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Effect of high-potash fertilizer and planting method on vegetative and flowering growth traits of Fennel *Foenicum Vulgare Mill* L.

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ABSTRACT

A factorial controlled experiment was carried out at the College of Medicinal and Industrial plants, Department of Medicinal and Industrial Plants, University of Kirkuk, This study was designed to systematically assess the individual and interactive effects of high-potassium fertilization and planting method on the vegetative growth performance of fennel (*Foeniculum vulgare* L.). A factorial experiment was implemented under field conditions using two planting methods (row sowing and broadcasting) and three concentrations of high-potash fertilizer (0, 2, and 3 g L^{-1}). The treatments were arranged in a randomized complete block design (RCBD) with three replicates to ensure experimental precision and minimize environmental variability. Statistical analysis was conducted using analysis of variance (ANOVA), and treatment means were separated according to Duncan's Multiple Range Test at a significance level of $P \leq 0.05$. The results demonstrated that increasing high-potassium fertilization significantly enhanced all evaluated growth parameters. The highest fertilizer concentration (3 g L^{-1}) produced the greatest values for plant height, number of branches per plant, stem diameter, days from planting to 50% flowering, and number of inflorescences. Furthermore, a significant interaction effect between fertilization level and planting method was observed, indicating that the combined application of optimal potassium supply and appropriate planting configuration maximized vegetative growth and reproductive development.

تأثير السماد عالي البوتاس وطريقة الزراعة في صفات النمو الخضرية والزهرية لنبات الحبة الحلوة (*Foeniculum vulgare* L.)

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الخلاصة

تُعدّ نباتات الحبة الحلوة (*Foeniculum vulgare* L.) من المحاصيل الطبية والصناعية ذات الأهمية الاقتصادية البالغة، حيث نُفِّذت هذه الدراسة في حقل كلية النباتات الطبية والصناعية بجامعة كركوك بهدف دراسة تأثير السماد عالي البوتاس وطريقة الزراعة والتأثير التداخلي بين التسميد وطريقة الزراعة في صفات النمو الخضري لهذا النبات. نفذت هذه التجربة العاملية وفق تصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات، وشملت المعاملات طريقتَي زراعة هما الزراعة بالسطور والنثر، وثلاثة تراكيز من السماد عالي البوتاس (0 و2 و3 غم/لتر). حُلِّلت البيانات إحصائيًا باستخدام تحليل التباين (ANOVA) وقورنت المتوسطات وفق اختبار دنكن متعدد المدى عند مستوى معنوية $P \leq 0.05$ ، حيث اظهرت النتائج أن زيادة تركيز السماد عالي البوتاس أدى إلى تحسين معنوي في جميع مؤشرات النمو المدروسة ، إذ أعطى التركيز الأعلى (3 غم/لتر) أعلى القيم لارتفاع النبات وعدد الأفرع للنبات الواحد وقطر الساق وعدد الأيام من الزراعة حتى بلوغ 50% من الإزهار وعدد النورات الزهرية. فضلًا عن ذلك، أظهرت نتائج التداخل تأثير معنوي بين مستوى التسميد وطريقة الزراعة، مما يدل على أن الجمع بين توفير المستوى الأمثل للبوتاسيوم وتهيئة الطريقة الزراعية الملائمة يحسن من النمو والتطور الخضري لنبات الحبة الحلوة.

