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Article

Effect of foliar application with potassium and biozyme on growth and yield of cauliflower (*Brassica oleracea var* botrytis)

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ABSTRACT

This study was conducted during the 2021–2022 agricultural season at the Research Station (A) of the College of Agricultural Engineering Sciences, University of Baghdad, Iraq, to evaluate the effect of foliar application of potassium sulfate, Biozyme, and their combinations on the vegetative growth and yield of cauliflower (*Brassica oleracea* var. *botrytis*, cv. Solid Snow). The experiment was arranged as a factorial randomized complete block design (RCBD) with three replications, including four concentrations of potassium sulfate (0, 3500, 5000, and 6500 mg L^{-1}) and three concentrations of Biozyme (0-, 0.45-, and 0.70-mL L^{-1}). Potassium sulfate was applied four times at 15-day intervals, and Biozyme was applied twice during the vegetative growth stage.

Results showed that spraying with potassium sulfate at 6500 mg L^{-1} significantly increased plant height (69.14 cm), number of leaves (28.08 leaves $plant^{-1}$), leaf area (8535.4 cm^2 $plant^{-1}$), and dry weight (286.9 g) compared with the control. Potassium sulfate at 5000 mg L^{-1} recorded the highest flower head weight (1.495 kg) and total yield (49.83 t ha^{-1}). Foliar application of Biozyme at 0.70 mL L^{-1} significantly enhanced all measured traits, including plant height (69.81 cm), head diameter (21.89 cm), head weight (1.511 kg), and total yield (50.39 t ha^{-1}). The interaction between 5000 mg L^{-1} potassium sulfate and 0.70 mL L^{-1} Biozyme (K2B2) produced the highest head weight (1.585 kg), head diameter (22.92 cm), and total yield (52.84 t ha^{-1}).

These findings indicate that combined foliar application of 5000 mg L^{-1} potassium sulfate with 0.70 mL L^{-1} Biozyme can be recommended to improve cauliflower growth and yield under the environmental conditions of Iraq.

Keywords: *Brassica oleracea* var. *botrytis*, foliar feeding, potassium sulfate, Biozyme, yield, vegetative traits.

INTRODUCTION

Knowing the factors that affect growth is the basis for improving growth and production. Among these factors is foliar feeding, which plays a fundamental role in enhancing vegetative characteristics by providing the nutritional elements necessary for the synthesis of primary and secondary metabolites, as they have an interconnected role in achieving optimal vegetative development. A deficiency in these elements causes deterioration in plant growth and may damage plant [1].

To improve and increase productivity per unit area, both quantitatively and qualitatively, it is necessary to adopt modern scientific and practical methods, as well as implement agricultural practices that increase yield, including fertilization to compensate for nutrient deficiencies in soils. Excessive application of fertilizers can harm the environment and human health. One approach to reducing excessive fertilizer application is foliar feeding, which has proven successful because many soil nutrients, such as potassium, are unavailable due to precipitation, adsorption, oxidation, or formation of complex compounds that cannot be absorbed by the root system or are lost through leaching in sandy soils [2].

Iraqi soils are characterized by their calcareous nature and high calcium carbonate content. Consequently, the availability of nutrients, especially micronutrients, is low due to precipitation and adsorption processes on soil colloids. This reduces the uptake of these elements by roots. Foliar spraying of macro- and micronutrients is thus considered an ideal approach to overcome the limitations of calcareous soils and to increase fertilizer use efficiency compared to soil application [3].

Cauliflower (*Brassica oleracea* var. *botrytis*), a member of the Cruciferae family, is a winter crop that requires moderate to cool temperatures. Its native range includes regions bordering the Mediterranean basin, particularly Cyprus. The edible part, known as the curd, consists of immature flower buds and thickened flower stalks, containing approximately 91.7% water, 25 calories, 4.9% carbohydrates, 2.4% proteins, and 72 mg phosphorus per 100 g fresh weight [4].

Cauliflower is biennial, producing the curd in the first season and flowers and seeds in the second. Foliar application of macronutrients offers a faster and more effective response than soil fertilization but often requires repeated applications to meet plant needs. Foliar fertilization effectively corrects tissue deficiencies in the vegetative organs, and optimal concentrations of certain elements in foliar sprays can enhance the uptake of other nutrients, particularly potassium [5].

Foliar feeding provides faster results than soil application, especially in saline, calcareous, or alkaline soils [6–8]. Moreover, it causes less environmental pollution compared to fertilizers applied to the soil [9].

