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Original article

Influence of Fertilization and Environmental Conditions on the Phenological and Morphological Development of Carrot Plants During Seed Production[1]

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Abstract

The main goal of the present study was to establish the influence of different rate of fertilization with nitrogen, phosphorus and potassium and interaction with the environmental conditions and their effect on phenological development of the carrot seed plant. The experiment was carried out in the Experimental fields of the Agricultural University of Plovdiv, Bulgaria with carrot variety Tushon. The plants were grown by conventional technology with steckling. Two way of fertilization was applied. In the first one, the total amounts of fertilizers were put in the autumn soil treatment and in the second one, it was split twice - in autumn the half and the other in spring in stecklings planting. The phenophases of beginning and mass: developed of leave rosette; appearing, flowering, developed and maturity of the seed of central, primary, secondary and tertiary umbels were recorded. Morphological characteristic of seed plant as a high and total vegetative weight was established. The average daily temperature, maximal and minimal temperature, rainfall and the hydrothermal coefficient of vegetation period were calculated. The relations between phenological behaviors and morphological development and elements of climatic conditions were determinated. The significance of the environmental conditions on the phenological development, especially for appearing of the umbels and flowering as well as the maturity of the seeds was established.

Keywords: Seed, Phenophases, Climate conditions, Development, Temperature.

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INTRODUCTION

According to Sparks et al. (2000) the phenological development of plants has a direct relation to temperature and in recent times, in connection with climate warming, the flowering of most species began earlier. The lower temperature limit for individual crops should be determined according to their development in the most southern regions of their distribution. The information about phenological development under specific climatic conditions, as it maintains Sadras et al. (2016) provides an opportunity for growers to direct plant development in the desired direction.

Based on a study of phenological development and temperature changes in the cultivation of six varieties of carrots for seed production, Florea and Stefănescu (2009) concluded that the results of the phenophases and the necessary temperature can serve to determine the appropriate area with optimal conditions for development of this crop. The decrease of the temperature below the optimum for the development of carrots according to Potapsky (2015) causes a delay in the duration of the individual phenophases. The fluctuation of day and night temperature has a great influence on the carrot seed production (George, 2004). An increase in day/night temperature form 20/10^{0}C to 30/20^{0}C reduced the mean weight per seed (Gray et al., 1988). The receptivity of the stigma in hybrid carrot seed production is directly related to the temperature and the phenophases of flower development. Chira et al. (2008) found that the male sterile forms at temperatures above 30° C retain their receptivity for a shorter period. Relatively longer receptivity demonstrates the petaloid form of male sterility.

Climatic specific features are of particular importance for the proper seed production zoning, especially for seed-to-seed technology (Duczmal and Tylkowska, 1997). Kahangi et al. (1996) found a strong effect of the temperature 9°C for the 2-8 week period on the development of carrot seed plants. In the case of seed production in higher temperature areas, 50% of the seed stalk is matured more rapidly. A warmer climate significantly improves the height of the plants and the obtained seeds are of superior quality. The changes in temperature have a particularly strong impact in the early stages of carrots development. Corbineau et al. (1995) find that their seeds germinate in the temperature range of 5-35°C, but at 5-10°C and above 30°C the germination is greatly reduced.

The mineral fertilization has a great importance in the production of carrots. Satyaveer et al. (1994) point out that nitrate fertilization levels of 80 and 120 kg/ha^{-1} of nitrogen cause an increase in the formation of more primary and secondary order umbels, which have a share between 21,67 and 12%, respectively, in total productivity. In experiments with fertilization of carrot seed production crops carried out under the conditions of the Republic of Belarus, Stepuro (2008) concludes that the highest yield is obtained by application of $N_{45}P_{55}K_{75}$ and $N_{55}P_{65}K_{90}$ kg/ha both with and without the previous fertilization with manure at a rate of 30 t/ha^{-1}.

Materials and Methods

The experiments were carried out in the Experimental Fields and the laboratories of the Department of Horticulture and of the Department of Botany and Agro-meteorology at the Agricultural University-Plovdiv, Bulgaria in the period of 2017-2018 with carrot variety Tushon. The following variants with the different amount in kg/da and term of fertilization – once or twice were tested:

Once fertilization	Twice fertilization
1. $N_0P_0K_0$ – control	
2. $N_7P_{14}K_{15}$ (recommended)	
3. $N_5P_9K_{10}$	11. $N_5P_9K_{10}$
4. $N_5P_9K_{20}$	12. $N_5P_9K_{20}$
5. $N_5P_{19}K_{10}$	13. $N_5P_{19}K_{10}$
6. $N_5P_{19}K_{20}$	14. $N_5P_{19}K_{20}$
7. $N_9P_9K_{10}$	15. $N_9P_9K_{10}$
8. $N_9P_9K_{20}$	16. $N_9P_9K_{20}$
9. $N_9P_{19}K_{10}$	17. $N_9P_{19}K_{10}$
10. $N_9P_{19}K_{20}$	18. $N_9P_{19}K_{20}$

The different levels of fertilization were determined on the base of recommended for carrot seed production in Bulgaria fertilizer quantity ($N_7P_{14}K_{15}$). In the once fertilization, the phosphorus and potassium were applied during the autumn plowing and the nitrogen before planting of stecklings (roots), while in the case of twice fertilization, half of the phosphorus and potassium fertilizers were placed in the autumn deep plowing, the other half before planting of the stecklings and the nitrogen - half in the planting of stecklings and the rest when the first appearance of the inflorescence. The triple superphosphate (P_2O_5 46%), potassium sulfate (K_2O 50%) and ammonium nitrate (N 34%) were applied.

