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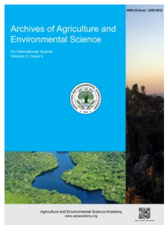

ORIGINAL RESEARCH ARTICLE

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Effect of boron and molybdenum on growth and yield attributes of cauliflower (*Brassica oleraceae* Var. Botrytis L) at Salyan, Nepal

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ABSTRACT

A research study was conducted to investigate the impact of varying levels of boron and molybdenum on the growth and yield parameters of the Silvercup-60 variety of cauliflower in the fields of Luham, Salyan during the winter season of 2022. The experiment comprised seven treatments arranged in a Randomized Complete Block Design (RCBD) with three replications. Each replication included seven treatments denoted as follows: T1 (Control), T2 (Borax @10 kg/ha), T3 (Ammonium Molybdate @1 kg/ha), T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha), T5 (Borax @10 kg + Ammonium Molybdate @2 kg/ha), T6 (Borax @20 kg/ha + Ammonium Molybdate @1 kg/ha), and T7 (Borax @20 kg/ha + Ammonium Molybdate @2 kg/ha), representing different doses of boron and molybdenum. Various growth parameters, including plant height, number of leaves, leaf length, and leaf width, were recorded at intervals of 15, 30, 45, and 55 days post-transplanting, along with yield parameters such as curd diameter and curd yield. Notably, treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha) exhibited significantly superior curd diameter (19.03 cm) and yield (16.41 mt/ha) compared to the control group, while the control group yielded the lowest values for these parameters. Based on the findings of this study, it can be concluded that the application of boron and molybdenum at a rate of 10 kg/ha of Borax and 1 kg/ha of Ammonium Molybdenum is recommended for cauliflower cultivation in the Salyan district, as it leads to enhanced growth and yield of cauliflower crops.

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INTRODUCTION

Cauliflower (*Brassica oleraceae* var. botrytis L.) holds significant economic importance as a winter vegetable within the Brassicaceae family. Originating primarily along the Mediterranean Sea coast, it has historically been recognized as a staple crop within Europe before its widespread dissemination across the globe (Lal, 1993). The cauliflower plant is primarily valued for its edible curd, which develops from a shoot system characterized by short internodes, branching structures, apices, and bracts. In Nepal, cauliflower cultivation thrives both seasonally and off-seasonally, offering substantial potential for exportation. It is the most important vegetable crop that occupies a significant portion of agricultural land, encompassing an area of 33,685 hectares, with a total production volume of 528,738 metric tons and a productivity of 14.94 metric tons per hectare accounting for 11.98% of the total area under vegetable cultivation. The productivity rate is 14.94 metric tons per hectare (MoALD, 2022). Salyan district located within the mid-hill region experiences a diverse range of tropical to temperate climates, rendering it conducive to cauliflower cultivation year-round across three distinct seasons. Consequently, the district has garnered recognition for its proficiency in off-season cauliflower production (Singh & Bhandari, 2015). In Salyan district cauliflower is cultivated across an area of 173 hectares, and exhibiting a productivity of 11.22 metric tons per hectare.

Cauliflower exhibits a notable responsiveness to macronutrients such as nitrogen, phosphorus, and potassium, crucial for its growth and yield. However, the significance of micronutrients, including boron, molybdenum, and magnesium, should not be overlooked, as they play pivotal roles in ensuring the healthy development and productivity of cauliflower (Fujimoto, 1998; Jaishy *et al*., 2000). Suboptimal nutrient management stands out as a primary factor contributing to diminished yields in cauliflower production, particularly concerning micronutrient deficiencies. Despite balanced applications of nitrogen, phosphorus, and potassium (NPK), insufficient attention to micronutrient supplementation hampers optimal cauliflower growth and yield in various regions worldwide. In Nepal, soil deficiencies, notably in boron (B), zinc (Zn), and molybdenum (Mo), pose significant challenges to crop production (Anderson, 2007). Boron deficiency, pervasive in Nepalese agricultural soils, affects approximately 80 to 90% of soil compositions, highlighting its ubiquitous nature (Anderson, 2007). Boron, despite its requirement in relatively small quantities for plant growth, exhibits a narrow threshold between deficient and toxic levels, thus necessitating precise management (Brdar-Jokanović, 2020). The depletion of boron from soils occurs primarily through leaching into lower layers and crop uptake, leading to a progressive diminution of the nutrient reserve over successive seasons (Satya *et al*., 2009). Cauliflower stands out as particularly sensitive to molybdenum deficiency, with symptoms such as whiptail deformation and inhibited head development observed in affected plants (Sharma, 2002). Molybdenum facilitates the utilization of soil-absorbed nitrates by plants, thereby impacting vegetative growth and yield potential (Ranjan *et al*., 2020). Studies have demonstrated the beneficial effects of foliar applications of boron and molybdenum in enhancing cauliflower yield and vegetative growth (Ranjan *et al*., 2020).

