**Original Research Article**

**Effect of foliar applications of micronutrients on the yield characteristics of cauliflower (*Brassica oleracea* var. *botrytis* L.)**

**ABSTRACT**

Cauliflower, a member of the Brassicaceae family, is an important vegetable crop with specific cultivation requirements (Campanelli & Canali, 2012). Cauliflower is a heavy feeder crop, balanced fertilization is very important for better productivity. Due to the intensive cultivation and judicious use of only nitrogenous fertilizers, soils are become deficit in secondary and micronutrients (Ali *et al*., 2008). Keeping in view above facts an experiment was carried out over two consecutive winter seasons, 2018-19 and 2019-20, at the Agricultural Research farm (25018' North latitude and 83003' E) of Banaras Hindu University, Varanasi. The aim was to assess the impact of foliar micronutrient application on the yield attributes of cauliflower. The study involved sixteen foliar micronutrient treatments. These treatments were: T1 (Control), T2 (Ammonium Molybdate (Mo) @ 0.20%), T3 (Ammonium Molybdate (Mo) @ 0.30%), T4 (Ammonium Molybdate (Mo) @ 0.40%), T5 (Boron @ 0.060%), T6 (Boron @ 0.080%), T7 (Boron @ 0.100%), T8 (Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.060%), T9 (Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.080%), T10 (Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.10%), T11 (Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.060%), T12 (Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.080%), T13 (Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.10%), T14 (Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.060%), T15 (Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.080%), and T16 (Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.100%). These were replicated three times using a Randomized Block Design. A recommended basal dose of nitrogen, phosphorus, and potassium (160:80:120 kg ha-1) was applied using urea, SSP, and MOP, respectively, in both years. Nitrogen was applied 50% as a basal dose and the rest at 40 days after transplanting (DAT). The total rainfall during the crop growth period was 29.4 mm in 2018-19 and 93.9 mm in 2019-20. The Snowball-16 variety of cauliflower was used as the test crop. Chelated zinc at a concentration of 0.5 g l-1 was applied to all treatments, while boron and molybdenum were applied according to the specific treatment. Other crop management practices were followed as per local recommendations. The data showed that the time taken for 50% curd initiation and 50% curd maturity was shorter, while the curd volume (577.33 cm3) and curd diameter (18.33 cm) in cauliflower were significantly larger when Ammonium Molybdate at 0.40% was applied along with boron at 0.10% (T16). This outcome was statistically comparable to the application of Ammonium Molybdate at 0.30% with boron at 0.10% (T13) and Ammonium Molybdate at 0.20% with boron at 0.10% (T10), surpassing other treatments in both individual years and in the combined analysis.

***Keywords:*** *cauliflower, micronutrients, Ammonium Molybdate, yield*

**1. INTRODUCTION:**

Vegetables are abundant in vital minerals and vitamins essential for the efficient operation of human metabolic activities, which is why they are regarded as 'protective supplementary food.' Growing vegetables is a lucrative business, particularly on small and marginal lands, owing to its high yield within a short timeframe. As a source of agricultural income, it plays a significant role in agricultural progress and national economy. There is a considerable demand for vegetables for both fresh consumption and processed goods within the country as well as for exports, which can bring in valuable foreign exchange for India. India is the second largest vegetable producer in the world after China, with a diverse range of crops cultivated nationwide. According to estimates, India produces 184.39 million tonnes of vegetables from 10.25 million hectares (Horticultural Statistics at a Glance, 2018). This represents about 13.38 percent of the global vegetable production, yet productivity is still low compared to that in developed countries. As a result, current production does not meet national requirements despite the potential for increased yield per unit area. There is also significant potential for exporting and processing vegetables. India is the leading producer of cauliflower globally (Thamburaj and Singh, 2001), with commercial cultivation spanning approximately 452.6 lakh hectares, producing 86.68 lakh tonnes annually, and a productivity rate of 19.2 MT ha-1 (Horticultural Glance, 2018). The main cauliflower-producing states in India are West Bengal, Bihar, Orissa, Uttar Pradesh, Assam, Haryana, Maharashtra, and Rajasthan. Uttar Pradesh alone has a cauliflower cultivation area of 17.53 thousand hectares, producing 400.81 thousand tons annually, contributing approximately 4.65 percent of the national cauliflower output (Horticultural Statistics at a Glance, 2018).

