A comparison of yield-related traits of *Coriandrum sativum* var. *microcarpum* DC. and *Coriandrum sativum* var. *sativum*

Сравнение между *Coriandrum sativum* var. *microcarpum* DC. и *Coriandrum sativum* var. *sativum* по признаци свързвани с добива

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Abstract

In this investigation we studied how yield-related traits of large-fruited (var. *sativum*) and small-fruited (var. *microcarpum* DC.) coriander differ at the Southeastern Bulgaria climatic conditions during 2010-2012. For this purpose, 20 genotypes from var. *microcarpum* and 20 genotypes from var. *sativum* were tested using a randomized complete block design with three replications at the Institute of Agriculture – Karnobat. Plant height, number of primary branches per plant, number of umbels per plant, number of fruits per umbel, fruit weight per plant of small-fruited coriander exceeded large-fruited coriander. Large-fruited coriander had higher fruit weight per umbel and 1000-fruits weight. According to variance analyses, the value of the 1000-fruits weight, fruit weight per umbel, fruit weight per plant and number of primary branches were determined by the coriander variety (var. *microcarpum* DC. or var. *sativum*) but other characteristics were more affected by the weather conditions of a particular year. Plant height was determined by the environment for both varieties of coriander. Number of primary branches was influenced by the genotype for var. *sativum* and by the year for var. *microcarpum*. The influence of the year was greater for the number of umbels per plant, number of fruits per umbel, fruit weight per plant and 1000-fruits weight of var. *sativum* compared with var. *microcarpum*.

Keywords: coriander, var. *microcarpum*, var. *sativum*, yield-related traits

Резюме

Проучени са различията в признаци свързани с добива от плодове при едроплодния (var. *sativum*) и дребноплодния (var. *microcarpum* DC.) кориандър при климатичните условия на Югоизточна България през периода 2010-2012 година. За тази цел в Институт по земеделие –Карнобат са изпитани 20 генотипа от var. *microcarpum* и 20 генотипа от var. *sativum* по рандомизиран блоков метод, в три повторения. Установено е, че дребноплодният кориандър се отличава с по-високи стойности на признаците - височина на растението, брой на първичните разклонения в 1 растение, брой на сенници в 1 растение, брой на плодове в 1 сенник. Теглото на плодовете от 1 сенник и масата на 1000 плода са по-високи при едроплодния кориандър. Значителна част от варирането на признаците - маса на 1000 плода, тегло на плодовете от 1 сенник, тегло на плодовете от 1 растение и брой на първичните разклонения в 1 растение се дължи на вариетета на кориандъра (var. *microcarpum* DC. или var. *sativum*), докато варирането на останалите признаци се обуславя преди всичко от климатичните условия на годината. Условията на годината са доминиращия фактор за варирането височината на растенията и при двата вариетета кориандър. Броят на първичните разклонения е повлиян най-силно от генотипа при var. *sativum* и от годината при *var. microcarpum.* Влиянието на годината върху варирането на броя на сенниците в 1 растение, броя на плодовете в 1 сенник, броя на плодовете в 1 сенник и масата на 1000 плода е по-голямо при var. *sativum* в сравнение с var. *microcarpum*.

Ключови думи: кориандър, признаци свързани с добива, var. *microcarpum*, var. *sativum*

Разширено резюме

Целта на настоящето проучване е да се сравнят признаците свързани с добива плодове при едроплодния (var. *sativum*) и дребноплодния (var. *microcarpum* DC.) кориандър; да се оцени влиянието на вариетета и годината на отглеждане върху проявлението на тези признаци; да се сравни ефекта на генотипа и годината на отглеждане при дребноплодния и едроплодния кориандър. Проучването е проведено в опитното поле на Институт по земеделие – Карнобат през периода 2010-2012 гадина. В изследването са включени 20 генотипа от var. *microcarpum и* 20 генотипа от var. *sativum*. Опитът е заложен по рандомизиран блоков метод, в три повторения. Върху 10 растения от всеки генотип и от всяко повторение са отчетени: височина на растението, брои на първичните разклоненията в 1 растение, брой на сенниците в 1 растение, брой на плодовете в 1 сенник, тегло на плодовете от 1 сенник , тегло на плодовете от 1 растение и маса на 1000 плода. Установено е, че при климатичните условия на Югоизточна България генотиповете кориандър от var. *microcarpum* имат по-високи продуктивни възможности в сравнение с тези от var. *sativum.* Дребноплодният кориандър се отличава с по-високи стойности на признаците - височина на растението, брой на първичните разклонения в 1 растение, брой на сенниците в 1 растение, брой на плодовете в 1 сенник, тегло на плодовете от 1 растение. Теглото на плодовете от 1 сенник и масата на 1000 плода са по-високи при едроплодния кориандър.

