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PRODUCTIVITY AND QUALITY OF THE SEEDS OF CARROT BY OPTIMZATION OF NUTRIENT REGIME IN THEIR SEED PRODUCTION

AUTHOREFERAT

Of the thesis for awarding of Education and Scientific degree “DOCTOR” in Scientific scope 6.1. “Crop Science” , Scientific speciality “Vegetable crops”

Scientific supervisor
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The dissertation is written on 218 pages and contains 60 tables and 21 figures. The list of cited literature indicates 158 sources, of which 37 in Cyrillic and 121 in Latin.

The experimental work was carried out in the Experimental Field of the Department of Horticulture at the Agricultural University - Plovdiv, during the period 2017-2019.

The dissertation was reviwed and directed for defense by the Department Council of the Department of Horticulture, Faculty of Viticulture and Horticulture, Agricultural University - Plovdiv.

The defense of the dissertation will be held on .... from ...... hours in ..... hall of the Faculty of Viticulture and Horticulture at the Agricultural University of Plovdiv - at a meeting of the Scientific Jury, appointed by the Rector of The Agraricultural University with Order № RD.16.282 with the following members:

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Gratitude

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I would like to thank the staff of the Department of Horticulture for the support, advice and help that they did not save during my studies as a PhD student, as well as for the positive attitude, which I highly appreciate.

The materials for defense are available to those who interested on the website of the Agricultural University - Plovdiv - www.au-plovdiv.bg

1. INTRODUCTION

Carrots are the main root vegetable crop, in which at present, despite the established experience and traditions, as well as the availability of appropriate conditions, almost no seed production. They are an economically important vegetable crop and high productivity and quality are of great importance. In order to achieve the needed yields, special attention must be paid to the quality of the sowing materials.

One of the possible ways to increase the productivity and viability of seeds is to ensure a proper nutrient regime. By means of its optimization, an opportunity is provided to achieve sustainable yields and improved quality parameters of the obtained seeds.

In our country for a long time there is no scientific activity on the nutrient regime in the seed production of this crop and its impact on seed yield and quality. This determines the need to carry out targeted scientific work in order to be able to specify the appropriate levels and methods of application of mineral fertilizers in seed production of carrots, ensuring good yields of seeds with guaranteed high quality.

2. AIM AND TASKS

The main goal of the study is to increase the yield and quality of carrot seeds, as well as to improve the vegetative and generative development of seed plants by optimizing the nutrient regime during their seed production, by studied the different levels and terms of fertilization with nitrogen fertilization, phosphorus and potassium.

To achieve this goal, the following tasks are set for solving:

1. Test of different levels and frequence of fertilization - once and twice with nitrogen, phosphorus and potassium.
2. Study of the vegetative and generative development of seed plants.
3. Determining the productivity and quality of the seeds.

3. MATERIALS AND METHODS

3.1. Setting of the experience

The experiments were conducted in the experimental field of the Department of Horticulture at the Agricultural University - Plovdiv, during the period 2017-2019 with the Tuchon variety.

Different levels of nitrogen, phosphorus and potassium were tested and two application terms – once and twice.

Once fertilization - the entire amount of phosphorus and potassium fertilizers in the autumn before deep plowing and nitrogen during planting were applied.

Twice fertilization, in which half of the phosphorus and potassium fertilizers were applied before the autumn deep plowing, the other half in the spring before planting, and the nitrogen fertilizer - half before planting, and the other part during the vegetation - at the beginning of flowering.

The following variants were investigated

Once fertilization: 1.$N_0P_0K_0$ – control; 2.$N_7P_{14}K_{15}$ (recommended); 3.$N_5P_9K_{10}$; 4.$N_5P_9K_{20}$; 5.$N_5P_{19}K_{10}$; 6.$N_5P_{19}K_{20}$; 7.$N_9P_9K_{10}$; 8.$N_9P_9K_{20}$; 9.$N_9P_{19}K_{10}$; 10.$N_9P_{19}K_{20}$;

Twice fertilization: 11.$N_5P_9K_{10}$; 12.$N_5P_9K_{20}$; 13.$N_5P_{19}K_{10}$; 14.$N_5P_{19}K_{20}$; 15.$N_9P_9K_{10}$; 16.$N_9P_9K_{20}$; 17.$N_9P_{19}K_{10}$; 18.$N_9P_{19}K_{20}$;

The different levels of fertilization are determined according to the recommended amounts of mineral fertilizers and the method of their application (variant 2) proposed by Madzharova (1966), Kolev (1977) and Minkov (1984).

The experiments were carried out by the block method in 4 replications with the size of the experimental plot of 7 m^2 and a reporting area of 6 m^2 and ensuring a distance between the individual plots of 0.8 m. The cultivation of the shteglings and the seed production crops was carried out according to the accepted technologies, described in detail in the dissertation.

The following mineral fertilizers were applied: ammonium nitrate (a.v. N 34%), triple superphosphate (a.v. P_2O_5 46%) and potassium sulfate (a.v. K_2O 50%). The harvesting of the seed plants took place when more than 60% of the seeds have matured, and the others were at wax maturity. The seed stalks were placed for post-harvest maturation in ventilated and shady rooms for a period of 10-12 days, after which the seeds were extracted, followed by seed cleaning and packaging of the seeds in paper packages. Storage was performed in these packages under room conditions.

3.2. **Indexes and research methods**

3.2.1. Agrometeorological characteristics for the period March-November for the three years of study and for a climatic norm of 50 years. The following are determined: average ten-day and monthly temperatures; average minimum and maximum temperature in ten days and months; mounth amount of precipitation (mm); average ten-day and monthly relative humidity.

3.2.2. Field soil characteristics of the

An average sample of 30 cm depth was taken from the experimental area, in which the following were determined: the content of mobile forms of nitrogen, phosphorus and potassium, as well as basic and important for the development of plants microelements such as calcium, magnesium, zinc, copper , iron, humus content, pH and mechanical composition of the soil

3.2.3. Phenological indicators

The beginning and mass manifestation of leaf rosette development, appearance of central umbel, flowering of central umbel, appearance of branches of I, II and III order were observed; flowering of inflorescences from branches of I, II and III order, formation of seeds from central umbel and in umbels from branches of I, II and III order, maturation of seeds from central umbels and from individual orders.

3.2.4. Morphological indexes

The height of the stalk (stmem) (cm); stalk diameter (mm); stalk weight (g); number and weight (g)of leaves; total vegetative weight (g) in the stage of mass flowering of the central umbel were established. Measurements were performed on 5 plants from each replication.

3.3.5 Generative behaviors

The following generative features: number of umbels on the branches of I, II and III order; diameter of umbels (cm) - central and of those of I, II and III order; number of flower partitions in umbels - central and those of I, II and III order; number of flowers in the central umbel and in umbels of branches of I, II and III order in full development of the umbels on 5 plants from each replication have been established.

3.3.6. Seed yield and elements of productivity

After seeds cleaning the: weight of seeds from the central umbel and from branches of I, II and III order, the linear sizes of the seeds of each order and fully developed seed of the central umbel and umbels from I, II and III order and the ratio of the individual orders to the formation of the total yield was determined. The yield of seeds per decare has also been established.

3.3.7. Quality of seeds from central canopy and from canopies of branches I, II and III order

The quality of the seeds is determined taking into account the following indicators: weight of 1000 seeds; germination energy germination - by ISTA method as well as filed germination; mean germination time; uniformity of germination; days for germination of 50% of the seeds; chronometric determination of the occurrence of the individual phases of seed germination; fresh weigh of one seedling; absolute dry weight of seedlings; deviations from the normal development of seedlings; storage of three-year seeds (from the first year harvest).

3.3.8. Chemical composition of seeds

The absolute dry weight; seed moisture; carbohydrate content; crude protein content; crude fat content; ash content were determined

3.3.9. Economic evaluation

The economic evaluation of the different variants was performed by determining the following indicators: total income; total cost; notional profit; rate of cost-effective (%). The assessment of the economic indicators is based on the average three-year data obtained for the yield.

3.3.10. Statistical processing

The statistical processing of the results includes dispersion, correlation and regression analyzes performed using the statistical product ANOVA.

The methods for determining all these indicators and their implementation are described in detail in the dissertation.

4. Soil and climate condition during the carring of the experiments

The content of mobile nitrogen is - 47.53 mg/kg soil. The content of mobile phosphorus can be determined as high - 52.6 mg/100g of soil. With regard to mobile potassium, the soil is also high - 60.45 mg/100 g of soil. Water-soluble calcium is 158.70 mg/kg, and magnesium is 58.66 mg/kg of soil, ie with a very high quantity. The measured water-soluble iron is 4.96 mg/kg. The water-soluble zinc and copper are 0.06 mg/kg and 0.14 mg/kg, respectively. The above mentioned indicate that the soil conditions are favorable for growing stecklings and carrot seeds and allow them to conduct experiments in this direction and compare the results.

For seed production of carrots, the climatic conditions from June-November for the production of stecklings and March-August for the cultivation of seed plants are important. The average daily temperatures for ten days from June to September are from 20.1^0C to 28.1^0C and cover the requirements of the crop. Their decrease in October and November is conducive to the adaptation and storage of stecklings. Growth of seed palnts and seed harvesting - the third decade of March to August, also takes place at temperatures that meet the requirements for good development of the carrot seed plants. Although they are not very demanding on the water regime, the amount of precipitation also affects their development. The lowest amount is reported in March 2019 and August 2017, and the highest - in June 2019. In September and October the amount of precipitation is not large and these conditions favor the normal harvest for storage of well-developed and undeformed stecklings. In general, it can be pointed out that the agro-climatic environment during the three years of the experiments, despite some deviations from the norm, was relatively favorable for seed production of carrots and meets their biological requirements.

5. RESULTS

5.1. Influence of different fertilizer rate and term of fertilization on the of biological behaviors of carrot seed stalk

5.1.1. Phenological behaviors

The different levels of and terms of fertilization cased influence on the phonological behaviors of the carrot seed stalk (Tables 1, 2 and 3).

The increase of nitrogen from 5 $kg.da^{-1}$ to 9 $kg.da^{-1}$ significantly accelerates the development of the leaf rosette and the appearance of a central umbel and umbels on branches of I, II, and III order.

Fertilization with more phosphorus and potassium fertilizers in combination with 9 $kg.da^{-1}$ N stimulates earlier flowering, seed formation and seed maturation. This positive effect has been particularly well established in the application of mineral fertilizers twice.

Table1. Phenological observation on the generative development of carrot seed stalk (days after transplanting)

Variants	Flowering							
	Central umbel		Umbels I oredr		Umbels II order		Umbels III order	
	B	M	B	M	B	M	B	M
Once fertlization								
$N_0P_0K_0$	56	64	66	74	78	84	92	96
$N_7P_{14}K_{15}$	57	64	67	74	79	84	89	95
$N_5P_9K_{10}$	54	62	62	70	76	81	89	93
$N_5P_9K_{20}$	58	66	65	72	77	83	90	96
$N_5P_{19}K_{10}$	56	65	62	70	76	83	90	94
$N_5P_{19}K_{20}$	59	67	64	72	81	86	93	97
$N_9P_9K_{10}$	57	66	63	72	77	84	90	95
$N_9P_9K_{20}$	54	64	63	69	75	80	89	93
$N_9P_{19}K_{10}$	59	67	63	69	77	82	90	95
$N_9P_{19}K_{20}$	58	65	64	72	77	83	89	95
Twice fertilization								
$N_5P_9K_{10}$	55	63	64	71	76	82	90	94
$N_5P_9K_{20}$	59	68	69	76	81	88	91	95
$N_5P_{19}K_{10}$	58	63	67	73	79	85	90	94
$N_5P_{19}K_{20}$	58	68	63	72	77	82	90	95
$N_9P_9K_{10}$	56	66	63	71	77	83	89	94
$N_9P_9K_{20}$	52	63	61	68	74	83	89	94
$N_9P_{19}K_{10}$	55	65	64	71	72	80	89	94
$N_9P_{19}K_{20}$	53	63	62	70	74	81	88	92
p=5%	**5.0**	**4.9**	**5.3**	**4.1**	**5.0**	**4.7**	**3.6**	**3.0**
GDp=1%	**6.7**	**6.6**	**7.2**	**5.5**	**6.7**	**6.3**	**4.8**	**4.1**
p=0.1%	**8.8**	**8.7**	**9.5**	**7.3**	**8.9**	**8.4**	**6.4**	**5.4**

B– *beginig of appearance of the phenophases;* ***M*** *– mass appearance of the phenophases*

Table.2. Phenological observation on the generative development of carrot seed stalk (days after transplanting)

Variants	Seed formation							
	Central umbel		Umbels I oredr		Umbels II order		Umbels III order	
	B	M	B	M	B	M	B	M
Once fertlization								
$N_0P_0K_0$	71	78	81	89	93	98	104	110
$N_7P_{14}K_{15}$	69	77	82	87	91	96	102	108
$N_5P_9K_{10}$	65	74	78	85	90	93	100	106
$N_5P_9K_{20}$	69	76	80	86	90	96	101	107
$N_5P_{19}K_{10}$	69	76	77	85	91	95	102	107
$N_5P_{19}K_{20}$	71	78	84	90	93	98	104	109
$N_9P_9K_{10}$	71	78	83	88	92	96	101	109
$N_9P_9K_{20}$	67	75	78	84	88	93	98	105
$N_9P_{19}K_{10}$	69	78	79	86	88	93	100	106
$N_9P_{19}K_{20}$	69	77	79	86	91	95	102	108
Twice fertilization								
$N_5P_9K_{10}$	68	74	76	89	90	94	103	108
$N_5P_9K_{20}$	73	80	83	87	91	97	102	109
$N_5P_{19}K_{10}$	71	78	81	85	91	97	101	107
$N_5P_{19}K_{20}$	69	76	80	86	91	95	101	108
$N_9P_9K_{10}$	70	77	80	85	89	96	102	108
$N_9P_9K_{20}$	66	74	79	90	89	95	101	107
$N_9P_{19}K_{10}$	68	74	78	88	89	94	101	108
$N_9P_{19}K_{20}$	67	73	77	84	89	93	101	107
p=5%	**4.4**	**3.9**	**4.8**	86	**4.6**	**3.3**	**4.5**	**3.8**
GDp=-1%	**5.8**	**5.2**	**6.5**	86	**6.2**	**4.4**	**6.1**	**5.0**
p=0.1%	**7.7**	**6.9**	**8.5**	89	**8.2**	**5.9**	**8.0**	**6.7**

B– *beginig of appearance of the phenophases;* ***M*** *– mass appearance of the phenophases*