In the agricultural landscape of Salyan district, Nepal, diminishing soil fertility presents a significant challenge for small-holder farmers. Additionally, inadequate knowledge among farmers regarding the optimal micronutrient application further exacerbates issues related to deficiency or toxicity symptoms in cauliflower (Sillanpaa, 1982). Numerous studies have investigated the boron and molybdenum needs of cauliflower in different global regions, yet there is limited data available regarding their requirements in Nepalese soil conditions. Furthermore, there is a lack of research on how boron and molybdenum affect cauliflower production specifically in the Salyan district. Thus, this study aimed to evaluate the impacts of varying doses of boron and molybdenum on the quality and yield characteristics of cauliflower in the Salyan district of Nepal.

MATERIALS AND METHODS

Location of the experimental site

The experiment was conducted within the agricultural field of Triveni Rural Municipality, situated in Salyan, Nepal, from March to June 2022. The site is located at 28.29°N latitude and 82.26°E and an elevation of 1009 meters above sea level. The region experiences a warm temperate climate, characterized by an average annual precipitation of 1165 mm, with the majority, around 80%, occurring during the monsoon season from June to August. The soil in this area is identified as silty loam in texture, with a pH level measured at 6.1. The soil exhibited 5.4% organic matter content, 0.27% total nitrogen (N), 99 kg/ha of available phosphorous (P), 168 kg/ha of exchangeable potassium (K), and 0.591 ppm of boron (B).

Plant material, design, and treatments of the experiment

For this experiment, Silver-Cup-60 hybrid variety of cauliflower was used which has been officially approved by the National Seed Board of Nepal. The study was structured according to a Randomized Complete Block Design (RCBD), encompassing seven distinct treatments that involved different combinations of Borax and Ammonium Molybdate. Each treatment was replicated three times, with plots consisting of seven units measuring 2m × 2m and accommodating 25 plants each. The distance between replications was maintained at one meter, while the separation between treatments was set at 50 cm. A planting density of 25 plants per plot was established, with individual plants spaced 45 cm apart within rows and between rows. The seven treatments were designated as follows: T1 = Control, T2 = Borax @ 10 kg/ha, T3 = Ammonium Molybdate @ 1 kg/ha, T4 = Borax @ 10 kg/ha + Ammonium Molybdate @ 1 kg/ha, T5 = Borax @ 10 kg/ha + Ammonium Molybdate @ 2 kg/ha, T6 = Borax @ 20 kg/ha + Ammonium Molybdate @ 1 kg/ha, and T7 = Borax @ 20 kg/ha + Ammonium Molybdate @ 2 kg/ha.

Experimental procedures

Seedling raising: Preparation of the nursery bed (3 m × 1 m) involved thorough ploughing of the land and incorporation of well-decomposed Farm Yard Manure (FYM) at a rate of 40 tonnes per hectare into the soil. The hybrid variety Silvercup-60 was sown at a depth of approximately 2 cm, maintaining a line spacing of 5 cm. Regular watering was administered as necessary. Upon complete germination and seedling growth, the seedlings were transplanted to the main field.

Land preparation: The experimental field underwent deep ploughing, followed by planking and levelling to achieve optimal soil tilth. Beds measuring 2.0 m × 2.0 m were meticulously prepared, with corresponding paths and channels constructed as per the layout.

Fertilization and manuring: The recommended fertilizer regimen for the Silvercup-60 variety included Farm Yard Manure (FYM) at a rate of 40 tonnes per hectare, Urea at 200 kg/ha, Diammonium Phosphate (DAP) at 120 kg/ha, and Muriate of Potash (MOP) at 100 kg/ha. The full dose of phosphorus and potash, along with half the dose of nitrogen, was applied as a basal application. Simultaneously, treatments involving boron (B) and molybdenum (Mo) were applied to the soil. The remaining half dose of nitrogen was applied 30 days after transplanting.