Potassium is the only monovalent cation (K^+) required by all plants, although it is not part of any organic molecule. Uptake of this element is an active process, as it accumulates in plant tissues against a concentration gradient relative to the external environment. The potassium requirement varies with species, cultivar, growth stage, and the desired quality of harvested organs. Potassium is critical for numerous plant functions, including the activation of growth- and development-related enzymes, nutrient transport from roots to shoots, and translocation of metabolites from source tissues to sink organs. It also regulates stomatal movement, improving water use efficiency, and strengthens cell walls, thereby enhancing tolerance to both biotic stress (pests and diseases) and abiotic stresses (salinity, drought, heat) when balanced with other nutrients [10].

Potassium's role in stomatal regulation is mediated by its presence as a free ion in guard cells, influencing osmotic changes through sugar accumulation. Increased sugar levels in guard cells promote water influx, leading to stomatal opening, whereas reduced sugar accumulation increases abscisic acid levels, causing water efflux and stomatal closure [11].

In a study on kohlrabi (*Brassica oleracea* var. *gongylodes*), two biofertilizer levels, three seaweed extract concentrations, and three potassium sulfate concentrations (0, 2, 4 g L^{-1}) were tested. Spraying with 4 g L^{-1} potassium sulfate significantly increased plant height (85.78 cm), while 2 g L^{-1} yielded the highest leaf number (15.48 leaves $plant^{-1}$) and leaf area (4109 cm^2 $plant^{-1}$) compared with controls. Biozyme, a plant growth stimulant used in foliar sprays, contains essential nutrients (Mg 0.14%, S 0.44%, B 0.30%, Fe 0.49%, Mn 0.12%, Zn) as well as very low levels of auxins, gibberellins, and cytokinins—specifically gibberellins (GA) at 32.2 ppm, auxins (IAA) at 32.2 ppm, and cytokinins (CK) at 83.2 ppm [12].

Plant biostimulants are organic compounds, excluding nutrients and vitamins, that are effective at very low concentrations and stimulate key physiological processes required for plant growth and development. These include auxins, gibberellins, and cytokinin's. Auxins act in concert with other hormones to stimulate cell division, elongation, and expansion, partly by activating cell wall–modifying enzymes. Gibberellins promote cell elongation and division, while cytokinin's delay senescence and stimulate cell division [13].

Al-Subaihi [14] found that spraying zucchini with 0.5 mL L^{-1} Biozyme three times during the 2018 spring and fall growing seasons increased vegetative growth and yield. This treatment recorded the highest plant height (43.17 and 46.92 cm), leaf number (25.33 and 36.17 leaves $plant^{-1}$), and leaf area (25.02 and 29.23 dm^2 $plant^{-1}$), as well as the highest fruit number (11.53 and 10.97 fruits $plant^{-1}$), fruit weight (120.21 and 116.31 g $fruit^{-1}$), and yield per plant (1.399 and 1.261 kg $plant^{-1}$).

MATERIAL AND METHODS

The field experiment was conducted during the autumn season of 2021 at the Scientific Research Station (A) of the College of Agricultural Engineering Sciences, University of Baghdad (Al-Jadriya Complex). Perpendicular tillage was performed to improve and level the soil. The land was divided into nine rows, each spaced 75 cm apart, with 40 cm between plants. The experimental unit area was 3 m^2, containing 10 plants.

Prior to planting, soil samples were collected from nine locations at a depth of 0–30 cm. These samples were mixed, and a composite sample was analyzed to determine the chemical and physical properties of the soil.

A drip irrigation system was installed for seedling establishment. Hybrid cauliflower (*Brassica oleracea* var. *botrytis*, cv. 'Solid Snow') seeds—characterized by excellent green coverage, gray-green wrinkled leaves, and a large, bright white curd—were obtained from Seminis (USA) and sown on August 15, 2021, in seedling trays (209 cells). Seedlings with four true leaves were transplanted to the field on October 4, 2021.

The drip irrigation system was used throughout the growing season. Seedlings were planted on one side of the drip lines. A fungicide was applied immediately after planting, and manual weeding was carried out as needed.

The experiment was laid out as a factorial arrangement in a randomized complete block design (RCBD) with three replications, comprising two factors (4 × 3), for a total of 12 treatment combinations and 36 experimental units. Data were analyzed using Genstat software, and treatment means were compared using the LSD test at $p \leq 0.05$ [15].

