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Nutrition and Physiology

Generative development of carrots (*Daucus carota* L.) during seed production depending on the fertilization

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Abstract. *The main aim of the present study was to establish the changes in the generative development of carrots seed stalk during seed production depending on the frequency and level of fertilization. Two times of fertilization were tested: once - phosphorus and potassium were applied in autumn and nitrogen in transplanting time, and twice - half of phosphorus and potassium in the autumn, while the other half and nitrogen in soil in spring and half nitrogen in flowering. The number of umbels in the branches of I, II and III orders was determined. The average number of constituent units of one umbel from the central umbel and from umbels of different orders, as well as the average number of flowers in one umbel were established. Differences between variants were identified. Fertilization has a significant impact on the number of umbels and flowers. The number of flowers in the central umbel and those of the other umbels was the highest in one-time fertilization with* $N_{90}P_{90}K_{200}$*/ha, while in two-times - with* $N_{50}P_{190}K_{200}$*/ha.*

Keywords: *Daucus carota* L., flowering, umbels, the morphology of umbels, order, seed production

Introduction

The nutrient regime about the growing of plant for seed production has a direct effect on their normal development and the obtaining of good seed yield and quality. In the production of carrot seeds, Ilyas et al. (2013) apply one-time phosphorus fertilization prior to planting, potassium and half of the nitrogen fertilizer they applied when planting the stecklings, the other part of the nitrogen was given 30 days later. The authors point out that as the amount of phosphorus increases, the number of branches, the number of sunshades, the number of flowers in the umbel and the quality of the obtained seed production increased.

Hooda et al. (2014) studied three levels of fertilization (60:30:30; 80:40:40; and 100: 50: 50 N: P: K kg/ha) and suggest that increasing the amount of fertilizer improves vegetative and generative development of seed plants, that increase the seed production. Kushawala (2009) established that with increasing nitrogen levels from 0 to 100 kg/ha, some features such as plant height, number of plant branches, number of umbels per plants, and seed per umbel also increase significantly. Similar conclusions made also Rao and Maurya (1998), and the authors suggest that increasing the nitrogen fertilizer rate increases the height of the plants and the number of secondary and tertiary branches and umbels of carrot stalk. Singh (1996) also reports that as the amount of nitrogen increased plants developed higher stalk, the numbers of one umbel and the yield of carrot seeds increase. Best results he observed after application of 150 kg/ha N.

Ravinder and Kanwar (2002) produced the carrot seed under different levels of nitrogen (0, 40, 60 and 80 kg/ha) and phosphorus (0, 20, 40 and 60 kg/ha). Phosphorus and 50% of nitrogen were applied during planting. The remaining amount of nitrogen was added in equal amounts at the appearance of umbels and in flowering. The highest plant height, the highest number of secondary and tertiary umbels and seed yields from the plant were found using the highest fertilizer rate for both nitrogen and phosphorus.

The main objective of the study was to investigate the impact of fertilization (one-time or two-times) with different levels of nitrogen, phosphorus and potassium on the generative development of the carrot seed plant.

Material and methods

The experiments were carried out in the Experimental Fields and the laboratories of the Department of Horticulture at the Agricultural University-Plovdiv, Bulgaria in the period of 2017-2018 with carrot variety Tushon. The following variants with different amount in kg/ha and term of fertilization – one-time or two-times were tested:

- One-time: 1) $N_0P_0K_0$ – control; 2) $N_{70}P_{140}K_{150}$ (recommended); 3) $N_{50}P_{90}K_{100}$; 4) $N_{50}P_{90}K_{200}$; 5) $N_{50}P_{190}K_{100}$; 6) $N_{50}P_{190}K_{200}$; 7) $N_{90}P_{90}K_{100}$; 8) $N_{90}P_{90}K_{200}$; 9) $N_{90}P_{190}K_{100}$ and 10) $N_{90}P_{190}K_{200}$.
- Two-times: 11) $N_{50}P_{90}K_{100}$; 12) $N_{50}P_{90}K_{200}$; 13) $N_{50}P_{190}K_{100}$; 14) $N_{50}P_{190}K_{200}$; 15) $N_{90}P_{90}K_{100}$; 16) $N_{90}P_{90}K_{200}$; 17) $N_{90}P_{190}K_{100}$ and 18) $N_{90}P_{190}K_{200}$.