Значителна част от варирането на признаците – маса на 1000 плода, тегло на плодовете от 1 сенник, тегло на плодовете от 1 растение и брой на първичните разклоненията в 1 растение се дължи на вариетета на кориандъра (var. *microcarpum* DC. или var. *sativum*), докато варирането на останалите признаци се обуславят преди всичко от климатичните условия на годината. Условията на годината са доминиращия фактор за варирането на височината на растенията и при двата вариетета кориандър. Броят на първичните разклонения е повлиян най-силно от генотипа при var. *sativum u* от годината при *var. microcarpum.* Влиянието на годината върху варирането на броя на сенниците в 1 растение, броя на плодовете в 1 сенник, броя на плодовете в 1 сенник и масата на 1000 плода е по-голямо при var. *sativum* в сравнение с var. *microcarpum*.

Introduction

Coriander (*Coriandrum sativum* L.) is a member of the *Apiaceae* with a broad diversity of uses (Diederichsen, 1996; Maroufi *et al.*, 2010; Chawla and Thakur, 2013). Coriander is divided into two types according to the size of the fruit (Purseglove *et al.*, 1981). Fruit size is an indication of volatile oil content and suitability for particular end uses. The large-fruited types (var. *vulgare* Alef. = var. *sativum*) has a fruit diameter of 3-5 mm while var. *microcarpum* fruits have a diameter of 1.5-3 mm. Large fruited types are grown mainly in tropical and subtropical climatic conditions and contain low volatile oil content (0.1-0.4%). Types with smaller fruit (var. *microcarpum* DC.) are produced in temperate regions and usually have a volatile oil content of around 0.4-1.8%, and are therefore highly valued as a raw material for the preparation of essential oil.

In Bulgaria, coriander presently covers about 85% of the area of medicinal and aromatic crops and it is an important export crop. There is little information available on yield performance of coriander accessions with diverse geographic origin in the agro-ecological conditions in Bulgaria (Dyulgerov and Dyulgerova, 2013a).

The aim of this work was the comparison of yield traits and variation of these traits in small-fruited and large-fruited coriander; the comparison of the influence of coriander variety and environment (growing year) on these traits; the comparison of the influence of genotype and environment separately on small-fruited and large-fruited coriander characteristics.

Material and method

The study was conducted at the Institute of Agriculture - Karnobat during the period 2010-2012. The experimental area is located in Southeastern Bulgaria**.** Average temperature and precipitation during the experimental period are shown on Figure 1 and 2. The soil of experimental field is leached chernozem-smolniza, slightly acid (pH is 6.2).

The experiment consisted of 39 coriander accessions obtained from the gene bank of IPK, Gatersleben (Germany) and 1 local cultivar – Mesten drebnoploden. These accessions were selected based on their botanical variety (*Coriandrum sativum* L. subsp. *microcarpum* DC. var. *microcarpum* (DC.) Hegi or *Coriandrum sativum* L. subsp.

sativum var. *sativum*) and their origin from different geographical regions worldwide (Table 1).

The experiment was laid out in a randomized complete block design with three replications. Spacing between plants and rows were kept as 15 and 30 cm, respectively. At maturity ten plants were randomly selected from each plot and data were collected for plant height (PH), number of primary branches per plant (NB), number of umbels per plant (NU), number of fruits per umbel (NFU), fruit weight per umbel (FWU), fruit weight per plant (FWP) and 1000-fruits weight (FW).

Statistical analyses were performed using the statistical package SPSS 16.0 (SPSS Inc., 2007, Chicago, IL, USA). The analyses of variance and the estimates of the component of variance due to coriander variety (var. *microcarpum* and var. *sativum*), environment (growing year) and genotypes were calculated and was expressed as % of the total sum of squares of G, E and GEI.