Experimental factors

Factor 1: Foliar application of potassium sulfate (44% K) at four concentrations:

- K_0: Control (no application)
- K_1: 3,500 mg potassium sulfate L^{-1}
- K_2: 5,000 mg potassium sulfate L^{-1}
- K_3: 6,500 mg potassium sulfate L^{-1}

Spray schedule:

- 1st spray: 20 days after transplanting (October 24, 2021)
- 2nd spray: November 8, 2021
- 3rd spray: November 23, 2021
- 4th spray: December 8, 2021

  Sprays were applied in the early morning until complete wetting of the foliage.

Factor 2: Foliar application of Biozyme plant growth stimulant at three concentrations:

- B_0: Control (no application)
- B_1: 0.45 mL L^{-1}
- B_2: 0.70 mL L^{-1} (manufacturer's recommendation: 0.45–0.70 mL L^{-1})

Spray schedule:

- 1st spray: 45 days after transplanting, upon completion of vegetative growth (November 18, 2021)
- 2nd spray: Three weeks later (December 9, 2021)

RESULTS

Measured attributes		Value	Unit of measure
$EC_{1:1}$		2.5	dsm.m^{-1}
pH		7.7	--------
Soil content of elements	Nitrogen	35.7	mg.kg $soil^{-1}$
	Phosphorus	10.0	
	Potassium	205.8	
O.M		7.5	g. kg^{-1}
Solubleions	Ca^{+2}	90	M Eq. L^{-1}
	Mg^{+2}	43	mEq. L^{-1}
	Cl^{-}	70.0	mEq. L^{-1}
	SO_4^{-2}	110.0	mEq. L^{-1}
Caly		392	mg. kg $soil^{-1}$
Silt		902	mg. kg $soil^{-1}$
Sand		318	mg kg $soil^{-1}$
Tissue class		Alluvial clay mixture	----------

Table 1. Chemical and physical properties of the experimental field soil before planting (autumn season 2021).

a b

Figure 1. ***A.*** **Cauliflower (*Brassica oleracea* var. *botrytis*, cv. Solid Snow) seedlings 25 days after transplanting, showing uniform growth.** ***B.*** **Cauliflower plants at the end of the season, ready for harvest.**

Treatments	Concentration
K_0B_0	Spray with distilled water only.
K_0B_1	Spraying biozyme at a concentration of 0.45 ml.L^{-1}
K_0B_2	Spraying biozyme at a concentration of 0.70 ml.L^{-1}
K_1B_0	Spraying potassium sulfate at a concentration of 3500 mg. L^{-1}
K_1B_1	3500 mg. L^{-1} + 0.45 ml Biozyme. L^{-1}
K_1B_2	Spraying potassium sulfate at a concentration of 3500 mg. L^{-1} + spraying Biozyme at a concentration of 0.70 ml.L^{-1}
K_2B_0	Spraying potassium sulfate at a concentration of 5000 mg. L^{-1}
K_2B_1	Spraying potassium sulfate at a concentration of 5000 mg. L^{-1} + Spraying biozyme at a concentration of 0.45 ml.L^{-1}
K_2B_2	Spraying potassium sulfate at a concentration of 5000 mg. L^{-1} + spraying Biozyme at a concentration of 0.70 ml.L^{-1}
K_3B_0	Spraying potassium sulfate at a concentration of 6500 mg. L^{-1}
K_3B_1	Spraying potassium sulfate at a concentration of 6500 mg. L^{-1} + spraying Biozyme at a concentration of 0.45 ml.L^{-1}
K_3B_2	Spraying potassium sulfate at a concentration of 6500 mg. L^{-1} + spraying Biozyme at a concentration of 0.70 ml.L^{-1}

Table 2. Experimental treatments: combinations of potassium sulfate (K) and Biozyme (B) levels applied via foliar spray.

Vegetative growth indicators:

- Plant height (cm):

Plant height was measured from the soil surface to the growing tip of the plant using a tape measure for five plants randomly selected for each experimental unit after all coefficients were completed.

- Total number of leaves of the plant:

The number of leaves was counted for five plants randomly selected for each experimental unit.

- Leaf area ($cm^2/plant^{-1}$):

The leaf area was measured using the Digimizer program. Three leaves of different sizes were taken randomly from five plants and photographed using a scanner. A colored line was used as an indicator for a known length of (10 cm).

