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EFFECT OF DIFFERENT FERTILIZATION REGIMES AND RATES IN THE CARROT SEED PRODUCTION ON THEIR SOWING PARAMETERS AND CHEMICAL COMPOSITION OF THE SEEDS

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Abstract

The main aim of the present study was to establish the influence of different fertilization regimes and rates in carrot seed production on some sowing parameters and the chemical composition of the seeds. The experiments were carried out with carrot 'Tushon' variety. The seed plants were grown using the standard technology through stecklings. Three levels of NPK fertilization were tested, as follows N - 0, 50, 70, 90 kg.ha^{-1}, P - 0, 90, 140, 190 kg.ha^{-1} and K - 0, 100, 150, 200 kg.ha^{-1}, applied once and twice, respectively. The weight of 1000 seeds, germination energy and germination were studied. The content of dry matter, moisture, ash, raw protein, carbohydrates and total lipids in carrot seeds were evaluated. The highest germination energy and germination were counted at $N_{90}P_{90}K_{200}$ for once application and for twice one it was observed for $N_{90}P_{90}K_{200}$ and $N_{50}P_{190}K_{100}$. The highest changes were observed in the content of total lipids. Middle to strong positive correlation was found between the content of raw protein, lipids and carbohydrate and germination energy. Polynomial regressions between evenly increased fertilization rate and content of above-mentioned compounds with high determination coefficients were established.

Key words: *Daucus carota* L., germination, fertilization, protein, lipids, regression.

INTRODUCTION

The optimal nutrient regime has a strong influence both on the size and development of carrot seeds and also on their viability potential (Panayotov, 2005). Most of the cultivated plants are propagated by seeds therefore the quality of the seed is essential (Panchev, 2015; Ivanova and Panchev, 2016).

Chilingirov et al. (2018) and Haytova and Ivanova (2016) emphasized that the seed viability status play significant role for the normal development of the plants. In experiments conducted by Ilyas et al. (2013) found that by the increasing of fertilizer rates, especially phosphorus, a much higher effect is achieved in the development of seed plants and the quality of the obtained seeds. Hooda et al. (2014) expressed the opinion that with the increase of fertilizer norms the yield and quality of carrot seeds increases.

This is due to the better growth of the plants, as well as to the better development of the central umbels and the higher number of secondary umbels. A similar conclusion is expressed by Kushwaha (2009) that increasing the rate of nitrogen fertilizer to 100 kg.ha^{-1} improves the generative development and viability of seeds from this crop.

The main chemical ingredients in the seeds that determine the level of their vitality are proteins, fats and carbohydrates (Panayotov, 2015). According to Ozcan and Chalchat (2007), carrot seeds are rich in protein, fiber and ash. Significant is the content of essential oil, as the major constituent of seed essential oil is carotol. The authors add that the moisture, crude protein, ash, crude fiber and crude oil contents and fatty acid compositions of carrot seeds are affected mainly by the variety and growth conditions.

Yili et al. (2006) and Imamu et al. (2007) pointed out that essential oils are the main active compounds in carrot seeds. Foster and Duke (1990) and Lawless (1995) argue that the variation in the essential oils component compositions in carrot seeds is probably due to growing conditions. The main components of carrot-seed essential oils, depending on the region of growing are α-pinene, β-pinene, carotol and β-bisabolene and also asarone and cis-α-bergamoten.

The main aim of the present study was to establish the influence of different fertilization regimes and rates in carrot seed production on some sowing parameters and chemical composition of the seeds.

MATERIALS AND METHODS

The experiments were carried out in the period 2017-2019 in the experimental field of the Department of Horticulture at the Agricultural University-Plovdiv, Bulgaria with carrot variety Tucson. The standard, established and widespread in Bulgaria, technology of carrot seed production was applied, with preliminary production of stecklings (Minkov, 1984). The seeds for the production of stecklings were sown at the end of June, and their harvesting and storage in a pit took place in mid-November. The planting of the stecklings took place in mid-March, according to the scheme 80 x 30 cm. Each variant was grown in four repetitions with a plot size of 7 m^2 and harvested area of 6 m^2. The soil was prepared by deep plowing in autumn and in the spring the furrows were profiled.

Two regimes of fertilization were studied: Once fertilization - application of phosphorus and potassium fertilizers with autumn deep plowing and nitrogen fertilizer at planting; Twice fertilization - half of the phosphorus and potassium fertilizers were applied with the autumn deep plowing, the other half - in the spring before planting, and nitrogen fertilizer - half before planting, and the other half - at the beginning of flowering.