Table.3. Phenological observation on the generative development of carrot seed stalk (days after transplanting)

Variants	Seed maturation							
	Central umbel		Umbels I oredr		Umbels II order		Umbels III order	
	B	M	B	M	B	M	B	M
Once fertlization								
$N_0P_0K_0$	92	100	99	107	107	115	114	121
$N_7P_{14}K_{15}$	91	97	97	104	106	111	114	118
$N_5P_9K_{10}$	88	94	97	103	105	111	112	117
$N_5P_9K_{20}$	86	94	98	105	106	112	113	118
$N_5P_{19}K_{10}$	87	95	95	103	105	112	112	117
$N_5P_{19}K_{20}$	91	97	98	105	107	112	115	119
$N_9P_9K_{10}$	91	98	100	106	105	112	112	118
$N_9P_9K_{20}$	86	94	95	102	104	110	108	112
$N_9P_{19}K_{10}$	88	94	96	104	105	111	111	118
$N_9P_{19}K_{20}$	88	94	97	103	104	110	110	116
Twice fertilization								
$N_5P_9K_{10}$	89	96	97	103	105	110	111	118
$N_5P_9K_{20}$	90	97	98	107	106	112	113	118
$N_5P_{19}K_{10}$	90	97	97	104	103	111	110	118
$N_5P_{19}K_{20}$	87	96	96	104	105	111	110	115
$N_9P_9K_{10}$	91	98	98	106	104	111	112	119
$N_9P_9K_{20}$	88	96	98	104	103	110	109	116
$N_9P_{19}K_{10}$	88	93	97	104	104	111	111	116
$N_9P_{19}K_{20}$	87	93	93	102	103	109	109	115
p=5%	**4.7**	**3.8**	**4.7**	**4.8**	**3.7**	**2.8**	**4.1**	**3.7**
GDp=-1%	**6.3**	**5.1**	**6.3**	**6.5**	**4.9**	**3.7**	**5.5**	**4.9**
p=0.1%	**8.3**	**6.7**	**8.3**	**8.6**	**6.5**	**4.9**	**7.3**	**6.5**

***B**– beginig of appearance of the phenophases; **M** – mass appearance of the phenophases*

5.1.2. Vegetative behaviors

The height of the flowering stalk is significantly influenced by the applied way of the mineral fertilizers as well as by the different levels of N, P and K (Fig. 1). A significant increase in flowering stalk height was observed after twice applications of $N_9P_9K_{20}$ and $N_5P_{19}K_{10}$ - 89.89 cm and 89.17 cm, respectively, at 63.11 cm and 73.33 cm for both controls. The fertilizer rate $N_9P_9K_{20}$ provoce the formation of the highest stems and at the first application period - 86.94 cm. It is noteworthy that increasing the rate of N from 5 kg.da^{-1} to 9 kg.da^{-1} improves the development of stems that reach greater heights, and this observed to both methods of fertilizer application.

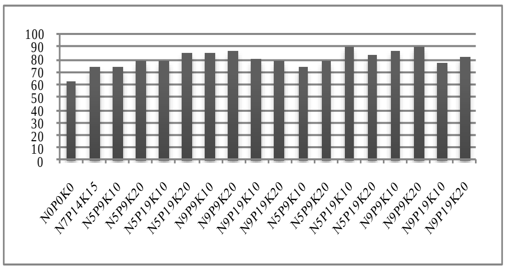

Fig. 1. Heigh of flowering stalk (cm)

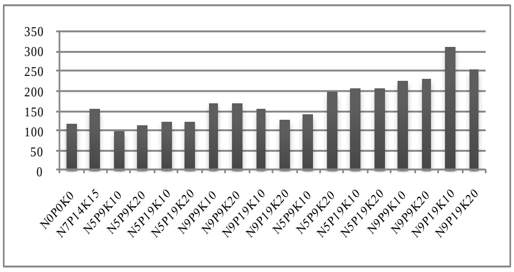

Fig. 2. Weight of flowering stem (g)

Both for the height of the stalk and for its weight there are differences in connection with the regime of application of the tested mineral fertilizers. The highest stems weight is in the variant fertilized twice with $N_9P_{19}K_{10}$ - 313.04 g, which is twice in comparison to the fertilization control and in the cultivation of plants without fertilization. The obtained results also show that the twice application of mineral fertilizers provoke significant increase in the weight of the carrots flowering stem, especially when fertilizing with higher N levels.

The obtained average values for the stem diameter (Fig. 3) for most of the tested variants are between 9 and 10 mm. A decrease is established after a once application of $N_5P_{19}K_{10}$ - 7.80 mm. On average for the three years, the thickness of the stem is the highest after twce application of $N_9P_9K_{20}$, i.e. when using relatively higher levels of fertilization. In summary, it can be pointed out that there are no significant differences between the variants and between the methods of application, once and twice. Nevertheless, it can be pointed out also that the closer application of mineral fertilizers leads to an increase in the diameter of the flowering stem.

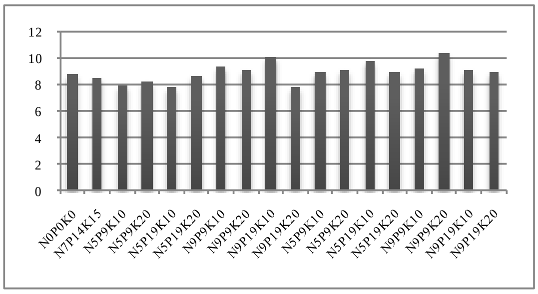

Fig. 3. Diameter of stalk (mm)

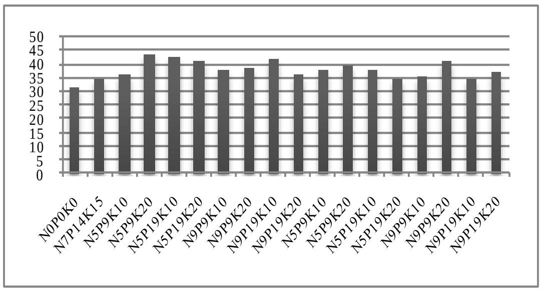

Fig. 4. Air-dry weight of stalk (%)

All tested fertilizer rates lead to a higher air-dry weight than the fertilizer and not fertlizing control (Fig. 4). The differences between the separate variants are small, and this also refers to the method of application of mineral fertilizers. The highest air dry mass was developed by plants fertilized once with $N_5P_9K_{20}$ - 43.09%. It can be pointed out that in all variants the air dry mass is relatively good.

The leaves are from essential significance about the course of photosynthetic processes in plants. Similar to the indicators for the vegetative development of carrot seed plants considered so far, the data on the formation of the leaves (Fig. 5) indicate that their number is significantly influenced by the imported amounts of nitrogen fertilizer.

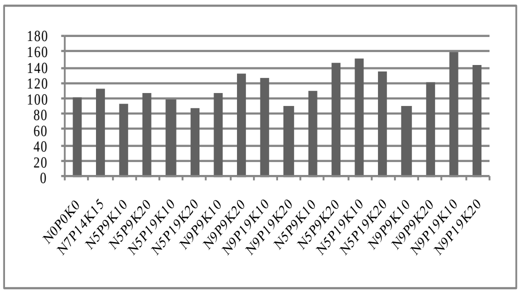

Fig. 5. Number of leaves

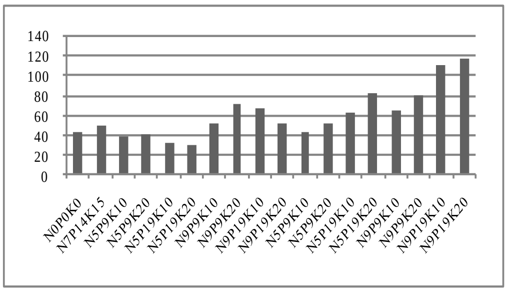

Fig. 6. Weight of leaves

With the increase of the fertilizer level of N from 5 $kg.da^{-1}$ to 9 $kg.da^{-1}$ there is an increase in the number of leaves, as on average for the test period it reaches a maximum value in the variant fertilized twice with $N_9P_{19}K_{10}$ - 159.33 numbers.

The quantity of the nitrogen fertilizer rate also has a significant effect on the leaves weight (Fig. 6). The most noticeable increase was found in the double application of $N_9P_{19}K_{20}$ (116.46 g), as well as in $N_9P_{19}K_{10}$ (110.12 g). This is an increase of more than two times in comparison the fertilizer and not fertilizer controls. A strong positive correlation with a correlation coefficient r = + 0.70 was found between the number of leaves and their weight. The leaves are characterized by a lower air dry weight than that of the stems (Fig. 7). Higher air-dry weight is developed by the leaves of plants grown in a once fertilizatiuon. The $N_5P_{19}K_{20}$ and $N_9P_{19}K_{10}$ variants are more impressive, with maximum values of 40.18% and 38.82%, respectively.

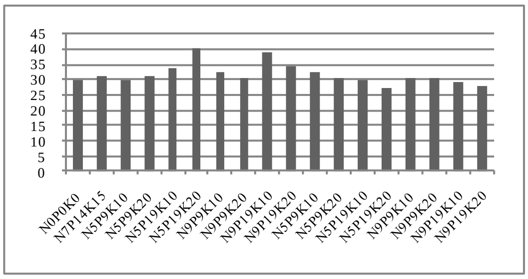

Fig. 7. Air-dry leaves weight

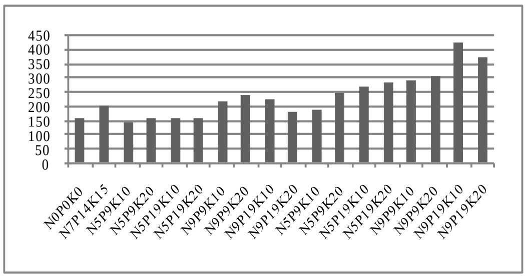

Fig. 8. Total leaves-stem weight

Significant increase in the values of the total leves-stem vegetative weigt (Fig. 8) is reported with an increase in the amounts of nitrogen, which is better expressed with the twice application of the mineral fertilizers. Fertilization twice with $N_9P_{19}K_{10}$ causes the formation of vegetative organs with the highest weight - 423.16 g. The total vegetative weight is determined mainly by the weight of the stem. The proportion of stem weight is between 68.5% for $N_9P_{19}K_{20}$ and 79.47% for variant $N_5P_9K_{20}$, twice application. The ratio of leaves weight in the formation of this trait is much smaller, as the variation is from 21.0% for $N_5P_{19}K_{10}$ once application to 31.49% for twice fertilization with $N_9P_{19}K_{20}$.

Summarasing, it can be pointed out that the vegetative development of carrot seed plants is significantly influenced by the fertilizer regime with mineral fertilizers. It is stronger in the variants with higher nitrogen levels. Twice fertilization contributes significantly to stronger vegetative growth of both the stems and the leaves and the accumulated air dry weight.

5.1.3. Generative behaviors

The generative characterisitcs of the plants are essential in the seed production of carrots, as one of the most important features is the number of developed umbels on the branches of different order - I, II and III (Fig. 9). Fertilization with $N_5P_9K_{10}$ provoke the formation of the highest number of umbels on the first-class branches at once fertilization - 12.21, while at twice fertilization they are the most for variant $N_9P_9K_{10}$ -13.97. A characteristic feature of carrot seed stalk is the formation of the highest number of umbels on the branches of the second order. A significant increase is reported in the application of the tested fertilizer rates twice. The maximum number was found in the combinations $N_5P_{19}K_{10}$ and $N_9P_9K_{10}$ - 22.72 and 23.52, respectively. The twice fertilization with $N_5P_{19}K_{10}$ leads to the formation of the highest number of umbels of the last III order (14.59 pcs.), which is an increase of 14.16% compared to the fertilized control and 25.99% compared to the not fertilied plants. It can be pointed out that in a once fertilization the increase of N from 5 $kg.da^{-1}$ to 9 $kg.da^{-1}$ in combination with higher levels of P_2O_5 and K_2O stimulates the formation of a higer number of branches in the carrots seed stakl. Lower amounts of fertilizer applied, but applied twice, lead to the formation of more umbels.

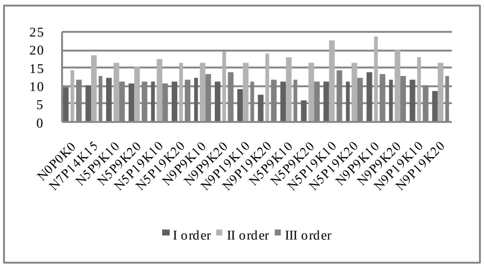

Fig. 9. Number of umbels in branches from I, II and III orders

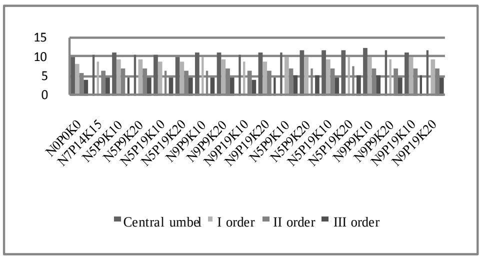

Fig. 10. Diameter of carrot umbels (cm), central and I, II and III orders

The fertilization methods (once and twice) and the different levels of N, P and K do not significantly affect the diameter of the umbels (Fig. 10). In the case of the central umbel, a slight increase compared to the two controls is reported in the variant $N_9P_9K_{10}$ (twice) - 12.11 cm. The size of the diameter decreases with increasing order of the order, but here also the effect of mineral fertilization is weak. An increase of 25.06% compared to the not ferlizated control was reported for first order umbels after application of $N_9P_9K_{10}$ (twice) and 24.07% for $N_5P_{19}K_{20}$ and $N_9P_{19}K_{10,}$ respectively again in twice aplication. Fertilization twice leads to the formation of umbels with a higher diameter on the branches of II order also, especially well expressed in the variant $N_5P_{19}K_{20}$ - 7.55 cm, followed by $N_9P_{19}K_{10}$ - 7.22 cm, at 6.44 cm for the recommended fertilizer rate for seed production. The values obtained for the umbles of the last III order varies very weak. Diameters above 5 cm are reported only for $N_5P_9K_{10}$ and $N_5P_{19}K_{20}$ applied twice, while for the other test variants it is about 4 cm. In most variants, umbels with a higher diameter are develop as a result of twice fertilization of the seed plants. The correlation analysis indicate that the relationship between the diameter of the umbels and the number of umbelates is positive, as it is strong and highest with a correlation coefficient for umbels of II order r = + 0.80, followed by those of the central umbel r = + 0.55 , and this correlation is average for the umbels of I and III order, respectively r = + 0.46 and r = + 0.48. The correlation between the diameter of the umbles and the number of flowers is similar.