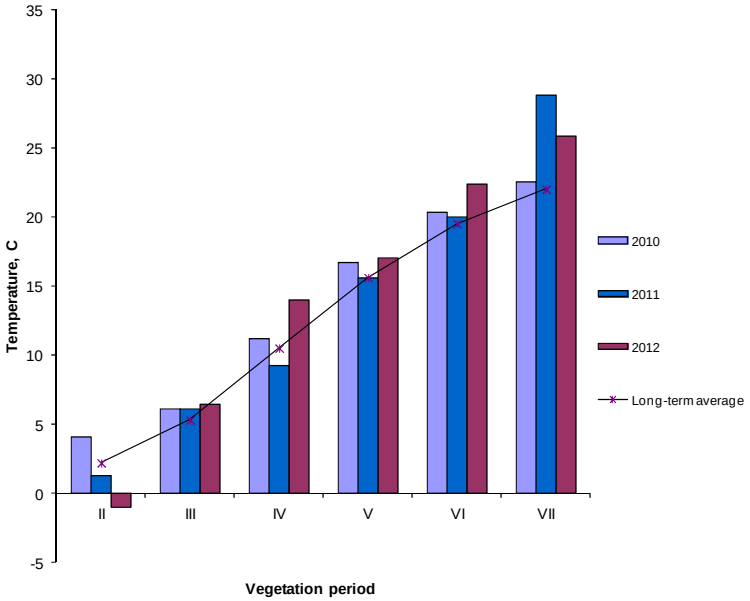

Figure 1. Temperature dates, ^{o}C of 2010-2011 years and long-term average in Karnobat, Southeastern Bulgaria

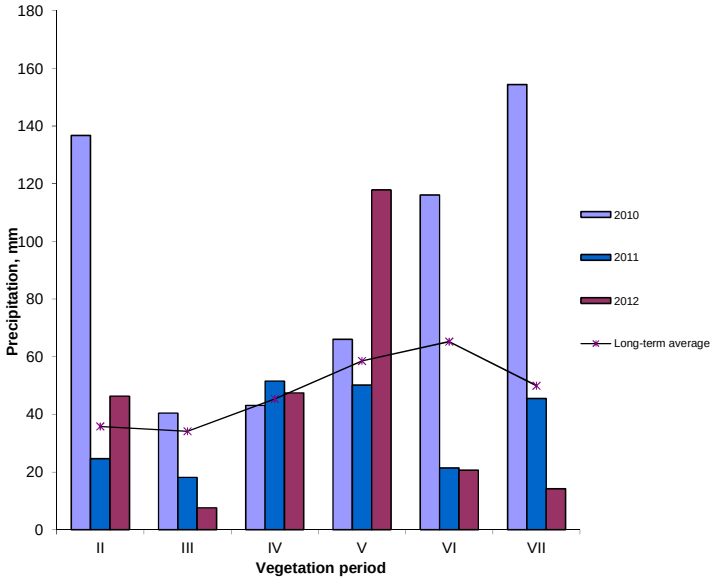

Figure 2. Precipitation dates, mm of 2010-2013 years and long-term average in Karnobat, Southeastern Bulgaria

Table 1. List of *Coriadrum sativum* L. accessions used in this study

Accession	Origin	Accession	Origin
var. *microcarpum*		var. *sativum*	
Cori 14	Germany	Cori 25	Hungary
Cori 20	unknown	Cori 280	Peru
Cori 21	Former USSR*	Cori 292	Holland
Cori 28	India	Cori 384	unknown
Cori 30	Former Czechoslovakia	Cori 410	unknown
Cori 114	unknown	Cori 412	unknown
Cori 177	unknown	Cori 36	Italy
Cori 186	Germany	Cori 105	Italy
Cori 209	unknown	Cori 144	Iraq
Cori 215	Former USSR	Cori 165	Netherlands
Cori 270	USA	Cori 176	unknown
Cori 272	Germany	Cori 202	unknown
Cori 282	Madagascar	Cori 223	Russian Federation
Cori 333	unknown	Cori 242	Spain
Cori 340	USA	Cori 269	Mexico
Cori 337	Morocco	Cori 287	Portugal
Cori 313	Azerbaijan	Cori 308	Russian Federation
Cori 315	Kazakhstan	Cori 458	Germany
Cori 316	Uzbekistan	Cori 448	Belgium
Mesten drebnoploden	Bulgaria	Cori 442	Germany

*Former Union of Soviet Socialist Republics

Results and Discussion

Results of analysis of variance revealed that effects of coriander variety (var. *microcarpum* and var. *sativum*) were statistically significant for all yield components (Table 2). The traits with which year and variety x year interaction were found significant were plant height, number of umbels per plant, fruit weight per umbel, fruit weight per plant and 1000-fruits weight.

Component of variance for each trait expressed as percentage illustrates the relative contribution of each source to total variation (G+E+GEI). The results showed a strong influence of the year on plant height and number of umbels per plant. Variety had strong impact on 1000-fruits weight and fruit weight per umbel. Fruit weight per plant and number of primary branches demonstrated a nearly equal effect of variety and sum of effects of year and interaction variety x year. Variety by year interactions was mainly observed for number of fruits per umbel.

Table 2. The portion of sums of squares (SS) attributed to variety, year, and variety x year interaction as a percentage of the total sums of squares remaining after removing sums of squares due to replication and error.