Soil cultivation included: at the end of October-beginning of November disc harrow processing, fertilizing with mineral fertilizers under the experimental scheme, autumn deep plowing of 28 cm, on the beginning of March the furrows through 80 cm with previous applied of the fertilizers according to the variants of the experiment were formed.

The stecklings were grown with sowing at the end of June with 7000 g/ha by scheme 60+20+20+20+20+20x3 cm. In a stage of 3 true leaves, the plants were thinning, while in a stage of 5 leaves and 25 days later they were fertilized twice with ammonium nitrate in dose 110 kg/ha. The stecklings were harvested in the begining of November and storage during the winter in soil-covered pits. The stecklings were planted on 27.03 2017 and on 13.04.2018 on the scheme 80 x 30 cm, with spatial distance between each variant of 80 cm. The experiments took place in four replicates and the size of the experimental plot was 7 m^2. Each necessary agro-technological practice during vegetation was applied.

The begining and mass of the following phenophases: formation of the leaf rosette; appearance, flowering, seed formation and maturity of the seeds of central (king) umbel, primary, secondary and tertiary umbels were observed. The beginning of the appearance of the respective phase was reported at its onset in 10% of the plants and mass - in 70% (Dimova and Marinkov, 1999).

The high and total vegetative weight (weight of stem and leave) of seed stalk in a mass flowering of secondary umbel to the begining of tertiary once on 15 stalks of each variant were determined.

The daily climatic information about 2017 and 2018 from Meteorological station - Plovdiv in the Experimental fields of Agricultural University, Plovdiv was used. The changes in the main meteorological factors during the vegetation period were determined. The basic climatic factors were air temperature (average daily, maximum and minimum), the sum of precipitations (about periods between different stages of development and per day of the period) and air relative humidity. The agro-climatically parameters for the development of carrots established. The Hydrothermal coefficient (HTC) as a complex character for temperatures and humidity were applied for characterization of the moisture condition (Selianinov, by Kouzmova, 2003). HTC<1.0 characterize the drought conditions, HTC>1.6 characterize the over-wet condition. Statistical analysis for agrometeorological conditions was done through Excel with Visual Basic; for the yield by ANOVA.

Data of the study were subjected to analysis of variance, and the least significant differences between means were calculated by the Fisher test at $p = 0.05$. A method for ANOVA is described by Fowel and Cohen (1992).

Results

In 2017 the differences at the beginning of the formation of the leaf rosette are small (Table 1). Earlier it was formed in about three days in the $N_5P_9K_{20}$ variant, once fertilization and a more significant delay were observed when the fertilizer was applied twice at the highest doses of $N_9P_{19}K_{20}$. In 2018, all the variants with twice fertilization developed the rosette a little earlier (Table 2). A similar trend has been observed in its mass formation. At the earliest during the two years of study, the central (king) umbel was formed by fertilization with $N_5P_9K_{10}$ (once), i. e. with a lower quantity of the nutrient elements, 38 and 44 days after planting, respectively, which was 9 days less than the controls in 2018. In the case of twice fertilization, the best results were obtained in variants $N_9P_{19}K_{10}$ and $N_9P_9K_{20}$ respectively in 2017 and 2018. The earlier mass appearance of a central umbel, compared to controls, was registered in 2018, especially also in combination $N_9P_9K_{20}$ (twice), as well as $N_5P_9K_{10}$ (once) - overtaking 11 days.

In both years, the beginning of the appearance of primary umbels was more rapid in twice fertilization. The term of fertilization was of particular importance in 2018 for the variant with a higher nitrogen fertilization - $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$ - 9 days earlier compared to the once fertilization. Good results also indicated $N_9P_9K_{10}$, with a higher nitrogen content too. In the above-mentioned variants, the accelerated development was established also observed in the mass formation of the primary umbels, 8 days earlier for combination $N_9P_{19}K_{10}$ twice fertilization. In 2017, in most of the variants except for $N_5P_9K_{20}$, a delay in this phenophase was reported.

Table 1. Phenological observation of vegetative and generative development of carrot seed stalk in 2017 (date after planting)

Variants	Leave rosette		Central umbel		I order umbel		II order umbel		III order umbel	
	begin-ning	mass	begin-ning	mass	begin-ning	mass	begin-ning	mass	begin-ning	mass
Once fertilization										
1	04.4	10.4	08.5	18.5	14.5	18.5	21.5	28.5	10.6	16.6
2	04.4	08.4	06.5	18.5	13.5	17.5	20.5	27.5	10.6	15.6
3	04.4	13.4	12.5	20.5	17.5	21.5	24.5	01.6	11.6	20.6
4	01.4	12.4	04.5	22.5	11.5	18.5	17.5	28.5	07.6	16.6
5	04.4	13.4	11.5	20.5	16.5	20.5	20.5	28.5	09.6	18.6
6	04.4	13.4	10.5	20.5	16.5	20.5	20.5	27.5	09.6	19.6
7	04.4	14.4	10.5	18.5	16.5	20.5	20.5	28.5	10.6	17.6
8	04.4	13.4	10.5	20.5	16.5	20.5	19.5	27.5	09.6	13.6
9	04.4	12.4	08.5	18.5	14.5	18.5	19.5	26.5	08.6	19.6
10	04.4	13.4	08.5	17.5	14.5	18.5	18.5	26.5	12.6	21.6
Twice fertilization										
11	04.4	12.4	08.5	21.5	14.5	21.5	19.5	26.5	04.6	15.6
12	06.4	12.4	12.5	20.5	16.5	20.5	19.5	28.5	11.6	20.6
13	06.4	13.4	12.5	20.5	17.5	21.5	20.5	27.5	12.6	18.6
14	04.4	14.4	06.5	17.5	12.5	20.5	19.5	26.5	06.6	13.6
15	04.4	12.4	06.5	17.5	12.5	20.5	17.5	27.5	07.6	15.6
16	05.4	13.4	12.5	22.5	17.5	23.5	22.5	29.5	07.6	18.6
17	04.4	11.4	04.5	18.5	10.5	17.5	17.5	27.5	10.6	16.6
18	09.4	15.4	12.5	17.5	17.5	22.5	22.5	30.5	08.6	17.6