Cauliflower requires a significant amount of nutrients, which makes balanced fertilization essential for achieving optimal yields. However, the practice of intensive agriculture and the predominant use of nitrogen-based fertilizers have resulted in soils lacking secondary nutrients and micronutrients (Ali *et al*., 2008). Although needed in small quantities, micronutrients are as vital as macronutrients and play a crucial role in regulating plant growth and yield (Hall *et al*., 2002). Among the various micronutrients, Boron, Molybdenum, Iron, Copper, Chlorine, Zinc, and Manganese, Boron and Molybdenum are particularly noteworthy because of their availability in soil, mobility within plants and soil, and reliance on soil pH (Kumar *et al*., 2012). Micronutrients improve the chemical composition of curds and overall health of plants (Hall *et al*., 2002). They enhance seed germination and macronutrient uptake, production, and quality by boosting photosynthetic efficiency and increasing leaf metabolite content (Chaudhari *et al*., 2017). Furthermore, they help reduce the incidence of diseases, pests, and disorders, while improving the postharvest quality of crops (Hemphill *et al*., 1982). Deficiency of these essential nutrients can significantly reduce crop yield and affect various physiological, morphological, and biochemical characteristics of cole crops during growth. Recently, it has been acknowledged that foliar spraying of micronutrients such as Zn, B, and Mo is advantageous for enhancing the yield, quality, and shelf life of cauliflowers (Kotecha *et al*., 2011). Foliar application is regarded as an effective and straightforward method to provide plants with the necessary nutrients at adequate concentrations (Alloway, 2008). Correcting micronutrient deficiencies via foliar application is effective because it allows for easy absorption through the leaves, leading to a profitable yield (Asad *et al*., 2003). Cauliflower plants often show deficiencies in boron and Mo, which appear as browning of the curd and whiptail formation in leaves, respectively. These problems render curds unsuitable for consumption and significantly reduce yield (Bhupenchandra et al., 2020). The addition of boron has been shown to significantly improves the diameter, weight, yield, and quality of cauliflower curds (Kumar *et al*., 2002). However, before applying boron fertilizer, it is essential to confirm a suspected deficiency through soil and plant analyses, as excess boron can be extremely harmful to plants. Nevertheless, information on the micronutrients for cauliflower cultivation in Uttar Pradesh is limited. Considering the aforementioned facts regarding adequate information and research in this area, this study was conducted to examine the impact of foliar micronutrient application on the yield characteristics of cauliflower.

**2. MATERIALS AND METHODS**

The research was carried out over two winter seasons, 2018-19 and 2019-20, at the Vegetable Research Farm (South Block) of the Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, situated in Varanasi, Uttar Pradesh (25010’ N latitude and 83003’ E longitude, with an altitude of 128.93 meters above sea level). The soil at this location was sandy clay loam, with a pH of 7.36, an electrical conductivity of 0.28 dSm-1, organic carbon content of 0.42%, available boron at 0.31 mg kg-1, available zinc at 0.57 mg kg-1, and available molybdenum at 0.26 ppm. The study utilized a randomized block design with three replications, examining sixteen different micronutrient treatments: (T1) control, (T2) Ammonium Molybdate (Mo) at 0.20%, (T3) Ammonium Molybdate (Mo) at 0.30%, (T4) Ammonium Molybdate (Mo) at 0.40%, (T5) Boron at 0.060%, (T6) Boron at 0.080%, (T7) Boron at 0.10%, (T8) Ammonium Molybdate (Mo) at 0.20% + Boron at 0.060%, (T9) Ammonium Molybdate (Mo) at 0.20% + Boron at 0.080%, (T10) Ammonium Molybdate (Mo) at 0.20% + Boron at 0.10%, (T11) Ammonium Molybdate (Mo) at 0.30% + Boron at 0.060%, (T12) Ammonium Molybdate (Mo) at 0.30% + Boron at 0.080%, (T13) Ammonium Molybdate (Mo) at 0.30% + Boron at 0.10%, (T14) Ammonium Molybdate (Mo) at 0.40% + Boron at 0.060%, (T15) Ammonium Molybdate (Mo) at 0.40% + Boron at 0.080%, and (T16) Ammonium Molybdate (Mo) at 0.40% + Boron at 0.10%. Furthermore, a consistent application of Zn (0.5 g l-1) was given to all treatments involving the Snowball-16 cauliflower variety. The crop was transplanted into the main field on November 14th, 2018, and November 16th, 2019. Foliar sprays were administered 20, 30, and 40 days after transplantation.

**2.1 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA**

The experimental data gathered for different parameters were examined using Fisher's analysis of variance (ANOVA), in accordance with the guidelines established by Gomez and Gomez (1984). The significance level for both the 'F' and 't' tests was set at p = 0.05. Critical difference values were calculated when the F-test showed statistical significance.