Then the program determined the boundaries of the plant part, provided that it did not touch the boundaries of the leaf on which it was attached. The total area of the specified part was calculated, and the average was extracted to calculate the area of one leaf. The average number of leaves in one plant was calculated in each experimental unit. Then the leaf area was calculated according to the following equation: Leaf area of the plant (cm^2) = area of one leaf (cm^2) × number of leaves in one plant. "Leaf area was expressed in centimeter squared per (cm^2 $plant^{-1}$), where "$plant^{-1}$" refers to per individual plant."

- Dry weight of the green group (grams):

Three plant leaves were taken from each experimental unit and the vegetative group was separated from the root. Then the vegetative group was cut to facilitate the process of placing it in paper bags. The samples were placed in an electric oven at a temperature of (65-70°C) for (72) hours until the weight was stable. Their weight was recorded and the dry weight of the vegetative group of one plant was calculated[17].

Yield indicators:

- Diameter of the disc flower (cm):

The circumference of the disc flower was measured for all experimental units of (6) disc flowers using a measuring tape, and the diameter of the disc flower was extracted by dividing the circumference by the value of the constant ratio (Pi "π").

- Weight of the disc flower (kg):

The weight of the disc flower was calculated by taking the weights of the disc flowers of all plants in the experimental unit and taking the average.

- **Total yield of disc flowers ($tons/ha^{-1}$):** According to the total yield for all crops through the following equation: Total yield ($tons/ha^{-1}$)

$$= \frac{The\ experimental\ unit\ yield\ of\ discs\ flower\ 2m\ x\ 10000}{Experimental\ unit\ area} \quad (1)$$

Table (3) indicates the superiority of the potassium sulfate (K_3) spray coefficientin the vegetative growth characteristics of the cauliflower plant, represented by the plant height (69.14 cm), the total number of leaves (28.08 leaves per $plant^{-1}$), the leaf area (8535.4 cm^2 per $plant^{-1}$), and the dry weight of the vegetative group (286.9 g), compared with the standard treatment (K_0), which gave the lowest values.

This is attributed to the fact that potassium has an effective role in the main physiological processes, such as the representation and transport of manufactured materials, through its role in the production of ATP. It also helps in the absorption and representation of nitrogen[7] and stimulates the plant to absorb gas (CO_2) through the stomata in the leaves.

Thus, the production of (ATP), which is important in filling the sieve tubes with the products of photosynthesis, also contributes to the conversion of light energy into chemical energy in the form of NADPH). (ATP) It is important in all vital processes in plant cells, such as the synthesis of proteins, carbohydrates, and fats[19]. It also plays an important role in cell division, and is therefore found in abundance in buds, leaves, roots, and newly growing cells, and in smaller quantities in older parts [20].

The results of Table (3) also showed that the treatment of spraying with the plant growth stimulant Biozyme (B_2) was superior in increasing the vegetative growth specifications represented by plant height (69.81 cm), number of leaves (28.08 leaves plant^{-1}), leaf area (8272.5 cm^2/plant^{-1}) and dry weight of the vegetative group (287.5 g) compared with the standard treatment (B_0) which gave the lowest values.

This is attributed to its containing nutrients (Mg, S, B, Fe, Mn, Zn) and the importance of these nutrients necessary for the growth and development of plants and carrying out important vital processes, as well as its containing auxins, gibberellins and cytokinins in very low concentrations that affect the increase in cell division and increase plant growth, which increases the absorption of nutrients from the soil.

Treatment	Plant height (cm)	No. of leaves (leaf. plant^{-1})	Leaf area (dcm^2 plant^{-1})	Dry weight of shoots (gm)
K_0	64.83	24.63	7336.6	242.2
K_1	66.70	26.05	8010.6	259.2
K_2	68.41	28.06	8518.3	279.9
K_3	69.14	28.08	8535.4	286.9
LSD	**1.223**	**0.557**	**47.92**	**6.59**
B_0	63.89	24.92	7626.2	243.2
B_1	68.11	27.12	8202.0	270.4
B_2	69.81	28.08	8272.5	287.5
LSD	**1.059**	**0.482**	**41.50**	**5.71**
$K_0 B_0$	60.27	22.68	6867.0	216.3
$K_0 B_1$	65.82	25.12	7415.0	245.5
$K_0 B_2$	68.41	26.11	7728.0	264.8
$K_1 B_0$	64.08	24.53	7646.0	242.8
$K_1 B_1$	67.19	26.34	8072.0	258.9
$K_1 B_2$	68.85	27.28	8314.0	276.1
$K_2 B_0$	65.23	25.90	7990.0	247.8
$K_2 B_1$	69.17	28.44	8618.0	285.6
$K_2 B_2$	70.84	29.86	8947.0	306.4
$K_3 B_0$	65.98	26.59	8002.0	266.2
$K_3 B_1$	70.27	28.58	8703.3	291.7
$K_3 B_2$	71.16	29.07	8901.0	302.8
LSD	**2.118**	**0.965**	**83.00**	**11.41**

