
Interactions [ns]	232905.6	10	23290.56	1.571474	0.14	2.011181
Within	800325	54	14820.83			

*F - test significant at P<0.05; **F - test significant at P<0.01; ns - non significant.

In coriander cultivation, seed quality is determined by the essential oil content. That characteristic is influenced by both the years with different climatic conditions and the foliar applied products (Figure 6). Unlike the other studied characteristics, which were higher in the year with the highest and evenly distributed rainfall, the essential oil content is favoured by dry, hot weather, as well as by the lesser amount of precipitation during the seed-ripening stage.

The highest oil content was reported in 2016 when the temperature during the seed-ripening stage was 2.10 times higher than that for a multiple-year period and there was almost no rainfall. The essential oil content ranged from 1.17 to 1.25% in the treated variants and 1.15% in the control, i.e. by 1.7 to 8.7% higher. In the other years of the experiment, the applied foliar treatment increased the essential oil content by 2.8 to 6.5% and by 5.3 to 15.9% in 2015 and 2017, respectively, compared to the control.

On average for the period 2015-2017, the values of that characteristic in all the treated variants exceeded the untreated control by 2.8 to 9.4%. The highest effect of the foliar treatment was reported in Variant 2 and Variant 4 - when applying Maxgrow and Yara Tera kristalon blue products.

The dispersion analysis about the effect of the factors Variant and Year, as well as their interaction, on the essential oil content in seeds shows a significant influence of the factors on the changes of the characteristic and statistically insignificant effect of the interaction between them (Table 9).

Table 9. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Variant**	0.232907	5	0.046581	9.77137	0.00	2.38607
Year**	0.498003	2	0.249001	52.23298	0.00	3.168246
Interactions**	0.050831	10	0.005083	1.066272	0.40	2.011181
Within	0.257425	54	0.004767			

*F - test significant at P<0.05; **F - test significant at P<0.01; ns - non significant.

As a result of the correlation analysis between the structural elements, seed yield and essential oil content (Table 10), a very strong correlation ($r > 0.9$), $p < 0.05$ was found between the following indicators: number of seeds per plant and seed yield; number of seeds per plant and number of umbels per plant; 1000 seed weight and seed yield; 1000 seed weight and number of umbels per plant; 1000 seed weight and number of seeds per plant.

Table 10. Values of the coefficient of correlation

	Yield seed	Number umbels	Number seed	Weight seed- g	Mass 1000 seeds-g	Test weight	Essential oil
Yield seed	1.000						
Number umbels	0.867	1.000					
Number seed	0.911	0.924	1.000				
Weight seed - g	0.807	0.802	0.868	1.000			
Mass 1000 seeds	0.908	0.902	0.921	0.853	1.000		
Test weight	0.678	0.557	0.633	0.523	0.627	1.000	
Essential oil	0.297	0.372	0.218	0.278	0.344	0.084	1.000

High positive values of r ($r > 0.8$ and $r > 0.6$) were reported for seed yield and number of umbels per plant; seed weight per plant and seed yield; seed weight per plant and number of umbels per plant; seed weight per plant and number of seeds per plant; 1000 seed weight and seed weight per plant; test weight and seed yield; test weight and 1000 seed weight; test weight and number of seeds per plant. Mean correlation was found between the indicators: test weight and number of umbels per plant ($r = 0.557$), $p < 0.05$; test weight and seed weight per plant ($r = 0.523$). Weak correlation ($r < 0.3$) was observed between the essential oil content of seeds and all the other indicators.

CONCLUSIONS

The studied products for foliar application increased the productivity and the essential oil content in coriander seeds of Yantar cultivar.

The structural elements of the yield, i.e. the number of umbels per plant, the number of seeds per plant, the seed weight per plant and the 1000 seed weight in the treated variants exceeded the untreated control by 4-15%, 5-15.2%, 3.2-15.4% and 6.5-12.5%, respectively.

The foliar fertilizers applied to coriander did not exert an effect on the test weight.

On average for the experimental period (2015-2017), the increase in seed yield after the foliar application of the products, ranged from 6.0 to 11.6% compared to the control. The highest yield was reported in the variant treated with Yara Tera kristalon blue at the rate of 2.5 kg/ha – 2110 kg/ha.

An increase in the essential oil content from 2.8 to 9.4% was established after treatment with the foliar applied products compared to the untreated control. The highest values were obtained when using foliar fertilizers Maxgrow – 1.16% and the Yara Tera kristalon blue – 1.15%.

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