**3. RESULTS:**

**3.1 DAYS TO 50% CURD INITIATION**

Table 1 displays the average data regarding the impact of different treatments on the number of days required for 50% curd initiation. The findings indicated that the foliar application of micronutrients significantly influenced the days to reach 50% curd initiation. For cauliflower, fewer days to 50% curd initiation are preferred. The number of days to 50% curd initiation showed significant statistical variation across different treatments, ranging from 63.57 to 74.58 days in the first year, 62.24 to 73.11 days in the second year, and 62.91 to 73.85 days in the pooled mean data. The shortest duration to 50% curd initiation, specifically 63.57 days (2018-19), 62.24 days (2019-20), and 62.91 days (pooled mean), was achieved with the application of (T16) Ammonium Molybdate at 0.40% + Boron at 0.100%, which was statistically comparable to (T13) Ammonium Molybdate at 0.30% + Boron at 0.100% and (T10) Ammonium Molybdate at 0.20% + Boron at 0.100% compared to the other treatments. Conversely, the longest duration to 50% curd initiation was recorded with the control treatment in both years and in the pooled mean data.

**3.2 DAYS TO 50% CURD MATURITY**

Data on the number of days required for 50% curd maturity was collected and the average results are shown in Table 1. For cauliflower, fewer days to reach 50% curd maturity is preferred. The analysis of variance indicated that the days to 50% curd maturity were significantly affected by the foliar application of different micronutrients over both years and on a pooled mean basis. The performance data and analysis of variance demonstrated that the days to reach 50% curd maturity varied significantly, ranging from 73.92 to 84.93 days in the first year, 72.59 to 83.46 days in the second year, and 73.25 to 84.19 days in the pooled mean data. The shortest time to 50% curd maturity, specifically 73.92 days in the first year, 72.59 days in the second year, and 73.25 days in the pooled mean, was achieved with the application of (T16) Ammonium Molybdate @ 0.40% + Boron @ 0.100%, which was statistically similar to (T13) Ammonium Molybdate @ 0.30% + Boron @ 0.100% and (T10) Ammonium Molybdate @ 0.20% + Boron @ 0.100% compared to other treatments. Conversely, the longest time to 50% curd maturity, 84.93 days (year 2018-19), 83.46 days (year 2019-20), and 84.19 days (pooled mean), was observed under the control treatment during both years of the study.

**Table 1:** Days to 50 percent curd initiation and 50 percent curd maturity of cauliflower as influenced by foliar application of micro nutrients

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Days to 50% curd initiation** | | | **Days to 50% curd maturity** | | |
| **2018-19** | **2019-20** | **Pooled** | **2018-19** | **2019-20** | Pooled |
| T1: Control | 74.58 | 73.11 | 73.85 | 84.93 | 83.46 | 84.19 |
| T2: Ammonium Molybdate (Mo) @ 0.20% | 70.46 | 69.45 | 69.96 | 80.81 | 79.80 | 80.30 |
| T3: Ammonium Molybdate (Mo) @ 0.30% | 70.12 | 69.06 | 69.59 | 80.47 | 79.41 | 79.94 |
| T4: Ammonium Molybdate (Mo) @ 0.40% | 69.87 | 68.59 | 69.23 | 80.22 | 78.94 | 79.58 |
| T5: Boron @ 0.060% | 71.59 | 70.41 | 71.00 | 81.94 | 80.76 | 81.35 |
| T6: Boron @ 0.080% | 71.12 | 69.97 | 70.55 | 81.47 | 80.32 | 80.89 |
| T7: Boron @ 0.100% | 70.84 | 69.71 | 70.28 | 81.19 | 80.06 | 80.62 |
| T8: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.060% | 69.45 | 68.37 | 68.91 | 79.80 | 78.72 | 79.26 |
| T9: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.080% | 68.12 | 66.89 | 67.51 | 78.47 | 77.24 | 77.85 |
| T10: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.100% | 66.42 | 64.18 | 65.30 | 76.77 | 74.53 | 75.65 |
| T11: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.060% | 68.79 | 67.51 | 68.15 | 79.14 | 77.86 | 78.50 |
| T12: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.080% | 67.96 | 66.45 | 67.21 | 78.31 | 76.80 | 77.55 |
| T13: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.100% | 64.47 | 63.36 | 63.92 | 74.82 | 73.71 | 74.26 |
| T14: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.060% | 68.49 | 67.34 | 67.92 | 78.84 | 77.69 | 78.26 |
| T15: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.080% | 67.12 | 66.14 | 66.63 | 77.47 | 76.49 | 76.98 |
| T16: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.100% | 63.57 | 62.24 | 62.91 | 73.92 | 72.59 | 73.25 |
| Sem ± | 1.04 | 1.01 | 1.03 | 1.08 | 1.04 | 1.05 |
| LSD (p=0.05) | 3.12 | 3.05 | 3.09 | 3.24 | 3.13 | 3.19 |

