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Effect of Different Nitrogen and Potassium Fertilization Levels on Vegetative Characteristics of Carrot

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تأثير التسميد بمستويات مختلفة من النيتروجين والبوتاسيوم على الصفات الخضرية للجزر

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Abstract
Two field experiments were conducted in a sandy soil at Al-Kufra City, Libya, during the two successive winter seasons of 2021and 2022, to study the effects of varying nitrogen and potassium fertilization levels, as well as their interaction, on vegetative characteristics of carrot. Data cleared that that nitrogen fertilizer levels treatments have significant effect on vegetative characteristics i.e., plant height, plant weight, number of leaves/plants, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants, in both seasons. The highest significant values for these traits were recorded as a result of increasing nitrogen fertilizer levels from 0 to 210 kg/ha regularly in both seasons. In relation to the impact of potassium fertilizer levels treatments, reveal significant effects on vegetative characteristics, in the two seasons. It is evident that the highest values were achieved as a result of increasing the potassium fertilization levels from 0 to 180 kg/ha regularly in both seasons. As for the interaction among nitrogen and potassium fertilizer levels treatments have significant effects for all vegetative characteristics, in both seasons. The most effective combined treatment, which resulted in the highest significant increase, was achieved by applying the highest nitrogen rate (210 kg/ha) along with the highest potassium rate (180 kg/ha).

Keywords: Carrot, nitrogen, potassium, vegetative characteristics.

الملخص
أُجريت تجربتان حقليتان في تربة رملية بمدينة الكفرة - ليبيا، خلال موسمي الشتاء المتتاليين لعامي 2021 و2022، بهدف دراسة تأثير مستويات مختلفة من التسميد بالنيتروجين والبوتاسيوم، وكذلك

التداخل بينهما، على الصفات الخضرية لنبات الجزر. أوضحت النتائج أن لمستويات السماد النيتروجيني تأثيرًا معنويًا على الصفات الخضرية المدروسة، مثل: طول النبات، الوزن الكلي للنبات، عدد الأوراق للنبات، الوزن الطازج للأوراق، الوزن الجاف للأوراق، طول الجذر وقطره، وذلك في كلا الموسمين. وقد سُجلت أعلى القيم المعنوية لهذه الصفات نتيجة للزيادة المنتظمة في معدلات السماد النيتروجيني من 0 إلى 210 كجم/هـ خلال الموسمين.

أما فيما يتعلق بتأثير مستويات السماد البوتاسي، فقد أظهرت النتائج أيضًا تأثيرات معنوية على الصفات الخضرية في الموسمين، حيث تبيّن أن أعلى القيم تحققت نتيجة للزيادة المنتظمة في معدلات السماد البوتاسي من 0 إلى 180 كجم/هـ.

كما أثبتت النتائج أن التداخل بين مستويات السماد النيتروجيني والبوتاسي له تأثير معنوي على جميع الصفات الخضرية في كلا الموسمين، وكانت المعاملة المشتركة الأكثر فاعلية، والتي أدت إلى أعلى زيادة معنوية، هي التسميد بأعلى معدل من النيتروجين (210 كجم/هـ) وأعلى معدل من البوتاسيوم (180 كجم/هـ).

الكلمات الدالة: الجزر، نيتروجين، بوتاسيوم، صفات خضرية.

Introduction

Carrot (*Daucus carota* L.), a member of the Apiaceae family, is one of the most widely cultivated root vegetables, valued for its nutritional richness and economic significance. It is an excellent source of beta-carotene a vital precursor of vitamin A as well as essential nutrients such as dietary fiber, sugars, vitamins, and minerals. Due to its health-promoting properties and broad utility in both culinary and industrial contexts, carrot production has expanded considerably in various regions worldwide.

The productivity and quality of carrot crops are strongly influenced by environmental and agronomic variables, with nutrient management being among the most critical factors. Nitrogen (N) and potassium (K) are two essential macronutrients that play a central role in supporting plant growth and vegetative characteristics development.

Nitrogen is a primary macronutrient required in substantial quantities for proper plant functioning. Among all essential nutrients, it is considered to have the most profound effect on crop productivity. Nitrogen is fundamental to various biochemical and physiological processes, forming a key constituent of nucleic acids, proteins, chlorophyll, and many enzymes. It also contributes structurally to cell walls and is integrally involved in metabolic pathways related to photosynthesis **(Marschner, 2012)**.