The correlation for the second order umbels is also strong positive and it is the highest with coefficient r = + 0.70. It is average for the central umbels and this of I order is with coefficients r = + 0.52 and r = + 0.41, respectively and it is weak, but also positive for III order umblels, with r = + 0.29.

The number of the umbelates in the whole umbel is also influenced by the nutrient revime in which the carrot seed plants are grown. The umbels of the central stems are characterized by the highest number of umbletaes, as this number decreases with increasing the order of the umbels (Fig. 11). The average amount of umbelates in the central umbel increases significantly after twice fertilization with $N_9P_9K_{10}$ - 115.44 pieces. The quantity of the umbelates of the first-class umbels is maximum for the plants fertilized once with $N_9P_9K_{20}$ - 92.33 pieces, followed by $N_5P_9K_{20}$ - 91.11 pieces. Fertilization with $N_9P_9K_{10}$ and $N_9P_9K_{20}$ provoces the development of more umbelates in the complex umbels in the second way of applying the mineral fertilizers - 97.77 pieces and 90.77 pieces, respectively. A significant decrease in the number of umbelates, compared to the central umbels and those of I order, is observed in umbels of II and III order. The average number of umbelates in umbels of the second order in all tested variants is higher than the fertilizer norm recommended for seed production as well as the not fertilized control. A more significant increase was reported in the combination $N_9P_9K_{10}$ puted twice - 67.44 pieces. Fertilization with higher levels of N, P and K stimulates the formation of more umbelates in the umbels of the last third order, which is better expressed when the application of mineral fertilizers is twice.

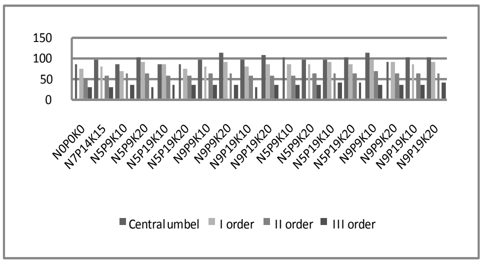

Fig. 11. Number of umbelates in whole umbel, central and I, II and III orders

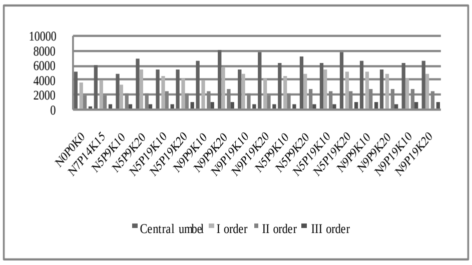

Fig. 12. Number of flower in umbel, central and I, II and III orders

The most important indicator of the generative development of carrot seed plants is the number of flowers formed in a umbels. This subsequently determines the seed productivity and, in a sense, the quality of the seeds.

The most flowers are set by the umbels from the central stems, as on average for the reporting period this number is maximum in the variant fertilized once with $N_9P_9K_{20}$ (8220) (Fig. 12). In the closer period of application of mineral fertilizers a more significant increase was observed in the combination $N_5P_{19}K_{20}$ (7709). A certain decrease was observed for the once fertilization with $N_5P_9K_{10}$ (4897), at 5150 pcs. and 5882 pieces, respectively for the not fertilization control and for the recommended fertilizer norm.

As the order of the umbels increases, the amount of flowers decreases. A significant increase in the number of flowers set in the umbels on the branches of the first order is reported at the fertilizer rate $N_9P_9K_{20}$ imported once - 5612 pieces. Compared to the fertilization control, this represents an increase of 42.50% and 55.07% compared to the plants grown without fertilization. The combinations $N_5P_9K_{20}$ (once) and $N_5P_{19}K_{10}$ (twice) also show good results - 5432 and 5394 pieces, respectively. A significant decrease in the number of formed flowers, compared to those of I order, is observed in the umbels of II and especially of III order. Nevertheless, the obtained results show that the application of mineral fertilizers has a positive effect and increases the number of formed flowers in complex umbels. The average number of flowers formed in the second umbels order ranged from 1836 for the zero control to 2764 for the $N_9P_9K_{20}$ (once). Fertilization with maximum amounts of the three fertilizers ($N_9P_{19}K_{20}$) significantly increases the number of flowers in the umbels of the last III order - 1080. The number of flowers is very closely related to the number of the umbelates. This can be seen very well from the established correlations between these two features. The correlation is strong and positive for umbels from all orders, as the highest coefficient is for the central umbel and for those from I order, respectively r = + 0.93 and r = + 0.92. This dependence is also positive and strong for the umbels from II oreder, but with lower coefficients - r = + 0.82 and the lowest is for umbels from III order r = + 0.62.

5.2. Influence of different fertilizer norms and fertilization terms on seed productivity in carrots

5.2.1 Seed yield in carrots

All tested variants form a higher seed yield compared to both fertilization control and non-fertilization plant cultivation. At the same time, there is an improvement in the productivity of the carrot seed plants with the twice application of the fertilizer combinations in comparison with the reciprocal ones applied once (Table 4).

The largest increase was reported for the combinations $N_9P_9K_{10}$ and $N_5P_{19}K_{10}$, respectively by 22.26% and 6.45%, compared to the same levels, but with a single application. The yield of carrot seeds is the highest for all tested variants at twice application of $N_9P_9K_{10}$ levels, reaching to 78.619 $kg.da^{-1}$, which is more with 36.58% and 27.13% for the unfertilized control and the recommended fertilization for seed production of carrots, respectively. It should be noted that the amounts of applied phosphorus and potassium fertilizers in this combination are significantly lower than previously recommended for seed production of carrots in Bulgaria, and nitrogen are higher. The differences are statistically proven.

A two-factor analysis of variance was performed to establish the influence of the factors "year" (A) and "fertilization regime" (B), as well as their interaction to dominate the seed productivity of carrots (Tables 5, 6 and 7).
The indicator "total yield" in the case of once fertilization is most strongly influenced by factor (B), i.e. the fertilization regime, whose influence is 49% and has a reliability of $p \leq 0.001$ on changes in this feature.

Table 4. Yield of seeds of carrot – kg.da^{-1}

Variant	2017	2018	2019	средно	%	%
Once fertilization						
$N_0P_0K_0$	55.862	59.572	57.248	57.560	100.0	93.07
$N_7P_{14}K_{15}$	60.888	62.772	61.864	61.841	107.43	100.0
$N_5P_9K_{10}$	62.266	63.950	62.276	62.830	109.15	101.60
$N_5P_9K_{20}$	67.162	68.200	64.462	66.608	115.71	107.70
$N_5P_{19}K_{10}$	70.124	66.800	68.356	68.426	118.87	110.64
$N_5P_{19}K_{20}$	65.370	70.400	66.424	67.398	117.09	108.98
$N_9P_9K_{10}$	64.774	65.036	63.100	64.303	111.71	103.91
$N_9P_9K_{20}$	77.490	75.648	70.800	74.646	129.68	120.70
$N_9P_{19}K_{10}$	62.966	68.258	74.612	68.612	119.20	110.94
$N_9P_{19}K_{20}$	66.288	64.000	65.872	65.386	113.59	105.73
Twice fertilization						
$N_5P_9K_{10}$	63.668	63.956	63.120	63.581	110.46	102.81
$N_5P_9K_{20}$	65.692	65.200	67.888	66.260	115.74	107.66
$N_5P_{19}K_{10}$	67.898	80.850	69.778	72.842	126.54	117.78
$N_5P_{19}K_{20}$	76.062	67.200	63.188	68.816	119.55	111.27
$N_9P_9K_{10}$	79.676	77.986	78.196	78.619	136.58	127.13
$N_9P_9K_{20}$	74.652	72.386	66.040	71.026	123.39	114.85
$N_9P_{19}K_{10}$	64.432	67.972	70.870	67.758	117.71	109.61
$N_9P_{19}K_{20}$	73.080	71.920	65.856	70.285	122.10	113.65
p=5.0%	**7.17**	**7.94**	**7.98**	**5.83**		
GDp=1.0%	**9.60**	**10.63**	**10.69**	**7.81**		
p=0.1%	**12.68**	**14.04**	**14.11**	**10.32**		
				r^*=0.78;r^{**}=0.66; r^{***}=0.61; r^{****}=0.71;		

r^* – correlation between nr of umbels and yield; r^{**} - correlation between umbelates and yielda; r^{***}- correlation between yield and percentage of normal developed seeds; r^{****} - correlation between yield and weight of seeds per umbel;

The influence of random factors (errors) is in second place with 40%. In the case of twice fertilization, the strongest influence on seed yield is the interaction of the two factors (AxB), which is 36%, and the effect of the fertilization regime is weaker - 17%. In this case, the impact of random errors reaches 43%. In the general consideration of the two regimes with a dominant influence of 42% is also a factor (B) - fertilization regime, as the reliability on the change of the indicator is p≤0.001. The interaction of the factors "year" and "fertilization regime" AxB has a 20% influence, and the unexplained influence due to random factors is 37%.When processing the data on the yield of carrot seeds as a result of different fertilization regimes, it is found that the strongest is the influence of factor (B) - fertilization regime, and in second place is the complex influence of the tested factors (AxB). For factor (A) no independent influence is observed.

Table 5. Two-factor analysis of the factors: A – year and B – regime of fertilization on the yield of carrot seeds (once fertilization)

ANOVA							Strength of influence
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Year (A) n.s.	16.42	2	8.21	0.37	0.694	3.15	0%
Regime of fertilzation (B)***	1646.21	9	182.91	8.18	0,000	2.04	49%
Interaction (AxB) n.s.	383.87	18	21.33	0.95	0,521	1.78	11%
Erros	1341.17	60	22.35				40%

*****, **, * -** proved respectively in p≤0.001, p≤0.01 and p≤0.05; n.s. – not prooved

Table 6. Two-factor analysis of the factors: A – year and B – regime of fertilization on the yield of carrot seeds (twice fertilization)

ANOVA							Strength of influence
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Year (A) n.s.	98.22	2	49.11	2.33	0.108	3.19	4%
Regime of fertilzation (B)***	397.90	7	56.84	2.70	0.019	2.21	17%
Interaction (AxB) n.s.	835.53	14	59.68	2.84	0.004	1.90	36%
Erros	1009.70	48	21.04				43%

Table 7. Two-factor analysis of the factors: A – year and B – regime of fertilization on the yield of carrot seeds (once and twice fertilization (total))

ANOVA							Strength of influence
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Year (A) n.s.	71.99	2	35.99	1.65	0.196	3.08	1%
Regime of fertilzation (B)***	2665.38	17	156.79	7.20	0.000	1.72	42%
Interaction (AxB) n.s.	1262.06	34	37.12	1.71	0.021	1.54	20%
Erros	2350.87	108	21.77				37%

On figures 13 and 14 are shown the regression lines that reflect the changes in seed productivity of carrots depending on the evenly increasing fertilization levels.

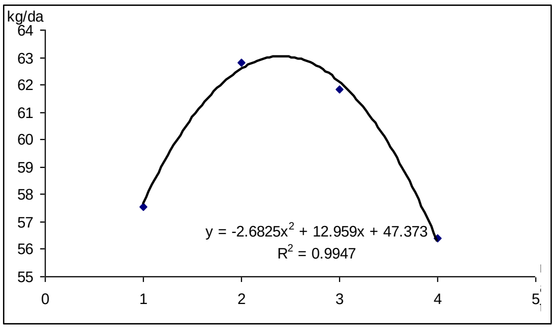

Fig.13. Regression dependence between yield in once fertilization with evenly increase level 1.$N_0P_0K_0$,2. $N_{50}P_{90}K_{100}$; 3.$N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

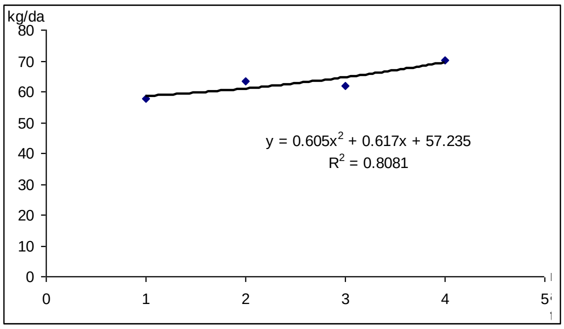

Fig.14. Regression dependence between yield in twice fertilization with evenly increase level 1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$; 3.$N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

The resulting regression is of the polynomial type. The determination coefficients, which show what percentage of the despersing of the resultant variable is explained by the action of the factor variable, are high R^2 = 0.9947 - for once fertilization and R^2 = 0.8082 - for twice application of mineral fertilizers. This means that in 99% and 80% of cases, respectively, depending on whether the fertilization is once or twice changes in the amount of mineral fertilizers will cause the observed changes in the yield.

5.2.2. Ration of the seeds from different umbels in the formation of seed yield and insemination of umbels in carrots

The specific morphology of the carrot seed stalk also determines the different participation of the individual umbels in the formation of the yield. On average for all tested variants the participation of first-class umbels is 50.61%, followed by second-class umbels with 30.57% (Table 8). This is due to the higher number of umbels, which develop on the branches of I and II order. The umbels of the lowest order (III order) and the umbles of the central stems are characterized by the least participation.