The different levels of fertilization were determined on the basis of recommended for carrot seed production in Bulgaria fertilizer quantity ($N_{70}P_{140}K_{150}$) (Madzarova, 1966; Kolev et al., 1977). In the one-time fertilization, phosphorus and potassium

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were applied during the autumn plowing and nitrogen before planting of stecklings (roots), while in the case of two-times fertilization, half of the phosphorus and potassium fertilizers were placed in the autumn deep plowing, the other half before planting the stecklings and the nitrogen - half in the planting of stecklings and the rest with 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 28cm, at the beginning of March the furrows through 80cm with previously applied fertilizers according to the variants of the experiment were formed.

The stecklings were grown by sowing at the end of June with 7.0 kg/ha by scheme 60+20+20+20+20+20x3 cm. At a stage of 3 true leaves, the plants were thinned, while at a stage of 5 leaves and 25 days later they were fertilized twice with ammonium nitrate at a dose of 110 kg/ha. The stecklings were harvested at the beginning of November and stored during the winter in soil-covered pits. The stecklings were planted on 27.03 2017 and on 13.04.2018 by the scheme 80x30cm, with spatial distance between each variant of 80cm. 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 number of umbels in the branches of I, II and III orders was determined. The average number of constituent units of one umbel from central umbel and from umbels of different orders, as well as the average number of flowers in one umbel were established in a mass flowering phase, and the average diameter of the individual umbels was determined after harvesting the seedlings. The analyses were performed on 15 stalks of each variant.

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 and a method for establishing the correlation coefficient are described in Fowel and Cohen (1992).

Results and discussion

The number of umbels in the given order (Table 1) differs, both in terms of their order and depending on the fertilization method applied. For the first order, average for the studied period, in the case of one-time fertilization, the highest results were recorded for $N_{50}P_{90}K_{100}$ - 14.56 and for variant $N_{90}P_{90}K_{200}$, while for the control it was 11.08. These two variants, in the case of two-times fertilization, also cause the formation of the largest number of umbels in the branches of order I, 16.40 and 13.90, respectively. The highest reduction was observed when the highest fertilization rates were applied. A higher number of umbels in the II order, both in one-time and two-times application of fertilizers were formed at the $N_{50}P_{90}K_{100}$ rate and also as in the I order at $N_{90}P_{90}K_{200}$. In the third order, this number in one fertilization was the highest for the recommended control - $N_{70}P_{140}K_{150}$ and follows from $N_{90}P_{90}K_{100}$ variant with a very small difference. Whereas in the two-times fertilization in the above-mentioned rate, there is a significant decrease compared to the two controls. Higher results for all three orders were observed in 2017. According to Singh (1996), nitrogen fertilization significantly improves the formation of a higher number of umbels from different orders of carrot stalk. Statistical significance between the variants were established.

