Phenological development of coriander (*Coriandrum sativum* L.) depending on genotype and some meteorological factors

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Abstract
Coriander is one of the major essential - oil crops, grown in Bulgaria. The field experiment was carried out in the 2020 and 2021 crop years on alluvial-meadow soils, on the land of Voyvodinovo village – Maritsa municipality, Plovdiv City region. The experiment was set by the method of fraction parcels in four repetitions, with size of the crop parcel - 15 m2, after a predecessor - wheat. Five coriander varieties in two different years were tested; Jantar, Maroccan, Mesten drebnoploden, Thüringen, and Marino. The main phenological stages were recorded: sowing, germination, rosette, stem elongation, budding, flowering, fruiting and ripening. Depending on the dates of the phenological stages, the duration of the inter-stage periods is calculated. The obtained results showed that the phenological development of coriander is determined by the genotype as well as by the meteorological factors. The increased rainfall in the second year of the study elongates the ripening phase and generally the entire growing period, while the dry and hot summers in the first harvest year contribute to a shorter duration of the ripening period and in the whole of the growing season. From the study related to the phenological development of coriander, it can be concluded that in the conditions of Voyvodinovo village the average vegetation period of the crop is 120 days. The difference between the earliest and the latest variety is 5 days. The shortest growing season is with the Maroccan variety 117 days, and the longest - Marino -122 days. The longest is the interphase period fruiting - ripening (31,5 days) and the shortest- rosette - stem elongation (20 days).

Key words: coriander; phenology; growth stages; meteorological factors

INTRODUCTION

Bulgaria has a long tradition in the cultivation of medicinal and aromatic crops and the production of essential oils. The cultivated areas of essential oil and medicinal plants are about 1.1% of all harvested in Bulgaria. The largest share is occupied by the areas of coriander (*Coriandrum sativum* L.), which is an annual essential oil crop belonging to the family Apiaceae. Coriander originates from the Mediterranean region and is characterized by a wide range of distribution. (Hedberg et al., 2003; Lopez et al., 2008; Uhl, 2000).

During the whole growing season of coriander, especially in the flowering and stem-elongation phases, the temperature regime in combination with the available humidity is crucial for obtaining a high yield. (Dyulgerov & Dyulgerova, 2016; Ghamarnia & Daichin, 2013; Nowak & Szemplinski, 2014). The optimum temperature for germination and initial growth of coriander is 20-25^{o}C. (Singhania et al., 2006). According to Sharma et al. (2003), the deviation from the optimal temperature for a given phenophase affects physiological processes, including photosynthesis and plant respiration. Relatively lower temperatures during the vegetative phase and higher temperatures during the generative phase are the most favorable for the development of coriander. (Tiwari et al., 2002).

Dyulgerov & Dyulgerova (2016) found that high average daily temperatures have the strongest negative impact on the productivity of coriander during the period from germination to stem elongation and during the period of fruit ripening. Higher rainfall favors the formation of higher yields in all vegetation subperiods, except flowering. The critical period for the formation of the yield in terms of the amount of precipitation is the period of stem elongation. High rainfall and high relative humidity during the flowering period have a negative effect on plant productivity, as they lead to sterility and abortion of flowers (Gramatikov et al., 2005).

The aim of the present study was to study the influence of the variety and the main meteorological factors - temperature and precipitation, on the phenological development of coriander (*Coriandum sativum* L.).

MATERIALS AND METHODS

The phenological development of coriander varieties was traced on the basis of data from a field experiment conducted in the period 2020 - 2021 in the village of Voyvodinovo, Maritsa municipality, district Plovdiv, on alluvial-meadow soil type.

The experiment was based on the method of fractional plots in four replicates with the size of the harvest plot of 15 m^2, after the predecessor wheat. Five varieties of coriander were included in the study: Jantar, Maroccan, Thüringen, Marino and Mesten drebnoploden, grown according to accepted agricultural techniques (Gramatikov et al., 2005). Tillage includes, stubble sole in July and plowing at depth of 20-22 cm in - September, double pre-sowing cultivation with harrowing, the latter was at depth of 5-6 cm (Dallev & Ivanov, 2015).

Phosphorus fertilizer was applied before plowing - 80 kg/ha, and nitrogen fertilizer with the last pre-sowing treatment - 10 kg/ha.

