Bulgarian Journal of Agricultural Science, 27 (Suppl. 1) 2021
Agricultural Academy

Mathematical approach to evaluation of the influence of different fertilization regimes on the main vegetative and generative development of carrot seed plants (*Daucus carota* L.)

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Abstract

Kuneva, V., Panayotov, N. & Trayanov, A. (2021). Mathematical approach to evaluation of the influence of different fertilization regimes on the main vegetative and generative development of carrot seed plants (*Daucus carota* L.). *Bulg. J. Agric. Sci. 27 (Suppl. 1)*, 161–165

The present study aimed to use a mathematical approach (cluster, correlation and factor analysis) to assess the similarity and remoteness of the impact of different fertilization regimes and their grouping based on main morphological and generative indicators of carrot variety Tushon. Data obtained from field experiments conducted in the period 2017 – 2019 in an Experimental field at the Agricultural University – Plovdiv, Bulgaria were used. Increasing levels of nitrogen, phosphorus and potassium fertilization in two periods of application – once and twice, were studied. Height, diameter and weight of the carrot stalk, number and weight of leaves, and the number of umbels from I, II and III orders were investigated. It has been found that the twice application of mineral fertilizers causes better development of seed plants. The results of the cluster analysis are in line with the conclusions made in the analysis of the applied fertilization regimes and their impact on the vegetative and generative behaviors. As a result of the conducted correlation analysis, correlations between the studied indicators were established. The strongest positive correlation is between indicators of weight and the number of leaves. The main indicators that have the greatest influence on the division of fertilization variants into clusters are the weight and diameter of the stalk and leaf weight united in the first factor, explaining 45.196% of the total variance of the variables.

Keywords: carrot; correlation; cluster analysis; factor analysis; plant morphology

Introduction

In the test of once and twice application of different levels of mineral fertilizers in the seed production of carrots Ilyas et al. (2013) found that with increasing the amount of used fertilizers, the yield of seeds increases significantly. The produced seeds are with better quality. Also the basic elements of yield are improved, such as the number of umbels and the number of flowers. Significance has also been established for the size of the stecklings. Stepuro (2008) recommends obtaining the highest yields of carrot seeds to be fertilized with $N_{45}P_{55}K_{75}$ and $N_{55}P_{65}K_{90}$ kg/ha.

In two-year field experiments, Singh (1996) tested the effect of different fertilizer rates of nitrogen – 50, 100 or 150 kg/ha and potassium – 20, 40, 60 or 80 kg/ha on the seed yield of Pusa Kesar carrots variety. It has been established that with the increase of the nitrogen fertilizer level the height of the plants, the number of umbels per plant and the seed yield increase, the best results are reported at the highest nitrogen level. Gunag et al. (2006) examined the effect of potassium fertilizers on the seed productivity of carrots, according to him the foliar application of 2 g/l KH_2PO_4 improves both the vegetative development of the seed plants and also significantly increases the seed yield.

Using a mathematical approach in the present study we set the following goals to:

1) Compare the similarity and remoteness of the impact of different fertilization regimes on the manifestations of important morphological and generative indicators of carrots seed plants, and to group them using cluster analysis;

2) Study the existence of a correlation between the studied indicators makes a more objective assessment;

3) Using the possibilities of factor analysis, to reduce their number by unifying those that correlate with each other in new factors.

Such an approach has been used for grouping and evaluation of varieties and lines from different crops (Ivanova et al., 2010; Krasteva et al., 2010; Panayotov et al., 2010; Milev et al., 2015) for grouping soil differences (Doneva et al., 2008).

Material and Methods

The experiments were carried out in the period 2017-2019 in the Experimental field of the Department of Horticulture and the laboratory of the Department of Mathematics and Informatics at the Agricultural University-Plovdiv with carrot Tushon variety. The standard and widely applied for Bulgaria technology for carrot seed production, using of pre-produced stecklings, was applied (Murtazov et al., 1984). Two fertilization regimes were tested: one – the whole amount of phosphorus and potassium fertilizers was applied in the autumn before deep plowing and nitrogen during planting; split application of fertilizers – half of the phosphorus and potassium fertilizers were applied before the autumn deep plowing, the other half in the spring before planting, and nitrogen fertilizer – half during planting, and the other part at the beginning of flowering. Each variant is presented in four replicates with a plot size of 7 m^2 and a yield establishing area of 6 m^2 (Barov, 1982). The variants with different levels of fertilization in $kg.ha^{-1}$ are:

Once fertilization and	twice fertilization:
1.$N_0P_0K_0$– control;	11.$N_{50}P_{90}K_{100}$;
2*.$N_{70}P_{140}K_{150}$;	12.$N_{50}P_{90}K_{200}$
3.$N_{50}P_{90}K_{100}$;	13.$N_{50}P_{190}K_{100}$;
4 .$N_{50}P_{90}K_{200}$;	14.$N_{50}P_{190}K_{200}$;
5.$N_{50}P_{190}K_{100}$;	15.$N_{90}P_{90}K_{100}$;
6.$N_{50}P_{190}K_{200}$;	16.$N_{90}P_{90}K_{200}$;
7.$N_{90}P_{90}K_{100}$;	17.$N_{90}P_{190}K_{100}$;
8.$N_{90}P_{90}K_{200}$;	18.$N_{90}P_{190}K_{200}$
9.$N_{90}P_{190}K_{100}$;	
10.$N_{90}P_{190}K_{200}$;	

*recommended (Madzharova, 1968; Kolev, 1977);

The indicators height, diameter and weight of the seed stalk, number and weight of leaves in the mass flowering phase on 15 plants of the variant were studied. The number of umbels of the first, second and third-order was also determined on 15 plants of the variety during their full development. Due to the presence of similarity in the result, the presented data are averaged three-year values.

The evaluation of the tested fertilization regimes was performed by comparing the following indicators determining the vegetative development of the carrot seed stalk: X_1 – height, X_2 – weight, X_3 – diameter and also, X_4 – number of leaves, X_5 – weight of leaves, X_6 – number of the umbels of I order, X_7 – number of the umbels of II order, X_8 – number of the umbels of III order. The grouping of the 18 studied variants of both fertilization regimes was done by hierarchical cluster analysis. The intergroup connection method was used (Ward, 1963; Dyuran & Odelly, 1977). The Euclidean intergroup distance was used as a measure of similarity:

A dendrogram was constructed, through which the formed clusters are graphically represented. The dotted horizontal line of the dendrogram shows the rescaled distance at which the clusters are formed. A correlation analysis was performed to establish the presence of statistically significant correlations between the studied indicators. The study was further continued using the factor analysis technique (Kline, 1994) to reduce number of the weight indicators initially included. Factor analysis was performed by the principal components method (PCA). The number of principal components is determined by the number of eigenvalues of the correlation matrix that are greater than 1 (Kaiser's criterion). Eigenvalues show the contribution of the Eigen factor in explaining the total variance in the variables.

The data processing was performed with the statistical program SPSS.

Results and Discussion

Twice application of mineral fertilizers causes the development of seed plants with higher stems (Table 1). In both regimens, the highest stalk stem was observed when used $N_9P_9K_{20}$, 86.94 cm for once and 89.89 cm for twice. All variants are characterized by higher stems compared to the control. The highest diameter was accounted in the mentioned variant for the twice fertilization, while for the other regime this was in the case for $N_9P_{19}K_{10}$. The decrease, compared to the control, was founded on the combinations $N_5P_9K_{10}$ and $N_5P_{19}K_{10}$ (once). With the highest stems weigh were the plants fertilized once with $N_9P_9K_{20}$ – 169.65 g and twice with $N_9P_{19}K_{10}$ – 313.04 g. Stronger suppression