Table 1. Numbers of umbels at different order of branches on the seed stalk

Vari-ants	Order of branches								
	I			II			III		
	2017	2018	average	2017	2018	average	2017	2018	average
One-time fertilization									
1	12.0	10.1	11.0	13.8	13.1	13.4	10.0	8.8	9.4
2	13.2	11.3	12.2	17.5	14.6	16.0	13.7	9.0	11.3
3	15.6	13.5	14.5	17.4	14.5	15.9	11.8	9.3	10.5
4	9.7	11.0	10.3	18.1	13.3	15.7	13.3	8.6	10.9
5	11.3	12.6	11.9	15.3	13.0	14.1	6.8	7.6	7.2
6	14.0	11.5	12.7	13.3	15.3	14.3	9.3	6.3	7.8
7	14.7	10.6	12.7	17.5	14.0	15.7	13.0	9.5	11.2
8	13.8	12.5	13.1	21.8	16.3	19.1	13.0	8.6	10.8
9	9.1	8.0	8.5	15.5	12.5	14.0	8.0	6.8	7.4
10	7.1	7.6	7.3	14.7	10.3	12.5	11.7	7.6	9.6
Two-times fertilization									
11	17.5	15.2	16.4	30.1	16.5	23.3	10.1	8.5	9.3
12	6.4	5.0	5.7	16.2	12.0	14.1	8.7	6.5	7.6
13	13.5	12.5	13.0	25.5	18.6	22.0	10.2	12.5	11.3
14	13.3	10.6	12.0	22.0	11.5	16.7	19.0	8.5	13.7
15	12.4	11.0	11.7	13.1	12.7	12.9	6.8	10.0	8.4
16	14.3	13.5	13.9	22.1	17.8	19.9	12.0	11.1	11.6
17	12.3	13.0	12.6	17.4	15.7	16.6	8.5	7.2	7.9
18	10.2	9.0	9.6	17.1	12.6	14.9	12.9	8.8	10.8
LSD p=0.05	1.8	1.2		3.3	2.4		3.2	1.9	

Except the number of umbels, fertilization also affects the number of constituent units in the individual umbels. For the central (king) umbel (Table 2) average for two years with one fertilization, the largest units in one umbel were reported for fertilization with $N_{90}P_{190}K_{200}$, $N_{90}P_{90}K_{200}$, and $N_{50}P_{90}K_{200}$, 118.50; 116.16 and 104.83 numbers, respectively. The two-times application is characterized by a stronger increase in this feature, especially for $N_{50}P_{190}K_{200}$ variants (117.83) and for $N_{90}P_{190}K_{100}$ (107.16). It may be underlined that the higher rates of fertilization, especially in 2017, caused the development of smaller units in the central umbels. The largest numbers of 137 and 120 were reported in one-time fertilization for 2018, of the $N_{90}P_{190}K_{200}$ and the $N_{90}P_{90}K_{200}$, respectively. As the number of orders increases, the number of constituent units per umbel decreases. In most of the variants the statistical proof is present.

Table 2. Number of constituent units of central (king) umbel

Variants	2017	2018	average
	One-time fertilization		
1	89.6	79.5	84.5
2	99.6	97.0	98.3
3	90.6	79.5	85.0
4	100.6	109.0	104.8
5	82.3	92.5	87.4
6	93.3	82.0	87.6
7	89.0	105.0	97.0
8	112.3	120.0	116.1
9	100.6	87.0	93.8
10	100.0	137.0	118.5
	Two-times fertilization		
11	96.0	105.5	100.7
12	103.0	116.0	103.0
13	95.0	109.0	102.0
14	106.6	129.0	117.8
15	110.0	101.5	105.7
16	96.6	90.5	93.5
17	91.3	123.0	107.1
18	114.0	82.6	98.3
LSD p=0.05	9.2	6.5	

The number (Table 3) in umbels of first order ranges from approximately 70-90, second 50 to 60, and third from 30 to 40. The highest values in the one-time application for all three orders were found for $N_{90}P_{90}K_{200}$. For the first and second order, the fertilizer effect is also strong from $N_{50}P_{90}K_{200}$, while for the third one in $N_{90}P_{190}K_{200}$. Higher differences depending on the quantity of the used fertilizer were observed in the two-times fertilization. The number of constituent units in the I and II order increases most after the application of $N_{50}P_{90}K_{100}$, the last variety indicates the most significant increase in the other way of fertilization. The highest amounts contributed to the formation of more constituent units in umbels of third order and reached 40.5. Ahmed and Tanki (1989) also pointed out that the different levels and combinations of nitrogen, phosphorus and potassium fertilizers contribute significantly to the development of seed carrot plants.