Twice fertilization in 2018 also causes a more rapid onset of secondary- umbels. It appeared between 48 days after planting in twice fertilization with higher doses of nitrogen and phosphorus up to 61 days for $N_5P_9K_{20}$. In the first year this was found, albeit less, in the same variants, but for the once application. Approximately 4 to 8 days more were required for the mass appearance of this phenophase to occur, the least was this period when the $N_5P_9K_{20}$ was applied twice. Again, in the case of twice fertilization in 2018, there was an earlier development of the secondary order, between 53-60 days after the planting, while for the reciprocal variations with once fertilization this period was 62 and 64 days.

Faster starts beginning and mass development of tertiary umbels in 2018. The beginning is still 61 days after planting by twice fertilization $N_9P_{19}K_{10}$ to 81 days in once fertilization with $N_5P_{19}K_{20}$, while in the previous year was slower, especially in once fertilization variants. For the occurrence of mass formation of tertiary umbels fewer days after their beginning, were needed in 2018, in most of the variants it is between 3-4 days and only in twice fertilization with $N_9P_9K_{20}$, the period between this phases was longer and reached up to 11 days. More days were recorded also for the mass formation of these umbels in 2017.

In flowering of the central umbels, differences between the years of study were observed (Table 3 and Table 4). In 2017, most of the variants with once fertilization as well as twice one were with more delay flowering on this umbel, especially with $N_9P_9K_{10}$ (once). In 2018, the central umbel of the fertilizer plants began to flowering significantly earlier, mostly with the combination of $N_5P_9K_{10}$ for both fertilization terms and also in twice with $N_9P_9K_{20}$ – overtaking with 6 days less in comparison to the control. Similar differences were found in the mass flowering of this umbel.

Table 2. Phenological observation of vegetative bad generative development of carrot seed stalk in 2018 (date form planting)

Variants	Leave rosette		Central umbel		I order umbel		II order umbel		III order umbel	
	begin-ning	mass	begin-ning	mass	begin-ning	mass	begin-ning	mass	begin-ning	mass
Once fertilization										
1	29.4	06.5	23.5	30.5	30.5	06.6	11.6	17.6	26.6	02.7
2	29.4	04.5	23.5	28.5	31.5	04.6	12.6	17.6	29.6	02.7
3	27.4	02.5	14.5	19.5	22.5	30.5	31.5	08.6	19.6	22.6
4	01.5	06.5	27.5	30.5	30.5	02.6	05.6	12.6	26.6	30.6
5	28.4	03.5	15.5	23.5	23.5	29.5	03.6	13.6	20.6	24.6
6	28.4	03.5	22.5	27.5	30.5	05.6	15.6	19.6	03.7	06.7
7	29.4	05.5	23.5	26.5	30.5	04.6	11.6	16.6	25.6	01.7
8	01.5	05.5	21.5	26.5	29.5	02.6	09.6	14.6	18.6	22.6
9	28.4	03.5	22.5	28.5	30.5	04.6	11.6	16.6	20.6	24.6
10	01.5	08.5	16.5	22.5	27.5	30.5	05.6	12.6	26.6	30.6
Twice fertilization										
11	27.4	02.5	13.5	19.5	21.5	30.5	08.6	13.6	20.6	26.6
12	25.4	01.5	15.5	28.5	30.5	05.6	13.6	17.6	27.6	01.7
13	28.4	03.5	20.5	24.5	29.5	04.6	08.6	13.6	22.6	26.6
14	25.4	01.5	19.5	22.5	24.5	30.5	10.6	15.6	19.6	26.6
15	29.4	05.5	23.5	28.5	26.5	02.6	05.6	12.6	22.6	26.6
16	25.4	03.5	09.5	19.5	20.5	28.5	31.5	08.6	17.6	28.6
17	27.4	05.5	21.5	25.5	21.5	27.5	31.5	05.6	13.6	18.6
18	27.4	03.5	15.5	20.5	23.5	29.5	31.5	05.6	16.6	20.6

Close to this trend are the results for the flowering of the primary umbel. In the first year, differences both in the beginning and in the mass flowering are weaker. In the next growing season, fertilization accelerates significantly flowering. All variants except $N_5P_9K_{20}$ flowered earlier than non-fertilized plants. More importantly, this was in the case of twice fertilization at the higher levels, as early as the beginning and the mass flowering started at $N_9P_9K_{20}$, respectively by 16 and 13 days than the control. Once fertilization with $N_5P_9K_{10}$ and $N_5P_{19}K_{10}$ causes early flowering with 12 days.