Transplanting and gap-filling: Prior to uprooting the seedlings for transplanting, the nursery beds received thorough irrigation. Healthy and uniform seedlings aged 28 days, with 3-4 true leaves, were transplanted during the last week of March 2022, at a spacing of 45 cm between rows and plants. Immediately post-transplanting, a light irrigation was provided using a watering can. One week later, damaged or deceased seedlings were replaced with healthy ones to maintain the desired plot population.

Intercultural operations: Initial irrigation was administered immediately after seedling transplantation, followed by subsequent irrigations at intervals of approximately 10-12 days, contingent upon soil conditions. Optimal moisture levels were meticulously maintained throughout growth and curd development. Intercultural activities, including irrigation, weeding, and fertilization, were conducted to promote robust growth and development of cauliflower seedlings. Manual weeding was performed 20 days post-transplanting, with a subsequent weeding session occurring 45 days post-transplanting. The remaining nitrogen dose was top-dressed at 45 days post-transplanting, followed by earthening up.

Plant protection measures: To mitigate cabbage butterfly, hopper, and aphid infestations, prophylactic measures were adopted, involving the application of Emamectin Benzoate 5% SG (KingstarTN) and Chlorpyriphos 50% + Cypermethrin 5% EC (Ghatak 505TN) at 15-day intervals, commencing 20 days post-transplanting until one week before crop maturity.

Data collection: Five randomly selected plants, accounting for potential border effects, were chosen from each plot of 25 plants (excluding border rows and plants) for parameter measurement. Data were recorded for growth parameters including Plant Height (cm), Number of Leaves per Plant, Length of Leaves per Plant (cm), Width of Leaves per Plant (cm), and yield parameters such as Curd Diameter (cm), Curd Weight with Leaves (kg), Yield per Plot (kg), Yield per Hectare (mt), and economic aspects including Cost of Cultivation, Gross Return, Net Return, and Benefit Cost Ratio.

Statistical analysis: Data obtained were organized using Microsoft Excel, and Analysis of Variance (ANOVA) was conducted utilizing the 'F' variance ratio test to assess the significance of boron application on cauliflower production. Mean values, Standard Deviation, and Coefficient of Variation for all treatments were calculated. Post-hoc analysis was performed using Duncan's Multiple Range Test (DMRT) to interpret probability levels. The R-STUDIO software was employed to compute the Coefficient of Variation, Grand Mean, and Standard Error of Mean.

RESULTS AND DISCUSSION

Growth parameters

Plant height: Significant increases in plant height were observed across all stages of observation with varying levels ($P < 0.05$) of boron and molybdenum. The treatment T4 (Borax 10 kg/ha + Ammonium Molybdate 1 kg/ha) exhibited the highest average maximum plant height (32.05 cm), while the control treatment showed the lowest (26.69 cm). Notably, all treatment combinations of boron and molybdenum outperformed the control regarding plant height. This response is likely attributed to the supplemental boron application. Similar outcomes have been reported in previous studies involving various crops such as sunflower (Ahmadvand *et al.*, 2012), rice (Farooq *et al.*, 2006), maize (Patel *et al.*, 2017), and wheat (Singh *et al.*, 2017). Consistent with Sharma (2002), it is suggested that the increased plant height and leaf count may be attributed to molybdenum's promotion of vegetative growth and subsequent enhancement of photosynthetic activities. However, according to Muthoo *et al.* (1987), the heightened vegetative growth may be induced by physiological processes influenced by factors affecting the plant's metabolism and growth.

Number of leaves per plant: The number of leaves per plant exhibited significant increases with different treatments of boron and molybdenum across all observation stages. The control treatment displayed the fewest leaves per plant (15.89), while treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha) recorded the highest (18.52). The correlation between increasing boron dosage and leaf number is corroborated by Kamal *et al.* (2013), indicating that boron significantly boosts leaf count in cauliflower. Enhanced nutrient uptake, photosynthesis, and heightened metabolic activity in plants due to boron may account for the observed increase in leaf number (Poudel *et al.*, 2022). Moreover, boron as a micronutrient has been shown to effectively increase leaf number in cauliflower (Moklikar *et al.*, 2018). The minimum number of leaves observed in the control treatment (15.89) could be attributed to boron and molybdenum deficiencies, which may lead to the demise of growing points by impairing active salt absorption and water relations in plants.