The most important indicator of the generative development of carrot seed plant is the number of developed flowers in one umbel. This determines consequently the seed productivity, and in some senses also the quality of the seeds. In Table 4 the number of flowers in the central umbels is shown. They varied in the one-time fertilization from 4608.5 for $N_{50}P_{190}K_{200}$ to 8568.0 for $N_{90}P_{90}K_{200}$. The other way of the application was respectively from 4914 pcs. for $N_{90}P_{90}K_{200}$ to 8101.5 for $N_{50}P_{190}K_{200}$. In both ways of fertilization $N_{50}P_{90}K_{200}$ was in the second place.

Significant differences between years, resulting in a strong decrease by almost 50% in 2018, observed in $N_{50}P_{90}K_{100}$. The aforementioned influence on the sequence of the order is also established about the flowers per umbel. The data in Table 5 shows that most flowers developed in umbels from I order after fertilization with $N_{90}P_{90}K_{200}$ (5985.5) and with $N_{50}P_{90}K_{200}$ (5885.5). The decrease in comparison with both controls was observed over both years for the $N_{50}P_{90}K_{100}$ and $N_{90}P_{90}K_{100}$ except for the latter variant in comparison with the fertilizer control. The number of flowers is high due to the two-times application of $N_{50}P_{190}K_{100}$ and $N_{50}P_{190}K_{200}$. In a second order, the number of flowers is in the range of 1971.0 for $N_{90}P_{190}K_{200}$ to 2693.5 for $N_{90}P_{90}K_{200}$ in one-time fertilization.

Table 3. Number of constituent units of separate umbels

Variants	Order of branches								
	I			II			III		
	2017	2018	average	2017	2018	average	2017	2018	average
	One-time fertilization								
1	75.0	71.6	73.3	58.6	41.0	49.8	43.6	24.5	34.0
2	79.0	73.3	79.0	67.0	41.0	54.0	35.0	26.0	30.5
3	66.7	69.0	67.8	67.3	52.0	59.6	38.0	24.0	31.0
4	89.3	103.0	96.1	64.0	57.0	60.5	39.3	27.0	33.1
5	86.3	84.5	85.4	66.0	43.5	54.7	35.3	27.0	31.1
6	77.6	64.0	70.8	67.3	41.0	54.1	38.0	29.0	33.5
7	71.3	74.0	72.6	78.3	45.0	61.6	43.0	26.0	34.5
8	103.3	90.0	96.8	72.0	48.0	60.0	47.3	26.0	36.6
9	79.0	84.0	81.5	65.0	47.0	56.0	39.0	22.0	30.5
10	77.0	93.0	85.0	67.3	47.0	57.1	47.5	24.0	35.7

Two-times fertilization									
11	82.6	94.5	88.5	68.6	47.5	58.0	40.3	27.5	33.9
12	74.3	86.5	80.4	74.3	52.0	63.1	41.6	21.5	31.5
13	92.6	89.0	90.8	76.0	50.0	63.0	50.5	28.0	39.2
14	83.3	97.0	90.1	68.3	46.5	57.4	49.0	28.0	38.5
15	88.0	88.0	88.0	73.6	46.5	60.0	48.6	22.5	35.5
16	86.3	95.0	90.6	81.0	45.0	63.0	43.6	25.5	34.5
17	78.3	93.0	85.6	69.6	44.5	57.0	48.3	26.5	37.4
18	96.0	84.7	90.3	60.5	51.0	55.7	50.0	31.0	40.5
LSD p=0.05	4.8	3.6		4.5	2.6		3.8	3.1	

Table 4. Number of flowers in central (king) umbels

Variants	2017	2018	average
	One-time fertilization		
1	6226	4152	5189.0
2	5743	5758	5750.5
3	6317	3045	4681.0
4	6448	8175	7311.5
5	5162	5212	5187.0
6	5691	3526	4608.5
7	6210	6583	6396.5
8	8736	8400	8568.0
9	5299	5220	5259.5
10	8444	8357	8400.5
	Two-times fertilization		
11	6024	7076	6550.0
12	7997	7553	7775.0
13	6726	6286	6506.0
14	7235	8968	8101.5
15	7535	5611	6573.0
16	5103	4725	4914.0
17	6249	7051	6650.0
18	8122	4927	6524.5
LSD p=0.05	143.1	265.4	

