Effect of the method of adding potassium fertilizer on the vegetative growth indicators and yield of cabbage plants *Brassica*o learacea var. capitata

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Article Info

E-ISSN: 3107-7145
Impact Factor (RSIF): 8.03
Volume: 02
Issue: 02
Received: 15-02-2026
Accepted: 18-03-2026
Published: 20-04-2026
Page No: 32-37

Abstract
A field experiment was conducted in the vegetable garden of the Horticulture and Landscape Engineering Department, College of Agriculture, Al-Qasim Green University during the autumn season of 2025-2026 to investigate the effect of different methods of potassium fertilizer application on growth and yield of cabbage. The experiment had two factors: how the fertilizer was applied, and two ways of doing this was by adding fertilizer to the soil or spraying fertilizer onto the foliage. The second factor involved adding potassium at five different levels: without adding water, adding potassium sulfate at a concentration of 1 g/L, and adding potassium sulfate at a concentration of [missing information].2 g L^{-1}, addition of high-potassium fertilizer at a concentration of 1.5 ml L^{-1}, addition of high-potassium fertilizer at a concentration of 3 ml L^{-1}. The experiment was laid out in a split plot design and means compared by least significant difference (LSD) at the 0.05 level of probability.

The results indicated that the application of high concentration of potassium (3 ml L-1) of fertilizer had significant effect on the studied traits. The K4 treatment showed the highest significant difference in terms of inplant height (44.90cm. plant -1), Leaf Leaf diameter (25.97)mm Plant-1Number of rolled-up sheets (35.0). In the case of plant-1, the measurements are as follows: Plant -1Head circumference (39.73) cm. Plant-1) Total plant yield (0.757) kg. Plant-1) Marketable head weight (1.090) kg. Plant-1) Chlorophyll content (68.8) spad uint.

The treatments also indicated significant superiority in fertilizing methods by potassium fertilization with the treatment superiorroadaddition Spraying in description plant height (45.12 cm. Plant -1)

The-ground based-addition method treatment was better in terms of characteristics such as Head circumference (43.19)cm. Plant-1),Number of folded papers(34.3 mm. Plant-1), Chlorophyll content(65.0spad uint) and Marketable head weight(0.845 kg. Plant-1), whereas in the case of DISTANCE method treatment, it was worse in every other characteristic.

The studied traits revealed significant superiority from the results of the interaction between treatments, where the combination treatment resulted in High potassium concentrationK4The method of application is by spraying. A1 In some qualities, plant height (46.07 cm. plant -1) Number of rolled-up sheets (35.3 Leaf. Plant -1Chlorophyll content (69.6spad unit)

Some characteristics, however, were significantly affected by the method of addition of soil, due to a high potash concentration. Leg diameter (27.90)mm Plant-1Head circumference (45.27) cm. Plant-1) Total plant yield(1.333 kg. Plant-1) Marketable head weight (1.009 kg. Plant-1).

DOI: https://doi.org/10.54660/IJANFR.2026.2.2.32-37

Keywords: Horticulture, Cabbage, Potassium fertilization, Foliar application, Soil application, Potassium sulfate, Plant growth

1. Introduction

The cabbage is part of the Brassicaceae family. A winter crop of vegetable crop grown for the curl foliage in the form of a head. It is eaten raw and in pickles and used in salads and stuffed. They can be consumed boiled (Chatterjee *et al*., 2014) [5]. Cabbage leaves are important because of the nutrients they contain. Dry matter, carbohydrates, proteins, fats and some vitamins are present in every 100g of fresh weight. It is also a source of potassium, phosphorus, magnesium, iron and 24 calories. It also contains folic acid, dietary fibre and glutamic acid. The plant possesses a number of medicinal properties such as the treatment of stomach ulcers, duodenal ulcers and reduction of blood sugar levels (Yuras *et al*., 2011) [4].

Potassium is one of the most important nutrients required for plant growth because it determines the type, amount and