Godebo *et al*., (2020) observed that applying nitrogen in the form of urea at rates of 246 kg/ha and 165 kg/ha in potato cultivation significantly delayed flowering, and enhanced several growth parameters including stem length, above-ground and below-ground biomass, number of branches, and number of stems, compared to the untreated control (0 kg N/ha). In a study on radish, **Ullah *et al*., (2023)** reported that nitrogen application had a significant positive influence on all measured traits. The highest values for number of leaves per plant, plant height, root diameter, root length, root weight, and total yield were observed with the application of 210 kg N/ha. In contrast, the control treatment (0 kg N/ha) recorded the lowest values across all these parameters.

Potassium, likewise, is crucial for carrot development, particularly due to its role in the translocation of photosynthates mainly sugars and carbohydrates from the

leaves to storage tissues in the roots. In addition to promoting root growth, potassium enhances plant resistance to pests and diseases and improves tolerance to both biotic and abiotic stresses such as drought and low temperatures. As a highly mobile nutrient, potassium is known for its "luxury consumption" behavior, where plants take up more than their immediate requirement, storing the surplus for future metabolic needs **(Rodrigues *et al.*, 2021)**. Several studies, including **Haque *et al.*, (2019)**, reported that the highest potassium application rate of 120 kg/ha significantly increased the number of leaves per plant, root length, root diameter, and fresh weight of carrot. Similarly, on radish, **Amin *et al.*, (2023)** reported that the application of potassium at a rate of 60 kg/ ha resulted in the highest values for root diameter, dry leaf matter, and number of leaves per plant.

Therefore, the present study aimed to assess the effects of different nitrogen and potassium fertilization levels, along with their interaction, on vegetative characteristics of carrot "Nantaise Amelioree" variety grown under the environmental conditions of Al-Kufra City, Libya.

Materials And Methods

Analysis of soil:

A random soil sample was collected from the experimental field at a depth of 0–30 cm prior to cultivation and soil preparation, with the aim of evaluating specific physical and chemical properties. The analytical procedures employed followed the protocols outlined by **Buurman *et al.*, (1996)**. The results are detailed in Table 1.

Table 1: Key physical and chemical characteristics of the experimental soil prior to cultivation across the two growing seasons.

K PPM	P PPM	CO^{3-} - %	pH	N (%)	E.C M/cm	Organic Matter (%)	Particle Size distribution			season
							Clay (%)	Silt (%)	Sand (%)	
75	82	0.8	7.1	0.23	1.30	0.10	2	3	95	**2021**
80	93	0.9	7.2	0.21	1.36	0.15	3	3	94	**2022**

The experimental design and treatments:

The field experiments were arranged in a randomized complete block design with a split-plot design system, comprising three replications. A total of 16 treatments were tested. The vertical plots (main plots) were assigned to four nitrogen fertilizer levels: 0, 70, 140, and 210 kg N/ha. Nitrogen was applied in four split doses by spreading. The initial application occurred 45 days after seeding, followed by additional applications at approximately 55, 65, and 75 days after the first.

The horizontal plots (sub-plots) were designated for four potassium fertilizer levels: 0, 60, 120, and 180 kg K/ha. Potassium was applied in four equal portions, synchronized with the nitrogen application schedule.

Each experimental unit occupied an area of one square meter.

Agricultural practices:

Urea (46% N) served as the nitrogen source, while potassium was supplied in the form of potassium sulfate (48% K_2O). All plots received a basal application of single superphosphate (15.5% P_2O_5) at a rate of 400 kg/ha.

A suitable field site was selected and prepared for the experiment. The area was cleared of debris, stones, and any other unwanted materials before being plowed and subdivided into replicates and experimental units. Carrot seeds of "Nantaise Amelioree" variety were sown during the first week of November in both 2021 and 2022, using a seeding rate of 10 kg/ha. Prior to sowing, the superphosphate fertilizer was incorporated into the soil during land preparation.

Standard agronomic practices recommended for commercial carrot production were followed throughout the study. A drip irrigation system was employed, and pest and disease control measures were implemented as necessary, in accordance with recommended guidelines.

