Research Journal of Agricultural Science, 57 (1), 2025; ISSN: 2668-926X

http://doi.org/10.59463/RJAS.2025.1.18

ASSESSMENT OF CORIANDER (CORIANDER SATIVUM L.) CULTIVARS FOR YIELD AND YIELD-RELATED PARAMETERS UNDER THE AGROECOLOGICAL CONDITIONS OF SOUTH-CENTRAL BULGARIA

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Abstract. *Coriander (Coriandrum sativum L.) is a valuable essential oil and spice crop, widely cultivated under various agroecological conditions due to its high economic importance. The optimal selection of cultivars is crucial for achieving high yields and good product quality, especially in the context of changing climatic conditions. The objective of this study was to assess the seed yield and its components, along with certain qualitative traits, of five coriander varieties —Yantar, Moroccan, Mesten Drebnoploden, Thüringen, and Marino—cultivated under the agroecological conditions of south-central Bulgaria. A field experiment was conducted in region of Plovdiv from 2020 to 2022 on alluvial-meadow soil, following winter wheat as a preceding crop. The results showed that the variety Mesten Drebnoploden exhibited the highest plant height, averaging 81.9 cm, followed by Thüringen at 72.6 cm. The cultivar Moroccan was distinguished by superior reproductive performance, recording averagely the highest number of umbels per plant (22.3), the highest number of seeds per plant (279), and the greatest seed weight per plant (1.19 g) average over the study period. Additionally, it had the highest mass per 1000 seeds and a test weight of 30.4 kg. The Moroccan variety also demonstrated the highest productivity, yielding 2137 kg/ha, while the Yantar variety had the lowest average yield for the period at 1454 kg/ha. Finally, the study revealed that both cultivar and growing conditions have a significant influence on the yield and yield components of coriander. These results highlight the importance of cultivar selection in maximizing coriander yield and quality under specific agroecological conditions.*

Keywords*: coriander, varieties, seed yield, agronomic traits, quality*

INTRODUCTION

Bulgaria has long enjoyed a reputation as an international supplier of coriander production. In 2023, the country exported approximately 19,295,600 kilograms of coriander seeds, valued at around $15.53 million. This positions Bulgaria as the third-largest exporter of coriander seeds globally, accounting for 7.92% of the world's coriander seed exports. Given the substantial export volumes, it can be inferred that a significant portion of Bulgaria's coriander production is destined for international markets mainly of Indonesia, Sri Lanka, India, Nepal, United Kingdom (WORLD BANK WITS, 2023).

Coriander (*Coriandrum sativum* L.) is a widely cultivated oilseed crop valued for its seeds, which possess considerable quantities of oil and protein. The seeds are primarily used as a spice, because of their mild, sweet, slightly pungent flavor reminiscent of citrus, accompanied by an aroma of sage. Coriander seeds, whether whole or ground, serve as an element in pickling spices and are utilized to enhance the flavor of numerous commercial goods, including quick soups, cakes, breads, pastries, alcoholic beverages, frozen dairy desserts, confections, and puddingc (AKGÜL, 1993).

Coriander originates from the Mediterranean and Asia Minor, and it flourishes in warm, dry regions (SAYED-AHMAD et al., 2017; SINGHT et al., 2024; NAWATA et al., 1995; ZANETTI et al., 2013). Despite this, the plant is highly adaptive and able to modifying its morphological characteristics based on environmental factors (SINGHT et al., 2006; DIEDERICHESEN, 1996).

Nowadays, their successful cultivation necessitates a comprehensive evaluation of production metrics and their fluctuations under various technological methods and resource allocations. An extensive assessment of existing varieties is crucial to develop enhanced types with superior yield potential, given its importance as a spice crop. Given the current agro-climatic circumstances characterized by abrupt temperature surges in the later phases of crop development, early-maturing enhanced cultivars have exhibited superior performance. Choosing optimal plant varieties is essential for producers seeking to improve and advance the crop. This study aimed to determine the seed yield and components, as well as some qualitative parameters, of five newly introduced coriander varieties grown in South-Central Bulgaria.