Table 3. Effect of foliar application of potassium sulfate and Biozyme, and their interaction, on vegetative growth characteristics of cauliflower. Values are expressed as means ± standard error. Different letters within the same column indicate significant differences according to LSD test ($p \leq 0.05$).

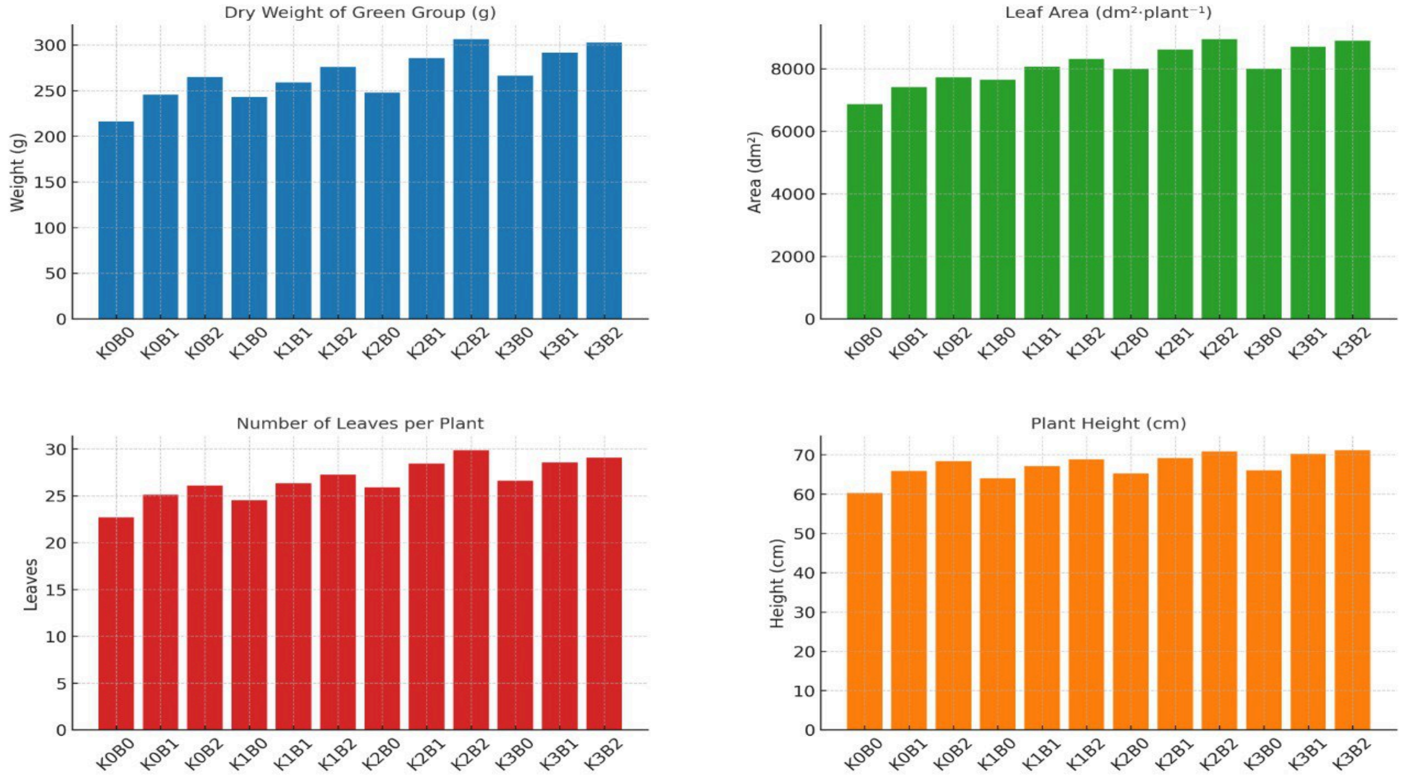

Figure 2. The interaction between potassium and Biozyme levels significantly influenced features such as leaf area, dry weight, and the number of leaves. The K_3B_2 treatment (highest potassium level combined with Biozyme) showed the highest values across all traits, indicating a synergistic effect between the two variables. Figure 1 demonstrates this trend, with key parameters increasing as both potassium and Biozyme levels rise.