**3.3 CURD VOLUME (CM3)**

The volume of each curd was measured for each treatment, with the average values presented in Table. The analysis of variance reveals a significant impact on curd volume due to the foliar application of different micronutrients. The curd volume data showed statistically significant differences across treatments, ranging from 483.61 to 572.14 cm3 in the first year, 489.65 to 582.52 cm3 in the second year, and 486.63 to 577.33 cm3 in the pooled mean data. The highest curd volume, specifically 572.14 cm3 (2018-19), 582.52 cm3 (2019-20), and 577.33 cm3 (pooled mean), was achieved with the application of (T16) Ammonium Molybdate @ 0.40% + Boron @ 0.100%, which was statistically comparable to (T13) Ammonium Molybdate @ 0.30% + Boron @ 0.100% and (T10) Ammonium Molybdate @ 0.20% + Boron @ 0.100% compared to the other treatments. The smallest curd volume was recorded with the control treatment in both years and in the pooled mean data.

**Table 2:** Curd volume of cauliflower as influenced by foliar application of micro nutrients

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments | Curd volume (cm3) | | |
| 2018-19 | 2019-20 | Pooled |
| T1: Control | 483.61 | 489.65 | 486.63 |
| T2: Ammonium Molybdate (Mo) @ 0.20% | 508.74 | 509.52 | 509.13 |
| T3: Ammonium Molybdate (Mo) @ 0.30% | 510.74 | 511.51 | 511.13 |
| T4: Ammonium Molybdate (Mo) @ 0.40% | 511.11 | 512.71 | 511.91 |
| T5: Boron @ 0.060% | 502.35 | 503.24 | 502.80 |
| T6: Boron @ 0.080% | 504.64 | 505.54 | 505.09 |
| T7: Boron @ 0.100% | 506.35 | 508.11 | 507.23 |
| T8: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.060% | 511.95 | 514.62 | 513.29 |
| T9: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.080% | 520.34 | 521.65 | 521.00 |
| T10: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.100% | 535.45 | 541.64 | 538.55 |
| T11: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.060% | 513.24 | 515.71 | 514.48 |
| T12: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.080% | 524.74 | 526.55 | 525.65 |
| T13: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.100% | 556.54 | 564.12 | 560.33 |
| T14: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.060% | 516.55 | 518.74 | 517.65 |
| T15: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.080% | 529.65 | 535.41 | 532.53 |
| T16: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.100% | 572.14 | 582.52 | 577.33 |
| SEmz | 38.34 | 15.07 | 14.21 |
| LSD (p=0.05) | 41.36 | 45.23 | 42.67 |

**3.4 CURD DIAMETER (CM)**

Table 3 display the average data on cauliflower curd diameter as affected by various treatments. The data reveal significant differences in curd diameter among the treatments. During the first year, the diameter ranged from 13.03 to 18.24 cm, in the second year from 13.21 to 18.41 cm, and on a pooled basis, it ranged from 13.12 to 18.33 cm, all due to the foliar application of different micronutrients. The largest curd diameter (18.24 cm in 2018-19, 18.41 cm in 2019-20, and 18.33 cm on a pooled basis) was achieved with the application of (T16) Ammonium Molybdate at 0.40% combined with Boron at 0.100%. This result was comparable to the treatments (T13) Ammonium Molybdate at 0.30% + Boron at 0.100% and (T10) Ammonium Molybdate at 0.20% + Boron at 0.100% during both years of the study. Conversely, the smallest curd diameter was recorded in the control treatment.