Table 8. Ratio of the seeds of the umbels by orders in formation of the yield and insemination of the umbels of carrot (%)

Variant	Ratio				Insemination			
	C	I	II	III	C	I	II	III
Once fertilziation								
$N_0P_0K_0$	10.69	49.37	33.39	6.10	78.65	71.39	67.95	61.59
$N_7P_{14}K_{15}$	10.48	52.09	30.78	6.58	79.12	77.39	69.12	62.15
$N_5P_9K_{10}$	11.48	53.39	25.83	7.49	80.06	77.49	72.98	63.01
$N_5P_9K_{20}$	16.24	45.26	30.63	7.85	80.65	76.97	72.62	63.39
$N_5P_{19}K_{10}$	10.20	52.12	31.26	6.40	79.75	74.96	71.12	64.78
$N_5P_{19}K_{20}$	9.59	44.53	37.30	8.55	83.19	76.39	71.31	64.77
$N_9P_9K_{10}$	12.59	53.47	26.43	7.47	81.34	77.09	72.59	66.10
$N_9P_9K_{20}$	13.09	48.47	31.68	6.97	83.48	75.36	73.95	66.56
$N_9P_{19}K_{10}$	13.42	51.31	29.21	6.03	82.75	75.53	73.12	64.71
$N_9P_{19}K_{20}$	11.84	49.22	28.06	8.37	80.75	75.39	69.92	65.30
Twice fertilziation								
$N_5P_9K_{10}$	8.27	52.61	31.68	5.98	81.21	76.12	73.21	64.86
$N_5P_9K_{20}$	15.67	40.50	33.86	9.95	82.00	74.55	70.96	67.50
$N_5P_{19}K_{10}$	8.28	52.39	33.00	5.19	81.36	76.13	70.47	65.98
$N_5P_{19}K_{20}$	11.08	52.89	27.42	8.58	79.92	71.76	67.64	64.72
$N_9P_9K_{10}$	9.43	56.77	28.44	5.33	84.31	77.88	75.79	68.70
$N_9P_9K_{20}$	10.20	47.71	34.51	7.56	83.45	76.67	71.62	65.24
$N_9P_{19}K_{10}$	11.14	59.10	23.73	6.02	83.27	75.48	71.15	65.64
$N_9P_{19}K_{20}$	10.33	49.81	33.13	5.21	82.44	73.94	69.27	63.63
p=5.0%	**6.45**	**12.90**	**7.90**	**4.61**	**3.65**	**3.43**	**2.65**	**3.97**
GDp=1.0%	**8.64**	**17.28**	**10.59**	**6.18**	**4.89**	**4.60**	**3.55**	**5.33**
p=0.1%	**11.40**	**22.81**	**13.98**	**8.15**	**6.46**	**6.08**	**4.69**	**7.03**

C – central umbel; **I, II and III** – orders

On average for the tested period, the share of the central umbel in productivity is the highest after once and twice fertilization with the combination $N_5P_9K_{20}$ - 16.24% and 15.67%, respectively. The proportion of first-order umbels increased more markedly after the application of $N_9P_9K_{10}$ (once) and $N_9P_{19}K_{10}$ (twice). For umbels of the last two orders - II and III, a more significant increase of the sharing percentage in the total seed yield is observed with a once fertilization with $N_5P_{19}K_{20}$ and twice - with $N_9P_9K_{20}$ and $N_5P_9K_{20}$.

The quantity of fully developed seeds is essential both for the successful seed production and for the quality of the obtained seeds. The differences between the individual variants are relatively small, and they are more significant depending on the sequence of the umbels (Table 8).

The highest percentage of fully developed seeds is reported for the umbels of the central stems. In the case of once fertilization, the values are between 78.65% for the non fertilized control to 83.48% for the $N_9P_9K_{20}$, this difference is statistically significant. In this variant, this percentage of fully developed seeds of umbels of the first, second and third order is also the highest, although the differences are smaller. In most of the variants the twice application of the fertilizers helps for the better development of the seeds from the central umbels, as the maximum values are reported for $N_9P_9K_{10}$ and $N_9P_{19}K_{20}$. Although with a small difference, compared to other variants in fertilization with $N_9P_9K_{10}$, the highest amount of normally formed seeds of the first, second and third order is reported. These are the highest values reported in this experiment. This indicate that this fertilization way provides a better nutrient revime and therefore the percentage of fully formed seeds is higher. Very close to them, for all orders, are the values when fertilization is with $N_5P_9K_{20}$.

It can definitely be pointed out that the twice application of the mineral fertilizers has a stronger and positive effect on the productivity of carrot seeds, as the effect is the highest from the combination $N_9P_9K_{10}$. Additionally, this statement is underlined by the established positive correlations between the main elements of yield and productivity.

5.2.3. Linear sizes of seeds from umbels of central, I, II and III order and weight of seeds per umbel in carrots

The seeds from the central umbels are characterized by the largest linear dimensions, followed by those from the first-class umbels. The different levels and terms of application of mineral fertilizers do not significantly affect the length, width and thickness of the seeds in carrots.

The average values obtained for the weight of seeds from the central umbels vary slightly. A more noticeable increase was observed with a once application of $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$ 3.51g and 3.44 g, respectively. When twice applying the mineral fertilizers, the combinations $N_9P_{19}K_{20}$ and $N_5P_{19}K_{10}$ are distinguished - 3.59 g and 3.53 g. The seed production of carrots is mainly formed by the first-class and second-class umbels, due to their larger number. In addition, higher values of the weight of seed production are reported. A significant increase for umbels of I order on average for the reporting period was observed with twice fertilization with $N_9P_9K_{10}$–12.05 g or almost two time above the unfertilized control and by 43.79% more than the fertilizer norm recommended for seed production. From a once application of fertilizers the highest results are found in $N_9P_9K_{20}$- 10.07 g with 20.16% and 80.14% more, respectively from the fertilized and unfertilized controls. The amount of seeds developed in the second-order umbels is approximately 50% lower than in those of the previous order. Larger amounts of seeds are formed in these umbels after a once fertilization with $N_9P_9K_{20}$ and $N_5P_{19}K_{20}$ - 4.94 g and 4.50 g, respectively. In the next period of application of the mineral fertilizers, a stronger increase is reported in the combination $N_5P_9K_{20}$, the weight reached to 3.54 g. The weight of the seeds obtained from the umbels of III order is much lower than those of the previous classes. The largest weight of 1.40 g was developed by the umbels from the variant of once application of $N_5P_9K_{20}$, followed by $N_9P_9K_{10}$, but in twice application - 1.32 g.

The results for the monitored indicators are presented in detail in tabular form in the dissertation.

5.3. Influence of different fertilizer rates and terms of fertilization on the quality of carrot seeds

5.3.1. Germination energy, laboratory and field germination

Germination energy is one of the most important indicators for establishing the vital properties of seeds. Its determination is in a significantly shorter time than germination. This provides information on the amount of earlier germinated seeds, which are characterized by greater vitality, higher potential and, consequently, better sowing qualities (Copeland and McDonald, 2001).

A significant increase in the average values of the energy with which the seeds germinate from the central umbel (Table 9) is reported during fertilization with $N_9P_9K_{20}$, regardless of the method of application - once or twice, respectively 83.44% and 81.11%. The seeds from I order umbels have a slightly lower germination energy, than those of the central umbel, and here is the best germination energy in both regime of fertilizer application due to the influence of $N_9P_9K_{20}$ - 79.32% and 77.44%. The three-year average values show that the seeds from II order umbels increase the most germination energy in a once application with $N_9P_9K_{20}$, which reaches 74.66%, and in the twice application for $N_9P_9K_{10}$ - 68.55%. Seeds of the third order umbels have the lowest value of this indicator in comparison with those of the other umbel orders. The $N_9P_9K_{20}$ (once) and $N_5P_9K_{20}$ (twice) variants cause maximum improvement in germination energy. It can be pointed out, that as a result of the applied fertilizer rates in both terms of application, the germination energy is higher and at the same time in most variants the diversity between the different umbel orders is relatively lower.

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Table 9. Vigour characteristics of carrot seeds (%)

Variant	**Germination energy**				**Laboratory germination**				**Field germination**			
	C	I	II	III	C	I	II	III	C	I	II	III
Once fertilization												
$N_0P_0K_0$	67.10	64.66	55.66	57.55	72.99	68.55	62.44	62.11	50.77	45.33	40.77	33.77
$N_7P_{14}K_{15}$	71.32	69.44	58.21	57.11	76.88	71.66	63.88	65.00	56.22	47.10	44.88	39.88
$N_5P_9K_{10}$	76.77	70.44	61.33	54.21	80.33	75.10	71.77	64.77	57.99	51.66	51.55	41.88
$N_5P_9K_{20}$	76.33	71.77	66.11	62.44	79.66	74.33	70.33	72.33	53.33	51.33	50.44	42.44
$N_5P_{19}K_{10}$	80.55	77.77	67.11	54.33	82.33	79.99	68.33	65.99	59.55	52.22	54.44	42.33
$N_5P_{19}K_{20}$	74.55	70.22	62.66	62.55	75.77	72.33	66.21	71.11	55.99	54.11	55.44	37.33
$N_9P_9K_{10}$	76.21	69.10	67.77	54.44	77.11	71.55	67.99	58.44	61.99	51.66	50.11	40.99
$N_9P_9K_{20}$	83.44	77.44	74.66	70.44	86.44	83.44	77.55	75.77	66.55	59.33	56.44	42.66
$N_9P_{19}K_{10}$	74.33	73.44	69.33	54.88	77.11	74.77	72.21	64.55	61.33	55.77	53.66	40.11
$N_9P_{19}K_{20}$	71.77	66.44	66.99	57.33	74.44	70.10	71.88	62.22	59.10	56.00	55.33	39.88
Twice fertilization												
$N_5P_9K_{10}$	79.11	74.10	68.10	46.88	81.10	77.44	72.33	58.22	58.33	55.55	53.66	40.55
$N_5P_9K_{20}$	78.77	73.77	66.44	63.99	81.88	75.44	71.77	67.77	61.77	52.22	50.55	41.21
$N_5P_{19}K_{10}$	75.44	69.44	65.55	49.66	76.77	74.00	64.66	72.66	59.88	54.55	52.88	41.10
$N_5P_{19}K_{20}$	75.77	68.88	65.10	58.00	81.32	71.55	65.88	64.44	59.22	54.99	51.22	41.44
$N_9P_9K_{10}$	72.55	69.55	68.55	51.33	76.99	71.33	64.44	61.33	62.32	53.77	51.33	42.44
$N_9P_9K_{20}$	81.11	79.32	66.77	57.33	85.99	80.16	74.66	69.88	58.33	53.10	54.22	42.55
$N_9P_{19}K_{10}$	78.10	72.55	66.66	45.10	79.88	77.00	71.21	55.10	59.10	51.55	50.77	40.77
$N_9P_{19}K_{20}$	72.99	66.44	62.55	52.77	75.55	69.99	66.88	56.22	60.99	54.33	52.44	43.77
p=5.0%	**5.70**	**5.55**	**8.26**	**11.93**	**4.78**	**4.64**	**6.25**	**9.72**	**3.14**	**3.40**	**3.26**	**3.68**
GDp=1.0%	**7.64**	**7.44**	**11.07**	**15.98**	**6.41**	**6.22**	**8.38**	**13.03**	**4.21**	**4.55**	**4.37**	**4.94**
p=0.1%	**10.09**	**9.82**	**14.62**	**21.10**	**8.46**	**8.21**	**11.07**	**17.20**	**5.56**	**6.01**	**5.77**	**6.52**

C – central umbel; **I**, **II**, **III** – orders

The three-year average values show that the seeds from II order umbels increase the most germination energy in a once application with $N_9P_9K_{20}$, which reaches 74.66%, and in the twice application for $N_9P_9K_{10}$ - 68.55%. Seeds of the third order umbels have the lowest value of this indicator in comparison with those of the other umbel orders. The $N_9P_9K_{20}$ (once) and $N_5P_9K_{20}$ (twice) variants cause maximum improvement in germination energy. It can be pointed out, that as a result of the applied fertilizer rates in both terms of application, the germination energy is higher and at the same time in most variants the diversity between the different umbel orders is relatively lower.

From the prepared analysis it was established that the regression dependence between the evenly increasing fertilization levels and the germination of carrot seeds is of a polynomial character (Fig. 15 and 16). The coefficients of determination, which show what percentage of the scattering of the resulting variable is explained by the action of the factor variable, are high, as for a single application it is R2 = 0.8331, and for the twice fertilization it is R2 = 0.6905. This gives ground to firm, that in 83% and in 69% of the cases, respectively in the once and twice fertilization, the changes in the amount of mineral fertilizers will lead to the obtained tendencies in the germination of the seeds.

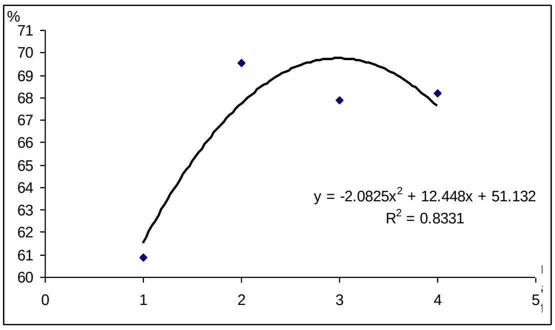

Fig. 15. Regression dependence between evenly increasing levels of once fertilization and germination (%) 1.$N_0P_0K_0$, 2.$N_{50}P_{90}K_{100}$;

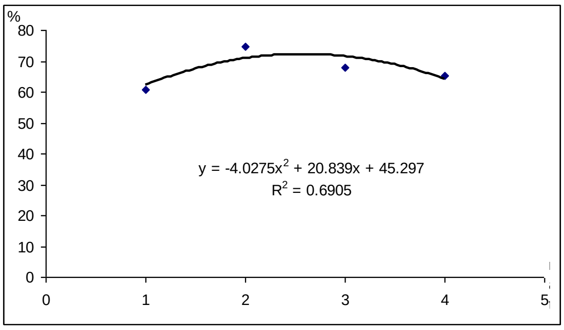

Fig. 16. Regression dependence between evenly increasing levels of twice fertilization and germination (%) 1.$N_0P_0K_0$, 2.$N_{50}P_{90}K_{100}$;

Germination is determined in a laboratory environment by providing optimal requirements for temperature and humidity. In practice, under field conditions, this temperature and humidity regime cannot be ensured for normal seed germination. Therefore, it is necessary to monitor the behavior of the seeds in the production environment. The values of field germination, expressing the percentage of ponies from a sample or batch, are always lower than those determining the laboratory germination (Cholakov 2009).

Field germination in carrot seeds decreases in according with the order of the umbels (Table 9). Significant increase in the central umbel, on average for the reporting period, was observed in the combination $N_9P_9K_{20}$ (once) - 66.55%. This represents an increase compared to the fertilization control by 18.37%, and in the cultivation of plants without fertilization this difference reaches 31.08%. At the closer term of application of the mineral fertilizers the seeds from the variants fertilized with $N_9P_9K_{10}$, $N_5P_9K_{20}$ and $N_9P_{19}K_{20}$ are characterized with higher germination - 62.32%, 61.77% and 60.99% respectively. Fertilization with higher levels of N, P and K increases the field germination of seeds and from first order umbels, which is better expressed when applying the fertilizer combinations once - $N_9P_9K_{20}$ (59.33), $N_9P_{19}K_{20}$ (56.00) and $N_9P_{19}K_{10}$ (55.77). The sowing qualities of the seeds from umbels - central and I order are significantly improved due to the introduction of higher rates P_2O_5 and K_2O, regardless of the background of nitrogen fertilization, i.e. the germination percentage increases at variable temperatures and humidity in field conditions.