method of fertilization. It is required at all stages of development; plays an important role in soil fertility and plant nutrition and also takes part in various physiological functions in plants. It is one of the limiting factors for production and one of the major elements as the plant requires high levels of it because of its role in various essential physiological processes and the activation of numerous enzymatic reactions in the plant (Ali *et al*., 2014).Nutrient application can be done in two ways, first via the plant's roots and second via foliar spraying. Foliar fertilizers are gaining popularity as they offer many benefits and are an effective supplement to crop growth to enhance the mineral status of the plant and thereby increase crop productivity and quality.KolotaandOsinska 2001) [8]
Thus, one of the most critical factors for achieving high fertilization efficiency to maximize crop yield is to ensure the right source of fertilizer for agriculture. Mineral and organic fertilizers are available. Potassium sulfate is one of the mineral fertilizers used, and is quite rich in potassium (Na'ma *et al*., 2011).
More (2006) [11] investigated the effect of five different concentrations of potassium (0, 15, 30, 45 and 60 mg L-1) on the height of cabbage plants (14.63 cm2 and 15.24 cm for 60 and 15 mg L-1 respectively).
Spraying hybrid cauliflower plants of Nahar variety with high potassium fertilizer at various concentrations (3, 1.5, 0) ml/L increased leaf number, the area of leaves, flower head weight, yield and dry matter percentage of flower heads when compared to the control treatment (Obaid *et al*., 2020) [7]. In the study of the effect of adding potassium fertilizer at different amounts (0, 100, 200, 300) kg/hectare, combined with two methods of adding potassium fertilizer (spraying and soil fertilization), it was added to cauliflower plants (Ibrahim *et al*., 2025) [6]. The leaves, flower disc diameter, leaf area, vegetative dry weight, and disc weight were all increased by foliar fertilization. The dry matter content of the discs was also increased when soil was fertilized. Moreover, the interaction coefficients of the traits had significant effects on majority of the studied traits.Based on the above, the aim of the study is:
It's all about which method and what level of K fertilizer: soil applied or foliage sprayed.

Materials and methods the job
The experiment was carried out in the vegetable field of the Department of Horticulture and Landscape Engineering, Al-Qasim Green University, College of Agriculture, in the autumn season (2025-2026). The experiment was conducted in split-plot with three replicates, each replicate had 10 treatments and each experimental unit consisted of 7 plants. The least significant difference (LSD) test was used to compare the means.At a 5% significance level, LSD is used to determine the significance of differences between means.
The experiment consisted of a study of two factors.

The first factor: The method of adding fertilizer (symbolized by the symbolA) contained two methods:
1. Fertilize using foliar spray.
2. Add fertilizer to the soil.

The second factor: Adding potassium, which included 5 levels.
This approach is known as 1- withoutAdd (water only), and is indicated by the symbolK0.

Add potassium sulfate at a concentration of 1 g/L.
It is symbolizedK1

Add potassium sulfate at 2 g/L
It is designated K2

K3 (4)-Add a high potassium fertilizer at a rate of 1.5 ml/L.
Fertilizer -5 (3ml/L K4).

All the fertilizers were applied in three equal amounts. The first batch was added on 11/17/2025 and the subsequent batches added every two weeks after that.
The additional to soil was in first batch 25 ml/Plant, second batch 50 ml/Plant and the third batch 75 ml/Plant. When it came to the spraying technique, it would be to spray the plant till it was dripping wet.
Cabbage seedlings were planted at 10/13/2025 and planting was done in raised bed with proper spacing between plants 0.4 m. Weedings and removal of bushes were done for the planted plants for the first day till the plant reaches maturity and the irrigation process was performed by drip irrigation.

The following characteristics were studied:
1 -Plant height (cm): The metric measuring tape measured the height of plant at the head maturity stage, from the point of contact of the plant stem with soil to the growing tip of the plant stem for the head selected for the experimental unit.
2 -Stem diameter (mm): Use a caliper to measure the width of the leg.For plants chosen for experimental units, at the head maturity stage, place Vernier, at the two widest points across the stem.At the head mature stage, measure Vernier across the two widest points of the stem for plants chosen to be experimental units.
3 -Number of curled leaves (Leaf/Plant-1): The leaves of all heads were harvested and all leaves were counted after removing the outer leaves not suitable for eating.
4 -Head circumference (cm): Head circumference was determined by measuring the widest part of the head around with a measuring tape.
5 -Total plant yield:(kg.plant-1): The experimental unit result was calculated and then the equation was used to calculate the overall result.
Determine the unit value of the experimental unit from the plant density and its properties by the ratio and proportion method.

Extract per hectare
Total yield (kg.ht) - Yield of experimental unit × 10000 m² experimental unit area.
Then the yield was calculated per ton.

The weight was calculated using the total head weight method and the outer leaves which were not marketable were removed from the head (6-Marketable head weight (kg. plant-1).
7– Chlorophyll content: The chlorophyll content was measured using a deviceSpad and five plantsThen calculate the average.

Results and Discussion

Plant Height (cm.plant-1)

The result of table showed (1) There was a significant difference among treatments of potassium supplementation in average plant height with the treatment given the highest amount of potassium, (K4) obtained the height of 44.90 cm. The lowest treatment (plant -1) recorded 41.77 cm. An important difference was also observed with respect to the fertilizer application treatments, with spray application better (the same table).On the other hand, the lowest height was recorded by the ground addition which was (43.73 cm. Plant -1). Table (1) also revealed interaction between the study factors in the plant height trait, in which the interaction treatment of superior was used.The comparison treatment was the lowest at (41.47 cm. plant -1) while K4A1 treatment recorded the highest height of 46.07 cm.