Annually sowing was carried out in the period 10-20 February with a row spacing of 12-15 cm and sowing rate of 250 hp m^2 at a depth of 3-4 cm.

The phenological development of coriander varieties was reported at the onset of the main phenophases (Diederichsen, 1996), as follows: sowing, germination, rosette, stem elongation, budding, flowering, fruiting and ripening. Depending on the dates of occurrence of the phenological phases, the duration of the interphase periods was calculated. For each of the varieties the duration was determined in days of the following periods: sowing-germination - until the date of germination of 50% of the plants; drooping - rosette; rosette - stem elongation; stem elongation - flowering; flowering - fruiting; fruiting - fruit ripening, as well as the length of the growing season - from the date of germination to full maturity of 75% of the fruit.

The data on the main climatic factors - the amount of precipitation and the average daily temperature values for the period 2020-2021, affecting the growth and development of plants are presented in Figure 1 and Figure 2. They show that in terms of rainfall during the growing season Coriander period, values are reported that exceed by 55.7 mm (in 2020) and 59 mm - (in 2021) those for the multiannual period, but are unevenly distributed. During the period II-IV, the amount of precipitation in 2020 and 2021 is 103 mm and 23 mm more than reported for the multiannual period, while in May-July 2020 it is 47.3 mm less, and for

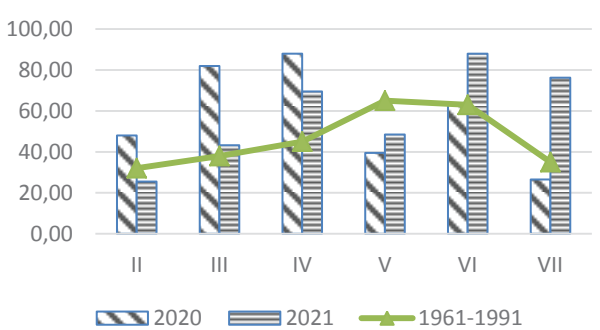

Figure 1. Rainfall, mm

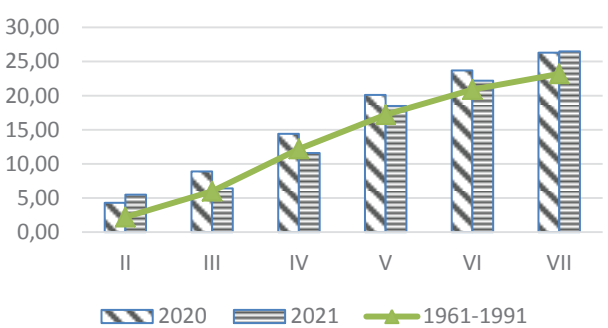

Figure 2. Average monthly air temperature, ^{0}C

2021 - 35.4 mm more than reported for the period 1961-1991.

Comparing the two economic years, it is found that the amount of rainfall is higher in 2020 during the growing season, while in 2021 during the generative one.

In the economic years 2020 and 2021 the reported average daily temperatures during the coriander vegetation are close or slightly higher than for the multi-year period, as significant deviations from the culture requirements are not observed and fully meet heat requirements from sowing to ripening.

RESULTS AND DISCUSSIONS

During its vegetation, coriander goes through the following main phenological phases: germination, rosette, stem elongation, budding, flowering, fruiting and fruit ripening. The aim of the present study is to study the phenological development of corinader varieties of different origins. The sowing of the seeds during the two harvest years in our experimental field was carried out on 19.02.2020 and 23.02.2021, respectively, taking into account the key factor for successful development of the crop - temperature. (Tiwari & Singh, 1993).

The optimum temperature for seed germination in coriander is 20-25 about ^{0}C (Sharma et al., 2003). The period from sowing to germination is slow and long, despite the sufficient amount of moisture and temperature values higher than the multiannual period. This period requires 18-20 to 35 days (Gramatikov et al., 2005).

The dates of occurrence of the phenological phases of coriander development and the variation in the duration of the phenophases between the studied coriander varieties during the first two years of the study are presented in Table 1, Figure 3 and Figure 4.