This tendency is maintained for seeds of II and III order. The seeds from II oreder umbels have shown the highest field germination after once application of $N_9P_9K_{20}$, and $N_5P_{19}K_{20}$, followed by twice application of $N_9P_9K_{20}$ and $N_5P_9K_{10}$. In the case of seeds from the third order umbels, a larger increase in germination under field conditions is observed in the variants $N_9P_9K_{20}$ and

$N_5P_9K_{20}$ applied once, and in the closer application term this is established for the combinations $N_9P_{19}K_{20}$ and $N_9P_9K_{20}$.

In practice, seeds obtained from whole plants are used and it is therefore important to monitor the influence of the tested regimes and fertilization levels on the vital indicators of the total amount obtained from all umbels (Table 10).

Table 10. Vigour characteristics of carrot seeds - total sample (%)

Variant	Germination energy	Laboratory germination	Field germinationa
Once fertilization			
$N_0P_0K_0$	59.22	60.88	42.66
$N_7P_{14}K_{15}$	64.55	67.88	47.02
$N_5P_9K_{10}$	62.66	69.55	50.77
$N_5P_9K_{20}$	69.22	73.10	49.38
$N_5P_{19}K_{10}$	68.44	70.44	52.13
$N_5P_{19}K_{20}$	66.88	70.44	50.71
$N_9P_9K_{10}$	61.77	72.21	51.19
$N_9P_9K_{20}$	78.88	80.88	56.25
$N_9P_{19}K_{10}$	73.99	76.66	52.71
$N_9P_{19}K_{20}$	63.55	68.22	52.57
Twice fertilization			
$N_5P_9K_{10}$	69.32	74.55	52.02
$N_5P_9K_{20}$	69.44	76.22	51.44
$N_5P_{19}K_{10}$	77.10	79.77	52.10
$N_5P_{19}K_{20}$	65.10	69.10	51.72
$N_9P_9K_{10}$	66.44	70.44	52.46
$N_9P_9K_{20}$	68.88	75.66	52.05
$N_9P_{19}K_{10}$	66.11	71.10	50.55
$N_9P_{19}K_{20}$	62.11	65.44	52.88
p=5.0%	**7.24**	**7.34**	**1.99**
GDp=1.0%	**9.70**	**9.84**	**2.67**
p=0.1%	**12.81**	**12.98**	**3.52**

The highest percentage of germination energy are characterized the seeds from the variant fertilized once with $N_9P_9K_{20}$ - 78.88%. Fertilization with $N_5P_{19}K_{10}$ (77.10%) leads to a maximum value of this indicator in the closer term of application of mineral fertilizers. The data for the germination of the seeds from the total sample are relatively lower than the results reported for the seeds from umbels central and I order, except for $N_9P_9K_{10}$, $N_9P_{19}K_{10}$ and $N_5P_{19}K_{10}$ for the seeds from I order umbels. Germination of seeds form the total sample is higher compared to those from III order umbels and II order umbels of more of the variants. Here, too, the improving effect of higher rates P_2O_5 and K_2O on the quality of seed production is observed, especially in $N_9P_9K_{20}$ (once) - 80.88% and $N_5P_{19}K_{10}$ (twice) - 79.77%. Average for all variants the differences with the total sample are the highest for the seeds from the central umbel and from III order umbels, and with smaller differences are characterized those from I and II order umbels. From this it can be assumed that the seeds from I and II order have a greater role on the proceeding of germination of seeds of the whole plant, i.e. of those seeds, which also have the largest share in the formation of total productivity.

Optimization of nutrition regime improves the germination of seeds from the total sample under field conditions. The percentage of germination in all tested variants is higher than the zero control, as well as the recommended fertilizer rate for seed production. The differences between the different variants are small, but it can be noted, that the highest percentage of germination on average for the test period is characterized the seeds from plants fertilized once with $N_9P_9K_{20}$ - 56.25%.

5.3.2. Mean germination time and uniformity of the carrot seeds

Mean germination time is one of the indicators that determine the vital potential of seeds. It expresses the required number of days for seed germination. As soon as the seeds germinate, the plants are sprout faster. The required number of days for germination in the seeds from the central umbels and the umbels from I order is about 4 (Table 8). Although the small differences, it can be noted, that the seeds from the central umbel germinated faster, as the shortest time reported for the combination, twice $N_9P_{19}K_{20}$ (3.32 days) average for the three years. In the case of seeds from the first order umbels a significant reduction in the germination period was reported with the twice application of $N_9P_9K_{10}$ - 3.79 days. Seeds from the second order umbels and mostly from the third order umbels germinate much more slowly, as the average number of days is between 5 and 6. A relatively short period was reported for the variant fertilized once with $N_9P_9K_{20}$. In the other method of application, the shortest time was established for $N_5P_{19}K_{20}$. This applies to the seeds from II order umbels, as well as those from the last III order.

Stronger diversity between seeds from the central umbel and first order umbels is found only for variant $N_9P_9K_{10}$, applied once, while for $N_5P_{19}K_{20}$ in the same regime and for $N_5P_{19}K_{20}$ in the other way of application it is almost absent. The differences in the mean germination time between the seeds from I and II order umbels are also small and increase slightly with twice the application of higher fertilizer rates, and compared to the central umbel is almost one day, but are lower than the control. The strongest diversity was observed in seeds from third order umbels with approximately two days for the control variants, while with the application of the tested fertilization decreased, especially for $N_5P_9K_{10}$ (twice) - almost double.

The uniformity of the carrot seeds shows the average number of germinated seeds per day, as a percentage of the total number of germinated seeds. Average, the seeds from the central umbel germinate most amicably, followed by umbels of a higher order - I, II and III. A higher percentage of the monitored indicator in the central umbel was found in the fertilization control - 15.70% (Table 11). Very close to this result are the variants fertilized with

$N_5P_9K_{20}$ (15.17%) and $N_9P_9K_{10}$ (15.16%) applied once, as well as in twice fertilization with maximum amounts of the three fertilizers $N_9P_{19}K_{20}$ (15.06%).

Table. 11. Mean germination time and uniformity of the carrot seeds

Variant	Mean germination time (days)				Uniformity of the seeds (%)			
	C	I	II	III	C	I	II	III
Once fertilization								
$N_0P_0K_0$	3.52	4.23	4.31	5.42	13.84	11.90	8.76	7.82
$N_7P_{14}K_{15}$	3.65	3.84	5.42	5.79	15.70	13.10	10.26	11.00
$N_5P_9K_{10}$	3.68	4.49	6.05	6.10	11.91	11.92	11.14	10.15
$N_5P_9K_{20}$	3.46	3.98	4.43	5.99	15.17	13.74	11.43	8.16
$N_5P_{19}K_{10}$	3.95	3.88	4.90	5.81	10.64	12.71	11.98	8.38
$N_5P_{19}K_{20}$	3.97	3.92	4.90	5.63	12.48	13.16	9.68	9.53
$N_9P_9K_{10}$	3.77	5.13	5.86	6.03	15.16	11.90	9.23	8.25
$N_9P_9K_{20}$	3.58	4.08	4.60	5.30	14.04	16.07	13.24	12.32
$N_9P_{19}K_{10}$	3.72	4.17	4.87	6.13	12.68	10.99	11.40	9.42
$N_9P_{19}K_{20}$	3.98	4.36	4.87	4.95	13.21	9.99	9.47	10.84
Twice fertilization								
$N_5P_9K_{10}$	3.71	4.07	5.11	6.01	12.75	12.15	11.62	7.49
$N_5P_9K_{20}$	3.69	4.37	4.83	5.62	13.31	11.42	9.50	9.92
$N_5P_{19}K_{10}$	3.75	4.28	4.77	6.13	14.07	12.37	12.93	9.30
$N_5P_{19}K_{20}$	3.75	3.89	4.73	5.15	11.78	13.78	9.44	9.36
$N_9P_9K_{10}$	3.52	3.79	4.78	6.31	12.07	12.73	9.82	7.19
$N_9P_9K_{20}$	3.64	4.07	5.16	5.75	12.11	15.50	11.53	10.31
$N_9P_{19}K_{10}$	3.72	4.17	5.01	5.29	13.01	12.80	9.35	8.99
$N_9P_{19}K_{20}$	3.32	4.11	5.01	6.21	15.06	10.10	10.71	6.65
p=5.0%	**0.55**	**0.79**	**0.92**	**1.27**	**4.11**	**3.54**	**1.92**	**2.41**
GDp=1.0%	**0.74**	**1.06**	**1.23**	**1.70**	**5.51**	**4.75**	**2.57**	**3.23**
p=0.1%	**0.98**	**1.40**	**1.62**	**2.25**	**7.28**	**6.27**	**3.39**	**4.26**

C – central umbel; **I**, **II**, **III** – orders

Seeds from first order umbels germinate much more amicably after fertilization with $N_9P_9K_{20}$, regardless of the method of application - once or twice, as values reaching 16.07% and 15.50% compared to 11.90% for unfertilized control. A significant decrease in the friendliness germination is established in II order umbels and especially in III order umbels. However, optimization of nutrition regime improves the quality of seeds from second order umbels, which is particularly well dispay in the application of $N_9P_9K_{20}$ in both fertilization term. The application of all tested combinations caused an increase in the friendliness germination of seeds from the third order umbels, as it was the highest again for $N_9P_9K_{20}$, respectively 12.32% for once and 10.31% for twice, compared to 7.82% for unfertilized control.

As a result of fertilization in both regime with $N_5P_9K_{10}$ and twice with $N_9P_9K_{10}$, the diversity between the seeds from the central and those from the first order umbels decreases more significantly. It is especially high for the two controls between the seeds from II and III order umbels and those from the central umbel. Improves more after application of $N_9P_9K_{20}$.

The seeds from the total sample germinate more slowly only than those obtained from the central umbel and from the branches of the I order and faster than the seeds from the II and III order umbels (Table 12). The seeds obtained from plants fertilized once with $N_9P_9K_{20}$ - 3.95 days, with 4.21 days for the unfertilized control, are characterized by the best speed. In most variants, the results are closer to those of seeds from I order umbels.

Table. 12. Speed and friendliness of germination of carrot seeds – total sample

Variant	Mean germination time (days)	Uniformity of the seeds (%)
Once fertilization		
$N_0P_0K_0$	4.21	9.63
$N_7P_{14}K_{15}$	4.42	12.12
$N_5P_9K_{10}$	5.02	12.64
$N_5P_9K_{20}$	4.48	11.31
$N_5P_{19}K_{10}$	4.40	13.19
$N_5P_{19}K_{20}$	4.41	10.11
$N_9P_9K_{10}$	5.43	10.19
$N_9P_9K_{20}$	3.95	13.62
$N_9P_{19}K_{10}$	4.32	11.29
$N_9P_{19}K_{20}$	4.44	10.07
Twice fertilization		
$N_5P_9K_{10}$	4.40	12.01
$N_5P_9K_{20}$	4.60	10.59
$N_5P_{19}K_{10}$	4.33	11.62
$N_5P_{19}K_{20}$	4.54	10.25
$N_9P_9K_{10}$	4.35	9.78
$N_9P_9K_{20}$	4.55	14.73
$N_9P_{19}K_{10}$	4.38	11.44
$N_9P_{19}K_{20}$	4.35	10.90
p=5.0%	**0.52**	**2.84**
GDp=1.0%	**0.69**	**3.81**
p=0.1%	**0.92**	**5.03**

Combination of N_9 with P_9 and K_{20} causes an increase in the uniformity with which the seeds from the total seed batch germinate (Table 12). In both terms of application of this fertilizer rate maximum resulst is established - respectively 13.62% and 14.73%. As with the speed, and here the obtained values are closer to those for the seeds from I order umbels.

From the obtained data, it can be summarized, that both indicators are influenced by the different nutrition regime in which the seed plants of carrots are grown. A stronger increase in values was observed for fertilization with higher levels of P_2O_5 and K_2O. No significant differences were found between the two terms of application of the mineral fertilizers. In most cases, the best results are obtained after application of $N_9P_9K_{20}$, especially for the uniformity of the seeds.

5.3.3. Morphological features of carrot seedlings

5.3.3.1. Length of embryo root and hypocotyl

Different fertilizer rates as well as the method of fertilization affect the length of the different parts of the carrot seedlings.

The seeds from the central umbel form ponies with a maximum average length of the embryo root when fertilized twice with $N_9P_{19}K_{10}$ - 2.54 cm (Table 13).

Table 13. Morphological features of carrot seedlings

Variant	Length of embryo root (cm)				Length of hypocotyl (cm)			
	C	I	II	III	C	I	II	III
Once fertilization								
$N_0P_0K_0$	1.64	1.77	2.02	1.79	4.24	4.57	4.88	4.63
$N_7P_{14}K_{15}$	2.14	2.31	2.29	1.98	4.84	4.77	5.08	4.95
$N_5P_9K_{10}$	2.39	2.03	2.25	2.38	5.14	5.06	5.06	5.12
$N_5P_9K_{20}$	2.39	2.33	2.12	2.04	5.05	4.98	5.05	4.92
$N_5P_{19}K_{10}$	2.24	2.51	1.90	1.98	4.97	4.87	4.70	4.66
$N_5P_{19}K_{20}$	2.14	2.36	2.20	1.93	4.75	5.10	4.86	4.54
$N_9P_9K_{10}$	2.18	1.91	1.79	2.53	4.98	4.66	4.91	4.90
$N_9P_9K_{20}$	2.31	2.31	2.26	2.13	5.15	5.12	5.20	4.91
$N_9P_{19}K_{10}$	2.11	1.78	2.20	1.65	4.77	4.26	4.83	4.41
$N_9P_{19}K_{20}$	1.96	2.24	2.10	1.99	4.37	4.82	4.65	4.77
Twice fertilization								
$N_5P_9K_{10}$	1.98	1.68	2.02	1.93	4.39	4.48	5.08	4.86
$N_5P_9K_{20}$	1.97	2.20	1.92	2.02	4.82	5.14	4.99	4.77
$N_5P_{19}K_{10}$	2.06	1.97	2.45	2.16	4.76	4.56	4.83	4.89
$N_5P_{19}K_{20}$	2.33	2.02	2.09	1.85	4.87	4.82	4.77	4.83
$N_9P_9K_{10}$	2.01	2.77	2.05	1.73	4.66	4.90	4.54	4.52
$N_9P_9K_{20}$	2.23	2.04	2.15	2.12	4.87	4.64	4.73	4.70
$N_9P_{19}K_{10}$	2.54	2.48	2.13	2.15	5.12	5.03	4.75	4.64
$N_9P_{19}K_{20}$	2.29	2.01	2.33	1.71	5.12	4.78	5.20	4.54
p=5.0%	**0.51**	**0.63**	**0.50**	**0.46**	**0.49**	**0.48**	**0.63**	**0.79**
GDp=1.0%	**0.69**	**0.84**	**0.68**	**0.62**	**0.65**	**0.64**	**0.84**	**1.06**
p=0.1%	**0.91**	**1.11**	**0.89**	**0.82**	**0.86**	**0.85**	**1.11**	**1.40**

C – central umbel; **I, II, III** – orders

For seeds from I order umbels, a significant increase in embryo root, average for the test period was observed in twice fertilization with $N_9P_9K_{10}$ - 2.77 cm, while for the zero control it was only 1.77 cm. Good results were also found for $N_9P_{19}K_{10}$ (twice) and $N_5P_{19}K_{10}$ (once), 2.48 cm and 2.51 cm, respectively. Relatively shorter embryo roots, in most of the tested methods of fertilization, develop seeds from II and especially from III order umbels. In the first, once fertilization has the strongest effect in the levels $N_9P_{19}K_{10}$, $N_9P_9K_{20}$ and $N_5P_9K_{10}$, respectively, for the three years. Seeds from III order umbels are characterized average with the longest embryo root length after a once application of $N_9P_9K_{10}$.