The following variants of fertilization in kg.ha^{-1} were investigated: once fertilization: 1. $N_0P_0K_0$ - control; 2. $N_{70}P_{140}K_{150}$ (recommended); 3. $N_{50}P_{90}K_{100}$; 4. $N_{50}P_{90}K_{200}$; 5. $N_{50}P_{190}K_{100}$; 6. $N_{50}P_{190}K_{200}$; 7. $N_{90}P_{90}K_{100}$; 8.$N_{90}P_{90}K_{200}$; 9. $N_{90}P_{190}K_{100}$; 10. $N_{90}P_{190}K_{200}$ and once fertilization: 11. $N_{50}P_{90}K_{100}$; 12. $N_{50}P_{90}K_{200}$; 13. $N_{50}P_{190}K_{100}$; 14. $N_{50}P_{190}K_{200}$; 15. $N_{90}P_{90}K_{100}$; 16. $N_{90}P_{90}K_{200}$; 17. $N_{90}P_{190}K_{100}$; 18. $N_{90}P_{190}K_{200}$. Fertilizer rates were determined based on the recommended to this moment fertilization for carrot seed production in Bulgaria - $N_{70}P_{140}K_{150}$ (Madzharova, 1968; Kolev, 1977). Ammonium nitrate (N 34%), triple superphosphate (P_2O_5 46%) and potassium sulfate (K_2O 50%) were used. All necessary agro-technological practices were applied during the vegetation. The seed stalks were harvested when 60-70% of the seeds were in the stage of maturity, and the remaining ones were in waxy maturity, after that they were placed for ten days for post-harvest ripening and seed extraction was performed.

The germination energy and germination of the seeds were studied, according to the require-ments of ISTA (2013), and the vigour - by the method of “Initial vegetative productivity of the seedlings” (Panayotov, 2013). The experi-ments were performed in four replications of 100 seeds each.

The content of absolute dry matter (by weight), moisture (by weight, AOAC 934.06, 2007a), carbohydrates by the the phenol-sulfuric acid method (Dubois, 1956; Nielsen, 2010), crude protein by Kjeldahl method (Bradstreet, 1965), total lipids according to the Soxhlet method (AOAC 920.39, 2012), ash (AOAC 940.26, 2007b) in the seeds were determinated.

Due to the uniformity in the trend of the results obtained during the study period, the presented values are three-year average data. The study data were subjected to analysis of variance and regression, with the least significant differences between the individual variants calculated by the Fisher test at p = 0.05. The methods of ANOVA, as well as regression analysis, are described by Fowel and Cohen (1992).

RESULTS AND DISCUSSIONS

The main elements that determine the main viability potential of seeds are germination energy and germination, which according to several authors depend on various factors, such as ecological and agrotechnological (Copeland and McDonald, 2001; Black et al., 2008 and Panayotov, 2015). In this regard, the tested regimes and levels of fertilization have a strong influence on the viability of the seeds (Table 1). Better germination energy, compared to the control, demonstrated all tested variants The highest values for once fertilization are reported for fertilizer combination $N_{90}P_{90}K_{200}$ - 78.88%, followed by fertilization with $N_{90}P_{190}K_{100}$ - 73.99%. In the other regime, the germination energy is the highest for variant $N_{50}P_{90}K200$ - 69.44% and also for $N_{50}P_{90}K_{200}$ - 68.88%. A slight decrease compared to the recommended fertilization rate was observed for $N_{90}P_{190}K_{200}$ in both regimes for $N_{50}P_{90}K_{100}$

as well as in once fertilization for $N_{90}P_{190}K_{200}$. The differences between most variants compared to the unfertilized control are mathematically proven, except for $N_{50}P_{90}K_{100}$ and $N_{90}P_{90}K_{100}$ (once fertilization) as well as for both regimes when using the highest fertilization rates.

