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Benefits of Environmental Conditions for Growing Coriander in Banat Region, Serbia

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As one of the oldest multi-purpose plants (spice, aromatic, honey and medicinal), coriander is widespread across Europe. Although in Serbia there are favorable conditions for its growth and development, it is grown on relatively small areas. During both investigated years it took more than 1200°C for transfer from vegetative to generative phase of development and over 2000°C for it to be ready for harvesting. Coriander is a photophilic plant, which requires around 1000 hours of light from sowing to ripening.. As for humidity, coriander grows well, if there are more than 200 mm of rainfall during growing season. In 2009. and 2010., the experiment carried out at the experimental field in Ostojićevo (Banat, Vojvodina province, Serbia) monitored the effect of parameters mentioned above on development of coriander plants, seed yield and essential oil content. The average yields of 1866 kg ha^{-1} (2009) and 2470 kg ha^{-1} (2010), and relatively high content of essential oil (1,06 % in both years) indicate a great potential of this plant species in Serbia, which is, however, greatly dependent on environmental conditions during year.

Keywords: *Coriandrum sativum*, yield, essential oil, temperature, precipitation, insolation, development stages.

Coriander has a long history of use. The Egyptians was used coriander for cooking and for children's digestive upset and diarrhea. The Greeks and Romans also used coriander to flavor wine and as a medicine [1]. Coriander produces a considerable quantity of nectar and thereby attracts many different insects for pollination, including honey bees – at one hectare of coriander they can collect about 500 kg of honey [2]. Today, coriander is primarily used in modern medicine as a flavoring agent in medicines and as a stomach soothing addition to more irritating compounds [3].

The uses of coriander fruits are related to their chemical composition. According to [2] the most important constituent is essential oil, whose content of the weight of ripe and dried fruits of coriander vary between 0.03 and 2.6%. The oil is obtained by hydrodistillation of the crushed fully ripe fruits, and mostly is used in the flavouring of a number of food products and in soap manufacture. The main components of essential oil are linalool (67.7% of total essential oil), α-pinene (10.5%), γ-terpinene (9.0%), geranylacetate (4.0%), camphor (3%). The other components (all with less than 2%) are: β-pinene, camphene, myrcene, limonene, borenol etc. [2]. The medicinal uses of coriander in the modern era is based upon linalool, eugenol, and methyl eugenol which had antimicrobial effects on some bacterias and fungus [4]. Eessential oil of coriander may be useful as natural bactericides for the control of bacterial diseases of plants and for seed treatment, in particular in organic agriculture [5].

Coriander is an annual herb originated from the Mediterranean countries and is nowadays mostly grown in Italy, India, Marocco and Eastern Europe [6]. Although in Serbia there are favorable conditions for its growth and development, it is grown on relatively small areas. Its production is possible in areas where the average daily temperature sum during growing season is at least 1700-1800°C [2]. Coriander is a photophilic plant, which requires 900-940 hours of light from germination to flowering [7]. As for humidity, coriander grows well, if there are more than 200 mm of rainfall during growing season [8].

Banat is located in the central part of the moderate thermal zone and is part of the Pannonian Plain. Mean annual air temperature is 11.3°C and 18.2°C during the growing season. Average rainfall is 563.4 mm, and the distribution of rainfall per month is evenly, which means there wasn't very rainy and very dry periods. Average insolation during the year is 2094 h, and during vegetation period 1483 h (Republic Hydrometeorological Service Serbia). The aim of this study was to evaluate the biological potential of coriander in the Banat region (Vojvodina province) in dependency on environmental conditions, primarily the effects of temperature, precipitation level and insolation on development of coriander plants, seed yield and essential oil content.

In two trial years (2009 and 2010), the experimental plots were in Ostojićevo (Banat region, Vojvodina province 45° 54' N, 20° 09' E), on soil classed as black soil: low carbonate – 2% $CaCO_3$, neutral soil with pH of 7.1, low humus soil type – 2.5%, with middle total nitrogen content – 0,16%) and optimal available of accessible phosphorus and potassium (22.4mg/100g soil and 21.7 mg/100g soil, respectively). Field experiment with different organic fertilizers applied (not shown in this paper) was set up according to the method of random block system with four repetitions; and the type of coriander used was domestic small-grained one (*C. sativum* L. *var. microcarpum* DC.), originating from Institute for Medical Plant Research "Dr. Josif Pančić", Belgrade, Serbia. Sowing was carried out during April, in continuous rows at the distance of 35 cm (5 rows, 3 m long make one experimental plot). After sprouting, crops were attenuated to 4-5 cm in order to obtain the optimum number of plants per square meter (circa 70 plants m^{-2}). As we applied all the principles of organic agriculture, weed control during the growing season was hoeing and hand weeding to early flowering stage of coriander.