The duration of the phenological subperiods strongly depends on the influence of climatic conditions during the individual years of the study. (Dyulgerov & Dyulgerova, 2013). The data show that the average length of the period from sowing to germination for all varieties in 2020 is 25.4 days, ranging from 21 days for Marrocan to 29 days for Mesten drebnoploden and Marino. For the varieties Jantar and Thüringen, the duration of the sowing-germination period is 24 days.

Table 1. Dates of occurrence of phenological phases of coriander development

Phenological stages	Varieties					Year
	Jantar	Thüringen	Marino	Mesten drebnoploden	Maroccan	
sowing	19.02.2020	19.02.2020	19.02.2020	19.02.2020	19.02.2020	2020
germination	14.03.2020	14.03.2020	19.03.2020	19.03.2020	19.03.2020	
rosette	03.04.2020	03.04.2020	18.04.2020	05.04.2020	03.04.2020	
stem elongation	25.04.2020	25.04.2020	09.05.2020	23.04.2020	20.04.2020	
budding	19.05.2020	19.05.2020	30.05.2020	15.05.2020	10.05.2020	
flowering	23.05.2020	23.05.2020	02.06.2020	20.05.2020	13.05.2020	
fruiting	14.06.2020	13.06.2020	25.06.2020	08.06.2020	30.05.2020	
ripening	10.07.2020	11.07.2020	17.07.2020	13.07.2020	03.07.2020	
growing season	**119**	**120**	**121**	**117**	**115**	
sowing	23.02.2021	23.02.2021	23.02.2021	23.02.2021	23.02.2021	2021
germination	21.03.2021	21.03.2021	25.03.2021	26.03.2021	18.03.2021	
rosette	09.04.2021	09.04.2021	21.04.2021	12.04.2021	06.04.2021	
stem elongation	29.04.2021	29.04.2021	13.05.2021	01.05.2021	24.04.2021	
budding	23.05.2021	23.05.2021	01.06.2021	23.05.2021	18.05.2021	
flowering	30.05.2021	29.05.2021	04.06.2021	29.05.2021	21.05.2021	
fruiting	21.06.2021	21.06.2021	29.06.2021	18.06.2021	08.06.2021	
ripening	19.07.2021	21.07.2021	26.07.2021	26.07.2021	15.07.2021	
growing season	**121**	**123**	**124**	**123**	**120**	

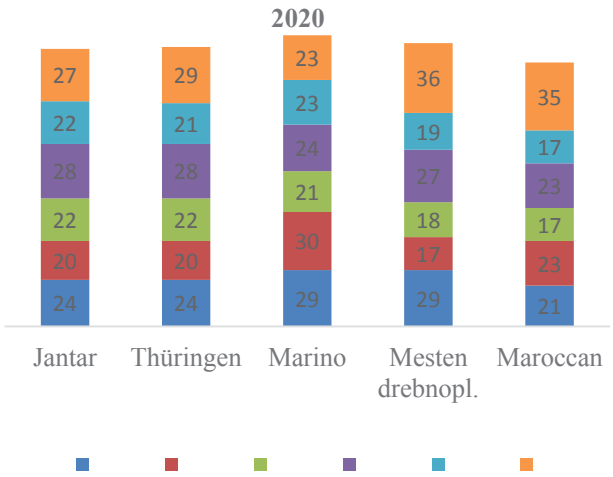

Figure 3. Duration of the phenophases, days 2020

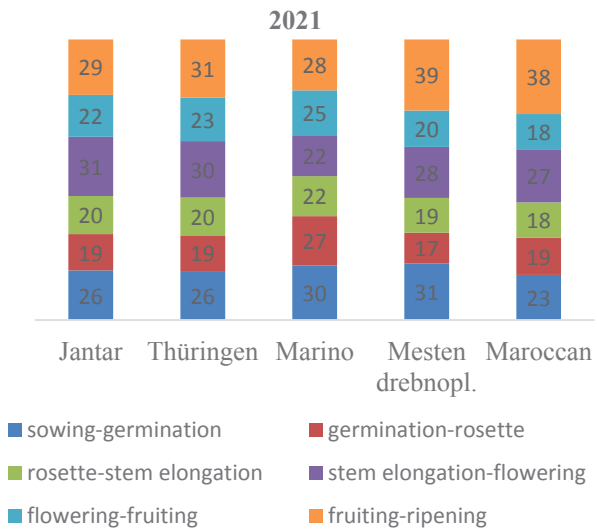

Figure 4. Duration of the phenophases, days 2021

The lower amount of precipitation 43.25 mm and the lower temperature 6.3^{0}C during the sowing-germination period of 2021 created conditions for the plants of all varieties to germinate by an average of 2 days slower, as the earliest sprouting is variety Maroccan - 23 days after sowing, followed by varieties Thüringen and Jantar - 26 days, variety Marino - 30 days and the latest sprouted variety is Mesten drebnoploden - 31 day.