Table 1. Sowing parameters of carrot seed after application of different nutrient regimes

Variants	Germination energy (%)	Germination (%)	Index of vigour
Once fertilization			
$N_0P_0K_0$	59.22	60.88	7.20
$N_{70}P_{140}K_{150}$	64.55	67.88	9.27
$N_{50}P_{90}K_{100}$	62.66	69.55	10.99
$N_{50}P_{90}K_{200}$	69.22	73.10	8.50
$N_{50}P_{190}K_{100}$	68.44	70.44	8.39
$N_{50}P_{190}K_{200}$	66.88	70.44	7.79
$N_{90}P_{90}K_{100}$	61.77	72.21	9.61
$N_{90}P_{90}K_{200}$	78.88	80.88	10.47
$N_{90}P_{190}K_{100}$	73.99	76.66	9.35
$N_{90}P_{190}K_{200}$	63.55	68.22	10.98
Twice fertilization			
$N_{50}P_{90}K_{100}$	69.32	74.55	9.84
$N_{50}P_{90}K_{200}$	69.44	76.22	9.25
$N_{50}P_{190}K_{100}$	67.10	79.77	8.97
$N_{50}P_{190}K_{200}$	65.10	69.10	8.48
$N_{90}P_{90}K_{100}$	66.44	70.44	10.59
$N_{90}P_{90}K_{200}$	68.88	75.66	10.14
$N_{90}P_{190}K_{100}$	66.11	71.10	9.66
$N_{90}P_{190}K_{200}$	62.11	65.44	9.04
LSD p=5.0%	7.24	7.34	2.04

The germination compared to the unfertilized and the recommended control, is higher for all studied levels and regimes of fertilization, except for $N_{90}P_{190}K_{200}$ (twice), where the reduction is insignificant. The highest values of this indicator - 80.88%, are reported after a once fertilization of plants with $N_{90}P_{90}K_{200}$. Next, with a very small difference was the twice application with $N_{50}P_{190}K_{100}$ - 79.77%. Relatively high germination was also developed by seeds from once regime with $N_{90}P_{190}K_{100}$ (76.66%) as well as twice - with $N_{50}P_{190}K_{200}$ (76.22%). Statistical significance of the differences compared to the control without fertilization was established, as such is missing only at $N_{90}P_{190}K_{200}$ (twice).

The high percentage of germinated seeds reported in the laboratory does not mean that the same seeds sown under field conditions will show the same germination and that the germinated seeds will develop typical seedlings and later normal plants. Therefore, the determination of the vigour is especially important for assessing the quality of seeds (Panayotov, 2013). No significant differences were found between the both periods of application of the fertilizer combinations. The vigour index reaches the highest levels of 10.99 and 10.98, with a once application of $N_{50}P_{90}K_{100}$ and $N_{90}P_{190}K_{200}$, respectively. In this regime, very good results are obtained also for variant $N_{90}P_{90}K_{200}$ (10.47). In the case of twice fertilization, high vigour is reported after fertilization with $N_{90}P_{90}K_{100}$ and $N_{90}P_{90}K_{200}$ - 10.59 and 10.14, respectively.

The viability behaviors of the carrot seeds were improved better after the application of the higher levels of phosphorus and especially potassium. Similar conclusions are also expressed by Rao and Maurya (1998), Hooda et al. (2014). The differences between the two fertilization regimes regarding to their viability status are relatively small.

The chemical composition of vegetable seeds is essential, as it must provide the seeds with the necessary nutrients and energy to be able to germinate, subsequently sprouting and develop the young plant (Copeland and McDonald, 1995; Panayotov, 2015). On Table 2 is presented the contents of the main substances that mainly affect the viability processes of the seeds.

Table 2. Chemical components of carrot seeds (%)

Variants	Moisture	Dry weight	Dust	Protein	Lipids	Carbohidrate
Once fertilization						
$N_0P_0K_0$	9.17	90.82	6.82	21.23	12.08	50.35
$N_{70}P_{140}K_{150}$	10.21	89.78	7.58	22.02	9.25	50.91
$N_{50}P_{90}K_{100}$	9.75	90.24	7.38	21.08	9.77	51.63
$N_{50}P_{90}K_{200}$	9.52	90.47	7.24	21.81	10.38	50.70
$N_{50}P_{190}K_{100}$	8.83	91.16	6.90	22.83	8.98	52.24
$N_{50}P_{190}K_{200}$	9.15	90.85	6.83	22.67	10.18	51.38
$N_{90}P_{90}K_{100}$	8.95	91.05	7.78	21.62	9.36	52.29
$N_{90}P_{90}K_{200}$	9.61	90.38	7.13	22.10	10.70	50.39
$N_{90}P_{190}K_{100}$	8.78	91.21	7.31	22.38	7.59	53.79
$N_{90}P_{190}K_{200}$	9.24	90.76	7.44	20.63	10.07	52.45
Twice fertilization						
$N_{50}P_{90}K_{100}$	8.85	91.14	6.68	23.14	7.55	53.42
$N_{50}P_{90}K_{200}$	8.99	91.01	6.83	22.72	10.46	50.86
$N_{50}P_{190}K_{100}$	12.30	87.69	7.70	21.44	8.71	49.47
$N_{50}P_{190}K_{200}$	9.31	90.68	7.26	21.91	9.93	51.35
$N_{90}P_{90}K_{100}$	9.14	90.85	7.07	21.39	10.30	51.37
$N_{90}P_{90}K_{200}$	9.90	90.09	8.26	21.71	8.17	51.34
$N_{90}P_{190}K_{100}$	8.70	91.29	7.49	21.34	7.70	53.65
$N_{90}P_{190}K_{200}$	9.00	90.99	7.72	21.74	9.22	51.18
LSD p=5.0%	2.19	2.18	0.95	2.10	4.22	4.75
r with germination				+0.74	+046	+0.41