Table (4) indicates the superiority of the potassium sulfate spraying coefficients (K_2) and (K_3) in the characteristics of the cauliflower plant yield in the diameter of the disc flower (21.52 cm), the weight of the flower disc (1.495 kg), and the total production of discs flower (49.83 tons/ha^{-1}) compared with the standard coefficient(K_0), which gave the lowest values.

This is because potassium plays a role in transporting nutrients from the roots to the upper parts of the plant and transporting metabolic products from the manufacturing sites to the places of need and storage. It has a role in the process of water absorption by opening and closing the stomata, thereby increasing the efficiency of water use.

It also affects directly or indirectly the activation of many enzymes important to the plant, especially those related to energy and nitrogen metabolism, including those involved in the manufacture of proteins, oxidation and reduction enzymes, and reductase, oxidase, and energy transfer enzymes.

Kinase and dehydrogenases, as well as potassium treatments had a positive effect on improving vegetative growth such as plant height, number of leaves, leaf area and dry weight of the vegetative group, which led to the strength of the plant and encouraged it to transfer manufactured materials to the floral discs, which indicates the importance of potassium and its effect on improving vegetative growth and yield, and these results agreed with [21, 22].

The results of Table (4) also showed that the coefficientof spraying with the growth stimulant Biozyme was superior in the yield characteristics of the disc flower diameter (21.89 cm), disc flower weight (1.511 kg) and the total yield of discs flower (50.39 tons/ha^{-1}) compared with the standard coefficient(B_0) which gave the lowest values.

Treatment	Head diameter (cm)	Head weight (kg.ha^{-1})	Total yield (ton ha^{-1})
K_0	19.35	1.328	**44.28**
K_1	20.59	1.436	**47.88**
K_2	21.43	1.495	**49.83**
K_3	21.52	1.493	**49.74**
LSD	**0.268**	**0.027**	**0.925**
B_0	19.32	1.340	**44.66**
B_1	20.97	1.462	**48.75**
B_2	21.89	1.511	**50.39**
LSD	**0.232**	**0.023**	**0.801**
K_0 B_0	18.49	1.218	**40.60**
K_0 B_1	19.10	1.351	**45.03**
K_0 B_2	20.48	1.417	**47.23**
K_1 B_0	19.04	1.342	**44.73**
K_1 B_1	21.15	1.465	**48.84**
K_1 B_2	21.58	1.502	**50.07**
K_2 B_0	19.65	1.390	**46.33**
K_2 B_1	21.74	1.510	**50.33**
K_2 B_2	22.92	1.585	**52.84**
K_3 B_0	20.10	1.412	**47.01**
K_3 B_1	21.89	1.524	**50.80**
K_3 B_2	22.57	1.543	**51.43**
LSD	**0.464**	**0.047**	**1.602**

Table 4. Effect of foliar application of potassium sulfate and Biozyme, and their interaction, on cauliflower yield traits: head diameter, head weight, and total yield. Values are expressed as means ± standard error. Different letters within the same column indicate significant differences according to LSD test ($p \leq 0.05$).