الكلمات المفتاحية: الشمر، التسميد البوتاسي، طريقة الزراعة، النمو الخضري، الإزهار

INTRODUCTION

The fennel seed (*Foeniculum vulgare* L. (fennel) is a member of the family Apiaceae (umbeliferae). Its medicinal and nutritional value make it one of the most prominent medicinal plants in Iraq and in the world. The Iraqi Herbal Medicine Center is one of the most active consumers of fennel fruits as these are ingredients in most of the herbal mixture preparations (Al-Zubaidi et al., 1993). This research aimed at treating the Fennel plant with potassium fertilizer that enhances production of medicinal plants and their concentration of active ingredients, which is of substantial importance in enhancing the physical characteristics of the soil. Potassium is an essential macronutrient in plant growth, and it is the third most essential among other nutrients, after nitrogen and phosphorus. It has a complex involvement in plant physiology, as it involves physiological and biochemical roles. Physically, potassium helps to improve the capability of the plant to survive several stresses in the environment such as; pathogen attacks, insect herbivory, high temperatures, drought, and salinity. It also plays an important role in osmotic regulation, as well as the translocation of carbohydrates synthesized into from source tissues to storage tissues. Protein synthesis and activation of more than 70 enzymes are biochemically necessary processes, making potassium important in enhancing the effectiveness of photosynthesis and the entire metabolic process. All these processes highlight the core position of potassium in enhancing plant growth, development and stress resistance. (Abu Dahi and Al-Younis, 1988; Ali et al., 2014). Potassium plays a vital role in photosynthesis, protein synthesis, controlling ionic balance, regulating plant materials and water use, and activating plant enzymes. Potassium plays an important role in facilitating the transfer of photosynthesis products (Reddya et al., 2004), in addition to many other photosynthetic processes to the seeds, where the manufactured materials are multiplied in the form of oil, and for its effective contribution Potassium stimulates the movement of carbohydrates from leaves to storage areas in seeds (Alak, 2007) and increases oil content in oil crops (Vakin, 2008). The choice of fertilizer depends on the soil content, nutrient types, solubility, and cost of fertilizers (Hebebrand and Laborde, 2023).

Potassium sulfate (K2SO4) and potassium chloride (KCl) have been used as sources of potassium in fertilizers. Potassium sulfate fertilizer contains 41% potassium and 18% sulfur. It is considered an expensive fertilizer due to its high manufacturing costs and the control of its production and raw materials by many countries. It is preferred for most economic crops, especially those sensitive to chlorine, and is also a good source of sulfur (Das and Mandal, 2015). Potassium is a highly mobile macronutrient in plant, crucial for both physiological and biochemical processes. It plays a key role in regulating cellular osmotic pressure and maintaining the balance of cations and anions in cytoplasm (Kaiser, 1982; Hu et al., 2016), while also enhancing stress tolerance, carbohydrate translocation, protein synthesis, and enzyme activation. Therefore, it regulates the opening and closing of stomata and cell elongation. One of the factors that lead to motivating plants to increase their economic yield is the optimal selection of factors that lead to modifying the related physiological processes, including determining the method of cultivation due to its importance in creation an optimal growth environment is essential for promoting healthy plant development and achieving high yields (Abdul Jawad et al., 1989). Al-Dughji et al., 2011, obtained when they cultivated two local Syrian Fennel varieties, "Foeniculum vulgare Mill. "Local Lebanese" was grown using the two methods of growing seedlings in permanent locations, in rows and in rows within panels, showing a significantly excelled in plant height and volatile oil percentage in plants grown on rows compared to those grown in rows within panels. When growing cumin, the "Local Syrian" variety, using the "Local Syrian" method (Cyminum L.), the "Local Syrian" method was found to have a marked superiority was observed in plant height, the number of lateral branches, and leaf count. fresh and dry biomass of vegetative tissues, seed yield, and number of inflorescences compared to plants grown using the pot method. The importance of the research stems from the nutritional, medicinal, economic, and industrial importance of Fennel the increasing demand for this plant in local markets, and the scarcity of studies on this crop. This experiment was conducted to determine the effects of fertilization, potassium, and the optimal cultivation method, as well as their interaction on some chemical traits of fennel. It also aimed to determine the optimal rates for achieving the highest yield in both quantity and quality.

MATERIALS AND METHODS

To determine the influence of high-potash fertilization and planting method on vegetative and flowering characteristics of fennel, a factorial experiment was conducted in the winter of 2024-2025 at the Department of Medicinal and Industrial Plant, College of Medicinal and Industrial Plants, University of Kirkuk. The experiment was a factorial experiment to determine the effect of two principal variables, which was conducted at the winter season of 2024-2025 in the Department of Medicinal and Industrial Plants, College of Medicinal and Industrial Plants, University of Kirkuk to investigate the effect of high-potash fertilizer and the planting method on the vegetative and flowering growth characteristics of Fennel plants.

Two factors were incorporated in the experiment, namely planting Fennel seeds in rows and scattered and the application of three levels of high-potash fertilizer (0 g L^{-1}, 2 g L^{-1} and 3 g L^{-1}) to the seed. The field-test of the experiment followed the Randomized Complete Block Design (RCBD) having three replications. Planting of the seeds was

carried out on November 15, 2024 in two plots. Maintenance activities of crops such as irrigation, weeding and pests were all done when necessary.