According to the requirements of ISTA (2013), to be able to the vegetable seeds to be stored well and to ensure normal metabolism, the moisture content should not exceed 13%. In most of the tested variants, the average water content in the seeds is about 9%. Some increase was found for the fertilizer control - 10.21%, as well as for the combination $N_{50}P_{190}K_{100}$ applied twice - 12.30%. No seeds with higher moisture than the standard were observed.

Dry matter is a summary indicator that characterizes the overall condition of the endosperm and the content of nutrients in the seed. The percentage of dry matter in the seeds, which is average for the period ranged from 87.69% for $N_{50}P_{190}K_{100}$ (twice) to 91.29 % for $N_{90}P_{190}K_{100}$ (twice). With the highest ash content were characterized the seeds of the variant fertilized twice with $N_{90}P_{90}K_{200}$ - 8.26%. The amount of ash for most of the tested combinations was above 7%, and this percentage decreases more significantly in the combinations $N_{50}P_{190}K_{100}$, $N_{50}P_{190}K_{200}$ (once) and $N_{50}P_{90}K_{100}$, $N_{50}P_{90}K_{200}$ (twice).

ccording to Copeland and McDonald (2001), proteins are a major building block of the reserve nutrients used primarily by the embryo for germination. The values obtained for the amount of protein in carrot seeds were close and vary within narrow limits between the different variants. Some increase was observed in the variant fertilized twice with $N_{50}P_{90}K_{100}$ - 23.14%, in contrast to the others, where 21-22% were reported. There is a strong positive correlation between protein content and germination with a coefficient r =+0.74. The established regression dependence (Figure 1 and Figure 2) between the evenly increasing fertilizer rates and the protein content is polynomial with high determination coefficients R^2 = 0.64 and R^2 = 0.79, respectively, in once and twice fertilization, which means that between 60% up to 80% will have the indicated effect of fertilization on protein synthesis.

Lipids are the main source of energy and in metabolism during germination their hydrolysis begins first in the embryo. Carrot seeds are generally characterized by high lipid content (Panayotov, 2015). The data obtained for the lipid content ranged from 7.55% for $N_{50}P_{90}K_{100}$ (twice) to 12.08% for the unfertilized control on average for the reporting period. There was a large variation in their content depending on the fertilization, stronger with a once regime, especially with $N_{50}P_{90}K_{200}$, $N_{90}P_{90}K_{100}$ and $N_{90}P_{190}K_{200}$. The correlation with germination is average and positive with r =+0.46. Polynomial regressions of this indicator according to the evenly increasing fertilizer rates are shown in Figures 3 and Figure 4. The determination coefficients for once and twice fertilization are R^2 = 0.98 and R^2 = 0.85, respectively, i.e. in approximately 90% these fertilization methods will cause the observed effect.

Carbohydrates are a very important source of energy and their content in vegetable seeds and their content in vegetable seeds is of the great significance. Lee et al. (1995) points out that the content of carbohydrates, and more specifically of the sugars released from the seeds, can serve to assess the level of their viability. The average content of carbohydrates was highest in the seeds of the once fertilizer with $N_{90}P_{190}K_{100}$ - 53.79%, which was almost 4% more than the two controls - fertilized and not fertilized. The same fertilizer rate provokes the highest percentage for the other term of application of mineral fertilizers - 53.65%, followed by $N_{50}P_{90}K_{100}$ - 53.42%. It can be pointed out that fertilization with $N_{90}P_{190}K_{100}$, both once and twice, as well as the combination of N_{90} with higher levels of P_2O_5 and K_2O contribute to an increase in the percentage of carbohydrates in the carrot seeds. The correlation with germination is average and positive with r =+0.41. The regressions of the evenly increased fertilization rates and the carbohydrate content (Figure 5 and Figure 6) are again polynomial, and the determination coefficients R^2 = 0.66 (once fertilization) and R^2 = 0.55 (twice fertilization) are relatively high and show that at approximately in 60% of this fertilization will have the identified impact.