MATERIAL AND METHODS

Field experiment

The field experiment was carried out in a specified area in Voivodinovo village, Plovdiv region (South-Central Bulgaria) between 2020 and 2022. It was conducted on alluvial-meadow soil using a block design method with four replications. The experimental plot covered an area of 15 m² and followed winter wheat as the preceding crop. The study tested the following cultivars: Yantar, Moroccan, Mesten Drebnoploden, Thüringen, and Marino.

The experiment was conducted using an established cultivation technology. Soil preparation involved incorporating the stubble through ploughing in June, followed by deep tilling at a depth of 20–22 cm in September, and two rounds of pre-sowing cultivation with harrowing to a depth of 5–6 cm (DALLEV and IVANOV, 2015). Phosphorus fertilizer was applied prior to tilling at a rate of 80 kg ha^{-1}, while nitrogen fertilizer was added during the final pre-sowing cultivation at a rate of 10 kg/ha. Sowing took place annually between February 10th and 20th, with a row spacing of 12–15 cm and a seeding rate of 300 seeds per m², at a depth of 3–4 cm.

The following parameters were recorded: seed yield, plant height, number of umbels per plant, number of seeds per plant, seed weight per plant, 1000-seed weight, and test weight.

Productivity and quality data were statistically analyzed using analysis of variance (ANOVA) and correlation methods. Differences among variants were evaluated using Duncan's Multiple Range Test.

Weather conditions

Meteorological conditions during coriander's growing season significantly affect its growth and productivity (DYULGEROV & DYULGEROVA, 2016). Coriander yield and quality are sensitive to a variety of factors, including biotic stress, phenotypic variability, climatic extremes, agricultural techniques, and genetic impacts. Notably, severe weather conditions, especially high rainfall and freezing temperatures during flowering, can hinder coriander growth and promote disease transmission, such as flower blight, resulting in significant yield losses (KHARE et al., 2017). Figures 1 and 2 illustrate the monthly precipitation levels and average air temperatures recorded between February 2020 and July 2022. Throughout three growing seasons, average daily air temperatures were slightly above the long-term averages, meeting coriander's thermal requirements from germination to ripening. No major deviations from optimal temperature conditions were observed. However, notable differences between the three years were found in precipitation levels during the vegetation period. In 2020, rainfall totaled 347.7 mm, or 55.7 mm more than the long-term average. In 2021, it reached 351 mm—59 mm above the 1961–1990 baseline—making it the most favorable year for coriander variety performance. The driest year was 2022, with only 224 mm of rainfall compared to the long-term average of 292 mm. In July 2022, during the ripening stage, rainfall decreased significantly, which positively affected the seed yield. The year 2021 proved the most favorable for seed yield. The rainfall data and these temperature trends directly influenced coriander's growth and development.