Vegetative and flowering growth traits:

The growth and flowering parameters in plants were determined based on ten randomly chosen plants within the middle of each experimental plot. The height of the plant was measured (cm per plant) at the soil surface to the apex of the plant with the help of the ruler, and the average height was determined in each plot. The count of lateral branches per plant was calculated by adding up the count of all the branches under the selected plants and the average was calculated. A Vernier caliper was used to measure main stem diameter (mm per plant) and the mean diameter calculated. The interval between sowing and 50% flowering was taken as the number of days that it took when half of the plants in each plot were in full flower. Lastly, the selected plants were counted the number of main inflorescences per plant and the average number of inflorescences per plant was counted.

Statistical analysis

The data obtained was analyzed statistically according to the experimental design and simple comparisons of means have been implemented using Duncan Multiple Range test at a level of significance of 0.05.

RESULT AND DISCUSSION

Most indicators of vegetative growth strength depend on cell division and elongation, which in turn are affected by the quantity and quality of nutrients absorbed by the plant, and can be influenced by varying environmental conditions. The high-potassium fertilization treatment (3 g L^{-1}) significantly increased plant height, reaching 75.55 cm, compared to the control treatment, which yielded the lowest value of 62.92 cm. The results in the table also indicated a significant effect of potassium fertilization treatments on the average number of branches per plant. The 300 g treatment yielded the highest average of 9.96 branches per plant, compared to the control treatment, which yielded the lowest average for this trait, reaching 6.60 branches per plant. The results in the same table also indicate that there were no significant differences in each of the levels of high potassium fertilizer in the stem diameter trait, except for superficial differences. The reason for the increase in vegetative traits may be due to the role of potassium in activating protein synthesis enzymes, as well as its effectiveness in activating all enzymes activated by single cations and oxidation synthetase enzymes, such as enzymes, reduction, hydrogenation enzymes, and energy-releasing enzymes, which contributed to activating the carbon metabolism process and thus increasing the vegetative traits in the plant (Helgi et al., 2005). Potassium also plays a role in the accumulation of carbohydrates in the stem and increasing the nodes and their thickness, which is positively reflected in the vegetative traits, and this is consistent with what was concluded by (Al-Khazraji, 2011). The effect of the seed planting method also had a positive impact on the vegetative growth traits of the plant, as shown in Table (1), as both plant height and number of branches increased with the row seeding method, as the row planting treatment gave the highest value for plant height, reaching 76.42

cm and 10.14 branches.plant^{-1} for the number of branches trait, respectively, while there were no significant differences in the stem diameter trait, except for apparent differences. These results are consistent with the findings of (Al-Jabouri, 2014), who found that providing sufficient spacing using a seeding method with appropriate quantities gives the best growth, yield and active ingredient as a result of less competition between plants for growth factors such as light, water and nutrients, achieving a high net yield of photosynthesis products and increasing the accumulation of solid compounds (oxygen compounds). On the contrary, high rates negatively affect growth, yield and active ingredient (Al-Jabouri, 2014).

The increase in the aforementioned vegetative traits of plants with row planting may be attributed to the increased spacing between plants, which consequently reduced competition between plants in the early stages of growth. This encouraged growth, elongation, and increased branching due to increased plant efficiency in photosynthesis. This certainly had a positive impact on increased vegetative growth (Singh et al., 1991). Reducing competition for food, thus increasing the accumulation of nutrients in the plant, as well as increasing the spacing between plants, leads to more efficient exposure to sunlight, thus increasing the efficiency of photosynthesis. These results are consistent with those reported by Bakry et al. (2011) and Thalji (2006).

Table (1) Effect of high-potash fertilization on some vegetative growth traits of Fennel plants.