In difference to the central and the primary order, the secondary umbels demonstrated an improvement of the flowering in both vegetation, although there were small differences between the years. Fertilization helps for an earlier flowering of these umbels, except $N_5P_9K_{20}$ during both seasons and $N_5P_{19}K_{10}$ in 2017. In 2018, the days of planting to the flowering of secondary umbels were significantly less, the shortest time was, from 61 days for $N_9P_{19}K_{10}$ (twice), while 16 days more were needed in the same variant but in the previous year. In 2017, the period between the mass flowering of the primary and the secondary order umbels was considerably shorter, for the individual variants it was between 7 and 12 days, while in the next year it is extended and even for N5P19K20 it reaches 24 days.

The beginning of the flowering of the tertiary inflorescences is characterized by small differences between the variants. More importantly, with 6 days, was the delay on once fertilization with $N_5P_{19}K_{20}$ in 2018. The fertilization in all variants in 2017 promotes faster beginning and mass flowering, the earliest occurring in after a once application of the $N_9P_9K_{10}$, and twice for the combination with the highest levels. The period between the mass flowering of the secondary and tertiary order of umbels was shorter in the second year, in contrast to the primary and secondary order.

Fertilization has no particular influence on the formation of seeds from the central umbel and in some of the variants, especially in the first year, there was a small delay. There were differences between both vegetations. At the earliest in 2017 it occurred in some of the combinations with lower amounts of nitrogen, in once fertilization at $N_5P_9K_{20}$ and in twice one with $N_5P_{19}K_{20}$. In the next year, however, in all the tested variants, seed formation began significantly earlier than in the non-fertilized control. The overtaking was with 13 and 9 days for the beginning and with 5 days for it mass, established for $N_5P_9K_{10}$ and $N_9P_{19}K_{20}$ for both once and twice. Despite the shorter deadline for this phase in 2018, for both years from mass flowering to mass seed formation, an average was needed approximately 10 to 11 days and 10 days for once and twice fertilization respectively.

A stronger positive effect of the applied fertilization ways was into account in the formation of the seeds from the primary order, especially in 2018. The best results were recorded in the once and twice insertion of $N_5P_9K_{10}$ - a decrease of the deadline by about 10 days, followed by combinations $N_5P_{19}K_{20}$ and $N_9P_{19}K_{20}$. More accelerate the twice fertilized plants are converted from mass flowering to mass formation of the seeds, and the differences between a central umbel and the primary order are approximately 10 days. Twice fertilization accelerates the seed formation of the secondary umbels. At both terms, in 2018, this process started at the earliest in $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$. During the previous vegetation, a higher overtake were recorded for $N_5P_9K_{20}$ (once) and for $N_5P_{19}K_{10}$ (twice). A similar trend is also observed in a tertiary order umbels where, in 2018, fertilization accelerates seed formation more strongly. With 12 days earlier it occurred as a result of once fertilization with $N_5P_9K_{10}$ and $N_9P_{19}K_{10}$ and twice with $N_9P_{19}K_{20}$. In the previous year, as well as the secondary order, the once fertilization with $N_5P_9K_{20}$ and twice with $N_5P_{19}K_{20}$ and with $N_9P_9K_{20}$ reduced this period with 4 days. In most cases, it may be thought that the presence of higher amounts of potassium helps accelerate the formation of seeds.

The ripening of the seeds from the central umbel in most of the variants in both years was more rapid. In 2018, it first began as a result of a once applied of $N_9P_9K_{20}$, followed by $N_5P_9K_{20}$ and $N_9P_{19}K_{20}$. The obtained results in the first year were weaker, but in this vegetation, the variant $N_5P_{19}K_{10}$, regardless of the fertilization periods, reduces the days required for ripening. For the mass maturation of the seeds from the central umbels from the time of planting the stecklings in 2018, between 77 days (once

$N_9P_9K_{20}$) and 90 days for the non-fertilized control was needed, while in 2017 this period was significantly longer between 106 and 110 days. As a result of the tested fertilization, the primary umbels in 2017 influenced weaker, but still, with the exception of N5P9K20, the improvement was noted in this phase. Higher differences from 6-7 days than the control were established for the next vegetation in N5P9K10 and N9P9K20 (once) as well as in twice for N5P9K10, N5P19K20 and N9P19K20. From planting until ripening of primary order seed in 2017, between 107 days for N9P19K20 (once) and 110 for N9P9K10 (twice) was required, while for non-fertilized plants this time was 114 days. This period is much shorter in 2018 - 84 days in twice fertilization with N5P19K20 and N9P19K20 or 11 days less than the control. Between 4 and 6 days was the difference in maturation of the seeds from the central and the primary order in 2107 and 2018, respectively. With 4 and 6 days earlier, respectively for beginning and mass maturation of the seed from secondary–order umbels, was established in fertilization with N9P9K20 (once) and with N5P19K20 (twice) in 2017. These variants in 2018, as well as once fertilization with N5P19K10 and especially twice with N9P9K20, have also manifested very good results.