Table 1. Vegetative and generative behaviors of carrot stalks

Variants	Seed stalk stem			Leaves		Number of the umbels		
	High, cm	Diameter, mm	Weight, g	Number	Weight, g	I order	II order	III order
Once fertilization								
$N_0P_0K_0$	63.11	8.76	116.87	101.55	43.54	9.63	14.35	11.58
$N_7P_{14}K_{15}$	73.33	8.51	153.82	112.66	48.65	10.31	18.31	12.78
$N_5P_9K_{10}$	74.55	7.93	100.90	92.16	38.66	12.21	16.56	11.39
$N_5P_9K_{20}$	79.11	8.16	114.73	105.66	40.64	10.51	15.18	11.16
$N_5P_{19}K_{10}$	78.72	7.80	124.46	99.61	33.10	11.04	17.74	10.87
$N_5P_{19}K_{20}$	85.67	8.63	123.37	88.83	31.06	11.38	16.59	11.70
$N_9P_9K_{10}$	85.33	9.32	167.83	107.22	51.70	12.12	16.29	13.07
$N_9P_9K_{20}$	86.94	9.10	169.65	131.33	70.98	11.41	19.80	13.79
$N_9P_{19}K_{10}$	79.83	10.02	155.51	127.33	66.43	9.38	16.52	11.32
$N_9P_{19}K_{20}$	79.05	7.83	125.16	89.94	52.07	7.45	18.94	11.75
Twice fertilization								
$N_5P_9K_{10}$	74.17	9.00	143.18	111.05	42.99	11.29	17.86	11.83
$N_5P_9K_{20}$	78.78	9.10	197.07	146.38	50.88	5.90	16.28	11.20
$N_5P_{19}K_{10}$	89.17	9.85	207.14	151.16	61.77	10.98	22.72	14.59
$N_5P_{19}K_{20}$	84.00	8.94	205.64	136.00	81.75	10.99	16.24	12.12
$N_9P_9K_{10}$	86.00	9.26	225.41	91.44	64.12	13.97	23.52	13.15
$N_9P_9K_{20}$	89.89	10.40	228.98	120.44	80.24	11.70	20.24	12.63
$N_9P_{19}K_{10}$	77.28	9.13	313.04	159.33	110.12	11.59	17.87	10.02
$N_9P_{19}K_{20}$	82.33	9.00	253.28	143.88	116.46	8.83	16.68	12.77

of this indicator was observed when $N_5P_9K_{10}$ was applied once. The largest number of leaves with the highest weight was observed in a once fertilization with $N_9P_9K_{20}$ – 131.33 numbers and 70.98 g, and in the twice for $N_9P_{19}K_{10}$ – 159.33 and 110.12 g. Reduced compared to the control, both in number and per weight, it is observed in a once fertilization with $N_5P_9K_{10}$, $N_5P_{19}K_{10}$ and $N_5P_{19}K_{20}$, as well as twice with $N_9P_9K_{10}$.

The number of umbels is a very important indicator of carrot seed production (George, 1999). The studied levels and regimes of fertilization contribute to the formation of more umbels in all three orders. For the first-order, they are highest in $N_9P_9K_{10}$ for both regimes. The highest is the number of umbels of the second order, reaching 23.52 numbers in the same variant, applied twice and 19.80 numbers for $N_9P_9K_{20}$ (once). In the next order again $N_9P_9K_{20}$ (once) shows the highest values, and in twice applied their number was the highest for $N_5P_{19}K_{10}$. It can be emphasized that in most of the cases, the plants from the variants with higher nitrogen levels developed more umbels. A similar conclusion is expressed by Singh (1996).

The cluster analysis shows that the influence of the fertilization regime on the morphological parameters of carrots is grouped into three main clusters. The results are presented both tabular, with the steps of combining the clusters and the intergroup distances (Table 2), and graphically by a dendrogram (Figure 1).

The first cluster is more homogeneous and unified variants 2, 11, 3, 5, 4 and 6 similar in indicators of height and

Table 2. Combining clusters and intergroup distances

Steps	Combined clusters		
	cluster 1	cluster 2	
1	2	11	1.59
2	3	5	1.604
3	3	4	1.951
4	3	6	3.541
5	8	13	4.522
6	14	18	4.650
7	2	3	5.160
8	8	16	6.668
9	9	12	6.823
10	2	10	7.282
11	2	7	8.776
12	8	15	9.792
13	9	14	10.131
14	1	2	10.218
15	9	17	15.178
16	1	9	18.793
17	1	8	21.366

diameter of the stalk, number of leaves, number of umbels from I, II and III order and with the least Euclidean distance between them.

The second main cluster includes variants 14, 18, 9 and 12. They have the greatest similarity: height and diameter of the stalk, number of umbels for II and III order. Variants 8, 13 and 16 from the third cluster, which are identical in terms of stalk height and diameter, number of umbels form I order.