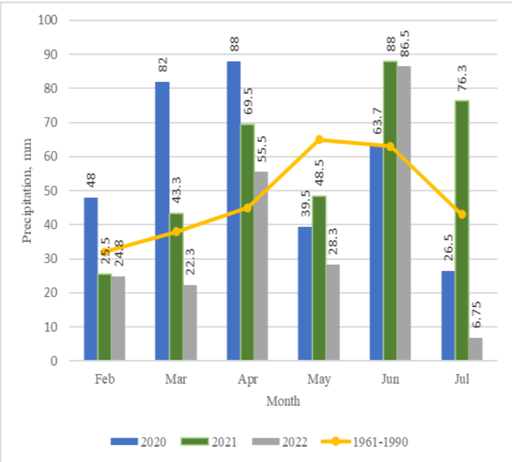

Figure 1. Precipitation, mm

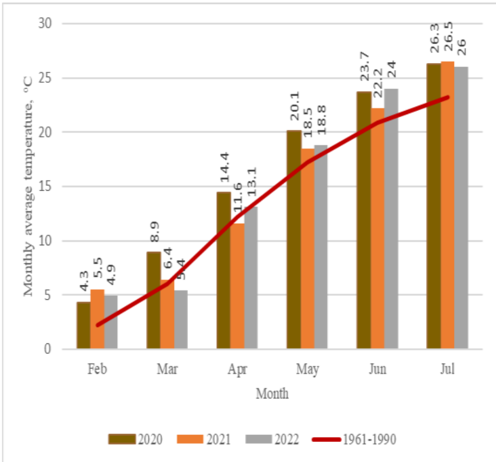

Figure 2. Average monthly air temperature, ^{0}C

RESULTS AND DISCUSSIONS

Seed yield

The advantageous combination of meteorological conditions, particularly the uniform distribution of precipitation during the coriander growing season in 2021, compared to 2020 and 2022, is essential for achieving higher seed yields from the examined types. The results of the research on seed yield (Table 1) demonstrate that, both annually and on average during the experimental period, the Moroccan variety exceeded the seed yields of every other variety examined in the study.

Table 1

Seed yield, kg ha $^{-1}$

Variety	Years of study			Average for the period (kg ha $^{-1}$)
	2020	2021	2022	
Yantar	1446 ^{e}	1525 ^{e}	1390 ^{e}	1454
Moroccan	2119 ^{a}	2209 ^{a}	2141 ^{a}	2137
Mesten Drebnoploden	2034 ^{b}	2141 ^{b}	2062 ^{b}	2079
Thüringen	1680 ^{c}	1768 ^{c}	1596 ^{d}	1681
Marino	1623 ^{d}	1712 ^{d}	1609 ^{c}	1648

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

The highest yields occurred in the advantageous coriander year of 2021, when rainfall and temperature continuously fulfilled the plant's needs during the whole growing season. The yields obtained reached up to 2209 kg ha-1 in the Moroccan variety. The cultivar's yield exceeded that of Yantar, Mesten drebnoploden, Thüringen and Marino by 44.9%, 3.2%, 24.9%, and 29.0%, respectively, with the differences being statistically significant. Seed yields in the third experimental year (2022) decreased by an average of 6.3% from 2021, ranging from 1390 kg ha^{-1} for the Yantar variety to 2141 kg ha^{-1} for the Moroccan variety. The Moroccan variety produced an average yield of 2137 kg ha^{-1} during the 2020–2022 experimental period, whereas Mesten Drebnoploden came in second with 2079 kg ha^{-1}. The Yantar cultivar has the lowest average yield, with 1454 kg ha^{-1}.

Table 2 shows the results of the Analysis of Variance (ANOVA) for the impact of variety and year on the seed yield indicator. The findings show that the factors under consideration have a statistically significant influence.

Table 2

Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Year**	3672187	4	1836094	919.27	0.00000	3.2043
Variety**	1733355	2	433338.9	216.958	0.00000	2.5787
Interaction*	136321.1	8	17040.13	8.53142	0.00000	2.1521
Within	89880.25	45	1997.339			

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

Plant height

The meteorological conditions in the investigated varieties have different impacts on the height of the plants, depending on the research years (Table 3). Compared to 2020 (from 55.9 cm to 82.0 cm) and 2022 (from 50.1 cm to 79.5 cm), the increased rainfall in 2021 generates the conditions for the studied varieties to develop plants with taller stems, ranging from 60.1 cm to 84.1 cm. At the end of the 2020 growing season, the variety Mesten drebnoploden had the tallest plants (82.0 cm), outperforming the other examined varieties by an average of 26.9%. The tallest plants in the 2021 experimental year were once again the Mesten drebnoploden variety (84.1 cm), followed by the Thüringen variety (74.2 cm), and the Yantar variety (60.1 cm). In the second experimental year, the more favorable climatic conditions satisfying the plants' need for coriander significantly led to the formation of taller plants in all tested varieties compared to 2020, with an increase of 0.8% in the Thüringen variety, to 7.5% in the Yantar and Marino varieties. In the last year of the study, like the previous ones, the variety Local small-fruited (79.5 cm) has the tallest plants, surpassing the others by 9.6 cm to 29.4 cm. On average, for the study period (2020 – 2022), the height of the plants of the examinated cultivars ranged from 55.4 cm to 81.9 cm. Significant differences (p≤0.01) in plant height were found between the coriander cultivars according to the analysis of variance (Table 4).