High potash fertilization treats g L^{-1}	Plant height cm.plant^{-1}	Number of branches. Plant^{-1}	Main stem diameter mm.plant^{-1}	The duration from sowing to 50% flowering	Number of inflorescences per plant $^{-1}$
control	62.92	6.60 A	4.22	143.76	10.44
2 g L^{-1}	66.87	7.44 A	4.77	144.66	11.02
3 gL^{-1}	75.55	9.96 A	4.86	149.80	16.12

In the table 2 that the addition of high-potassium fertilizer significantly affected the number of days until flowering, which increased with increasing levels of addition, reaching the highest value at the level (3 g L^{-1}), which gave the highest average of 149.80 days, compared to the control treatment, which gave the lowest value of 143.76 days. The table also showed a significant increase in the number of inflorescences, reaching (16.12 inflorescences.plant^{-1}).The extension of the flowering period by increasing levels of high-potassium fertilizer may be due to the role played by potassium in increasing the effectiveness of photosynthesis, activating enzymes, and transporting manufactured materials to storage areas. This, in turn, led to increased activity of vital processes and regulating the level of plant hormones that control meristematic cell division and growth, increasing the surface area of the leaves, and thus increasing the nutrients manufactured in the leaves, represented by carbohydrates and proteins, and transporting them to the areas of need and necessary for building plant tissues, thus increasing the number of branches and the number of inflorescences (Abdul Qader et al., 1982). The above factors, in turn, increase vegetative growth, leading to flowering (Al-Younis, 1990).

The cultivation method significantly affected the number of days from planting to 50% flowering, which increased when planting using the row planting method, yielding the highest value of 150.8 days, compared to the "scatter" method, which yielded the lowest value of 142.66 days. The reason for the delayed flowering of plants when sowing using the row method and the early flowering when sowing using the scattering method may be attributed to increased competition between plants for light and nutrients, and increased auxins resulting from shading of plants when sowing using the scattering method, unlike when sowing in rows, which led to a delay in flowering. This is consistent with what Al-Mohammadi (2009) found. Regarding the number of inflorescences, the "row" method yielded the highest value of 16.71 inflorescences. plant^{-1}, compared to the control treatment, which yielded the lowest value of 9.33 inflorescences.plant $^{-1}$.

Table (2) Effect of the cultivation method on some floral growth traits of the Fennel plant

Treatments of the cultivation method	Plant height cm.plant^{-1}	Number of branches. Plant^{-1}	Main stem diameter mm.plant^{-1}	The duration from sowing to 50% flowering	Number of inflorescences per plant $^{-1}$
control	63.88	6.81	4.32	142.66	9.33
scatter	67.16	7.66	4.80	144.88	10.11
lines	76.42	10.14	4.89	150.08	16.71

The findings show that the levels of High-potassium fertilizer and the cultivation process interact significantly in their influence on the vegetative growth features and floral growth features (plant height, number of branches, stem diameter, number of days to 50% flowering, and inflorescence number), respectively.

The treatment (3 g. L w + scatter) registered the top figure in the height of the plant (77.45), number of branches (10.51), stem diameter (8.28), number of days taken by planting till 50 percent flowering (151.08), and inflorescences (16.71), respectively.

Table (3) Effect of cultivation method on some floral growth traits of Fennel plants

High potash fertilization treatments	Planting Method treatments	Plant height cm.plant^{-1}	Number of branches. Plant^{-1}	Main stem diameter mm.plant^{-1}	The duration from sowing to 50% flowering	Number of inflorescences per plant $^{-1}$
	control	62.33	6.8	4.32	142.66	9.33
control	Scatter	63.30	6.22	4.50	143.88	9.11
	Lines	67.30	6.22	4.55	144.08	9.71
	control	61.24	6.32	4.88	144.66	9.33
2 g LW	Scatter	66.22	6.88	4.79	145.88	10.11
	Lines	68.30	7.01	5.89	146.08	11.71
	control	60.55	7.22	4.32	146.66	11.33
3 g LW	Scatter	67.32	8.26	5.80	150.88	15.11
	Lines	77.45	10.51	8.27	151.08	16.71

CONCLUSIONS

Based on the results obtained and in accordance with the environmental conditions of the research area, the following conclusions are drawn: High-potassium fertilizer yielded the best results for most of the studied traits, such as vegetative growth indicators, High-potassium fertilizer yielded the best results for most of the studied traits, such as floral growth indicators Fennel plants responded to the row planting method in most vegetative and floral traits. The combination of high-potash fertilizer and planting method yielded the best results, reaching the significant level for most of the studied traits.

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