Leaf length per plant: Treatment effects on mean leaf length per plant were evident across all observation stages. The highest leaf length per plant (22.49 cm) was recorded under treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha), while the control treatment exhibited the lowest leaf length per plant (19.195 cm). The majority of other treatments demonstrated comparable results. Choudhary & Mukharjee (1999) suggested that the enhanced growth qualities associated with boron application may be attributed to its specific functions, including excess cation precipitation, buffer action, and maintenance of conducting tissues, thus supporting these findings.

Leaf width per plant: Treatment-wise analysis of leaf width per plant revealed significant variations, with treatment T4 (Borax @ 10 kg/ha + Ammonium Molybdate @ 1 kg/ha) recording the highest leaf width per plant (19.03 cm). In contrast, the control treatment exhibited the lowest (16.46 cm). The role of

Table 1. Growth characteristics of cauliflower influenced by boron and molybdenum treatments.

Treatment	Plant height (cm)				No of leaves/plant				Length of leaves (cm)				Width of leaves (cm)			
	15 DAT	30 DAT	45 DAT	55 DAT	15 DAT	30 DAT	45 DAT	55 DAT	15 DAT	30 DAT	45 DAT	55 DAT	15 DAT	30 DAT	45 DAT	55 DAT
T1	13.40	23.56	31.62	38.32	6.72	13.33	19.34	24.18	6.40	15.10	25.11	30.01	4.00	15.05	20.20	26.66
T2	15.80	24.32	34.00	43.60	7.81	13.69	22.60	25.73	8.15	16.87	27.31	32.01	5.90	17.08	22.06	28.65
T3	15.51	24.57	34.91	45.33	7.17	13.62	21.29	25.21	8.37	17.07	26.39	31.46	4.91	16.01	21.04	27.57
T4	17.20	24.96	37.8	48.26	8.27	14.46	23.86	27.50	9.80	18.05	28.97	33.14	6.50	17.77	22.77	29.25
T5	16.6	24.67	34.82	42.51	7.83	14.28	23.66	26.29	8.58	17.28	27.1	31.33	4.89	15.93	21.01	27.35
T6	15.8	24.56	35.24	45.83	7.71	13.82	23.28	26.07	7.54	16.44	27.21	30.79	4.20	15.25	20.40	26.76
T7	16.80	24.66	36.61	46.13	7.72	13.64	23.78	26.91	8.44	17.14	26.29	31.09	5.67	15.05	21.86	28.33
LSD(0.05)	1.15	0.68	1.12	1.53	0.18	0.23	0.28	0.31	0.79	1.29	1.13	2.09	0.34	1.11	1.30	1.31
Sem (±)	0.374	0.07	0.366	0.497	0.049	0.028	0.075	0.082	0.25	0.368	0.37	0.68	0.11	0.09	0.42	0.68
C.V %	4.11	1.56	1.81	1.94	1.39	0.95	0.71	0.74	5.4	3.78	2.37	3.74	3.74	3.78	3.42	2.64
Grand Mean	15.772	24.47	34.99	44.25	7.60	13.83	22.54	23.48	8.18	16.85	26.91	31.04	5.15	16.25	21.33	27.79

molybdenum in atmospheric nitrogen fixation processes, enhancing plants' nitrogen fixation capability and facilitating the conversion of nitrates to ammonia and amino acids within plant cells, may contribute to these findings. These results align with previous studies by Prasad and Yadav (2003), Kumar (2004), Kumar (2005), and Mahmud *et al*. (2005).

Yield parameters

Diameter of curd: Significant influence of different boron and molybdenum treatments on average curd diameter was observed across various days after transplantation. Treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha) exhibited the highest curd diameter (19.03 cm), followed by treatment Borax @20 kg/ha + Ammonium Molybdate @2kg/ha (17.51 cm), while the control treatment showed the lowest (15.13 cm). The notable increase in curd diameter (18.03 cm) associated with boron application may be attributed to its specific functions, including excess cation precipitation, buffer action, and maintenance of conducting tissues, aiding in nitrogen absorption and playing a crucial role in vegetative and reproductive phases, thus influencing curd yield. The application of boron and molybdenum has been reported to enhance cauliflower curd diameter (Kumar and Chaudhary, 2002), possibly due to increased carbohydrate synthesis and translocation to the curd, resulting in larger cauliflower curds.