Number of umbels per plant

The number of canopies per plant is an indicator that is greatly influenced by both the genotype and the environmental conditions and agrotechnical measures applied in plant cultivation (GIL et al., 2002; UZUN et al., 2010; YALDIZ et al., 2022). In actuality, coriander plants are upright and heavily branched, with each branch ending in an inflorescence (umbel). Umbels occur and grow gradually throughout a plant's life cycle, allowing flowers and fruits at varying stages of ripening to coexist on the same plant. Because primary umbels mature while secondary umbel fruits are still green, and ripe fruits detach easily from the umbels, significant fruit losses due to shattering from primary umbels may occur early (DIEDERICHSEN, 1996).

Table 3

Biometrical parameters and yield components in coriander cultivars

Variety	Year	Plant height, cm	Nr of umbels per plant	Nr of seeds per umbel	Nr of seeds per plant	Weight of seeds per plant, g
Yantar	2020	55.9	11.6	9.3	109	0.61
	2021	60.1	12.1	9.9	120	0.66
	2022	50.1	10.9	9.7	106	0.58
	Avarage for the period	**55.4**	**11.5**	**9.6**	**112**	**0.62**
Moroccan	2020	66.0	22.0	12.4	273	1.18
	2021	70.4	23.1	12.5	289	1.24
	2022	65.8	21.8	12.6	276	1.16
	Avarage for the period	**67.4**	**22.3**	**12.5**	**279**	**1.19**
Mesten Drebnoploden	2020	82.0	21.5	11.6	250	1.07
	2021	84.1	21.0	12.9	271	1.13
	2022	79.5	20.9	12.0	252	1.08
	Avarage for the period	**81.9**	**21.1**	**12.1**	**258**	**1.09**
Thüringen	2020	73.6	15.0	14.6	220	0.97
	2021	74.2	15.6	14.7	229	1.05
	2022	69.9	14.4	14.2	204	0.95
	Avarage for the period	**72.6**	**15.0**	**14.4**	**218**	**0.99**
Marino	2020	65.4	12.7	12.2	156	0.70
	2021	70.3	12.9	12.5	162	0.74
	2022	64.5	12.5	12.0	149	0.66
	Avarage for the period	**67.3**	**12.7**	**12.2**	**156**	**0.70**

In the duration of the experiment, the second year exhibited the highest precipitation levels and temperatures near ideal for coriander development, enabling the building of a greater number of umbels per plant compared to 2020 and 2022. This indicator recorded values from 12.1 to 23.1 in 2021, while in the first and third business years – 11.6 to 22.0 (2020) and from 10.9 to 21.8 (2022) for the tested varieties. The Moroccan variety had the most umbels per plant in the second year of the trial – 23.1, followed by the Mesten drebnoploden variety – 21.0. In the third year, the lowest number of umbels per plant was recorded, varying from 10.9 to 21.8, probably related to reduced storage of moisture in April and May compared to preceding experimental years, which negatively affected the growth and development of coriander, especially with regard to the formation of primary branches and umbels

(DYULGEROV & DYULGEROVA, 2016; INAN et al., 2014). In 2022, the largest number of umbels was formed by the Moroccan variety – 21.8. Second in terms of the number of formed umbels per plant, similar to the two previous years, is the variety Mesten drebnoploden with – 20.9. The average value of the indicator ranges from 11.5 for the Yantar to 22.3 for the Moroccan variety. The analysis of variance (ANOVA) regarding the impact of year and variety on the number of umbels per plant, as well as their interaction, reveals that the factors have a statistically insignificant effect on the interaction between them and a significant influence on changes in the characteristic (Table 4).