A once application of $N_9P_9K_{20}$ leads to formation of seedlings with a longer hypocotyl length, this applies to seeds of all orders. In the closer application term of the mineral fertilizers, an increase is reported for the combinations $N_9P_{19}K_{10}$, $N_9P_{19}K_{20}$, $N_5P_9K_{20}$ and $N_5P_{19}K_{10}$.

The seeds from the total sample are characterized with a maximum length of the embryo root in the variant fertilized with $N_5P_9K_{20}$ (2.45), regardless of the way of application - once or twice (Table 14).The values for the length of the hypocotyl in the seeds from the total sample vary slightly, as a certain increase observed in the variant fertilized once with $N_9P_9K_{20}$ - 5.20 cm.

Table 14. Morphological features of carrot seedlings – total sample

Variant	Length of embryo root (cm)	Length of hypocotyl (cm)
Once fertilization		
$N_0P_0K_0$	2.20	4.48
$N_7P_{14}K_{15}$	2.04	5.05
$N_5P_9K_{10}$	2.09	5.18
$N_5P_9K_{20}$	2.45	5.00
$N_5P_{19}K_{10}$	2.22	4.83
$N_5P_{19}K_{20}$	2.20	5.11
$N_9P_9K_{10}$	1.95	5.04
$N_9P_9K_{20}$	2.21	5.20
$N_9P_{19}K_{10}$	2.06	4.97
$N_9P_{19}K_{20}$	2.24	4.64
Twice fertilization		
$N_5P_9K_{10}$	2.02	4.44
$N_5P_9K_{20}$	2.45	4.74
$N_5P_{19}K_{10}$	1.98	4.70
$N_5P_{19}K_{20}$	2.30	4.91
$N_9P_9K_{10}$	2.21	4.90
$N_9P_9K_{20}$	2.19	4.79
$N_9P_{19}K_{10}$	1.94	5.01
$N_9P_{19}K_{20}$	2.09	4.94
p=5.0%	**0.41**	**0.52**
GDp=1.0%	**0.55**	**0.70**
p=0.1%	**0.73**	**0.92**

5.3.3.2. Fresh mass of one seedling and absolute dry mass of seedlings

The fresh mass of the seedlings helps to more fully characterization of their morphology and hence the status of the seeds.

The fresh mass of seedlings in the seeds from central umbel significantly increased in the variant fertilized twice with $N_9P_9K_{20}$, as average for reporting period is 13.25 mg or 27.89% above the unfertilized control and 12.67% above the fertilizer control. Very close to this result was reported in the fertilizer rate with maximum amounts of N, P and K - 12.58 mg (Table 15).

The mass of one sprout in the seeds from umbels I order is the highest after application of $N_5P_9K_{10}$ (once) - 12.30 mg, in contrast to the zero and fertilizer control, where it is respectively 10.50 mg and 11.57 mg. The average weight of the ponies in the seeds from second order umbels for most of the tested combinations is about 10 mg.

Table 15. Morphological indicators of carrot seedlings

Variant	Fresh mass of one seedling (mg)				Absolute dry mass (%)			
	C	I	II	III	C	I	II	III
Once fertilization								
$N_0P_0K_0$	10.36	10.50	10.00	10.22	3.99	3.29	2.88	3.22
$N_7P_{14}K_{15}$	11.76	11.57	10.44	8.45	3.33	3.33	3.22	3.44
$N_5P_9K_{10}$	12.85	12.30	10.38	9.27	3.88	3.72	3.55	3.66
$N_5P_9K_{20}$	11.56	12.01	10.34	10.28	3.63	3.33	2.99	3.77
$N_5P_{19}K_{10}$	10.09	10.79	9.83	8.97	4.21	2.88	3.21	3.55
$N_5P_{19}K_{20}$	8.49	10.74	9.67	8.88	3.73	3.44	2.55	3.32
$N_9P_9K_{10}$	11.07	9.55	9.70	9.68	3.86	3.77	2.99	3.33
$N_9P_9K_{20}$	11.17	10.20	11.37	9.64	3.66	3.21	2.66	3.11
$N_9P_{19}K_{10}$	9.08	10.20	9.45	10.00	3.88	3.11	3.11	2.99
$N_9P_{19}K_{20}$	9.43	10.88	10.14	9.66	3.77	2.99	3.33	2.99
Twice fertilization								
$N_5P_9K_{10}$	9.03	10.18	10.07	10.30	4.33	4.22	3.21	3.88
$N_5P_9K_{20}$	11.04	10.72	10.51	10.23	3.99	3.88	3.33	4.22
$N_5P_{19}K_{10}$	10.56	9.22	10.28	8.76	3.55	3.66	2.99	2.88
$N_5P_{19}K_{20}$	11.51	10.59	8.56	9.33	3.66	3.66	3.10	2.66
$N_9P_9K_{10}$	9.71	11.33	9.63	7.87	3.88	3.66	3.66	3.33
$N_9P_9K_{20}$	13.25	9.50	9.88	10.30	3.88	3.88	3.55	3.77
$N_9P_{19}K_{10}$	11.68	10.98	10.36	9.75	3.88	3.88	3.22	3.66
$N_9P_{19}K_{20}$	12.58	9.84	9.76	8.85	4.55	3.77	3.33	4.22
p=5.0%	**3.03**	**2.38**	**2.47**	**3.28**	**0.96**	**0.81**	**0.90**	**0.80**
GDp=1.0%	**4.07**	**3.18**	**3.31**	**4.39**	**1.29**	**1.08**	**1.20**	**1.08**
p=0.1%	**5.37**	**4.20**	**4.38**	**5.80**	**1.71**	**1.43**	**1.59**	**1.43**
	r^*=0.65 r^{**}=0.53	**r^*=0.52 r^{**}=0.47**	**r^*=0.48 r^{**}=0.35**	**r^*=0.35 r^{**}=0.33**				

r^* – correlation between the fresh mass of seedlings and the length of the hypocotyl;
r^{**}- correlation between the fresh mass of seedlings and the length of the embryo root;
C – central umbel; **I, II, III** – orders;

A more noticeable increase was found at the fertilizer rate $N_9P_9K_{20}$ (once) - 11.37 mg. The values obtained for the seeds from the last third order, average for the reporting period are in the range from 7.87 mg for $N_9P_9K_{10}$ (twice) to 10.30 mg for $N_5P_9K_{10}$ and $N_9P_9K_{20}$, again applied twice. The fresh mass of seedlings, as an element of their morphological characteristics, is directly related to the other components - the length of the embryonic root and the hypocotyl. In this regard, for the separate orders of the seed plant are established positive correlations.

The establishment of the parameters of the absolute dry mass of the seedlings allows for a more complete monitoring of their development and condition. The values obtained for this indicator vary slightly, and it can be pointed out, that the application of different amounts of N, P and K has a smaller effect on the absolute dry mass of seedlings in carrots compared with the way of fertilization, where higher results are reported in the twice application of mineral fertilizers (Table 15).

The improvement of the nutrition regime leads to the formation of seedlings with higher mass and in the total sample (Table 16). In most of the tested variants, the percentage of absolute dry mass increase almost double compared to the cultivation of carrot seed plants without fertilization. The highest percentage is for once fertilization with $N_5P_9K_{10}$ and $N_5P_{19}K_{10}$ - 4.21% and 4.10%. Such results in twice fertilization are obtained in the higher levels - $N_9P_9K_{20}$ and $N_9P_{19}K_{10}$, respectively 4.11% and 4.10%.

Table 16. Morphological indicators of carrot seedlings – total asmple

Variant	Fresh mass of one seedling (mg)	Absolute dry mass (%)
Once fertilization		
$N_0P_0K_0$	11.23	2.66
$N_7P_{14}K_{15}$	10.99	4.21
$N_5P_9K_{10}$	11.77	4.11
$N_5P_9K_{20}$	11.65	3.88
$N_5P_{19}K_{10}$	10.27	4.10
$N_5P_{19}K_{20}$	10.19	3.33
$N_9P_9K_{10}$	9.88	3.55
$N_9P_9K_{20}$	11.24	3.66
$N_9P_{19}K_{10}$	9.82	3.21
$N_9P_{19}K_{20}$	8.73	3.44
Twice fertilization		
$N_5P_9K_{10}$	9.15	3.88
$N_5P_9K_{20}$	10.46	3.22
$N_5P_{19}K_{10}$	9.44	3.66
$N_5P_{19}K_{20}$	9.40	3.11
$N_9P_9K_{10}$	9.06	3.88
$N_9P_9K_{20}$	10.07	4.11
$N_9P_{19}K_{10}$	9.64	4.10
$N_9P_{19}K_{20}$	10.28	3.44
p=5.0%	**1.90**	**0.88**
GDp=1.0%	**2.55**	**1.18**
p=0.1%	**3.36**	**1.55**
	r^*=0.42 **r^{**}=0.40**	

r^* – correlation between the fresh mass of seedlings and the length of the hypocotyl;
r^{**}- correlation between the fresh mass of seedlings and the length of the embryo root;

5.3.4. Chronometric course of the individual phases of germination and diversion from the normal development of seedlings in carrots

Seed germination was associated with a number of physiological processes that lead to certain anatomical and morphological changes in the embryo. Seeds of all orders absorb water on average for about 1 hour, and this is found for most of the tested variants. Between 2 and 4 hours were needed for the seeds of all orders to swell, and no significant difference was found between the separate umbels and variants. Significant contrast in the quality of the seeds was observed in the last two phases of germination - development of the embryo root and embryo apex, where with increasing the order of the umbel increases the time of occurrence of the respective phase. The optimization of the nutrition regime has a greater influence at the onset of the phase - development of the embryo apex, expressed more clearly in the fertilizer rates $N_5P_9K_{20}$ (once) and $N_5P_9K_{10}$ (twice), as well as in $N_9P_9K_{20}$ for both methods of application.

Indications of diversion from the normal germination are essential for the quality of seed yield, as they show the ability of the seed to develop a normal plant. The most common diversion from the normal development of seeds in carrots were expressed in the lack of pappus and branches on the embryo root. Fertilization with higher amounts of K in combination with lower levels of P and N leads to a reduction in the percentage of diversion from normal seedling development in carrots. The data for the indicated indicators were presented in detail in the dissertation.

5.3.5. Vigour index of carrot seeds

Determining the vigour index of seeds is especially important to establish their sowing qualities. In it, much earlier than for germination were established occurring in the seed changes, leading to loss of vigor.

The average values obtained for the seeds from the central umbel for most of the variants are between 9 and 10. A more significant increase was reported for a once fertilization with $N_9P_{19}K_{10}$ (13.71) (Table 17).

Table 17. Vigour index of carrot seeds (test "Initial vegetative productivity of seeds")

Variant	Orders				Total sample
	C	I	II	III	
Once fertilization					
$N_0P_0K_0$	9.72	10.56	8.41	3.58	7.20
$N_7P_{14}K_{15}$	9.31	9.74	8.61	6.54	9.27
$N_5P_9K_{10}$	12.79	10.80	10.93	8.99	10.99
$N_5P_9K_{20}$	7.38	7.91	8.27	8.04	8.50
$N_5P_{19}K_{10}$	8.88	8.11	8.24	5.61	8.39
$N_5P_{19}K_{20}$	8.24	8.03	7.53	6.76	7.79
$N_9P_9K_{10}$	8.54	9.79	8.57	7.99	9.61
$N_9P_9K_{20}$	9.16	9.76	10.79	9.54	10.47
$N_9P_{19}K_{10}$	13.71	10.69	6.86	5.61	9.35
$N_9P_{19}K_{20}$	11.91	10.43	9.80	12.34	10.98
Twice fertilization					
$N_5P_9K_{10}$	9.96	10.21	10.31	6.78	9.84
$N_5P_9K_{20}$	10.49	9.36	7.43	7.83	9.25
$N_5P_{19}K_{10}$	9.18	9.39	8.51	6.31	8.97
$N_5P_{19}K_{20}$	8.26	10.56	8.03	6.66	8.48
$N_9P_9K_{10}$	10.79	10.08	8.66	8.54	10.59
$N_9P_9K_{20}$	9.29	9.24	11.86	5.21	10.14
$N_9P_{19}K_{10}$	8.42	11.08	10.36	6.03	9.66
$N_9P_{19}K_{20}$	13.13	9.46	7.66	5.18	9.04
p=5.0%	**4.51**	**5.06**	**4.45**	**4.08**	**2.04**
GDp=1.0%	**6.05**	**6.79**	**5.96**	**5.47**	**2.74**
p=0.1%	**7.98**	**8.96**	**7.87**	**7.22**	**3.61**

C – central umbel; **I, II, III** – orders;

Twice fertilization with $N_9P_{19}K_{10}$ leads to maximum values of the commented indicator - 11.08, for seeds from first order umbels.

The vigour index decreases especially strongly in the seeds from umbels of II and especially III order. The vigour index of the seeds from the second order umbels increases after twice fertilization with $N_9P_9K_{20}$ - 11.86, which is 37.74% and 41.02% more than the fertilization control and when growing the plants without fertilization. The average values for the seeds from the umbels of the last third order are in range from 3.58 for the zero control to 12.34 for the $N_9P_{19}K_{20}$ (once). For the seeds from total sample, increase in the monitored indicator average for the reporting period was found for $N_5P_9K_{10}$, $N_9P_{19}K_{20}$ and $N_9P_9K_{20}$ for once application and for $N_9P_9K_{10}$ and $N_9P_9K_{20}$ for twice fertilization.