**Table 3:** Curd diameter of cauliflower as influenced by foliar application of micro nutrients

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments | Curd diameter (cm) | | |
| 2018-19 | **2019-20** | Pooled |
| T1: Control | 13.03 | 13.21 | 13.12 |
| T2: Ammonium Molybdate (Mo) @ 0.20% | 15.55 | 15.73 | 15.64 |
| T3: Ammonium Molybdate (Mo) @ 0.30% | 15.71 | 15.94 | 15.83 |
| T4: Ammonium Molybdate (Mo) @ 0.40% | 15.85 | 16.04 | 15.95 |
| T5: Boron @ 0.060% | 14.67 | 14.89 | 14.78 |
| T6: Boron @ 0.080% | 14.86 | 15.09 | 14.98 |
| T7: Boron @ 0.100% | 15.19 | 15.41 | 15.30 |
| T8: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.060% | 15.97 | 16.16 | 16.07 |
| T9: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.080% | 16.56 | 16.75 | 16.66 |
| T10: Ammonium Molybdate (Mo) @ 0.20% + Boron @ 0.100% | 17.34 | 17.59 | 17.47 |
| T11: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.060% | 16.05 | 16.27 | 16.16 |
| T12: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.080% | 16.72 | 16.98 | 16.85 |
| T13: Ammonium Molybdate (Mo) @ 0.30% + Boron @ 0.100% | 17.89 | 18.05 | 17.97 |
| T14: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.060% | 16.23 | 16.49 | 16.36 |
| T15: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.080% | 17.02 | 17.11 | 17.07 |
| T16: Ammonium Molybdate (Mo) @ 0.40% + Boron @ 0.100% | 18.24 | 18.41 | 18.33 |
| SEmz | 0.39 | 0.41 | 0.40 |
| LSD (p=0.05) | 1.18 | 1.25 | 1.21 |

**4. DISCUSSION**

The research revealed that the shortest time for 50% curd initiation was achieved using (T16) Ammonium Molybdate at 0.40% in combination with boron at 0.100%. Micronutrients play essential roles in plant development and can enhance crop nutritional quality, yield, biomass production, and resilience to environmental stresses (Dimkpa & Bindraban, 2016). Targeted application of micronutrients, potentially in combination with other agronomic practices like mulching or growth regulators, can significantly improve curd initiation and development in cauliflower (Kumar et al., 2016). As the application levels of micronutrients increased, the time needed for curd initiation in plants decreased. This phenomenon is likely due to the positive role of these micronutrients in promoting balanced nutrient uptake, which enhances physiological functions and leads to the production of endogenous growth hormones that trigger early curd formation in plants (Thapa et al., 2021). These findings are consistent with those of Kumar and Choudhary (2002) and Verma (2009) on cauliflowers. The shortest duration for 50% curd maturity was recorded under the same treatment with Ammonium Molybdate and Boron. Boron is essential for improving the transport of carbohydrates from their production site to the reproductive tissues (Vera-Maldonado et al., 2024) in the cauliflower curd, whereas molybdenum enhances photosynthetic activities and metabolic processes (Huang et al., 2021). Similar significant responses to micronutrients have been documented by Singh (2003) and Chattopadhyay and Mukhopadhyay (2003) in cauliflowers. The combined effect of micronutrients increases curd diameter and weight by promoting physiological activities such as photosynthesis, during which the plant produces food, and the translocation of assimilates from leaves to the curd, where they are stored, with zinc being a contributing factor as noted by Lashkari *et al*. (2008). The notable curd development due to micronutrients (B and Mo) can be attributed to their positive interaction with enzymes and active involvement in physiological processes, such as cell formation and protein and carbohydrate metabolism in plants. These observations are consistent with the findings of Upadhyay *et al*. (2012) for cabbage. The increase in curd volume may be due to the enhanced compactness of the curd resulting from the beneficial effects of these micronutrients (B and Mo). This could also be a result of the translocation of carbohydrates from their synthesis site to the storage tissues in the curd, as boron is known to facilitate carbohydrate translocation (Sisler *et al*., 1956), ultimately leading to an increase in both the curd weight and volume. Similar outcomes were reported by Prasad and Yadav (2003).

**CONCLUSION**

Cauliflower is an important vegetable crop in India and particularly in Uttar Pradesh, and effective nutrient management is essential for its improved growth. The data showed that the time taken for 50% curd initiation and 50% curd maturity was shorter, while the curd volume (cm3) and curd diameter (cm) in cauliflower were significantly larger when Ammonium Molybdate at 0.40% was applied along with boron at 0.100% (T16). This outcome was statistically comparable to the application of Ammonium Molybdate at 0.30% with boron at 0.100% (T13) and Ammonium Molybdate at 0.20% with boron at 0.100% (T10), surpassing other treatments in both individual years and in the combined analysis. Thus, foliar application of the micronutrient Ammonium Molybdate at 0.40% and boron at 0.100% is beneficial for enhancing yield attributing characters of cauliflower in eastern Uttar Pradesh.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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