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# INFLUENCE OF BORON AND ZINC NUTRITION ON BIOCHEMICAL AND QUALITY ATTRIBUTES OF CAULIFLOWER (*Brassica oleracea* var. *botrytis* L.) CV. PUSA SNOWBALL K-1

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**ABSTRACT**

An experiment was conducted to study the response of cauliflower to foliar application of boron and zinc at different concentrations during the *Rabi* season of 2022–23. The experiment was laid out in a Randomized Block Design (RBD) with three replications and nine treatments. Zinc sulphate was applied as a foliar spray at concentrations of 0.3% and 0.5%, while boron was applied at 0.2% and 0.4% showed significant differences among biochemical and quality attributes of cauliflower. The experiment was conducted in plots measuring 1.80 m × 1.80 m, with a plant spacing of 45 cm × 45 cm. Foliar applications of boron and zinc were carried out at 30 to 45 days after transplanting (DAT). Among the different treatments, the combined application of boron @ 0.2% + zinc sulphate @ 0.5% ($T_7$) recorded the highest total sugar (4.10%), reducing sugar (0.89%), non-reducing sugar (3.21%) and ascorbic acid (vitamin C) content (67.17 mg/100g). The highest TSS (7.19 $^0$Brix) and TSS:acidity ratio (20.78) were recorded with boron @ 0.4% + zinc sulphate @ 0.5% ($T_9$). In contrast, the maximum titratable acidity (0.39%) was recorded in the control treatment ($T_1$). Overall, the findings demonstrated that foliar application of boron and zinc, particularly their combined application at appropriate concentrations, improved the biochemical composition and quality characteristics of cauliflower under sub-humid conditions.

***Key words :*** Boron, cauliflower, foliar application, quality parameters and zinc sulphate.

## Introduction

Cauliflower (*Brassica oleracea* var. *botrytis* L.), from the Latin *caulis* (stem) and *floris* (flower), is a member of the Cruciferae family and one of the most economically important cole crops. Its edible curd - a compact, prefloral apical meristem - is rich in protein, carbohydrates, vitamin C and minerals (Sitapara *et al.*, 2011). Among cultivars grown in India, Pusa Snowball K-1 is widely preferred for its compact curd, early maturity and broad adaptability.

As a heavy feeder, cauliflower requires not only N, P and K, but also micronutrients like boron and zinc, deficiencies of which are common and contribute to poor soil health and yield stagnation (Kumar *et al.*, 2023). Boron is critical for cell division, cell wall elongation, pollen formation and sugar translocation from leaves to curd, directly influencing TSS content (Thakur *et al.*, 2019). Zinc supports enzyme activity, chlorophyll synthesis and protein metabolism and enhances ascorbic acid and sugar content (Ahmed *et al.*, 2024; Bhat *et al.*, 2018). Foliar application of both nutrients is a simple, efficient way to correct deficiencies and improve yield and quality (Alloway, 2008; Kotecha *et al.*, 2011).

Studies on cauliflower cv. Pusa Snowball K-1 show that combined boron and zinc application produces greater curd weight and quality than either nutrient alone (Kumar *et al.*, 2023; Thakur *et al.*, 2019), a synergy also seen in other Brassica and horticultural crops (Safdar *et al.*, 2023 and Agha *et al.*, 2026).

However, research specifically focused on the **biochemical** effects of boron and zinc -ascorbic acid, TSS, sugars, protein and chlorophyll - on Pusa Snowball K-1 remains limited, with most studies emphasizing yield alone. This study was therefore undertaken to evaluate the influence of boron and zinc nutrition on the biochemical attributes of cauliflower cv. Pusa Snowball K-1, to identify the best combination for improved curd quality and productivity

## Materials and Methods

### Experimental site

The experiment entitled "Influence of Boron and Zinc Nutrition on Biochemical and Quality Attributes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)" was conducted during the *Rabi* season of 2022–23 at Horticulture Research Farm-I, Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India. The soil of the experimental field was sandy loam in texture. The experimental site was located at 26°50′ N latitude and 80°52′ E longitude, at an elevation of approximately 111 m above mean sea level (MSL). The climate of Lucknow is characterized as humid subtropical, with an average annual rainfall of approximately 750–1100 mm and relative humidity generally ranging from 60 to 90%. These agro-climatic and edaphic conditions provided a suitable environment for evaluating the effects of boron and zinc nutrition on the biochemical characteristics of cauliflower. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The research comprised nine treatments, including a control, to evaluate the individual and combined effects of boron and zinc on the biochemical and quality attributes of cauliflower. The treatments were designated as follows, $T_1$ – Control; $T_2$ – Boron @ 0.2%; $T_3$ – Boron @ 0.4%; $T_4$ – Zinc @ 0.3%; $T_5$ – Zinc @ 0.5%; $T_6$ – Boron @ 0.2% + Zinc @ 0.3%; $T_7$ – Boron @ 0.2% + Zinc @ 0.5%; $T_8$ – Boron @ 0.4% + Zinc @ 0.3% and $T_9$ – Boron @ 0.4% + Zinc @ 0.5%.