Studied Characters:

Vegetative characteristics:

At 120 days after seeding, and following the completion of all fertilizer applications, samples were randomly collected from each experimental treatment. The following parameters were subsequently estimated:

- Average plant height.
- Average plant weight.
- Average number of leaves/plants.
- Average fresh leaf weight.

Dry leaf weight: Leaf samples were oven-dried at 70 °C until a constant weight was achieved, and the final dry weight was recorded.

- Average root length.
- Average root diameter.

Statistical analysis

Data were statistically analyzed using the MSTAT-C software package. Analysis of variance (ANOVA) was performed according to a randomized complete block design (RCBD) with a split-plot arrangement, following the methodology of **Gomez and Gomez (1984)**. Treatment means were compared using the least significant difference (LSD) test at the 5% level of significance, as outlined by **Snedecor and Cochran (1980)**.

RESULTS AND DISCUSSION

Effect of nitrogen fertilizer levels treatments:

Data present in Table 2 show that nitrogen fertilizer levels treatments have significant effects on vegetative characteristics *i.e.,* plant height, plant weight, number of leaves/plants, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants, in both seasons. The highest significant values for these traits were recorded as a result of increasing nitrogen fertilizer levels from 0 to 210 kg/ha regularly

in both seasons. The increase in these characteristics with increased nitrogen fertilizer levels in both seasons can be attributed to the vital role nitrogen plays in numerous biochemical and physiological processes within plants. It is a primary macronutrient required in substantial quantities for proper plant functioning. Among all essential nutrients, it is considered to have the most profound effect on crop productivity. Nitrogen is fundamental to various biochemical and physiological processes, forming a key constituent of nucleic acids, proteins, chlorophyll, and many enzymes. It also contributes structurally to cell walls and is integrally involved in metabolic pathways related to photosynthesis, as mentioned by **(Marschner, 2012)**. These findings are consistent with the conclusions reported earlier by **Godebo *et al*., (2020)** on potato and **Ullah *et al*., (2023)** on radish.

Effect of potassium fertilizer levels treatments:

In relation to the impact of potassium fertilizer levels treatments, data in the same table reveal a significant effect on vegetative characteristics, in the two seasons. It is evident that the highest values were achieved as a result of increasing the potassium fertilization levels from 0 to 180 kg/ha regularly in both seasons. This improvement can be attributed to the essential role of potassium in enhancing the growth and development of carrot plants. Potassium, likewise, is crucial for carrot development, particularly due to its role in the translocation of photosynthesize mainly sugars and carbohydrates from the leaves to storage tissues in the roots. In addition to promoting root growth, potassium enhances plant resistance to pests and diseases and improves tolerance to both biotic and abiotic stresses such as drought and low temperatures. As a highly mobile nutrient, potassium is known for its "luxury consumption" behavior, where plants take up more than their immediate requirement, storing the surplus for future metabolic needs, as mentioned by **(Rodrigues *et al.,* 2021)**. These findings are consistent with the conclusions reported earlier by **Haque *et al.,* (2019)** on carrot and **Amin *et al.,* (2023)** on radish.

Effect of interactions:

The interactions among nitrogen and potassium fertilizer levels treatments have significant effects vegetative characteristics *i.e.,* plant height, plant weight, number of leaves/plant, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants, in both seasons are present in Tables 3 and 4. The most effective combined treatment, which resulted in the highest significant increase, was achieved by applying the highest nitrogen rate (210 kg/ha) along with the highest potassium rate (180 kg/ha).

Table 2: The main effects of nitrogen and potassium fertilizer levels on plant height, plant weight, number of leaves/plants, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants in the two study seasons.