Table 1: Impact Method of adding potassium fertilizer to cabbage plant height (cm plant – 1

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	41.47	42.07	41.77
K1	45.13	42.73	43.93
K2	44.87	43.73	44.30
K3	45.07	44.13	44.52
K4	46.07	42.97	44.90
middleHow to add	45.12	43.73	
LSD=0.05	(k)=1.959	(A)=1.041	(A*K)=1.382

Leg diameter (mm. Plant -1)

The table gave the result of the average stem diameter where (2) There is a significant effect between the addition of potassium treatments with the treatment (K4) giving the highest average diameter of stems. To The diameter of the stem reached (25.97 mm) Plant-1)The control treatment was the lowest, recording (20.60 mm plant-1). A very significant effect was also found between the levels of fertilizer application treatment, wherein the fertilizer application via soil application treatment was superior.The leg reached under the spraying treatment (A1) was the highest at (25.77)mm. while the lowest average was (21.45)mm. (Plant -1) As the table shows (2) The interaction between the study factors in the average stem diameter trait, in which the interaction treatment using K4A2 was the highest, reached (27.90).mm. Plant -1The comparison treatment was the lowest, and reached (17.20).mm. Plant -1).

Table 2: Impact Method of adding potassium fertilizer to the stem diameter of a cabbage plant (mm. plant -1).

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	17.20	24.00	20.60
K1	19.07	27.40	23.23
K2	22.20	27.73	24.97
K3	25.33	22.67	24.00
K4	23.47	27.90	25.97
middleHow to add	21.45	25.77	
LSD=0.05	(k) = 4.665	(A) = 3.344	(A*K)=6.105

Number of leaves wrapped around a cabbage plant (leaf per plant -1)

Table (3) illustrates that there was a significant difference between the treatments of potassium addition in terms of the average number of curled leaves on the cabbage plant, the treatment with potassium addition got the best results (35.0 leaves). The lowest in comparison was the treatment of plant -1) (31.7 sheets).Plant -1. There was also a highly significant effect between the fertilizer application treatments with the soil application being better, as seen in the same table.A2) The highest number was (34.3 leaves. Plant -1)While the spray application method recorded the lowest number, which was (33.8 leaves. plant -1) Table (3) also showed the interaction between the study factors in the trait of the number of plant leaves, where the interaction treatment used was superior.K4A1) produced the highest number of leaves per plant (35.3) and performed better than rest of the treatments. The lowest being the comparison treatment where it recorded (31.0 leaves. Plant -1).

Table 3: ImpactMethod of adding potassium fertilizer in the number of curled leaves of the cabbage plant (leaf. plant -1).

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	31.0	32.3	31.7
K1	33.0	31.0	32.0
K2	32.7	35.0	33.7
K3	34.0	33.7	33.8
K4	35.3	34.7	35.0
middleHow to add	33.8	34.3	
LSD=0.05	(k)=7.34	(A)=7.95	(A*K)=9.99

Mediumhead circumference plant(cm. Plant-1)

The comparison treatment recorded the lowest with (39.73)cm in the table while the highest was achieved by (4) treatment (Potassium addition) with (45.22)cm. There is also a large treatment effect between fertilizer application treatments (Table) with the treatment using soil application superior.A2) with the highest averageFor the head circumference of the cabbage plantIt reached (43.19) cm. Plant-1)Meanwhile, the spray application method recorded the fewest leaves.UnwrappedIt's length was (40.65)cm. The interference treatment used was the best as indicated by the table (4Interaction between study factors in the average traitFor the head circumference of the cabbage plant).The comparison treatment recorded the lowest (36.53)cm for the head circumference of the cabbage plant, while the rest of the treatments were higher with the highest one being (45.27).cm in Plant-1).

Table 4: impactHow to add potassium fertilizer inThe head circumference of a cabbage plant.

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	36.53	42.20	39.73
K1	40.00	41.47	40.73
K2	39.80	44.47	42.13
K3	41.17	45.27	43.22
K4	43.17	45.27	45.22
middleHow to add	40.65	43.19	
LSD=0.05	(k)=2.32	(A)=2.98	(A*K)=5.999

MediumTotal yield of cabbage plant(kg. Plant-1)

The results indicated (5There is a significant effect between potassium addition treatments in terms of averageThe total yield of the cabbage plant, the treatment that added (K4) registered the highest average and the comparative treatment registered the lowest average. The same table also indicates a highly significant difference between the treatments of fertilizer application with soil application being superior.A2) with the highest averagetoThe total amount reached (1.115kg. The application method using the spray recorded the lowest average (0.976 kg. Plant-1); As the table shows (5Interaction between study factors in the average trait toFor the overall result, where the intervention treatment used was superiorK4A2)) on all other transactions by giving the highest averagetofor the total (reached)1.333 kg. Plant-1The comparison treatment was the lowest, where it recorded (0.747 kg. Plant-1).