Curd weight with leaves: The assessment of curd weight with leaves was conducted across all treatments, revealing significant influences attributable to the applied treatments. Treatment Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha exhibited the highest curd weight with leaves (0.656 kg), followed by treatment T7 (Borax @20 kg/ha + Ammonium Molybdate @2 kg/ha) with a recorded weight of 0.530 kg. Notably, boron and molybdenum exerted discernible effects on curd weight. The highest curd weight (0.656 kg) was obtained from treatment T4, followed by treatments T7 and T6, while the control treatment yielded the lowest curd weight (0.354 kg). The observed increase in curd weight can be attributed to the application of optimal boron and molybdenum levels under deficient conditions, which facilitated enhanced uptake of major nutrients, thereby augmenting plant photosynthesis and improving curd size, production, and quality of cauliflower. Singh (2003) noted that foliar application of boron and molybdenum led to an increase in cauliflower curd weight. These findings corroborate those reported by Sharma *et al*. (1988) and Singh *et al.* (2002).

Yield per plot: The yield per plot exhibited significant variation due to the application of different treatments involving boron and molybdenum. Notably, treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha) demonstrated superiority in yield per plot (6.56 kg) compared to other treatments, while the control treatment yielded the lowest (3.54 kg). Additionally, treatment T7, comprising Borax @20 kg/ha and Ammonium Molybdate @2 kg/ha, exhibited a significant influence with a

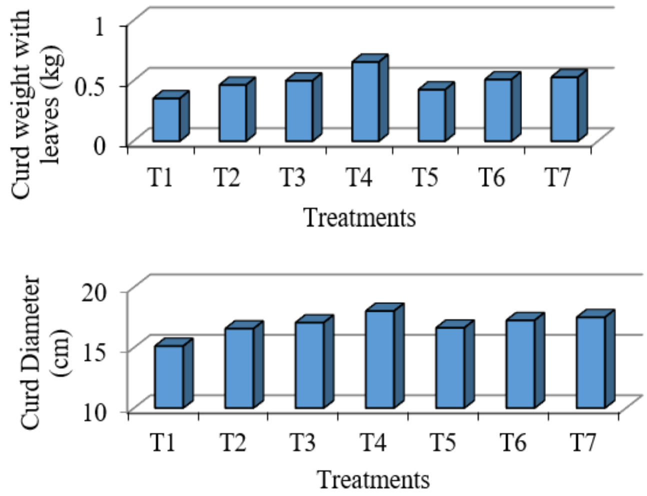

Figure 1. *Effect of different treatments on curd diameter and curd weight with leaves of cauliflower.*

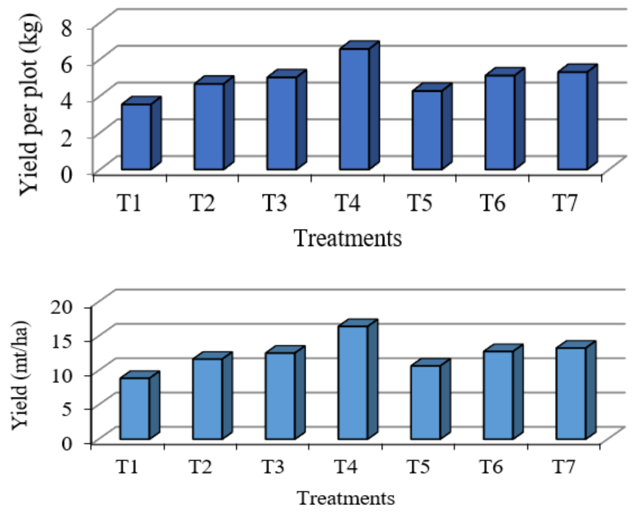

Figure 2. *Effect of different treatments on yield per plot and yield per hectare of cauliflower.*