The most distant are the variants 1 and 8, with an intergroup distance with a coefficient of 21.366 shown in Table 2.

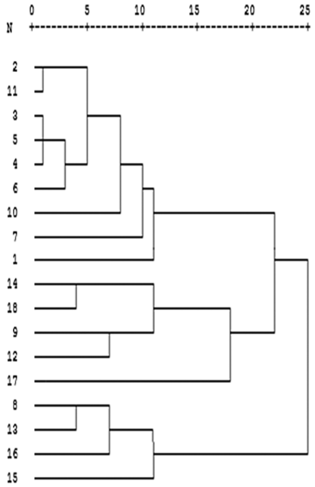

Fig. 1. Dendrogram based on average intergroup distance

The correlation coefficients expressing the relationship between the studied indicators are presented in the correlation matrix (Table 3). A strong positive correlation was found between the weight of the stem (x_1) and the number of leaves (x_4) and weight of leaves (x_5) with correlation coefficients – r = 0.741 and r = 0.882, respectively. The correlation between the indicator number of leaves and leaf weight is r = 0.717. The correlations on one hand between the height and diameter of stem and on other with height and number of umbels of II order and III order are less pronounced, respectively with correlation coefficients – r = 0.484, r = 0.575 and r = 0.550; also between the weight and diameter of stem – r = 0.573, diameter and number of leaves, leaves weight with coefficients r = 0.530, r = 0.472, respectively. All these correlation coefficients are statistically proven at the level of significance.

The performed correlation analysis and the established high, statistically proven values of r give us reasons to apply the methodology of factor analysis. When performing the factor analysis, applying the method of the principal components, it turned out that two factors have own vector values greater than 1, which determined the choice of two principal components (Figure 2). Table 4 presents the factor weights and shows how the variation is distributed among the main components

The main components explain 69.992% of the total variance of the sample. The first main component (the first factor) explains 45.196% of the variance, and the second – respectively 38.3% of it. The indicators height, weight and diameter of the stem as well as leaf weight have high factor weights in

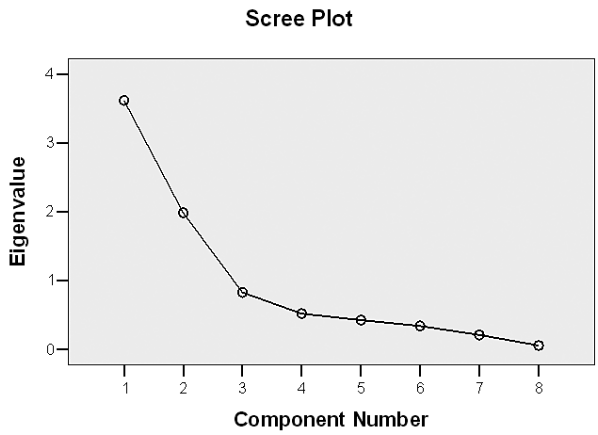

Fig. 2. The values of own vectors

Table 3. Correlation matrix

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_1	1	0.397	0.484*	0.226	0.301	0.294	0.575*	0.550*
X_2		1	0.573*	0.741**	0.882**	0.099	0.380	0.129
X_3			1	0.530*	0.472*	0.144	0.362	0.419
X_4				1	0.717**	-0.268	0.079	0.109
X_5					1	-0.011	0.182	0.115
X_6						1	0.396	0.258
X_7							1	0.614**
X_8								1

Table 4. Factor matrix obtained by the principal of the components method

N	Indicators	Main components	
		1	2
1.	Height of stem	0.698	0.412
2.	Weight of stem	0.855	-0.367
3.	Diameter of stem	0.779	-0.014
4.	Number of leaves	0.688	-0.605
5.	Weight of leaves	0.764	-0.483
6.	Number of umbels of I order	0.228	0.639
7.	Number of umbels of II order	0.622	0.577
8.	Number of umbels of III order	0.545	0.581
Percentage of the total variation ,%		45.196	38.324
Cumulative percentage of the total variation ,%		45.196	69.992

the first component. We could define this factor as summarizing for those indicators that have the greatest relative weight the grouping of carrots seed stalk. The second component is mainly related to the number of umbels of I order.