Source of variation	PH	NB	NU	NFU	FWU	FWP	1000FW
Variety	11.63***	51.25*	10.70***	27.16***	84.26***	51.14***	90.63***
Year	87.35***	31.01ns	79.47***	26.74***	2.74*	30.37***	4.29***
Variety x Year	1.02***	17.74ns	9.82***	46.10***	12.99***	18.49***	5.07***

ns, * , ***: non-significant at the 0.05 and significant at 0.05 and 0.001 level, respectively; PH - plant height, NB - number of primary branches per plant, NU - number of umbels per plant, NFU - number of fruits per umbel, FWU - fruit weight per umbel, FWP - fruit weight per plant and 1000 FW -1000-fruits weight.

The effects of genotype, year, and genotype x year interaction were significant for all traits except for number of primary branches per plant in *microcarpum* accessions (Table 3) and for all studied traits in *sativum* genotypes (Table 4).

The influence of genotype was greater than the influence of year and genotype x year interaction for number of fruits per umbel, fruit weight per umbel and plant, and 1000-fruits weight in *microcarpum* accessions. For accessions from var. *sativum* genotypic effects were mainly observed for the traits number of primary branches, fruit weight per umbel and per plant.

Plant high was significantly affected by year conditions in both coriander varieties, explained in 87.95% in var. *microcarpum* and 78.95% in var. *sativum* of the total variation. There are reports indicating that plant height was tightly associated with coriander yield (Diederichsen, 1996; Tripathi *et al.*, 2010; Kassahun *et al.*, 2013). Reducing plant height allows producers to seed at higher rates, makes cultivation practices easier, and preventing lodging. The plant height of *microcarpum* accessions was higher compared to *sativum* genotypes (Table 5). According to the means of the

three years plant height was determined between 80.87 and 101.83 cm (average 92.50 cm) in *microcarpum* accessions and between 55.17 and 99.50 cm (average 75.75cm) in *sativum* accessions. The variation of plant high between *sativum* genotypes (CV=12.78%) was more than two time higher compare to *microcarpum* accessions (CV=6.01%).

Table 3. Analysis of variance of 7 yield-related traits of 20 coriander accessions from var. *microcarpum*. The portion of sums of squares (SS) attributed to genotype, year, and genotype × year interaction as a percentage of the total sums of squares remaining after removing sums of squares due to replication and error

Source of variation	PH	NB	NU	NFU	FWU	FWP	1000FW
Genotype	4.15***	36.36***	39.98***	62.76***	54.71***	70.51***	65.64***
Year	87.95***	2.77ns	33.67***	1.30***	5.39***	2.49***	2.45**
Genotype x Year	7.90***	60.87***	26.35***	35.93***	39.90***	27.01***	31.90**

ns, ** , ***: non-significant at the 0.05 and significant at 0.01 and 0.001 level, respectively; PH - plant height, NB - number of primary branches per plant, NU - number of umbels per plant, NFU - number of fruits per umbel, FWU - fruit weight per umbel, FWP - fruit weight per plant and 1000 FW -1000-fruits weight.

Table 4. Analysis of variance of 7 yield-related traits of 20 coriander accessions from var. *sativum*. The portion of sums of squares (SS) attributed to genotype, year, and genotype × year interaction as a percentage of the total sums of squares remaining after removing sums of squares due to replication and error

Source of variation	PH	NB	NU	NFU	FWU	FWP	1000FW
Genotype	15.84***	51.96***	31.62***	38.75***	64.16***	52.30***	41.75***
Year	78.86***	1.93**	26.87***	42.99***	12.07***	17.69***	33.78***
Genotype x Year	5.29***	46.11***	41.52***	18.25***	23.77***	30.01***	24.46***

ns, ** , ***: non- significant at the 0.05 and significant at 0.01 and 0.01 level, respectively; PH - plant height, NB - number of primary branches per plant, NU - number of umbels per plant, NFU - number of fruits per umbel, FWU - fruit weight per umbel, FWP - fruit weight per plant and 1000 FW -1000-fruits weight.

Traits number of branches per plant and umbels per plant are in particular interest in coriander breeding because correlation and path coefficient analysis indicated that these traits were ones of the most important traits as they exerted positive direct effect on seed yield (Singh *et al.*, 2006; Dyulgerov and Dyulgerova, 2013b). Number of primary branches was found to have a moderate genotypic effect, as well as a relatively large genotype x year interaction in var. *microcarpum* (Table 3). While this trait in var. *sativum*

demonstrated a nearly equal effect of genotype and environment (52% vs. 46%), with little genotype x year interaction (Table 4). Number of primary branches per plant varied from 6.58 to 9.57 in *microcarpum* genotypes and from 5.31 to 9.33 in *sativum* genotypes (Table 5).