Number of seeds per umbel

A significant part of the variation in the trait of the number of seeds per umbel is determined by the genotype (DYULGEROV & DYULGEROVA, 2013). All varieties showed higher values in 2021 compared to the previous year due to the interaction between genotype and year (climatic conditions). The varieties Yantar, Moroccan, Mesten drebnoploden, Thüringen, and Marino saw increases in the number of seeds per umbel of 6.5%, 0.8%, 11.2%, 0.7%, and 2.5%, respectively. In the third harvest year, looking at the indicator number of seeds per umbel, it is noticed that the highest values are the Thüringen variety - 14.2, followed by the varieties Moroccan - 12.6, Mesten drebnoploden and Marino - 12.0. In all cultivars, the average number of seeds per umbel during the test period varied from 9.6 to 14.4. The ANOVA variance analysis indicated a significant statistical effect of both parameters on the number of seeds per umbel, although it could not demonstrate their interaction mathematically (Table 4).

Number of seeds per plant

One key factor influencing yield is the quantity of seeds produced by a single plant. Data on the number of seeds per plant showed significant variance across coriander varieties. Depending on the coriander variety and testing year, the number of seeds produced per plant varied between 109 and 273 for the first year, 120 and 289 for the second year, and 106 and 276 for the third year (Table 3). Throughout the study period, the cultivar Moroccan demonstrated the highest average seed per plant count at 279, whereas the other varieties varied between 112 and 258. Overall, for the entire period, an impact on climatic conditions was observed on the indicator for all experimental varieties, with an increase from 3 to 11 seeds per plant for the Yantar variety, from 3 to 13 for the Moroccan variety, from 2 to 21 for the Mesten drebnoploden, from 4 to 25 for the Thüringen variety and from 6 to 13 for the Marino variety.

Weight of seeds per plant

One of the important yield components that is heavily impacted by genotype, environment, and their interaction is the weight of seeds per plant (KULDIPSINH KANAKSINH, D. A. B. H. I., 2022). Elevated values of those indicators were recorded between 2020 and 2022, corresponding with meteorological circumstances during seed formation, filling, and ripening. The growing of plants with a higher seed mass per plant is made possible by improved water availability in 2021 and temperatures being close to that of the multi-year period. The second year exhibited the highest seed weight per plant, ranging from 0.66 g to 1.24 g, compared to the next two years, which varied from 0.58 g to 1.18 g (Table 5). The statistically analysis of data indicated that varieties considerably differed ($p<0.05$) in terms of the Weight of seeds per plant (Table 4).

Table 4

Analysis of variance ANOVA

Parameter	Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Plant height, cm	Year**	345.933	2	172.967	683.81	0.00000	0.704
	Variety**	4436.009	4	1109.002	4384.37	0.00000	0.852
	Interactions *	71.752	8	8.969	35.458	0.00000	0.932
	Within	11.383	45	0.253			
Nr of umbels per plant	Year*	7.0643	2	3.532	15.254	0.00001	0.7039
	Variety**	1162.758	4	290.689	1255.377	0.00000	0.852
	Interactions ns	3.687	8	0.4609	1.9905	0.06954	0.932
	Within	10.42	45	0.232			
Nr of seeds per umbel	Year*	2.096	2	1.0482	5.513	0.00722	0.7039
	Variety**	140.581	4	35.145	184.867	0.00000	0.852
	Interactions ns	2.667	8	0.3334	1.7536	0.11209	0.932
	Within	8.555	45	0.1901			
Nr of seeds per plant	Year*	1960.033	2	980.017	30.129	0.00000	0.7039
	Variety**	240035.2	4	60008.81	1844.848	0.00000	0.852
	Interactions *	1589.967	8	198.746	6.1100	0.00003	0.932
	Within	1463.75	45	32.5278			
Weight of seeds per plant, g	Year*	0.05956	2	0.02978	14.820	0.00001	0.7039
	Variety**	3.149	4	0.787	391.816	0.00000	0.852
	Interactions ns	0.0040	8	0.0005	0.2492	0.97852	0.932
	Within	0.09043	45	0.00201			

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

Weight of 1000 seeds

Depending to their unitary weight, fruits are divided into two categories: small-sized (subsp. microcarpum, with 1000 fruits <10 g) and large-sized (subsp. sativum, with 1000 fruits > 10 g) (DIEDERICHSEN and HAMMER, 2003).