Table 3. Phenological observation on the generative development of carrot seed stalk in 2017 (by date after planting)

V	Flowering								Seed formation								Maturity							
	C		I		II		III		C		I		II		III		C		I		II		III	
	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M	B	M
Once fertilization																								
1	29.5	06.6	04.6	10.6	16.6	21.6	06.7	12.7	11.6	18.6	22.6	01.7	01.7	08.7	16.7	25.7	02.7	15.7	10.7	19.7	19.7	27.7	26..7	01.8
2	30.5	07.6	07.6	11.6	18.6	21.6	30.6	09.7	12.6	20.6	24.6	01.7	01.7	08.7	17.7	24.7	04.7	15.7	10.7	16.7	20.7	25.7	30.7	01.8
3	31.5	07.6	06.6	10.6	18.6	21.6	04.7	10.7	11.6	19.6	24.6	01.7	04.7	07.7	20.7	25.7	04.7	12.7	12.7	19.7	19.7	25.7	27.7	31.7
4	27.5	06.6	01.6	10.6	12.6	19.6	02.7	10.7	09.6	18.6	18.6	26.6	26.6	05.7	12.7	20.7	01.7	11.7	08.7	16.7	15.7	22.7	23.7	29.7
5	31.5	08.6	06.6	10.6	16.6	21.6	02.7	09.7	13.6	19.6	22.6	01.7	01.7	07.7	16.7	23.7	01.7	11.7	12.7	18.7	20.7	25.7	27.7	30.7
6	30.5	08.6	04.6	11.6	13.6	20.6	05.7	10.7	10.6	18.6	22.6	01.7	01.7	08.7	19.7	24.7	06.7	14.7	08.7	18.7	18.7	25.7	28.7	01.8
7	31.5	10.6	04.6	10.6	15.6	19.6	02.7	07.7	12.6	20.6	24.6	01.7	02.7	06.7	17.7	24.7	04.7	12.7	14.7	20.7	17.7	24.7	24.7	30.7
8	26.5	06.6	06.6	10.6	11.6	19.6	02.7	08.7	10.6	19.6	18.6	24.6	01.7	05.7	12.7	20.7	02.7	12.7	08.7	16.7	14.7	21.7	17.7	22.7
9	30.5	08.6	04.6	10.6	15.6	19.6	04.7	11.7	11.6	18.6	20.6	29.6	01.7	06.7	20.7	25.7	04.7	12.7	09.7	16.7	17.7	24.7	28.7	01.8
10	29.5	07.6	05.6	13.6	13.6	20.6	07.7	13.7	10.6	19.6	20.6	30.6	04.7	09.7	16.7	24.7	03.7	12.7	10.7	12.7	16.7	237	20.7	25.7
Twice fertilization																								
11	25.5.	08.6	04.6	10.6	13.6	18.6	02.7	08.7	12.6	19.6	18.6	29.6	01.7	06.7	17.7	24.7	06.7	13.7	10.7	16.7	17.7	24.7	25.7	30.7
12	02.6	09.6	08.6	15.6	17.6	27.6	06.7	10.7	14.6	21.6	26.6	02.7	03.7	09.7	17.7	24.7	05.7	12.7	12.7	20.7	21.7	27.7	27.7	31.7
13	02.6	08.6	09.6	15.6	18.6	26.6	03.7	10.7	15.6	23.6	22.6	02.7	28.6	07.7	13.7	21.7	01.7	11.7	10.7	17.7	15.7	22.7	22.7	27.7
14	26.5	07.6	02.6	10.6	11.6	18.6	01.7	08.7	09.6	16.6	18.6	24.6	01.7	05.7	12.7	20.7	01.7	11.7	07.7	16.7	14.7	21.7	17.7	22.7
15	26.5	08.6	03.6	10.6	14.6	20.6	01.7	08.7	10.6	18.6	20.6	26.6	26.6	06.7	15.7	22.7	02.7	12.7	08.7	15.7	15.7	21.7	26.7	30.7
16	29.5	08.6	04.6	10.6	12.6	23.6	02.7	09.7	12.6	21.6	22.6	29.6	02.7	08.7	12.7	20.7	03.7	12.7	10.7	17.7	17.7	24.7	19.7	24.7
17	28.5	12.6	06.6	10.6	12.6	18.6	05.7	10.7	10.6	16.6	18.6	26.6	29.6	06.7	16.7	22.7	04.7	12.7	10.7	16.7	15.7	22.7	24.7	29.7
18	29.5	09.6	04.6	12.6	12.6	20.6	01.7	07.7	10.6	16.6	18.6	24.6	01.7	05.7	15.7	21.7	03.7	11.7	08.7	19.7	15.7	22.7	21.7	26.7

V- variants; C- central umbel; I- primary umbels; II –secondary umbels; III – tertiary umbels.

Table 4. Phenological observation on the generative development of carrot seed stalk in 2018 (by date after planting)