Number of umbel per a plant was determined by the environment and interaction genotype x year for both varieties of coriander. Number of umbel per a plant ranged from 20.83 to 46.52 with an average of 34.89 in accessions from *microcarpum* variety and ranged from 23.99 to 39.54 with an average of 34.89 in accessions from *sativum* variety (Table 5).

Table 5. Average date for accessions from var. *microcarpum* and var. *sativum* (2010-2012)

	PH /cm/	NB	NU	NFU	FWU /g/	FWP /g/	1000FW /g/
			var. *microcarpum*				
Mean	92,50	8,12	35,78	34,89	0,18	3,05	5,37
Mininum	80,87	6,58	21,44	20,83	0,12	1,19	3,80
Maximum	101,83	9,57	50,80	46,52	0,29	4,30	7,17
CV%	6,01	11,32	32,88	23,14	28,39	28.48	18,46
			var. *sativum*				
Mean	75,75	7,65	31,62	28,94	0,24	2,22	9.75
Mininum	55,17	5,31	23,99	19.19	0,10	1,47	7.08
Maximum	99,50	9,33	39,54	46.43	0,39	4,97	11,33
CV%	12,78	14,48	19,70	22.90	30.67	44.44	13,51

PH - plant height, NB - number of primary branches per plant, NU - number of umbels per plant, NFU - number of fruits per umbel, FWU - fruit weight per umbel, FWP - fruit weight per plant and 1000 FW -1000-fruits weight.

Average number of fruits per umbel was 34,89 in *microcarpum* genotypes compared to 28,94 in *sativum* accessions (Table 5). The genotype has lower impact on the number of fruits per umbel in *sativum* accessions (Table 3) compared to *microcarpum* accessions (Table 4). According to Diederichsen (1996) low temperature and rainfall in flowering periods limited insect visiting and pollination. Since var. *sativum* flowered earlier than var. *microcarpum*, often period of flowering of this variety coincides with late spring rainfalls in Southeastern Bulgaria. Poor pollination and abortion of flowers due to spring rainfalls in flowering stage reduce the number of fruits per umbel in var. *sativum.* Yield losses caused by pollination problems in the years with late spring rainfall in var. *sativum*

for semi-arid climatic conditions of the Central Black Sea Region, Turkey has also been reported by Telci et al., 2006.

The influence of the genotype was greater for the fruit weight per umbel in var. *sativum* than in the var. *microcarpum*. Average fruit weight per umbel was 0.24 g in var. *sativum* and 0.18 g in var. *microcarpum*.

The effect of genotype for fruit weight per plant was greater in var. *microcarpum* (70.51%) than in var. *sativum* (52.30%). Fruit weight per plant in small-fruited accessions varied from 1.19 to 4.30 g with a CV=28.48%. This trait in large-fruited accessions range from 1.47 to 4.97 g with a CV=44.44%.

The 1000-fruits weight was between 3.80 and 7.17 g in var. *microcarpum* and between 7.08 and 11.33 g in *sativum* accessions. According Diederichsen and Hammer, 1994 *Coriandrum sativum* L. var. *sativum* has weight of 1000 fruits more than 10 g and *Coriandrum sativum* L. var. *microcarpum* DC. less than 10 g. In our study 4 of 20 accessions of var. *sativum* had average 1000-fruits weight more than 10 g, 5 genotypes between 9 and 10 g and 1 accession less 9 g. This can be explained by drought during the fruit maturation in 2011 and 2012 (Figure 2).

Conclusion

The results, based on the data of the 20 *microcarpum* and 20 *sativum* accessions indicated that var. *microcarpum* had higher yield potential under Southeastern Bulgaria climatic conditions. There were significant differences between the plant height, number of primary branches per plant, number of umbels per plant, number of fruits per umbel, fruit weight per umbel, fruit weight per plant and the 1000-fruits weight between the two coriander types.

The value of the 1000-fruits weight, fruit weight per umbel, fruit weight per plant and number of primary branches were determined by the coriander variety but other characteristics were more affected by the environment (year).

If the two coriander varieties are compared separately plant height was determined by the environment for both varieties of coriander. Number of primary branches was influenced by the genotype for var. *sativum* and by the year for var. *microcarpum*. The influence of the year was greater for the number of umbels per plant, number of fruits per umbel, fruit weight per plant, and 1000-fruits weight of var. *sativum* compared with var. *microcarpum*.

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