The findings show that the weight of 1000 seeds (g) varied between 4.53 g and 6.36 g for the five cultivars under experimental conditions and within the parameter under investigation. The Marino and Moroccan cultivars displayed close values for the mass per 1000 seeds across individual studied years: 6.15 g and 5.97 g in 2020; 6.36 and 6.20 g in 2021; and

Research Journal of Agricultural Science, 57 (1), 2025; ISSN: 2668-926X
http://doi.org/10.59463/RJAS.2025.1.18

5.80 g and 6.05 g in 2022. According to Table 5's results, the average mass of the 1000 coriander seeds analyzed in the study varied between 4.75 and 6.19 g. The ANOVA variance analysis revealed a substantial statistical effect of both parameters on the weight of 1000 seeds, although it was unable mathematically to display their interaction (Table 6).

Test weight

Coriander seed test weight results typically ranged between 28 and 33 kg. The seed's specific mass, moisture content, shape, seed arrangement within the volume, and the kind and presence of exogenous substances all influence this property. Table 5 displayed the synthesis data related to the test weight value from the experimental period. Values exceeding 29 kg were recorded for the Moroccan variety over the duration of the three-year period, with measurements of 31 kg in 2020, 31.3 kg in 2021, and 29 kg in 2022. The variety Yantar had the lowest average test weight, measuring 26.9 kg. The obtained results are statistically significant. The ANOVA variance analysis indicates a substantial impact of the two parameters, cultivar and year, on test weight. Their interaction has also been substantiated (Table 6).

Table 5

Qualitative indicators in in coriander cultivars

Variety	Year	1000 seed weight (g)	Test weight (kg)
Yantar	2020	5.16	27.3
	2021	5.75	27.1
	2022	5.02	26.2
	Avarage for the period	**5.31**	**26.9**
Moroccan	2020	5.97	31.0
	2021	6.20	31.3
	2022	5.80	29.0
	Avarage for the period	**5.99**	**30.4**
Mesten Drebnoploden	2020	4.61	29.0
	2021	5.12	28.8
	2022	4.53	27.0
	Avarage for the period	**4.75**	**28.3**
Thüringen	2020	5.40	28.2
	2021	6.08	27.7
	2022	5.14	28.0
	Avarage for the period	**5.54**	**28.0**
Marino	2020	6.15	29.5
	2021	6.36	28.3
	2022	6.05	29.9
	Avarage for the period	**6.19**	**29.2**

Table 6

Analysis of variance ANOVA

Parameter	Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
1000 seed weight (g)	Year*	0.0596	2	0.02978	14.820	0.00001	0.70393
	Variety**	3.1493	4	0.7873	391.816	0.00000	0.85195
	Interactions [ns]	0.0040	8	0.0005	0.2492	0.97852	0.93186
	Within	0.0904	45	0.0020			
Test weight	Year*	9.758333	2	4.87917	23.069	0.00000	0.70393
	Variety**	85.291	4	21.3228	100.817	0.00000	0.85195
	Interactions *	20.175	8	2.5219	11.923	0.00000	0.93186
	Within	9.5175	45	0.2115			

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

CONCLUSIONS

Based on the study, the productivity and quality parameters of the evaluated coriander varieties are significantly affected by the cultivar's genetic profile, annual environmental conditions, and—above all—the amount and distribution of vegetative rainfall.

The Moroccan variety had the highest seed yield due to its higher values of yield structural characteristics. The Thüringen variety had the highest average quantity of seeds per umbel, whereas the Mesten drebnoploden cultivar had the tallest plants. The values of the indicators 1000 seeds weight were highest by the cultivar Marino. With an average test weight of 30.4 kg, the Variety Moroccan has the highest values.

The results of the study could be beneficial to select coriander varieties in the region. We anticipate that comprehensive assessments of yield components and qualitative characteristics will enhance the knowledge of yield formation mechanisms and optimize process of the coriander cultivation.

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