V	Flowering								Seed formation								Maturity							
	C		I		II				C		I		II				C		I		II			
	B	M	B		B	M	B		B	M	B		B	M	B		B	M	B		B	M	B	
Once fertilization																								
1	30.5	05.6	15.6	20.6	25.6	01.7	04.7	07.7	21.6	24.6	28.6	05.7	11.7	15.7	19.7	22.7	09.7	12.7	10.7	17.7	20.7	24.7	25.7	31.7
2	01.6	10.6	14.6	18.6	26.6	30.6	03.7	06.7	16.6	20.6	26.6	30.6	04.7	07.7	14.7	18.7	03.7	06.7	11.7	14.7	17.7	20.7	21.7	26.7
3	24.5	31.5	02.6	08.6	15.6	20.6	27.6	01.7	08.6	13.6	18.6	22.6	29.6	03.7	08.7	13.7	26.6	01.7	04.7	08.7	15.7	18.7	18.7	22.7
4	05.6	12.6	12.6	15.6	26.6	30.6	03.7	06.7	15.6	19.6	26.6	30.6	06.7	10.7	13.7	17.7	26.6	30.6	06.7	10.7	17.7	20.7	24.7	27.7
5	31.5	07.6	03.6	08.6	20.6	24.6	03.7	06.7	12.6	17.6	17.6	22.6	06.7	09.7	15.7	18.7	29.6	05.7	06.7	09.7	15.7	18.7	20.7	23.7
6	05.6	15.6	05.6	12.6	03.7	06.7	10.7	13.7	19.6	22.6	03.7	06.7	10.7	13.7	17.7	20.7	03.7	06.7	13.7	17.7	17.7	20.7	23.7	27.7
7	03.6	09.6	08.6	15.6	22.6	30.6	04.7	07.7	19.6	24.6	28.6	02.7	06.7	11.7	14.7	18.7	05.7	08.7	10.7	13.7	14.7	18.7	20.7	25.7
8	02.6	07.6	05.6	07.6	19.6	24.6	01.7	05.7	13.6	18.6	22.6	26.6	28.6	03.7	06.7	10.7	24.6	29.6	03.7	07.7	14.7	17.7	16.7	20.7
9	05.6	12.6	06.6	09.6	21.6	24.6	02.7	06.7	15.6	21.6	23.6	27.6	29.6	05.7	08.7	13.7	26.6	02.7	05.7	12.7	16.7	19.7	17.7	23.7
10	02.6	05.6	05.6	12.6	22.6	26.6	26.6	03.7	12.6	19.6	19.6	26.6	03.7	06.7	13.7	17.7	26.6	30.6	06.7	13.7	13.7	17.7	20.7	24.7
Twice fertilization																								
11	27.5	03.6	05.6	12.6	20.6	24.6	01.7	04.7	08.6	13.6	17.6	24.6	03.7	06.7	15.7	18.7	29.6	03.7	03.7	08.7	15.7	18.7	18.7	24.7
12	05.6	12.6	17.6	20.6	29.6	04.7	03.7	06.7	20.6	24.6	29.6	03.7	06.7	10.7	13.7	17.7	03.7	06.7	06.7	13.7	13.7	17.7	20.7	27.7
13	31.5	05.6	13.6	17.6	26.6	30.6	03.7	06.7	17.6	20.6	26.6	01.7	10.7	13.7	16.7	20.7	06.7	09.7	10.7	13.7	16.7	20.07	20.7	27.7
14	05.6	12.6	05.6	13.6	22.6	26.6	03.7	06.7	15.6	18.6	22.6	26.6	06.7	10.7	13.7	17.7	26.6	03.7	03.7	06.7	13.7	17.7	20.7	24.7
15	05.6	12.6	05.6	13.6	24.6	28.6	03.7	06.7	17.6	22.6	24.6	28.6	06.7	10.7	15.7	18.7	08.7	11.7	10.7	18.7	15.7	18.7	22.7	25.7
16	24.5	02.6	29.5	07.6	17.6	26.6	01.7	04.7	07.6	15.6	18.6	28.6	29.6	06.7	15.7	18.7	28.6	04.7	08.7	11.7	09.7	15.7	18.7	27.7
17	30.5	03.6	05.6	12.6	13.6	20.6	29.6	03.7	13.6	17.6	21.6	26.6	01.7	05.7	13.7	18.7	29.6	03.7	06.7	11.7	15.7	18.7	18.7	22.7
18	28.5	03.6	05.6	12.6	17.6	22.6	29.6	02.7	12.6	15.6	20.6	24.6	01.7	04.7	12.7	16.7	26.6	30.6	03.7	06.7	13.7	17.7	18.7	23.7

V- variants; C- central umbel; I- primary umbels; II –secondary umbels; III – tertiary umbels

The beginning and mass occurrence of this phenophase in the tertiary order during the two years began at the earliest after once fertilization with N9P9K20, and twice one in the first year at N5P19K20, followed by N9P9K20, while in the second year - for N5P9K10 and N9P19K10. The shortest period for seed maturation between secondary and tertiary order umbels during both vegetations was in once fertilization with N9P9K20. In this variant, at the least days of planting until the maturing of the seed of this order 98 and 117 in 2018 and 2017, respectively, were recorded. On average, for all the variants during the first vegetation, the maturation of the seeds in the last umbels was recorded at 123 days after planting and significantly earlier - on 102 days during the second one, however in both years due to fertilization this period was shorter.

In much of the variants in 2017, the period of ripening between the seeds of the central and the last (tertiary) order umbels was shorter, and the fertilization decreased it further with 4 to 7 days. It is longer in 2018, with the highest duration it was in once fertilization with $N_5P_9K_{20}$ - 7 days longer than the control.

The applied fertilizers in the carrot seed production significant affect on its vegetative development of seed stalk (Table 5). The height of the stem resulting from fertilization changes, as in the first year in each tested variant it was higher. The highest stems were developed in seed plants after application of $N_9P_{19}K_{20}$ in both once and twice fertilization, reaching an average of two years to 82.92 cm and 93.5 cm. Next are those of the $N_9P_9K_{10}$ and $N_9P_{19}K_{10}$ variants for once and $N_5P_{19}K_{20}$ and $N_9P_{19}K_{10}$ for twice, respectively. It can be said that in most cases the twice fertilization promotes the growth of plants with higher stems, with the exception of combinations $N_9P_9K_{10}$ in the first year and $N_9P_{19}K_{10}$ in the second year in comparison to the respective variants in once fertilization. However, the average values, are higher when fertilizers are applicated twice.