5.4. Chemical composition of carrot seeds depending on the applied fertilization regime

The chemical composition of vegetable seeds is essential because it must provide the seeds with the necessary nutrients and energy to be able to germinate, subsequently emerge and develop young plants (Copeland and McDonald, 1995; Panayotov, 2015).

Average for the period, the percentage of dry matter in the seeds for most of the tested variants is about 90% (Table 18).

Table 18. Content of some main chemical components in carrot seeds

Variant	Dry metter (%)	Protein (%)	Fat (%)	Carbohydrates (%)
Once fertilization				
$N_0P_0K_0$	90.82	21.23	12.08	50.35
$N_7P_{14}K_{15}$	89.78	22.02	9.25	50.91
$N_5P_9K_{10}$	90.24	21.08	9.77	51.63
$N_5P_9K_{20}$	90.47	21.81	10.38	50.70
$N_5P_{19}K_{10}$	91.16	22.83	8.98	52.24
$N_5P_{19}K_{20}$	90.85	22.67	10.18	51.38
$N_9P_9K_{10}$	91.05	21.62	9.36	52.29
$N_9P_9K_{20}$	90.38	22.10	10.70	50.39
$N_9P_{19}K_{10}$	91.21	22.38	7.59	53.79
$N_9P_{19}K_{20}$	90.76	20.63	10.07	52.45
Twice fertilization				
$N_5P_9K_{10}$	91.14	23.14	7.55	53.42
$N_5P_9K_{20}$	91.01	22.72	10.46	50.86
$N_5P_{19}K_{10}$	87.69	21.44	8.71	49.47
$N_5P_{19}K_{20}$	90.68	21.91	9.93	51.35
$N_9P_9K_{10}$	90.85	21.39	10.30	51.37
$N_9P_9K_{20}$	90.09	21.71	8.17	51.34
$N_9P_{19}K_{10}$	91.29	21.34	7.70	53.65
$N_9P_{19}K_{20}$	90.99	21.74	9.22	51.18
p=5.0%	**2.18**	**2.10**	**4.22**	**4.75**
GDp=1.0%	**2.92**	**2.82**	**5.65**	**6.36**
p=0.1%	**3.86**	**3.72**	**7.47**	**8.40**

The established values for the amount of protein in carrot seeds are close and vary within narrow limits between the different variants. Some increase was observed in the variant fertilized twice with $N_5P_9K_{10}$ - 23.14%, in contrast to the others, where 21-22% were reported.

Fats are the main source of energy and in metabolism during germination their hydrolysis begins first in the embryo. Carrot seeds were generally characterized with high fat content (Panayotov, 2015). There was a large variation in the percentage of fat content in carrot seeds depending on the regime and method of fertilization, as data are in the range from 7.55% for $N_5P_9K_{10}$ (twice) to 12.08% for the unfertilized control average for the reporting period.

Carbohydrates are a very important source of energy, the most important of which is sucrose, which has a significant impact on seed viability. The average content of carbohydrates is highest in the seeds of the variant fertilized with $N_9P_{19}K_{10}$ (once) - 53.79%, which is almost 4% more than the two controls - fertilized and zero. The same fertilizer rate leads to the highest percentage in the other term of application of mineral fertilizers - 53.65%, followed by $N_5P_9K_{10}$ - 53.42%. It can be stated that fertilization with $N_9P_{19}K_{10}$, both once and twice, as well as the combination of N_9 with higher levels of P_2O_5 and K_2O lead to an increase in the percentage content of carbohydrates in carrot seeds.

5.5. Storage of carrot seeds depending on the applied fertilization regime

The vitality of the seeds changes after a long period of storage, as usually observed a decrease in the energy with which they germinate, as well as the total number of germinated seeds.

The different approach of nutrition of carrot seed plants has the effect of obtaining better quality seeds that maintain their vitality for a longer period, providing well garnished crops. The seeds from the central umbel are characterized with the best vitality and the values are lower with increasing sequence.

The germination energy of the seeds from the central umbel decreases average between 10 and 15% compared to the first year, with smaller differences observed in the combinations $N_5P_{19}K_{20}$ $N_9P_9K_{20}$ applied once and $N_9P_9K_{10}$ and $N_9P_9K_{20}$ applied twice, where the decrease compared to the first year is between 5 and 10 % (Table 19). Data for germination energy for seeds from umbels I order after storage are in the range from 53.33% for $N_5P_9K_{10}$, $N_9P_9K_{10}$ (once) and $N_5P_9K_{10}$ (twice) to 66.33% for $N_9P_9K_{20}$ (once). The smallest decrease compared to the first year of testing was found for $N_5P_{19}K_{20}$ (twice) - 66.66% (2017 year) and 60.00% (2019 year). The germination energy of the seeds from umbel second order after the storage period has a maximum value in the variant fertilizered both once and twice with $N_9P_9K_{20}$ - respectively 60.00% and 60.33%. Compared to the first year, this represents a decrease of 16.66% and 9.67%, respectively. The seeds from third order umbels are distinguished by the lowest quality. Nevertheless, optimization of the fertilization regime helps to increase their vitality. In the first term of fertilization with better germination energy after storage, are characterized the seeds from variants $N_9P_9K_{20}$ (57.33) and $N_5P_{19}K_{20}$ (55.33). In the other regime, the seed germination energy is higher after fertilization with $N_5P_9K_{20}$ (50.66) and $N_9P_9K_{20}$ (45.33).

Table 19. Vigour of carrot seeds after three-year storage

Variant	Germination energy (%)							
	Central umbel		I order umbels		II order umbels		III order umbels	
	2017	2019	2017	2019	2017	2019	2017	2019
Once fertilization								
$N_0P_0K_0$	69.33	61.66	68.33	60.33	53.66	50.00	50.66	41.33
$N_7P_{14}K_{15}$	72.66	62.00	71.66	61.66	56.66	52.33	59.33	34.00
$N_5P_9K_{10}$	79.33	54.66	69.33	53.33	51.33	34.66	46.66	31.33
$N_5P_9K_{20}$	79.00	65.33	72.00	64.00	70.00	56.66	68.00	40.00
$N_5P_{19}K_{10}$	82.00	70.33	77.33	65.33	66.00	52.33	54.00	50.66
$N_5P_{19}K_{20}$	72.33	66.00	68.00	65.33	56.00	52.00	62.66	55.33
$N_9P_9K_{10}$	78.66	56.00	70.33	53.33	62.66	41.33	45.33	19.33
$N_9P_9K_{20}$	86.00	76.66	77.33	66.33	76.66	60.00	80.00	57.33
$N_9P_{19}K_{10}$	74.66	57.33	72.66	54.00	72.00	52.00	44.66	42.00
$N_9P_{19}K_{20}$	70.66	61.33	67.33	58.66	61.00	54.66	60.00	45.33
Twice fertilization								
$N_5P_9K_{10}$	80.00	63.33	74.00	53.33	63.33	48.66	40.00	36.00
$N_5P_9K_{20}$	81.00	70.33	76.33	58.66	69.33	52.33	68.66	50.66
$N_5P_{19}K_{10}$	73.00	62.00	60.00	56.33	54.66	52.00	55.00	35.33
$N_5P_{19}K_{20}$	80.00	62.33	66.66	60.00	62.66	55.33	50.00	39.33
$N_9P_9K_{10}$	67.66	60.66	65.33	59.66	62.66	50.00	56.00	42.00
$N_9P_9K_{20}$	83.00	68.66	82.66	62.33	70.00	60.33	59.33	45.33
$N_9P_{19}K_{10}$	76.66	64.00	67.33	58.00	60.66	56.66	44.66	38.66
$N_9P_{19}K_{20}$	63.00	60.66	60.00	54.66	59.00	37.33	49.00	19.33
p=5.0%	**13.13**	**30.98**	**19.47**	**21.84**	**16.58**	**25.53**	**31.85**	**20.88**
GDp=1.0%	**17.59**	**41.51**	**26.09**	**29.26**	**22.22**	**34.21**	**42.68**	**27.98**
p=0.1%	**23.22**	**54.79**	**34.44**	**38.63**	**29.33**	**45.15**	**56.33**	**36.93**

The total number of germinated seeds from the central umbel also decreases after the storage period. The seeds from variants $N_9P_9K_{20}$ (once) and $N_5P_9K_{20}$ (twice) are characterized with the closest values to the harvest year - 78.00% and 74.00%, respectively (Table 20). Seed germination from I order umbels decreases average with 15% compared to the first year. The strongest germination reported for the harvest year is preserved with twice application of $N_9P_{19}K_{20}$ with a difference of only 3.34%. The fertilizer rate $N_9P_9K_{20}$, regardless of the way of application, leads to the preservation of the vigor of the seeds from the second order umbels after three years of storage. The seeds from the last third order from variants $N_5P_9K_{20}$ and $N_9P_9K_{20}$ (once and twice) preserve relatively high vigor. The decrease compared to 2017 year for these variants is average between 10% and 20%.

Table 20. Vigour of carrot seeds after three-year storage

Variant	Germination (%)							
	Central umbel		I order umbels		II order umbels		III order umbels	
	2017	2019	2017	2019	2017	2019	2017	2019
Once fertilization								
$N_0P_0K_0$	79.33	62.00	70.33	60.66	56.66	53.33	64.00	44.00
$N_7P_{14}K_{15}$	80.00	64.00	72.66	62.66	68.66	56.00	72.00	48.00
$N_5P_9K_{10}$	82.66	67.33	71.33	66.00	70.00	58.00	64.00	50.66
$N_5P_9K_{20}$	82.66	68.66	76.33	65.00	73.66	63.33	76.66	62.66
$N_5P_{19}K_{10}$	84.00	65.66	80.00	65.33	68.00	56.66	63.33	54.00
$N_5P_{19}K_{20}$	74.66	68.00	71.33	66.00	56.66	59.00	72.00	56.33
$N_9P_9K_{10}$	79.33	58.00	73.33	54.00	65.33	52.66	47.33	44.66
$N_9P_9K_{20}$	86.00	78.00	85.33	68.00	78.00	62.33	80.00	60.00
$N_9P_{19}K_{10}$	76.00	58.66	74.66	56.66	72.66	52.66	59.33	50.66
$N_9P_{19}K_{20}$	73.33	63.33	72.66	60.66	70.00	55.33	67.33	52.00
Twice fertilization								
$N_5P_9K_{10}$	81.33	68.66	79.33	59.33	66.66	53.00	54.66	50.66
$N_5P_9K_{20}$	83.66	74.00	77.00	61.33	73.33	59.33	78.00	58.33
$N_5P_{19}K_{10}$	75.00	66.00	72.00	64.66	60.66	56.33	76.00	52.00
$N_5P_{19}K_{20}$	82.66	64.66	69.33	62.00	63.33	56.33	58.66	50.66
$N_9P_9K_{10}$	72.33	65.00	68.00	60.33	62.66	56.00	66.66	49.33
$N_9P_9K_{20}$	86.33	69.33	78.33	66.66	72.00	63.33	74.66	54.00
$N_9P_{19}K_{10}$	77.33	68.66	69.33	63.33	66.33	59.66	48.66	42.66
$N_9P_{19}K_{20}$	69.00	64.66	64.00	60.66	62.00	57.33	56.00	32.66
p=5.0%	**10.03**	**32.03**	**13.23**	**21.40**	**12.17**	**19.08**	**24.97**	**23.20**
GDp=1.0%	**13.44**	**42.91**	**17.73**	**28.68**	**16.31**	**25.56**	**33.46**	**31.09**
p=0.1%	**17.74**	**56.64**	**23.40**	**37.86**	**44.17**	**33.74**	**44.17**	**41.04**

Table 21. Vigour of carrot seeds after three-year storage – total sample

Variant	Germination energy (%)		Germination (%)	
	2017	2019	2017	2019
Once fertilization				
$N_0P_0K_0$	60.00	56.66	60.00	60.66
$N_7P_{14}K_{15}$	70.00	63.33	71.33	71.33
$N_5P_9K_{10}$	64.00	54.00	72.66	67.33
$N_5P_9K_{20}$	73.33	58.00	76.66	67.33
$N_5P_{19}K_{10}$	72.00	62.00	72.66	69.33
$N_5P_{19}K_{20}$	64.00	62.66	68.00	68.66
$N_9P_9K_{10}$	60.66	47.33	72.66	61.33
$N_9P_9K_{20}$	82.66	72.66	84.66	80.00
$N_9P_{19}K_{10}$	75.33	58.66	78.00	68.66
$N_9P_{19}K_{20}$	61.33	56.00	65.33	66.66
Twice fertilization				
$N_5P_9K_{10}$	70.66	70.00	76.00	82.66
$N_5P_9K_{20}$	77.33	64.66	85.33	71.33
$N_5P_{19}K_{10}$	76.00	66.66	77.33	72.66
$N_5P_{19}K_{20}$	56.66	52.00	60.00	57.33
$N_9P_9K_{10}$	68.00	60.66	73.33	68.66
$N_9P_9K_{20}$	75.33	68.66	76.66	76.00
$N_9P_{19}K_{10}$	65.33	58.00	66.66	63.33
$N_9P_{19}K_{20}$	59.00	56.66	61.00	63.33
p=5.0%	**15.87**	**20.13**	**15.12**	**21.16**
GDp=1.0%	**21.26**	**26.97**	**20.27**	**28.36**
p=0.1%	**28.07**	**35.59**	**26.75**	**37.43**

The germination energy of the seeds from the total sample after storage is in the range from 47.33% for $N_9P_9K_{10}$ (once) to 70.0% for $N_5P_9K_{10}$ with twice fertilization, while for the harvest year it is in the range from 56.66% ($N_5P_{19}K_{20}$, twice) to 82.66% ($N_9P_9K_{20}$, once) (Table 21).

The average reduction for all variants is in the range from 9.36% to 12.66%. The closest values to those reported in the harvest year after storage show the seeds from plants fertilized twice with $N_5P_9K_{10}$, with a difference of a minimum of 0.66%. Variants $N_5P_{19}K_{20}$ (once) $N_9P_{19}K_{20}$ (twice) also show good storage, with a decrease of 1.34% and 2.34%, respectively.

The lowest germination after storage show variant $N_5P_{19}K_{20}$ with twice fertilization - 57.33%, as well as the unfertilized control. The highest values are for $N_9P_9K_{20}$ (once) 80.0%, as well as for twice fertilization with $N_5P_9K_{10}$ and $N_5P_{19}K_{10}$ - 72.66%. After storage period with highest values of germination to those from fist year are characterized the seeds from variant $N_5P_{19}K_{20}$ with a once application – with difference of only 1.33%, as well as from $N_9P_9K_{20}$ and $N_9P_{19}K_{20}$ - with differences of 1.66% and 1.67%.