Table 5: impactHow to add potassium fertilizer inTotal yield of cabbage plant. (kg.plant-1)

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	0.747	0.767	0.757
K1	0.887	1.150	1.018
K2	0.947	1,200	1.073
K3	1.233	0.927	1.080
K4	0.867	1.333	1.100
middleHowtoadd	0.976	1.115	
LSD=0.05	(k)=0.108	(A)=0.121	(A*K) = 0.371

Medium Marketing yield of cabbage(kg. Plant-1)

The other treatment (Medium Marketing yield of cabbage(kg. Plant-1) was the least with a result of (0.633kg. Plant-1)Plant-1)Table 1 indicates that the addition of potassium level (K4) was the highest. Plant-1) There is also a highly significant effect between the fertilizer application treatments, and the treatment using soil application is superior.The spray method produced the lowest yield of cabbage at 0.845kg. Plant-1) while the middle(reached) recorded 0.613kg. Plant-1) As the table indicates (6Interaction between study factors in the

average traitFor the head circumference of the cabbage plantThe interference treatment used was better.It was also found that the highestMedium Marketing yield of 1.009 kg. Plant-1 was recorded at K4A2) while the lowest yield was obtained from the comparison treatment, which was 0.567 kg. Plant-1 of cabbage(reached).

Table 6: Impact How to add potassium fertilizer to the marketable yield of cabbage plants.(kg.plant1-).

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	0.567	0.700	0.633
K1	0.583	0.747	0.660
K2	0.573	0.890	0.722
K3	0.600	0.907	0.793
K4	1,000	1.009	1.090
middleHow to add	0.613	0.845	
LSD=0.05	(k)=0.220	(A)=0.369	0.338 = ((A*K

Chlorophyll content in leavesSpad Unit

The result obtained showed that there was a significant difference between the average chlorophyll content in the leaf of the different potassium addition treatments (K4 having the highest effect and (K1) having the lowest effect).(60.9) (spad unit) A very high effect exists between fertilizer application treatments, which is superior treatment of soil application (as indicated in the same table).Meanwhile, the spray application method recorded the lowest content (63.4) and the content of (65.0) was recorded for A2). As it is indicated at the table (7Interaction between study factors in the characteristic Chlorophyll content in leavesThe interference treatment used was superior), it is clear that the interaction between the study factors was not significant in the characteristic Chlorophyll content in leaves.The treatment comparison recorded the lowest content of (61.1)spad unit) while K4A1 recorded the best (69.6)spad unit).

Table 7: impactHow to add potassium fertilizer in the percentage of chlorophyll in the cabbage plant.

Potassium (K)	How to add fertilizer (A)		Medium potassium
	Spraying method (A1)	Ground addition (A2)	
K0	61.1	60.8	60.9
K1	59.2	65.5	62.4
K2	61.8	63.4	62.6
K3	66.2	66.9	66.5
K4	69.6	68.2	68.8
middleHow to add	63.4	65.0	
LSD=0.05	(k)=1.57	(A)=1.30	(A*K)=7.57

This is attributed to the availability of potassium sulfate in soil and readily absorbed by the plants and its stimulating effect on enzymes which accelerates the synthesis of carbohydrate compounds after which it is transported to plant parts (Ramadan, 2015) [3]. The marked superiority in potassium could be attributed to the physiological functions of potassium—controlling opening and closing of stomata, carbohydrate formation and regulating water balance in leaves—of plant growth (Krauss, 1995) [9]. The increase might also be because of the soil's nitrogen-fixing capability, which was stimulated by the potassium fertilizer, resulting in rapid uptake of nutrients from the soil and therefore more food being produced by the plant (photosynthesis) and more being transported to the heads.Thus increasing the yield of the plant.

Conclusions

Based on the study results andinThe experimental conditions led to the following conclusions:

thatThe method of applying potassium fertilizer (spraying and soil application) significantly affected all vegetative growth and yield characteristics of cabbage plants. Similarly, the levels of potassium fertilizer applied significantly affected all growth and yield characteristics of cabbage plants. Furthermore, the interaction between the method of potassium fertilizer application and the fertilizer levels significantly affected all studied vegetative growth and yield characteristics.

Recommendations

Based on the results obtained, we recommend thatUsePotassium sulfate with a concentration of 3gm. liter^{-1}distilled waterBy spraying the soil. We also recommend conducting studies with other concentrations of fertilizer on other plants.

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How to Cite This Article
Hadrovic A. The Vranica Mountain in Bosnia and Herzegovina: Living in a sustainable way. Int J Multidiscip Res Growth Eval. 2025 Sep–Oct;6(5):718–758. doi:10.54660/.IJMRGE.2025.6.5.718-758.