Good results are also obtained from $N_{90}P_{90}K_{100}$. In the two-times fertilization the increase was most pronounced by 36.48% of $N_{50}P_{90}K_{200}$ and 30.82% of $N_{90}P_{90}K_{200}$ compared to the non-fertilized plants. A significantly stronger effect of the two-times application was observed on the flower number of the third order, ranging from 745 for $N_{50}P_{90}K_{100}$ to 1232.0 at the highest rate, their change in the one-time method varied from 565.0 for control to 893.5 again for $N_{90}P_{90}K_{200}$. In this order, the influence of individual years is very well demonstrated and the development of the flowers was much better in 2017. The one-time and two-times fertilization of carrot seed plants, according to Ravinder and Kanwar (2002), has a strong effect on the development of umbels and the number of flowers in them. The differences between the variants are with statistical significance.

About the morphological features of the umbels, their diameter is of high importance. Under the influence of different levels and ways of fertilization, the changes in this characteristic are relatively small. The central umbels increase very weakly only with $N_{90}P_{190}K_{200}$ and $N_{90}P_{90}K_{200}$, compared to the fertilized control (Table 6). Higher reduction by 14.34% was established for $N_{50}P_{190}K_{200}$. Higher values were found for the two-times fertilization. The size of the diameters decreases with decreasing the sequence of the order, but here the effect of the mineral fertilization was weak. In this index there is no statistical significance.

Table 5. Total numbers of flowers in one umbel at different order of branches on the seed stalk

Variants	Order of branches								
	I			II			III		
	2017	2018	average	2017	2018	average	2017	2018	average
	One-time fertilization								
1	3408	3735	3571.5	2387	1522	1954.5	964	425	694.5
2	4194	3176	3685.0	2396	1275	1835.5	619	511	565.0
3	2648	3042	2845.0	2287	1684	1985.5	804	523	663.5
4	5900	5871	5885.5	2699	1539	2119.0	831	621	726.0
5	4395	4166	4280.5	2914	1348	2131.0	735	578	656.5
6	5002	3264	4133.0	2152	1435	1793.5	1175	580	877.5
7	3603	3282	3442.5	3003	1623	2313.0	1057	648	852.5
8	5941	6030	5985.5	3323	2064	2693.5	1033	754	893.5
9	4304	4788	4546.0	2461	1927	2194.0	963	572	767.5
10	4349	4464	4406.5	1650	1692	1671.0	570	480	525.0

Two-times fertilization									
11	4419	5039	4729.0	2480	1700	2090.0	1017	473	745.0
12	3856	5107	4481.5	3562	1772	2667.0	803	527	665.0
13	5125	5354	5239.5	3052	1590	2321.0	1110	476	793.0
14	5066	5655	5360.5	3257	1100	2178.5	1422	588	1005.0
15	5088	4091	4589.5	2974	1641	2307.5	1253	549	901.0
16	4446	5165	4805.5	3584	1530	2557.0	1118	419	768.5
17	4611	4328	4469.5	3536	1456	2496.0	1244	678	961.0
18	5643	4623	5133.0	2640	1885	2262.5	1657	807	1232.0
LSD p=0.05	328.2	265.3		245.2	458.1		125.5	201.1	

Table 6. Average diameter of central (king) umbel (cm)

Variants	2017	2018	average
One-time fertilization			
1	11.3	10.0	10.6
2	12.3	10.1	11.2
3	11.8	10.7	11.2
4	11.0	10.5	10.7
5	10.8	10.7	10.7
6	10.6	9.0	9.8
7	11.6	10.6	11.1
8	12.0	11.2	11.6
9	11.3	9.0	10.1
10	10.8	13.0	11.9
Two-times fertilization			
11	11.3	11.7	11.5
12	12.8	13.0	12.9
13	11.1	13.2	12.2
14	12.5	12.0	12.2
15	12.6	11.2	11.9
16	13.6	11.2	12.4
17	11.6	12.0	11.8
18	13.0	11.3	12.1
LSD p=0.05	0.9	1.1	