Plant development was constantly monitored throughout trial. Number of days required for a plant to pass through different stages of development was noted: sowing-sprouting, sprouting-forming a rosete leaves, forming a rosete leaves-stem elongation, stem elongation-flowering, flowering-ripening. Duration of development phases was measured in days and was shown through the sum of average daily temperatures, sum of precipitation (mm) and insolation (h). Plant height was measured during flowering (10 plants from each variant of organic fertilization). Seed were harvested when primary umbels completely ripe in at least 90% of the plants. Harvest was performed manually by cutting off umbels from each experimental plot, and after additional drying of umbels they were manually threshed and separation of fruit was performed. The ripe fruit is determined by the essential oil content and the percentage of its fundamental components.

The GC analysis was carried out on a gass chromatograph HP 5890 series II, fitted with a FID and a column HP-5, 25m x 0.32mm, film thickness 0.52μm, carrier gas H_2, with flow rate 1mL min^{-1}, injector temperature 250°C (split ratio=1:50), detector temperature 280°C. The temperature programe was 40-280°C (heating rate 4°C min^{-1}). The GC/MS analysis was performed using chromatograph Hp G1800C, with GCD Series II, equipped with split/splilless injector and a column HP-5MS (Crosslinked 5% PH ME Siloxane) 30m x 0.25mm, film thickness 0.25μm, carrier gas H_2, with flow rate 0.9mL min^{-1}, injector temperature 250°C (split ratio=1:50), detector temperature 280°C. The temperature programe was 40-280°C (heating rate 4°C min^{-1}). Aqusition was carried out in a scan mode from 45:450.

The identification of each compound was carried out by comparison of RRT with retention times of standard substances and by matching mass spectral data of oil constiteunts with those in MS libraries (NBS library/Wiley), using a computer search and literature. The percentage composition of the oil was computed from GC (FID) peak areas without using correction factors.

Weather conditions during two experimental years (2009 and 2010) were significantly different. Climatic parameters (rainfall and temperatures) during vegetation period of coriander for both experimental year is shown on figure 1. In 2009, during vegetation period of coriander that lasted 107 days (from April 5th to Jule 21st) the sum of temperatures was 2008°C, whereas the sum of precipitation equalled to 203 mm and duration of insolation was 1019 hours. In 2010, the sum of temperatures was 363°C higher than in the previous year, while there was twice as much precipitation than the last year (501 mm) and there were 24 mm less hours of insolation than in 2009, while vegetation period lasted 9 days longer (from April 27th to Avgust 21st). Late growing season in 2010 was caused by high humidity in the soil (as already mentioned above).

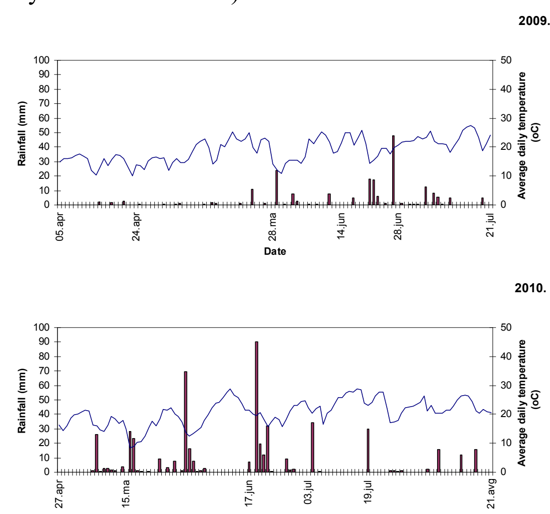

Figure 1: Daily values of average daily air temperature (°C) and rainfal (mm) recorded in Weather station Kikinda during vegetation season of corinader 2009 and 2010 (the dates on graph represent the beginning of some developmental stages coriander starting with sowing and finished with harvesting).