5.6. Economic evaluation of different fertilization regimes in carrot seed production

The prepared economic assessment for seed production of carrots shows that the different regimes and different levels of application of mineral fertilizers have a strong influence on the efficiency of seed production. The received incomes are closely related to seed yield (Table 22). All tested variants have higher incomes compared to the two controls. For the whole experiment with the highest incomes, is characterized the variant with twice application of $N_9P_9K_{10}$, as well as the once in $N_9P_9K_{20}$. The increase compared to the non-fertilizing control is by 36.59% and 29.68%, respectively, and compared to the currently recommended method of fertilization, this increase is by 27.13% and by 20.71%.

The total costs depend primarily on the amount of fertilizers and the terms of their application. For this reason, in both regimes the highest cost variant is $N_9P_{19}K_{20}$, i.e. the combination with the highest levels of the three fertilizers. In the case of a once regime, variants are observed that have lower total costs, compared to the recommended control - $N_7P_{14}K_{15}$. This is the case when the amount of phosphorus and especially potassium fertilizer are smaller, i.e. fertilizers that have a higher price - $N_5P_9K_{10}$, $N_5P_{19}K_{10}$, $N_9P_9K_{10}$ and $N_9P_{19}K_{10}$. With twice fertilization, relatively higher costs can be observed for $N_5P_{19}K_{20}$ and $N_9P_9K_{20}$,, also combinations with a higher amount of potassium.

One of the most important and significant indicators of economic evaluation is the notional profit. In the case of a once fertilization, the increase compared to the unfertilized control is from 7.07% to 30.06% for the recommended norm and for $N_9P_9K_{20}$, respectively.

Table. 22. Economic evaluation of different fertilization regimes in carrot seed production

Variant	Incoms		Total cost		Notional profit		Rate of cost-effective	
	% toward control	% twoard recomnded	% toward control	% twoard recomnded	% toward control	% twoard recomnded	% toward control	% twoard recomnded
Once fertilization								
$N_0P_0K_0$	100.00	93.08	100.00	88.33	100.00	93.39	100.00	105.74
$N_7P_{14}K_{15}$	107.44	100.00	113.22	100.00	107.07	100.00	94.57	100.00
$N_5P_9K_{10}$	109.16	101.60	108.81	96.11	109.18	101.97	100.34	106.09
$N_5P_9K_{20}$	115.72	107.71	114.18	100.85	115.82	108.17	101.44	107.26
$N_5P_{19}K_{10}$	118.88	110.65	111.28	98.29	119.36	111.47	107.26	113.42
$N_5P_{19}K_{20}$	117.09	108.99	116.64	103.03	117.12	109.38	100.41	106.17
$N_9P_9K_{10}$	111.71	103.98	109.79	96.97	111.84	104.45	101.86	107.71
$N_9P_9K_{20}$	129.68	120.71	115.16	101.71	130.60	121.97	113.41	119.92
$N_9P_{19}K_{10}$	119.20	110.95	112.26	99.15	119.64	111.74	106.57	112.69
$N_9P_{19}K_{20}$	113.60	105.73	117.62	103.89	113.34	105.86	96.36	101.89
Twice fertilization								
$N_5P_9K_{10}$	110.46	102.81	118.57	104.73	109.95	102.69	92.73	98.05
$N_5P_9K_{20}$	115.11	107.15	123.93	109.46	114.56	106.99	92.44	97.74
$N_5P_{19}K_{10}$	126.55	117.79	121.03	106.90	126.90	118.52	104.85	110.86
$N_5P_{19}K_{20}$	119.56	111.28	126.40	111.64	119.12	111.25	94.24	99.65
$N_9P_9K_{10}$	136.59	127.13	119.55	105.59	137.66	128.57	115.15	121.76
$N_9P_9K_{20}$	123.39	114.85	124.91	110.33	123.30	115.15	98.71	104.37
$N_9P_{19}K_{10}$	117.72	109.57	122.01	107.77	117.45	109.69	96.26	101.78
$N_9P_{19}K_{20}$	122.11	113.65	127.38	112.51	121.77	113.73	95.60	101.09

High values, above the control, this indicator has also with the application of $N_9P_{19}K_{10}$ (c 19.64%) and in $N_5P_{19}K_{10}$ (c 19.36%), as well as $N_5P_{19}K_{20}$ (17.36%) (17.36%). The twice application of mineral fertilizers is also characterized by an increase in notional profit. By 37.66% it is higher than the unfertilized control, followed by that for $N_5P_{19}K_{10}$ and $N_9P_9K_{20,}$by 26.90% and by 23.30%, respectively. In most of the variants it exceeds the reciprocal variants in once fertilization. It is noteworthy that in the variants with higher notional profit, higher seed yields were obtained.

An important economic indicator in the evaluation of various technologies applied in agriculture is the rate of cost-effective. It has a complex expression of the economic efficiency of an agro-technological event. The highest rate of rate of cost-effective of 21.76% above the recommended control was reported for twice fertilization with the combination $N_9P_9K_{10}$. With a once fertilization, this index is the highest for $N_9P_9K_{20}$ with 19.92% above the fertilization control.

6. CONCLUSIONS AND RECOMMENDATION

1. The application of different regimes and levels of fertilization have a significant impact on the development and productivity of carrot seed plants, with a higher effect observed in the twice application of mineral fertilizers.

2. The course of the individual phenophases of the carrot seed stalk, especially those related to generative development, is accelerated as a result of the use of mineral fertilizers, more pronounced with increasing amounts of N, P_2O and K_2O, the interphase periods being shorter in their twice application.

3. The vegetative development of carrot seed plants is significantly influenced by the regime of fertilization with mineral fertilizers, and this is better manifested by increasing the nitrogen fertilizer rate from 5 $kg.da^{-1}$ to 9 $kg.da^{-1}$. Twice fertilization promotes higeher vegetative growth and accumulation of more air-dry weight.

4. The generative behaviors of the carrots seed stalsk are more strongly affected after twice fertilization. Increasing nitrogen levels in combination with higher levels of P_2O5 and K_2O stimulates the formation of a higher number of branches, as well as the setting and formation of more umbelates in the umbel and especially a higher number of flowers.

5. The highest number of flowers are formed in the central umbel. Positive correlations have been established between the number of umbelate in a umbel with the number of flowers, as well as with the diameter of the umbel.

6. The seed weight per umbel and the part of fully developed seeds increase most strongly under the influence of a once fertilization with $N_9P_9K_{20}$ and in twice fertilization with $N_9P_9K_{10}$. Strong positive correlations were found between vegetative and generative behaviors of the carrot seed plant - number of umbels, number of umbelate, percentage of normally formed seeds, their weight per umbel and productivity.

7. Twice fertilization causes a stronger increase in yield. The highest productivity was observed with twice fertilization with $N_9P_9K_{10}$, followed by a once- with $N_9P_9K_{20}$, approximately 30% above control. These results with twice fertilization are achieved by applying reduced amounts of phosphorus and potassium than recommended.

8. The seed productivity of carrots is formed mainly by the seeds develpoed in the umbels of the first and second order. With a evenly increase of fertilization levels for both regimes, productivity is characterized by a polynomial regression with high coefficients of determination.

9. The viability of the seeds improves as a result of nutrient regime. Germination energy, germination and field germination, as well as absolute seed weight increase significantly due to $N_9P_9K_{20}$ fertilization, being higher for once fertilization. This combination also has a stronger positive effect to reduce the germination period and to increase the uniformity. The dependence of germination with evenly increasing levels of fertilization is described by polynomial regression with high coefficients of determination.

10. Seedlings has better morphological behaviors and their development is characterized by fewer deviations when applying higher levels of potassium, combined with reduced amounts of phosphorus and nitrogen. The most common deviations from their normal development are expressed in the absence of hairs and branches on the embryo root.

11. The vigour of carrot seeds is highest after once application of $N_5P_9K_{10}$ and twice – in $N_9P_9K_{10}$. The chronometric course of germination is more influenced in the phase development of the vegetative peak by the combinations

$N_5P_9K_{20}$ (once) and $N_5P_9K_{10}$ (twice). These signs are high also after aplication of $N_9P_9K_{20}$.

12. The sowing qualities, for all seeds of the plant, are determined most strongly by the values of the seeds of the first and second order. As the order of the order increases, they decrease evenly. As a result of the applied levels and regimes of fertilization, the heteroblasty between the seeds of the individual orders is reduced in many of the indexes.

13. The dry weight of the seeds from the tested fertilization regimes is about 90%, exceeding the slightly the recommended control. The lipids content varies significantly and as a result of fertilization decreases, and the amount of protein and carbohydrates varies within narrow limits.

14. After storage of carrot seeds, their sowing qualities decrease, as the highest germination is established for once fertilization with $N_9P_9K_{20}$, but with the best storage and with the closest values to those of the harvest year are those of varieties $N_5P_{19}K_{20}$ (once) and $N_9P_9K_{20}$ (twice).

15. As a result of higher economic efficiency and notional profit, as well as the highest productivity, with increased seed quality, twice fertilization with $N_9P_9K_{10}$ and once fertilization with $N_9P_9K_{20}$ are recommended for use in seed production of carrots.

7. CONTRIBUTIONS

7.1. Scientific contributions

1. For the first time in the conditions of our country, a stronger influence of the twice application of mineral fertilizers, compared to the once fertilization, on the development and productivity of the plants in seed production of carrots has been established.

2. A polynomial regression between evenly increasing levels of fertilization with the yield of carrot seeds and their germination, with high coefficients of determination, has been determined.

3. It was found that the productivity of carrot seeds and their sowing qualities are formed mainly by the seeds formed in the umbels of the first and second order.

4. Strong positive correlations were found between vegetative and generative behaviors of the carrot seed plant and seed yield, as well as between the number of umbelaters in a umbels with the number of flowers and the diameter of the umbel.

5. The obtained results, in scientific aspect, can serve as a good theoretical basis for scientifically-based application and solution of the problems related to mineral fertilization in carrot seed production.

7.2. Scientific and applied contributions

1. It is pointed out that with the application of the tested levels and regimes of fertilization the heteroblasty between the seeds of the different orders decreases.

2. It is emphasized that the best productivity from carrot seeds is obtained with twice application of $N_9P_9K_{10}$ and once use of $N_9P_9K_{20}$, which is recommended to be applied in practice.

3. It is proved that the carrot seed storage has been improve most strongly as a result of a once application of $N_5P_{19}K_{20}$ as well as twice fertilization with $N_9P_9K_{20}$ and $N_9P_{19}K_{20}$.

4. It has been found that the viability of carrot seeds can be improved by the applied fertilization methods and regimes, especially after once application of $N_5P_9K_{10}$ and twice of $N_9P_9K_{10}$.

8. LIST OF PUBLICATIONS ON THE DISSERTATION

1. Trayanov, A., Panayotov, N. & Kouzmova, K. 2018. Influence of fertilization and environmental conditions on the phenological and morphological development of carrot plants during seed production. International Journal of Innovative Approaches in Agricultural Research, 2(4), 408-424.

2. Trayanov, A., 2019. Vegetative development of carrot seed stalks in depends on the way of fertilization. Scientific Works of the Union of Scientists in Bulgaria - Plovdiv. Series C. Technics and Technologies. Vol. XVII., 220-223.

3. Trayanov, Al., 2019. Generative development of carrots (*Daucus carota* L.) during seed production depending on the fertilization. Agricultural science and technology, vol. 11, No 3, pp 211-216.

4. Trayanov., A., 2020. Morphological characteristic of carrot seeds depending on the fertilization regime and umbel orders. Scientific Research of the Union of Scientists in Bulgaria – Plovdiv, series B. Natural Sciences and Humanities, VIIIth International Conference Of Young Scientists 23-26 July 2020, Vol XX, 27-31.

PRODUCTIVITY AND QUALITY OF THE SEEDS OF CARROT BY OPTIMIZATION OF NUTRIENT REGIME IN THEIR SEED PRODUCTION

Summary

The main goal of the study is to increase the yield and quality of carrot seeds, as well as to improve the vegetative and generative development of seed plants by optimizing the nutrient regime during their seed production, by studied the different levels and terms of fertilization with nitrogen, phosphorus and potassium.

The experiments were carried out in 2017-19 with carrot Tushon variety. Seed production was performed by conventional technology, with stecklings. Two regimes of fertilization: once-with application of P_2O_5 and K_2O in autumn plowing and N in transplanting; twice-half of P_2O_5 and K_2O in autumn plowing, the rest before transplanting, N-half in transplanting, the rest in stage of flowering, were tested. The levels of N-0,5,7,9 $kg.da^{-1}$, P_2O_5-0,9,14,19 $kg.da^{-1}$ and K_2O-0,10,15,20$kg.da^{-1}$ were investigated. These quantities were determinate according to recommended now levels of fertilization. The phenological observations was done. Morphological and generative behaviors were established. Seed yield and elements of productivity and participation of different umbels were determinate. Main part of thesis was dedicated to determination of seed quality parameters. The seed chemical components, storability and economic evaluation also were done.

The application of different regimes and levels of fertilization have a significant impact on the development and productivity of carrot seed plants, with a higher effect observed in the twice application of mineral fertilizers. The generative development is accelerated as a result of the use of mineral fertilizers. Twice fertilization promotes higher vegetative growth and accumulation of more air-dry weight. The generative behaviors of the carrots seed stalk are more strongly affected after twice fertilization, more branches, umbels, umbelates and flowers were developed. The highest productivity was observed with twice fertilization with $N_9P_9K_{10}$, followed by a once- with $N_9P_9K_{20}$, approximately 30% above control and it formed mainly by the seeds developed in the umbels of the first and second order. The viability of the seeds improves as a result of nutrient regime. Germination energy, germination and field germination, as well as weight of 1000 seeds increase significantly due to $N_9P_9K_{20}$ fertilization. The vigour of carrot seeds is highest after once application of $N_5P_9K_{10}$ and twice-of $N_9P_9K_{10}$. Chemical components and storability were improved. Strong positive correlation between main vegetative and generative indexes and yield were established. The yield and germination in evenly increase level of fertilizers are described by polynomial regression, with high determination coefficients.

As a result of higher economic efficiency and notional profit, as well as the highest productivity, with increased seed quality, twice fertilization with $N_9P_9K_{10}$ and once fertilization with $N_9P_9K_{20}$ are recommended for use in seed production of carrots.