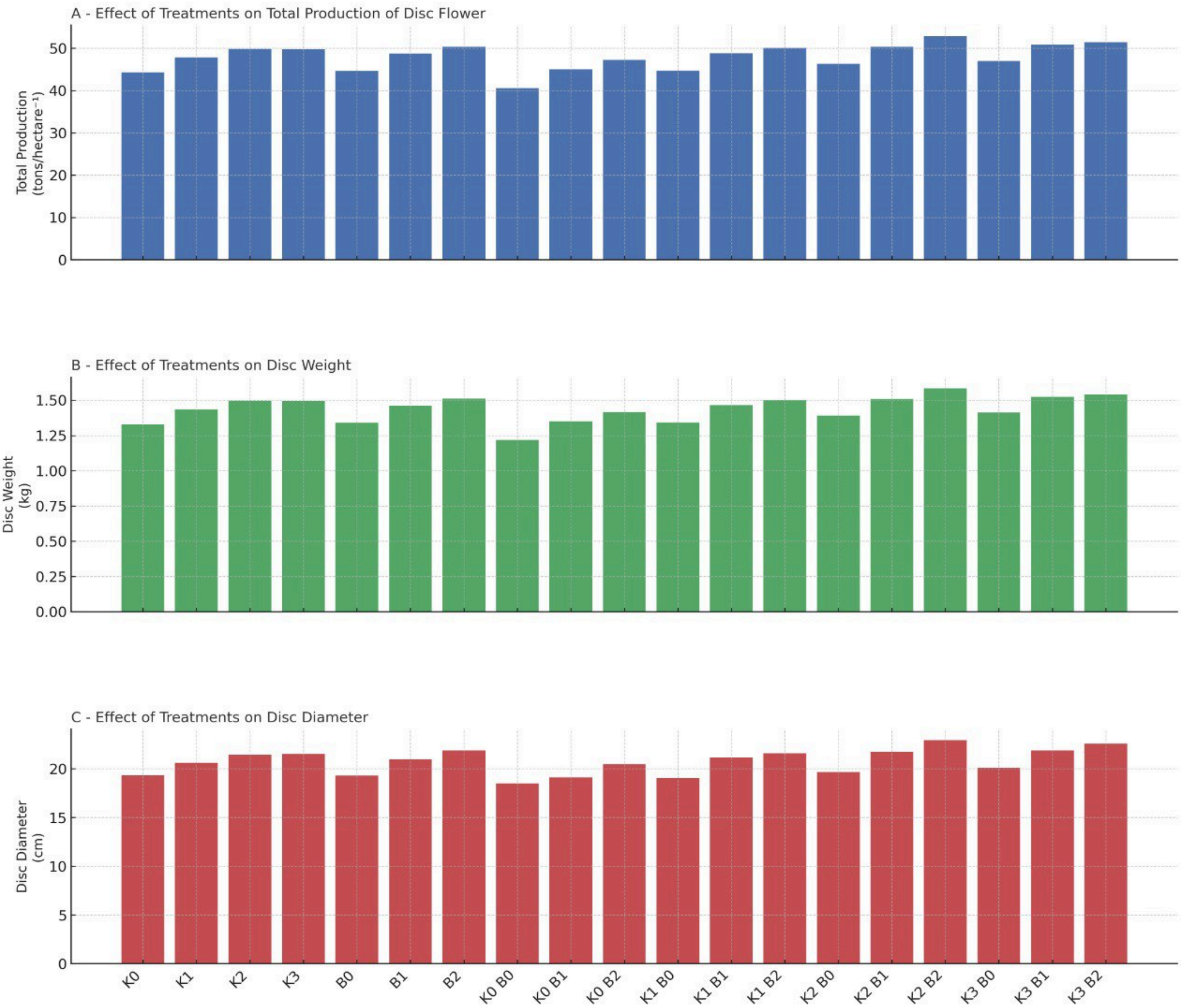

Figure 3. Effect of foliar application of potassium sulfate and Biozyme on total cauliflower yield, head weight, and head diameter. The K2B2 and K3B2 combinations achieved the highest values for all evaluated traits.

DISCUSSION

The results obtained in this study clearly demonstrate that foliar application of potassium sulfate and Biozyme significantly influenced vegetative growth parameters and yield traits of cauliflower (*Brassica oleracea* var. *botrytis*, cv. Solid Snow) grown under calcareous soil conditions in Iraq.

Effect of Potassium Sulfate on Vegetative Growth and Yield

Potassium sulfate application produced a marked improvement in plant height, number of leaves, leaf area, and shoot dry weight compared with the untreated control. The highest values for plant height (69.14 cm), number of leaves (28.08 leaves·plant^{-1}), leaf area (8535.4 cm^2·plant^{-1}), and shoot dry weight (286.9 g) were achieved at 6500 mg·L^{-1} (K_3). These findings are consistent with previous reports indicating that potassium plays a central role in essential physiological processes, including osmotic regulation, stomatal function, and nutrient translocation [1,2,8,10,19,20]. Potassium enhances ATP synthesis, which drives energy-dependent processes such as phloem loading, protein and carbohydrate biosynthesis, and the transport of photoassimilates from source leaves to sink organs [2,8].