The graph in figure 2 shows the trend of the development stages of coriander in two trial years. In both investigated year sprouting was less than 3 weeks (19 and 18 days, i.e from April 5th to 24th 2009, and from April 27th to May 15th 2010). Another phenological phases are forming of basal leaves in rosete and steam elongation. First mentioned period in both years has lasted over a month (34 and 33 days, ie in 2009 from April 24th to May 28th, and in 2010 from May 15th to June 17th). Another mentioned period (stem elongation) has lasted 17 and 16 days. Caruba [8] referes that from sowing to emergence get more on 3 weeks, and vegetative phase lasted 40 to 146 days depending on sowing time and weather conditions during the year, and this is always more than 50% of total length cycle durations. In our investigation vegetative phase lasted 70 days in 2009 and 67 days in 2010, which makes 65.4% or 57.8% of total vegetative season of coriander. Generative phase start with flowering, and it was June 14th 2009 and Jule 3rd 2010. As we can see in 2009 this phase was shortier for 2 days than in 2010, but next phase – ripening in 2010 was longer for 10 days because of lower temperature and higher precipitation than in the same period in previous year.

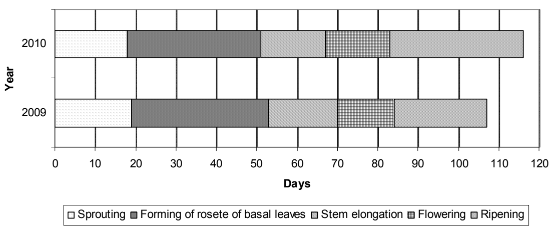

Figure 2: The duration (in days after sowing) of individual development stages in coriander according to year of cultivation (2009 and 2010).

Graph in figure 3 shows development trend of coriander plants during the period of both years, dependant on the sum of temperatures. As it may be observed, during both of these years it took more than 1200°C for coriander to transfer from vegetative to generative phase of development and over 2000°C for it to be ready for harvesting. According to coefficients of determination, duration of vegetation in both these experimental years was explained by sum of temperatures in 99%.

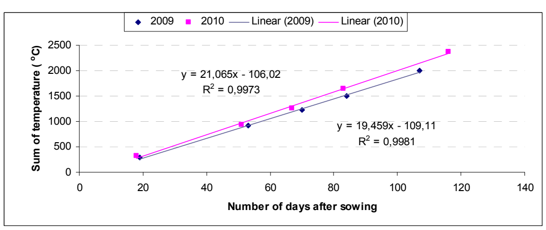

Figure 3: The duration of developmental stages of coriander plants depending on the temperature sum in both investigated years (2009 and 2010)

Precipitation manifested the highest variability during the two experimental years. Winter precipitation sum (November 2008 – February 2009) equalled to 162.2 mm, while in the period from March to coriander harvest in 2009 there was additional 27.2 mm of precipitation, which equals to total of 189.4 mm. During the vegetation season of coriander in 2009 a total of 202.9 mm of rain fell, out of which only 68.7 mm in vegetation period, while from the beginning of flowering until the harvest there was additional 134.2 mm of precipitation.

In 2010 there was much higher quantity of precipitation: winter precipitation 298.1 mm, from March until the harvest 60.6 mm, which equals to 349.7 mm or 84.6% more than the previous year. Significantly higher degree of moisture in the ground led to delayed harvest. During the vegetation season of coriander there was 451.3 mm of precipitation, out of which 336.8 mm in vegetation period and 114.5 mm in generative period. Graph in figure 4 shows development stadiums of coriander plants dependant on precipitation in both experimental years.

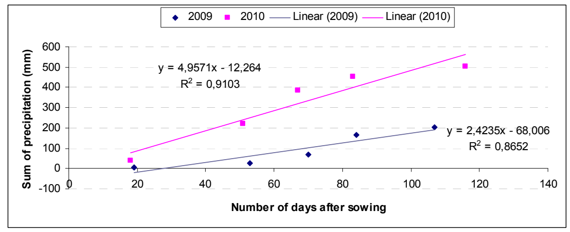

Figure 4: The duration of developmental stages of coriander plants depending on the precipitation in both investigated years (2009 and 2010)

During the vegetation phase in development of coriander 30.7% more insolation was registered in 2009 than in 2010, while during generative phase there was 36.3% more insolation in 2010 than in 2009. By application of simple linear model, regression analysis indicates the existence of high statistically significant influence of insolation on duration of the vegetation period of coriander, while the calculated determination coefficient is 99% for both experimental years (Figure 5).