The formation of 8-10 leaves (rosette phase) begins in the first year at the earliest 17 days after emergence for the variety Mesten drebnoploden and latest 30 days - for the variety Marino. For the other varieties the interphase period is from 20 to 23 days. In the second year, the shortest and longest periods of the rosette phase are again distinguished by the Mesten drebnoploden variety with 17 days and the Marino variety with 27 days.

The interphase period rosette - onset of stem elongation varies from 17 (Maroccan variety) to 22 (Jantar and Thüringen varieties) days in the first year, from 18 days (Maroccan variety) to 22 days (Marino variety) in the second year and takes place at an optimal combination of temperature and humidity.

Stem elongation in the studied varieties occurs on average about 42 days after germination in 2020 and 40 days in 2021. In the case of different varieties, the duration of the period until the appearance of the stem is from 35 days (2020) and 36 days (2021) in Mesten drebnoploden variety to 51 days (2020) and 49 days (2021) in Marino variety. During the two experimental years, the duration of stem elongation and branching was from 20 days in the Maroccan variety till to 24 days in the varieties Jantar and Thüringen.

The flowering in 2020 in the case of coriander varieties it starts on average 68 days after germination, as the shortest is in Mesten drebnoploden - 62 days, and the longest in Marino - 75 days, similarly in 2021. The earliest flowering starts with the Mesten drebnoploden variety - 64 days, the latest with the Marino variety - 71 days and the average for the year - 67.6 days. The interphase period of stem - flowering in the studied varieties varies in the first year from 23 days for Maroccan variety to 28 days for varieties Jantar and Thüringen and from 22 days for Marino variety to 31 days for Jantar variety in the second year. The duration of this period for the Mesten drebnoploden variety is 27 days in 2020 and 28 days in 2021.

The flowering in coriander varieties lasts from 17 to 23 days in 2020 and from 18 to 25 days in 2021. The accelerated course of this process in both experimental years is due to the insufficient amount of precipitation during the period.

The duration of the interphase period of fruit formation - ripening in the tested varieties in 2020 is from 23 days at Marino to 36 days at Mesten drebnoploden. For the varieties Jantar, Maroccan and Thüringen, this period lasts 27, 35 and 29 days, respectively. The higher amount of precipitation in the months of June - 88 mm and July - 76.25 mm in

2021 led to an extension of the interphase period of fruiting - ripening in all tested varieties by an average of 3 days.

The average duration of the period from germination to ripening in 2020 in the studied varieties is 118.4 days, the shortest is period at Maroccan variety - 115 days, followed by variety Mesten drebnoploden - 117 days and Jantar - 119 days, Thüringen - 121 days, and the longest is at Marino variety - 121 days. As a result of the higher rainfall in 2021 the vegetation period of all varieties is 3-6 days longer compared to 2020 and varies from 120 days for the Maroccan variety to 124 days for the Marino variety.

CONCLUSIONS

The studied factors - genotype and climatic factors, influence the phenological development of coriander. The higher amount of precipitation in the second year of the study, prolong the ripening phase and the whole growing season, while the dry and hot summers in the first harvest year contribute to a shorter duration of this period.

From the study related to the phenological development of coriander it can be concluded that in the conditions of Plovdiv district the average vegetation period of the crop is 120.3 days. The difference between the earliest and the latest variety is 5 days. The shortest growing season is in the Maroccan variety - 117.5 days on average, and the longest one is in the Marino variety - 122.5 days. The longest is the interphase period of fruit formation - fruit ripening - 31.5 days, and the shortest period of rosette - stem elongation - 19.9 days.

The study was presented at the 2022 International Scientific Conference entitled "140 Years of Agricultural Science in Sadovo and 45 Years Institute of Plant Genetic Resources", which was held in Plovdiv from September 28 to September 29, 2022.

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