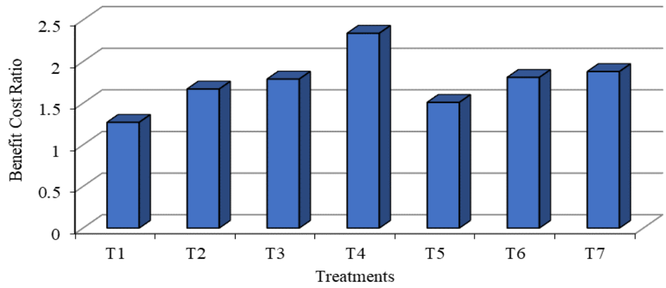

Figure 3. *Effect of different treatments on the benefit-cost ratio of cauliflower.*

yield per plot of 5.30 kg, followed by treatment T6 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha), statistically on par with treatment T3, yielding 5.01 kg per plot. The observed enhancement in curd yield could be attributed to the favourable effects of molybdenum on vegetative growth, leading to increased photosynthesis activities. Furthermore, boron application enhanced water metabolism, water relations, carbohydrate metabolism, and nitrogen metabolism in plants, potentially contributing to improved curd yield. The increase in curd yield with increasing boron dose may be attributed to its role in nutrient uptake, metabolism, and transport of essential biomolecules in plants. These findings align with previous studies by Sharma (2002), Kumar and Choudhary (2002), and Chattopadhyay and Mukhopadayay (2003).

Yield per hectare: The yield per hectare also varied significantly among different treatments. Treatment T4 (Borax @10 kg/ha + Ammonium Molybdate @1 kg/ha) yielded the highest per hectare (16.41 mt/ha), followed by treatment T7 (Borax @20 kg/ha + Ammonium Molybdate @2 kg/ha) with 13.27 mt/ha. Conversely, the control treatment exhibited the lowest yield per hectare (8.87 mt/ha). Treatment T6 (Borax 20 kg/ha + Ammonium Molybdate @1 kg/ha) also recorded a relatively higher yield (12.77 mt/ha). The variation in curd yield can be attributed to the impact of boron and molybdenum fertilizers. Molybdenum stimulates photosynthesis and metabolism, while boron enhances carbohydrate translocation from leaves to reproductive tissues in curd. The lowest curd yield was observed in the control treatment, possibly due to retarded plant growth resulting from low boron concentrations. Conversely, foliar application of boron, molybdenum, and other micronutrients significantly increased cauliflower yield and quality, consistent with previous studies. This finding resonates with research by Islam et al. (2015), demonstrating the significant effect of boron dosage on broccoli curd yield. Lower yields under control treatment may be attributed to impaired plant growth and development due to inadequate boron concentrations, impacting enzymatic and non -enzymatic oxidation processes.

Economics: It is revealed from the data obtained that treatment borax 10Kg/ha + Ammonium Molybdate 1 Kg/ha recorded the maximum crud yield of 16.41 mt/ha in the cauliflower variety "Silvercup-60". The net profit was Rs. 234.57 /ha and cost: benefit ratio of 2.34 was found under the same treatment as a soil application, followed by treatment 7 i.e., Borax @10kg/ha + Ammonium Molybdate @2 kg/ha gave 13.27 mt /ha yield with the net return of Rs. 154.9/ha with cost-benefit ratio 1.88. While lowest curd yield (8.87 mt/ha) and net profit of Rs. 46.85 along with a B: C ratio of 1.27 was recorded in treatment control. As the treatment, T4 (Borax @ 10 kg/ha + Ammonium Molybdate @ 1 kg/ha) possessed superior growth and yield character the treatment was economically superior. Similar findings were reported by (Ningawale *et al*., 2016).

Conclusion

From the data and findings obtained, it can be concluded that soil application of Borax at a rate of 10 kg/ha and Ammonium Molybdate at 1 kg/ha resulted in the highest curd yield compared to other treatments and the control group. Furthermore, this treatment exhibited the highest benefit-to-cost ratio, indicating its economic viability. However, given that this research was conducted under specific climatic and topographic conditions, it is imperative to extend similar studies to diverse climates, topographies, and soil textures over a longer duration to derive more robust conclusions. Additionally, future research should explore a wider range of cauliflower varieties to ascertain the generalizability of the findings.

Authors contribution

Conceptualization: NC, KK and SS; Methodology: NC and KK.; Software and validation: NC, KK, and BA.; Formal analysis and investigation: KK and NC.; Resources: BA.; Data curation: KK and SS; Writing—original draft preparation: KK, NC and BA.; Writing- review and editing: KK and NC.; Visualization: BA.; Supervision: NC.; Project administration: KK and BA.; Funding acquisition: NC.; All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

Ethical approval: Not applicable.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

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