N kg/ ha	K kg/ ha	Plant Height(cm)	Plant Weight (g)	Number of Leaves/ plant	Fresh Leaf Weight (g)	Dry Leaf Weight (g)	Root Length (cm)	Root Diameter (cm)
First Season								
0		12.34C*	20.26 D	4.71B	5.4C	1.575C	7.125D	1.53B
70		34.47B	42.66C	6.05AB	9.08B	3.58B	9.2C	2.35AB
140		49.01A	72.45B	7.10A	12.25A	4.53AB	11.50B	2.86A
210		46.09A	81.38A	7.37A	13.675A	6.3A	13.43A	2.93A
	0	35.22B	52.05B	6.20A	10.125A	3.86A	9.59C	2.39A
	60	36.41AB	53.79AB	6.3 A	10A	3.775A	10.30B	2.4A
	120	39.49A	54.71A	6.28A	10.075A	4.02A	10.31B	2.43A
	180	39.79A	56.21A	6.46A	10.208A	4.23A	11.05A	2.45A
Second Season								
0		29.26C	31.65C	5.61C	5.30 D	2.27B	7.95B	2.05B
70		34.05BC	42.38C	6.20B	6.86C	2.42B	10.18AB	2.56AB
140		40.94AB	66.875B	6.69AB	10. 5B	4.78A	11.108A	2.93A
210		44.5A	91.516A	7.008A	13.8 A	5.41A	11.5A	2.95A
	0	35.65A	33.53C	5.84C	A8.65	3.34B	8.31C	2.375B
	60	35.6A	51.81C	6.21 B	9.008A	3.35B	9.88B	2.55AB
	120	38.60A	61.72B	6.75AB	9.225A	3.98AB	11.15AB	2.77A
	180	38.89A	65.55A	7.06A	9.591 A	4.21A	11.38A	2. 80A

*Values followed by the same letter (s) of the alphabet, within each group, are means for each trait, and do not differ significantly from each other according to the least significant difference (LSD) method at a significance level of 0.05.

Table 3: Effect of the interaction between nitrogen and potassium fertilizer levels on plant height, plant weight, number of leaves/plant, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants in the first season.

N kg/ha	K kg/ha	Plant Height(cm)	Plant Weight (g)	Number of Leaves/ plant	Fresh Leaf Weight (g)	Dry Leaf Weight (g)	Root Length (cm)	Root Diameter (cm)
0		17.6g*	13.66g	4.5g	5f	1.16i	6.6g	1.36g
		19.5fg	19.33f	4.5g	5.8f	1.9hi	7.03g	1.66g
		22.26fg	19.33f	4.86fg	5.13f	1.25i	7.5fg	1.73g
		26ef	23.53ef	5e-g	5.66f	2.00g-i	7. 36fg	2.2f
70	**0**	32.4d	40.33d	5.73d-f	8.66e	3.16f-h	8.46f	2.43d-f
	60	33.7de	41.33d	6.06c-e	9e	3.65e-h	8.46f	2. 9a-c
	120	34.6d	44d	6.1c-e	9e	3.7e-g	9.93e	2.33ef
	180	37.2cd	45d	6.33b-d	9.66e	3.6e-h	9.93e	2. 43d-f
140		43.7a-c	71c	6.96a-c	11.83d	3.9ef	10.63de	2.63c-e
		50. 53a	72c	7a-c	12d	3.9ef	11.4cd	2.66b-e
		50. 66a	72.5c	7.03a-c	12.33cd	4.23d-f	11.36cd	2.73a-d
		51.13a	7 4.33bc	7.43ab	12.83b-d	8.23ab	11.46bc	3.01ab

210	0	42.63bc	78.3ab	7.2a	13a-d	8.29ab	12.63bc	3.03a
	60	45.86ab	82a	7.2a-c	13.7ab	9.45a	12.56bc	3.06a
	120	46.7ab	82.3a	7.5a-c	13.66a-c	9.48a	13.2b	3.6a
	180	49.16ab	83a	7.6ab	14.33a	9.73a	16.5a	1.36g

*Values followed by the same letter (s) of the alphabet, within each group, are means for each trait, and do not differ significantly from each other according to the least significant difference (LSD) method at a significance level of 0.05.

Table 4: Effect of the interaction between nitrogen and potassium fertilizer levels on plant height, plant weight, number of leaves/plant, fresh leaf weight, dry leaf weight, root length and root diameter of carrot plants in the second season.