Similar are the results obtained for the total vegetative weight. Also, for the variants $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$, the highest values of both ways of fertilization were recorded in this index. The maximum total vegetative weight of 478.91 g was measured by twice fertilization with $N_9P_{19}K_{10}$, good results in this method of fertilizer application were also obtained in a similar combination but with double more quantity of potassium - $N_9P_{19}K_{20}$. The differences between the variants are of statistical significance.

Overall, 2017 was extremely hot and dry, which is correspondence with global trends. The early phases of carrot seed stalk development to the formation of the different order of umbels air temperatures in April and May of 2017 are close to normal (Fig. 1). However, sharply warming occurs during the period of active vegetation when the most important phases of carrot seed plant development - flowering, formation and maturation of seeds are observed which coincide with about 2°C above normal average monthly air temperature. Already in early of June 2017, an absolute maximum temperature of 41.2°C (30.06.2017) and 41.0 ° C (01.07.2017) was recorded (Table 6). On the background of insufficient rainfall throughout the growing season, these conditions adversely affect the carrot seed plant growth rate, regardless of variant and a dose of fertilization (Fig. 2 and 3).

It was fundamentally different in 2018 - warm as a whole but excessively moist during the whole period from the beginning of May to the end of July, when the most important phases of the carrots seed stalk - from the formation of a central umbel to maturing are observed. Average monthly temperatures throughout the growing season are about 2 ° C above normal, but absolute maximum air temperatures are not as high as in 2017 (about 30-33 ° C), with the highest temperature recorded on 22.07. 2018 (34.5 ° C). Extreme values of 41 ° C as in 2017 did not observe. However, the rainfall is 173% and 189% respectively in May and June and in July even reaches 280% of the norm. These precipitations have a torrential character and, in addition to development, they also negatively affect the quantity and quality of the seed production. The rainfall for just of one day - on July 29, 2018 (47 mm), is almost the same as the norm for the whole month of July (49 mm).

Table 5. Vegetative behaviors of carrot seed stalk and total vegetative weight in different fertilization

№	Variants	Height of stalk (cm)			Total vegetative weight (g)		
		2017г.	2018г.	Average	2017	2018	Average
Once fertilization							
1	$N_0P_0K_0$	75,33	55,00	65,16	170,33	104,25	137,29
2	$N_7P_{14}K_{15}$	85,00	63,66	74,33	230,99	147,79	189,39
3	$N_5P_9K_{10}$	80,50	57,50	69,00	127,50	86,54	107,02
4	$N_5P_9K_{20}$	84,33	70,00	77,16	165,99	120,14	143,06
5	$N_5P_{19}K_{10}$	80,00	65,50	72.75	197,00	108,40	152,70
6	$N_5P_{19}K_{20}$	90,00	61,00	75,50	179,00	104,28	141,64
7	$N_9P_9K_{10}$	92,00	67,00	79,50	180,00	116,59	148,29
8	$N_9P_9K_{20}$	93,33	72,50	82,92	253,33	164,91	209,12
9	$N_9P_{19}K_{10}$	89,50	70,00	79,75	248,50	142,73	195,61
10	$N_9P_{19}K_{20}$	88,50	57,00	72,75	258,50	95,88	177,19
Twice fertilization							
11	$N_5P_9K_{10}$	85,50	70,00	72,75	197,50	161,03	179,26
12	$N_5P_9K_{20}$	79,00	72,00	75,50	318,50	236,05	277,27
13	$N_5P_{19}K_{10}$	96,00	71,50	83.75	384,00	216,41	300,20
14	$N_5P_{19}K_{20}$	90,50	72,50	81,50	384,50	222,36	303,43
15	$N_9P_9K_{10}$	88,50	72,50	80,50	384,00	265,27	324,63
16	$N_9P_9K_{20}$	112,00	75,00	93,50	380,50	250,51	315,50
17	$N_9P_{19}K_{10}$	96,00	68,50	82,25	619,50	338,33	478,91
18	$N_9P_{19}K_{20}$	91,00	68,00	79,50	554,50	264,72	409,61
LSD (p=0.05%)		4.25	3.80		6.36	8.22	

Table 6. Agrometeorological parameters for the development of carrots

Year	Month	Mean air tem-perature °C	Absolute maximum of tempe-rature, °C	Absolute minimum of tempe-rature, °C	Sum of precipitations, mm	Hydrothermal Coefficient (HTC)	Relative humidity, %
2017	April	12.7	27.5	-1.2	26.1	0.6850	62
	May	17.6	31.5	3.8	52.7	0.9659	68
	June	23.7	41.2	11.0	15.4	0.2166	60
	July	25.1	41.0	13.6	29.8	0.3830	58
2018	April	16.4	30.5	0.4	25.0	0.5081	65
	May	19.2	30.2	9.4	112.3	1.8868	73
	June	22.0	33.2	11.4	118.9	1.8015	68
	July	24.2	34.5	16.0	137.0	1.8262	70