With respect to yield traits, foliar potassium sulfate at 5000 mg·L^{-1} (K_2) recorded the highest head weight (1.495 kg) and total yield (49.83 t·ha^{-1}), while K_3 achieved the largest head diameter (21.52 cm). This agrees with studies in *Brassica* crops, where adequate potassium supply improved curd size, uniformity, and marketable yield by optimizing water use efficiency and enhancing carbohydrate partitioning to the inflorescence [1,9,10,16,21,22].

Effect of Biozyme on Vegetative Growth and Yield

Application of Biozyme at 0.70 mL·L^{-1} (B_2) significantly increased all vegetative and yield parameters relative to the untreated control. In this study, B_2 achieved the highest plant height (69.81 cm), number of leaves (28.08), leaf area (8272.5 cm^2), shoot dry weight (287.5 g), head diameter (21.89 cm), head weight (1.511 kg), and total yield (50.39 t·ha^{-1}). Similar results have been reported for seaweed-based biostimulants containing auxins, gibberellins, cytokinins, and micronutrients, which enhance chlorophyll content, stimulate cell division, and improve nutrient uptake [4,12–14].

Biozyme's micronutrient content (Mg, S, B, Fe, Mn, Zn) likely corrected latent deficiencies typical of calcareous soils, while its hormonal constituents may have promoted faster canopy development and more efficient resource allocation to the curd. These results corroborate findings in other vegetable species, where biostimulants improved vegetative vigor, reproductive development, and final yield [4,12,13,15].

Synergistic Interaction Between Potassium Sulfate and Biozyme

The interaction between potassium sulfate and Biozyme was significant for most measured parameters. The combination of 5000 mg·L^{-1} potassium sulfate with 0.70 mL·L^{-1} Biozyme (K_2B_2) produced the highest head diameter (22.92 cm), head weight (1.585 kg), and total yield (52.84 t·ha^{-1}). This combination also increased leaf area (8947 cm^2·plant^{-1}) and shoot dry weight (306.4 g).

Such synergy can be explained by the complementary roles of potassium and biostimulants: potassium optimizes water and nutrient transport and supports carbohydrate translocation, while Biozyme enhances cell division, photosynthetic activity, and sink strength in the curd [4,12,13,22]. These results align with studies in *Brassica* crops such as Brussels sprouts, where integrated potassium and organic biostimulant treatments maximized productivity and resource use efficiency [5,12,13,22].

Agronomic and Practical Implications

From an agronomic perspective, the K_2B_2 combination appears more efficient than applying the highest potassium rate alone, as it achieved superior yield performance while potentially reducing fertilizer costs and environmental risks. This is particularly relevant for cauliflower cultivation in calcareous soils, where foliar feeding bypasses root uptake limitations and ensures direct nutrient assimilation by the leaves [1,2,4,12].

Given the global push for sustainable agriculture, combining moderate potassium doses with biostimulants aligns with integrated nutrient management strategies that aim to maximize yield, maintain soil health, and reduce input waste [2,4,12,16].

Limitations and Future Perspectives

This study was conducted in a single location and season, which may limit its generalizability. Climatic variations, soil types, and irrigation practices could influence treatment performance. Future research should include multi-location and multi-season trials to validate these results, as well as studies evaluating the impact of these treatments on curd nutritional composition, postharvest shelf life, and resistance to abiotic stresses. Additionally, economic analyses comparing cost–benefit ratios between different treatment combinations would further support adoption by farmers.

CONCLUSIONS

Foliar application of potassium sulfate and Biozyme had a significant positive effect on the vegetative growth and yield of cauliflower (*Brassica oleracea* var. *botrytis*, cv. Solid Snow) under the conditions of calcareous soils in Iraq.

Potassium sulfate applied at 5000–6500 mg L^{-1} increased plant height, leaf area, and biomass, while Biozyme at 0.70 mL L^{-1} enhanced both growth and yield parameters. The combination of 5000 mg L^{-1} potassium sulfate with 0.70 mL L^{-1} Biozyme (K2B2) produced the highest head diameter, head weight, and total yield, demonstrating a synergistic effect between mineral nutrition and biostimulant application.

From an agronomic perspective, the K2B2 combination offers an optimal balance between yield improvement and input efficiency, making it a practical recommendation for cauliflower production in calcareous soils. Further multi-location and multi-season studies are recommended to confirm these results and to assess the impact of these treatments on curd quality and postharvest performance.

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Conflicts of Interest: The author reports no Conflicts of interest.

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