N kg/ ha	K kg/ ha	Plant Height (cm)	Plant Weight (g)	Number of Leaves/ plant	Fresh Leaf Weight (g)	Dry Leaf Weight (g)	Root Length (cm)	Root Diameter (cm)
0		24.8f*	15.16i	4.56f	4.6g	1.49f	5.73g	1.5g
		27.4af	26.6i	5.16ef	5.1fg	1.83ef	7.76fg	1.96fg
		32.43d-f	34h	5.56d-f	5.7efg	2.29d-f	8.2efg	2.1eg
		32.43d-f	40.5g	5.73c-f	5.83efg	3.49cd	8.96d-f	2.66b-d
70	0	33.7c-f	40.8g	6.03b-e	6.33efg	2.16d-f	9.3d-f	2.4d-f
	60	33.63c-f	42.86g	6.6b-d	6.8ef	2.16d-f	9.26d-f	2.6cd
	120	33. 83c-e	44.33g	6.9bc	6.8ef	2.32d-f	9.73c-f	2.76a-d
	180	35.03b-e	51.86f	6.13b-e	7.5e	3.31c-e	10c-f	2.5c-e
140		36.9a-d	62.16e	6.16b-e	10d	4.46bc	10.1c-f	2.66b-d
		41 a-d	60.33e	6.23b-e	10.33d	4.50bc	10.5b-e	2.83a-d
		41.66a-c	68d	6.53b-d	10.66cd	4.67bc	10.9a-d	2.83a-d
		43.13ab	77c	6.83bc	11cd	5.51ab	11.9a-d	2.83a-d
210	0	44.2a	86.33b	6.93bc	12.53bc	4.77a-c	12.03a-c	2.93a-c
	60	44.46a	89b	6.96b	13.66ab	5.05ab	13.06e-c	3.1ab
	120	45.1a	92.2a	7.06b	14ab	5.57ab	12.93ab	3.13ab
	180	45.3a	93a	8.66a	15a	6.57ab	13.46a	3.23a

*Values followed by the same letter (s) of the alphabet, within each group, are means for each trait, and do not differ significantly from each other according to the least significant difference (LSD) method at a significance level of 0.05.

Conclusion

The findings of this study clearly demonstrate the crucial role of nitrogen and potassium fertilization in enhancing the vegetative growth characteristics of carrot plants under sandy soil conditions in Al-Kufra, Libya. Increasing nitrogen application up to 210 kg/ha and potassium application up to 180 kg/ha consistently improved plant height, plant weight, number of leaves, fresh and dry leaf weight, root length, and root diameter across both growing seasons. Furthermore, the interaction between nitrogen and potassium levels revealed that the combined application of the highest rates of both nutrients (210 kg N/ha + 180 kg K/ha) produced the most significant improvements in all measured parameters.

These results highlight the importance of balanced nutrient management in optimizing carrot growth and productivity. For growers in regions with similar agro-climatic and soil conditions, the recommended fertilization regime of 210 kg N/ha and 180 kg K/ha can be adopted to maximize vegetative performance and overall crop potential. Future research could focus on evaluating the effects of these fertilization levels on yield quality and storage characteristics to provide a more comprehensive fertilization strategy for carrot production.

Recommendations

Optimal Fertilization Strategy

Farmers cultivating carrot under sandy soil conditions similar to those in Al-Kufra, Libya, are advised to apply 210 kg/ha of nitrogen in combination with 180 kg/ha of potassium. This treatment consistently produced the best vegetative growth traits, ensuring higher productivity.

Balanced Nutrient Management

It is crucial to avoid under- or over-application of fertilizers. Excessive nitrogen without sufficient potassium may lead to imbalanced growth and lower quality, while insufficient nitrogen or potassium reduces vegetative performance. Therefore, balanced fertilization is strongly recommended.

Adoption of Split Application

Since nutrients in sandy soils are prone to leaching, the split application method used in this research (applying fertilizers in multiple doses) should be followed. This ensures efficient nutrient uptake, reduces losses, and supports consistent plant growth.

Soil Testing Before Fertilization

Farmers should conduct regular soil analyses to determine nutrient status before fertilizer application. This will help optimize fertilization levels according to the actual soil fertility and avoid unnecessary costs.

Integration with Other Nutrients

While nitrogen and potassium were the focus, phosphorus and micronutrients also play important roles in carrot development. Further studies and field trials should include these elements to develop a comprehensive fertilization package.

Future Research Recommendations

Additional studies are needed to evaluate the effects of nitrogen and potassium fertilization on carrot yield quality, nutritional composition, and storage life.

Research should also test these fertilization levels under different soil types and climatic conditions to confirm the broader applicability of the results.

Extension and Farmer Training

Agricultural extension programs should disseminate these findings to farmers. Training on proper fertilizer handling, timing, and application techniques will maximize the benefits and reduce potential negative environmental impacts.

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