The results obtained through the applied factor analysis are in synchronous with the results of the cluster analysis in their distribution in clusters according to their proximity based on the same indicators.

Conclusion

The twice application of mineral fertilizers than once fertilization improves more the vegetative development and the number of formed umbels in carrot seed plants, especially for rates $N_9P_{19}K_{10}$ and for $N_9P_9K_{20}$.

The proposed mathematical approach allows increasing the objectivity in the assessment of the complex impact of fertilization levels on the main morphological components of carrots seed plants. The results of the cluster analysis are in line with the conclusions made in the analysis of the applied fertilization regimes and their impact on indicators determining the development of carrots stalk.

As a result of the conducted correlation analysis, correlations between the studied indicators were established. The strongest positive correlation is between the indicators weight of stem and leaf weight as well as the number of leaves and leaf weight.

The main indicators that have the greatest influence on the division of fertilization variants into clusters are the weight and diameter of the stem, leaf weight, united in the first factor, explaining 45.196% of the total variance of the variables.

References

Barov, V. (1982). Analyzes and schemes of the field experiments. NAPS, Sofia, 668, (Bg).

Doneva, K., Ivanova, I. & Ilieva, V. (2008). Grouping of common soil differences by cluster analysis based on data on basic soil properties and their thermal properties, *II Balkan Scientific Conference The Science, the Education and the Art in 21st Century, Bulgaria,* Blagoevgrad , September 26-27, 325-332 (Bg).

Dyuran, B. & Odelly, P. (1977*)*. Cluster analysis, Moskow, Statistika *(*Ru).

George, R. (1999). Vegetable seed production. A. Rowe Limited, Estabourne, UK., 328.

Guang, Xing, Z., Jiang Hua & Hong Xia, S. (2006). Effect of foliar spraying KH_2PO_4 on seed production of carrots (*Daucus carot*a L.). China vegetables (7) Beijing: Institute of Vegetables and Flowers, 11-13.

Ilyas, M., Ayub, G., Ahmad, N., Ullah, O., Hassan, S. & Ullah, R. (2013). Effect of different stickling size and phosphorous levels on seed production in carrot (*Daucus carota* L.). *Middle East Journal of Scientific Research, 17 (3),* 280-286.

Kline, P. (1994). An easy guide to factor analysis. Routledge, London, 208.

Kolev, N., Michov, A. & Bachvarov, St. (1977). Vegetable seed production. Zemizdat, Sofia, 403 (Bg).

Krasteva, L.,. Ivanova, I. & Velcheva, N. (2010). Grouping of determinate local tomato varieties on the basis of cluster analysis. *Agricultural Science and Technology*, *2 (3),* 113-115.

Madzharova, D. (1968). Root vegetable crops. Publishing House of Bulgarian Academy of Sciences, Sofia, 184 (Bg).

Milev, M., Nikolova, K., Ivanova, I. & Dobreva, M. (2015). Usage of K-Cluster and factor analysis for grouping and evaluation the quality of olive oil in accordance with physico-chemical parameters, *AIP Conf. Proc.*1690, 020021-1—020021-5.

Murtazov, T., Minkov, I. & Petrov, H. (1984). Vegetable production with breeding and seed production of vegetable crops. "Hr. G. Danov", Plovdiv, 379 (Bg).

Panayotov, N., Gueorguiev, V. & Ivanova, I. (2000). Characteristics and grouping of F_1 pepper (*Capsicum annuum* L.) hybrids on the basis of cluster analysis by morphological characteristics of fruits. *Capsicum & Eggplant Newsletter,* № 19, University of Turin, Italy, 62-65.

Singh, A. K. & Singh, A. K. (1996). Effect of nitrogen and potash on seed yield of carrot (*Daucus carota* L.) cv. Pusa Kesar. *Crop Research (Hisar), 12 (2),* 182-184.

Stepuro, M. F., (2008). Chemical composition of seeds, removal and balance of the nutritive elements in soil in seed production of carrot and fennel in greenhouse conditions*. Ovoshchevodstvo (Belarus), 14,* 256-264 (Ru).

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association. 58,* 236-244.

Received: May, 19, 2021; *Accepted:* June, 25, 2021; *Published:* September, 2021