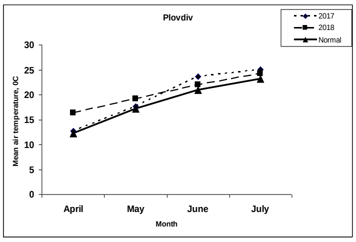

Figure 1. Changes in mean air temperature in Plovdiv

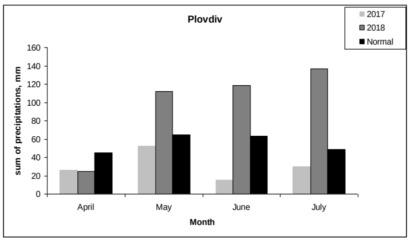

Figure 2. Changes in sum of precipitations in Plovdiv

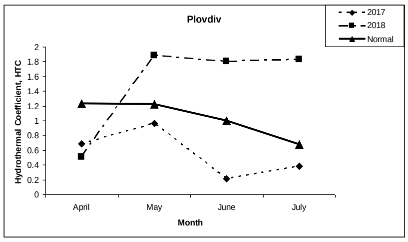

Figure 3. Changes in Hydrothermal Coefficient (HTC) in Plovdiv

Discussion

Some differences between the variants as well as vegetation seasons in the phenological observation of carrot plants for seed production were observed. In 2017 the dates for the development of leave rosette are very close, while in the next year the differences increased. The twice fertilization improved much more the appearance of leave rosette in the second year of study, especially for the beginning of this phase. Higher differences were established in the formation of the umbels from the different order. The central (king) umbel is important for the development of the seed stalk in carrots and for their productivity (Satyaveer et al., 1994; Panayotov, 2010). In most of the case, the lower level of fertilizers improved much more is development. The distinction between variants between years as well as fertilization terms is more significant in the formation of primary order umbels. Twice fertilization helps for more rapid its formation. It could point out that the fertilization in two terms provokes also faster development of the umbels of the secondary order. The growing season reflects more substantial by the formation of the tertiary order umbels. It could be asserted because it beginning and mass development was started significantly earlier in 2018 than the previous year.

The flowering is the most important phenophase in seed carrot production, of which to the greatest extent determine the high seed productivity and quality. At the same time, it is in direct relation to the temprature (Atherton et al., 1990; Craigon et al., 1990). The conditions in both years influenced not uniformity on the flowering of separate umbels. The inflorescences of central and primary order, the flowering begin earlier in the second year, while the flowering of the secondary umbels is improved in both seasons.

With regard to seed production, it is extremely important to determine the timing within which begins the formation of seeds in umbels by the individual orders. In addition to their maturation time, their share in yield formation is quite different (Gray et al., 1983). The applied fertilization has a different effect in seed formation. The fertilizers influenced a little the development of the seeds from central umbel, but strong positive effect is observed in the seed formation form primary umbels and most accelerate it is in twice fertilization. Also application in two terms improved this process in seeds of secondary and tertiary order umbels.

The ripening of the seeds also depends on applied fertilization as well as from the vegetation conditions. The maturation of seeds from central umbels is influenced much well after fertilization than those of primary and secondary one. Extremely important for the successful and loss-free harvesting of carrot seeds is to determine its optimum term (Ashwort, 2002). Therefore it is necessary an information for the period of ripening between the seeds of the central and the last (tertiary) order umbels. The environmental behaviors during the vegetation season influenced strongly this stage and in 2017 this period is significantly shorter than in the next year.

The use of more higher nitrogen amounts causes a stronger increase of the height of stem of carrot seed stalk. Similar conclusions point out Ravinder and Kanwar (2002) and Kushawala (2009), emphasized that with an augmentation of the nitrogen fertilizer from 0 to 100 kg/ha, the height of the stem increases considerably, with the best results are obtained when they have used 80 kg/ha. The results of our studies clearly outline the tendency of higher growth of the vegetative weight in twice fertilization, possibly due to the nitrogen fertilization in period closest to the moment of intensive vegetation. The higher doses of nitrogen provoke the development of carrot seed stalk with higher total vegetative weight. Close to these are the data reported by Singh (1996) and Rao and Maurya (1998).

It is important to note that the agrometeorological conditions during the vegetation period differed significantly in the two experimental years. However, they also play a significant impact on the rate of development, both during the individual periods between separate phases as well as periods throughout the growing season. In summary, when comparing the two years, it can indicate that 2017 are hotter, while 2018 characterized as moister and very high amount of rainfall. These quite different conditions are reflected on the productivity and especially on the quality of carrot. seed production.

Conclusions

The occurrence and the duration of individual phenophases in carrot seed stalk are influenced by both the conditions of the individual vegetation and the fertilization methods. Summarizing it could be pointed out that the periods after planting of steckling to the occurrence of most phases are shorter in 2018. Combination $N_5P_9K_{20}$ improves the most phenological development, especially the formation of leaf rosette, central umbel and flowering of primary once. A stronger positive effect, especially for the formation of the separate umbels, for their flowering, as well as for the formation of the seeds, is observed when applying twice fertilization. More Strongly the applied ways of fertilization affect the maturing of the seeds from the central umbles. Fertilization significantly increases the growth of the stem and the total vegetative weight, especially after the application of higher levels of nitrogen, as it is in the $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$ variants. The variations in the rate of development between the different variants are more pronounced in drought conditions and the significant decrease in wet years, regardless of the fertilization way and dose. Variant $N_9P_{19}K_10$ in 2017 and variant $N_9P_9K_{20}$ in 2018 are distinguished with the fastest rate of development.

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