An increase by 7.04% was recorded for first-order umbels after application of $N_{50}P_{90}K_{200}$ and $N_{90}P_{90}K_{200}$ (on-time) and by 14.46% in $N_{90}P_{90}K_{100}$ (two-times) (Table 7). At a 6.58 cm diameter for the fertilizer control after the one-time fertilization with $N_{90}P_{90}K_{200}$, it reached up to 7.50 cm and after two-times - up to 8.16 cm with $N_{50}P_{190}K_{200}$. Only third-order umbels, form plants fertilized one-time with $N_{50}P_{90}K_{200}$ have grown more and their diameter exceeds the control by 3,46%. In two-times fertilization, the highest increase was observed for $N_{50}P_{90}K_{100}$, $N_{50}P_{90}K_{200}$ and $N_{50}P_{190}K_{200}$ by 16.08% and 15.27%, respectively. Summarized for most of the variants, the umbels with higher diameter were developed as a result of two-times fertilization of the carrot seed plants.

Table 7. Average diameter of umbels at different order of branches on the seed stalk (cm)

Vari-ants	Order of branches								
	I			II			III		
	2017	2018	average	2017	2018	average	2017	2018	average
One-time fertilization									
1	10.0	7.5	8.7	5.8	6.1	5.9	4.5	4.5	4.5
2	9.8	8.1	8.9	6.6	6.5	6.5	5.0	4.8	4.9
3	9.8	9.2	9.5	6.6	7.7	7.2	4.3	4.7	4.5
4	9.8	9.5	9.6	7.5	6.5	7.0	5.1	5.0	5.0
5	9.6	8.2	8.9	6.5	6.7	6.6	4.1	5.2	4.7
6	9.3	7.5	8.4	6.6	6.0	6.3	4.3	4.5	4.4
7	8.1	9.8	8.9	6.5	7.1	6.8	4.8	4.8	4.8
8	9.6	9.6	9.6	7.5	7.5	7.5	4.6	5.0	4.8
9	9.6	8.0	8.8	7.5	6.5	7.0	4.0	5.0	4.5
10	8.8	9.5	9.1	6.1	7.5	6.8	4.1	5.5	4.8
Two-times fertilization									
11	10.1	10.5	10.3	6.8	8.0	7.4	4.6	6.7	5.7
12	10.3	10.0	10.1	7.1	7.5	7.3	5.8	5.5	5.6
13	9.5	10.2	9.8	7.2	7.2	7.2	4.7	4.7	4.7
14	10.6	10.5	10.5	8.3	8.0	8.1	5.8	5.5	5.6
15	10.8	9.7	10.2	7.3	7.5	7.4	5.1	5.5	5.3
16	10.1	9.2	9.7	7.8	6.7	7.2	5.1	5.0	5.0
17	10.0	10.5	10.2	8.0	7.0	7.5	5.1	5.2	5.2
18	9.5	10.0	9.7	8.2	7.1	7.7	4.7	5.0	4.8
LSD p=0.05	0.85	1.25		1.4	1.1		0.95	1.25	

Conclusion

It was found that: a) the generative development of seed plants of carrots were significantly affected by the different rates and ways of fertilization; with an increase of the sequence of order the generative development being weaker; b) the significant reduction in the number of umbels in the first order was achieved after application of $N_{50}P_{90}K_{100}$ and $N_{90}P_{90}K_{200}$; c) the number of constituent units in the central umbels was higher under the influence of $N_{90}P_{90}K_{200}$ in one-time fertilization and in $N_{50}P_{190}K_{200}$ (two-times); the variant $N_{90}P_{90}K_{200}$, irrespective of the way of fertilization, promotes development of the highest units of I, II and III order; the number of flowers in the central umbel and those of the other umbels was the highest in one-time fertilization with $N_{90}P_{90}K_{200}$, but in the two-times - with $N_{50}P_{190}K_{200}$; d) umbels diameter is influenced weakly by the application of different amounts, combinations and ways of fertilization.

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