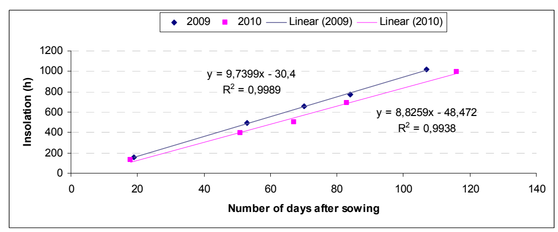

Figure 5: Developmental stages of coriander plants depending on the insolation in both investigated years (2009 and 2010)

Some morphological characteristic (plant height and number of umbels per plant) and seed yield are reported in table 1. If we observe the height of the plants we can establish that it is ranged from 60.0 cm to 76.9 cm. It is obvious that weather conditions (i.e. precipitation, temperature and insolation) significantly influenced the fact that plants in vegetation period in 2010 were averagely 14.9% taller than in 2009 (Table 1). By analysis of variance it was established that there are large statistically significant differences in height of plants between two experimental years ($p < 0.001$). In our research number of umbels per plants was equable (28.2 in 2009 and 28.9 in 2010). By using analysis of variance it was established that there is no statistically significant difference in the nnumber of umbels per plant in the two experimental years ($p = 0.680$). Higher seed yield of coriander was obtained in 2010 (averagely 2469 kg ha^{-1}) in relation to 2009 (average yield of 1866 kg ha^{-1}). There was statistically significant difference in yield between two experimental years ($p < 0.001$).

Table 1: Plant height, number of umbels per plant and seed yield of coriander in two investigated year (2009 and 2010).

Year	Plant height (cm)	Number of umbels per plant	Seed yield
2009	66.4[b]	28.2[a]	1866[b]
2010	76.3[a]	28.9[a]	2470[a]
Average	71.4	28.6	2168

The same letter used for tested years represents statistically equal value at the level of α=0,05.

According to data from the literature [9,10], plant height is ranged from 54.16 to 97.5 cm depending to experimental year and type of fertilizer in conditions of Egypt. By the same authors, number of umbels per plant is ranged between 27.45-113.7. In Mediterranean conditions, Caruba [8] referes that in draught year (about 200 mm rainfall from November to June) plant height is low frequency range around 58.3, and number of umbels per plant is only 9.7, and overall productivity was very low (less than 900 kg ha^{-1}). In two others experimental years with 420 and 505 mm rainfall during the same period, plants reached the height of 81.0 and 88.8 cm, respectively. Also, the number of umbels per plants was significant higher – 23.5 and 27.5, respectively, and production of seed yield is almost doubled (1706 and 2126 kg ha^{-1}). In our case, influence of weather condition on seed yield is very strong express like as above mention author – in the year with higher precipitation yield is 24.45% higher than in dry conditions.

Climatic conditions were not significantly affected the essential oil content in fruits as well as on its components. This can be explained by the relatively stable chemical composition of fruits and its more dependent on the genotype or variety. The average essential oil content was 1.06% (Table 4). Also, the percentage of limonene (average 2.31%), β-pinene (0.80%) and borenol (0.23%) was not significantly different according to the analyzed years. Effect as a factor expressed only in the content of linalool and α-pinene. Thus, the contents of the first in the less favorable (2009.) Amounted to 64.59%, and was for a 1.79% higher than in the 2010. In contrast, the content of α-pinene was significantly higher in the favorable climate 2010 (9.21%), or by 0.46% higher compared to year 2009.

Table 2: Essential oil content (%) and their composition (% of total essential oil) in the ripe coriander fruits

	2009	2010	Average
Essential oil content (%)	1,057[a]	1,064[a]	1,061
linalool (%)	64,59[a]	62,80[b]	63,70
α-pinene (%)	8,75[b]	9,21[a]	8,98
limonene (%)	2,18[a]	2,41[a]	2,31
β- pinene (%)	0,76[a]	0,83[a]	0,80
borenol (%)	0,24[a]	0,22[a]	0,23

The same letter used for tested years represents statistically equal value at the level of α=0,05.

When environmental conditions are favorable, vegetative growth generally receives resource priority over secondary metabolism and storage [11]. Obtained a high average yield of coriander and relatively high essential oil content in both analyzed years indicate a great potential of this plant species in Banat and Vojvodina Province. Further investigations must include improvement of production processes of coriander, primarily to reduce the effects of unfavorable climatic factors and to obtain high and stable production. Unfavorable conditions can be moderate by timely implementation of appropriate cultural practices (sowing date adjustment, applying fertilizer etc.). Also, given the increasing importance of this crop species in organic farming systems (which is in expanse in Serbia), it would be useful to conduct analogous studies from the aspect of organic production. Further efforts and research by being directed in that way.

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