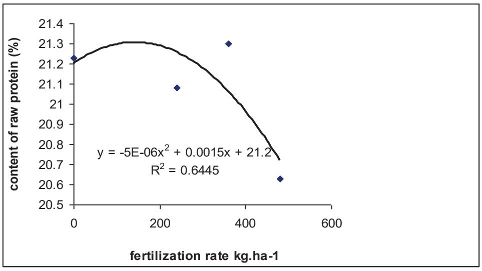

Figure 1. Regression dependence between evenly increasing levels in once fertilization and content of raw proteins
1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$;
3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

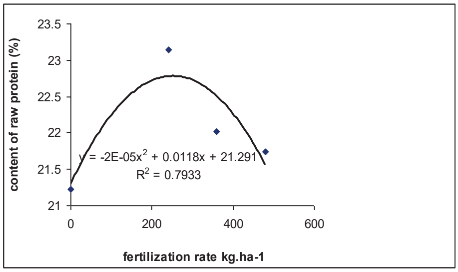

Figure 2. Regression dependence between evenly increasing levels in twice fertilization and content of raw proteins
1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$;
3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

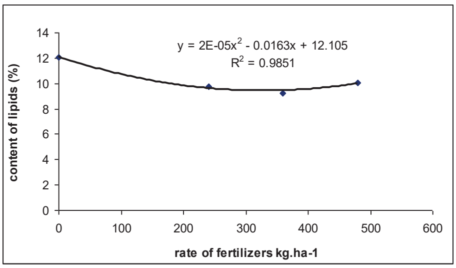

Figure 3. Regression dependence between evenly increasing levels in once fertilization and content of lipids
1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$;
3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

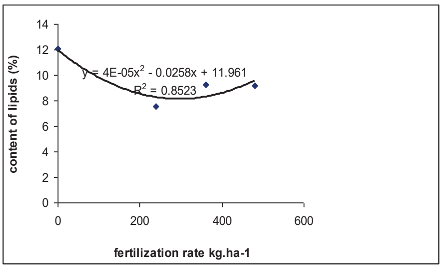

Figure 4. Regression dependence between evenly increasing levels in twice fertilization and content of lipids
1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$;
3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

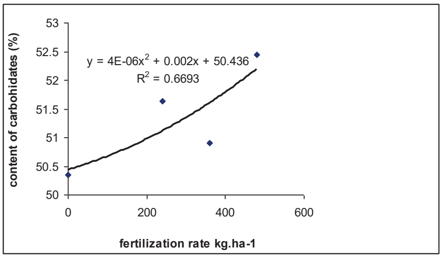

Figure 5. Regression dependence between evenly increasing levels in once fertilization and content of carbohydrates 1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$; 3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

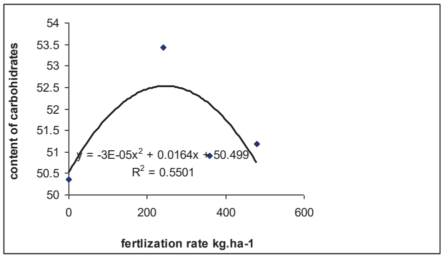

Figure 6. Regression dependence between evenly increasing levels in twice fertilization and content of carbohydrates 1.$N_0P_0K_0$, 2. $N_{50}P_{90}K_{100}$; 3. $N_{70}P_{140}K_{150}$; 4. $N_{90}P_{190}K_{200}$

CONCLUSIONS

The different fertilization regimes and rates significantly improved the viability of carrot seeds, and the effect is stronger when applying the higher levels of phosphorus and especially potassium.

Germination in once fertilization with $N_{90}P_{90}K_{200}$ and in twice fertilization with $N_{50}P_{190}K_{200}$ exceeds by approximately 20% that of the control variant.

The main chemical ingredients in carrot seeds are affected as a result of the application of mineral fertilizers. Higher changes were found in the content of crude lipids and carbohydrates.

Medium to strong positive correlations of the basic chemical components with germination has been established. The regressions of the evenly increase of the fertilizer rates and the content of proteins, fats and carbohydrates are polynomial with high determination coefficients.

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