### Plant Material and Nursery Raising

Seeds of cauliflower cv. Pusa Snowball K-1 (*Brassica oleracea* var. *botrytis* L.) were procured from the Indian Agricultural Research Institute (IARI), New Delhi. Seedlings were raised on well-prepared raised beds measuring 1.80 × 1.80 × 0.15 m (L × B × H). The upper 5 cm layer of the nursery beds was thoroughly mixed with an equal quantity of well-decomposed farmyard manure (FYM) and sieved soil to provide a suitable medium for seedling establishment.

Seeds were sown in October 2022. Light and regular irrigation was provided using a rose can, and weeds were removed periodically to maintain a clean nursery. Necessary plant protection measures, including two pesticide applications as required, were adopted to ensure healthy seedling growth.

### Fertilizer application

The recommended dose of fertilizers - 160:80:120 kg N:$P_2O_5$ :$K_2O$ $ha^{-1}$ - was applied through urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. Nitrogen was applied in two equal splits: 50% as a basal dose and the remaining 50% at 40 days after transplanting (DAT) full dose of P and K was applied as basal dose.

### Transplanting

Healthy, vigorous seedlings measuring approximately 15–20 cm in height and possessing 3–4 fully developed true leaves were selected for transplanting. Seedlings were transplanted in the experimental field at a spacing of 45 × 45 cm. Sixteen healthy plants were tagged in each plot for recording observations on growth, yield, and biochemical characteristics.

### Foliar treatments

Foliar treatments comprising different concentrations of boron and zinc, applied either alone or in combination, were sprayed at 30 and 45 DAT. Boron was supplied in the form of boron, while zinc was applied as zinc sulphate ($ZnSO_{„}$ ).

### Quality parameters

### TSS (°Brix)

Curd samples were crushed and squeezed through muslin cloth to extract juice. Total soluble solids (TSS) were measured using a digital refractometer (Model HI 96801) and readings were expressed in °Brix.

### Ascorbic acid (mg/100 g)

Ascorbic acid content was determined by the 2,6-dichlorophenol indophenol dye titration method (Ranganna, 1986). A known sample weight was extracted in 3% metaphosphoric acid, filtered, and made up to a final volume of 100 ml. An aliquot of the extract was titrated against the dye to a pink end point. Ascorbic acid content was calculated using the dye factor and expressed as mg/100 g of curd.

### Acidity (%)

Titratable acidity was estimated by the acid-alkali titration method (A.O.A.C., 1970). Diluted juice was titrated against 0.1 N NaOH using phenolphthalein as an indicator until a pink end point was reached. Acidity was expressed as citric acid equivalent using the formula:

Acidity (%) = 0.128 × Titre value

**Total sugars (%)**

Total sugar content was estimated by the phenol-sulphuric acid method of Dubois *et al.* (1956), using a standard glucose curve and expressed as a percentage per 100 g of curd.

**Reducing sugars (%)**

Reducing sugar content was estimated using the dinitrosalicylic acid (DNS) method of Miller (1959), calculated against a standard curve, and expressed as a percentage per 100 g of curd.

**Non-reducing Sugars (%)**

Non-reducing sugar content was calculated as:

Non-reducing sugar (%) = (Total sugars – Reducing sugars) × 0.95

**Cultural practices**

All recommended cultural practices were followed uniformly throughout the experimental period to ensure proper crop growth and a reliable assessment of the effects of foliar-applied boron and zinc on cauliflower.

## Results

Quality parameters, including TSS, total sugars, reducing sugars, non-reducing sugars, ascorbic acid, titratable acidity and TSS: acidity ratio, were analyzed on a fresh-weight basis. Fresh cauliflower curds were evaluated for physicochemical and biochemical quality attributes. The results are presented in Table 1.

**TSS ($^0$Brix)**

The data presented in Table 1 and Fig. 1 revealed that foliar application of boron and zinc significantly influenced the TSS content of cauliflower. The highest TSS (7.19 °Brix) was recorded under $T_9$ (boron @ 0.4% + zinc @ 0.5%), followed by $T_8$ (boron @ 0.4% + zinc @ 0.3%) and $T_7$ (boron @ 0.2% + zinc @ 0.5%), which recorded 6.87 and 6.63 °Brix, respectively. The lowest TSS (5.63 °Brix) was observed in the control treatment. Overall, the combined application of boron and zinc resulted in a greater improvement in TSS than their individual application, indicating a positive interaction between these micronutrients in enhancing the soluble solids content of cauliflower curds.

**Total sugar (%)**

The data presented in Table 1 and Fig. 1 revealed that foliar application of boron and zinc significantly influenced the total sugar content of cauliflower curds. The highest total sugar content (4.10%) was recorded in $T_7$ (boron @ 0.2% + zinc @ 0.5%), followed by $T_9$ (boron @ 0.4% + zinc @ 0.5%) and $T_9$ (boron @ 0.4% + zinc @ 0.3%), which recorded 3.44 and 3.16%, respectively. The lowest total sugar content (1.76%) was observed in the control treatment. Overall, the combined application of boron and zinc significantly improved total sugar content compared with their individual application, demonstrating the beneficial effect of balanced micronutrient nutrition on the biochemical quality of cauliflower curd.

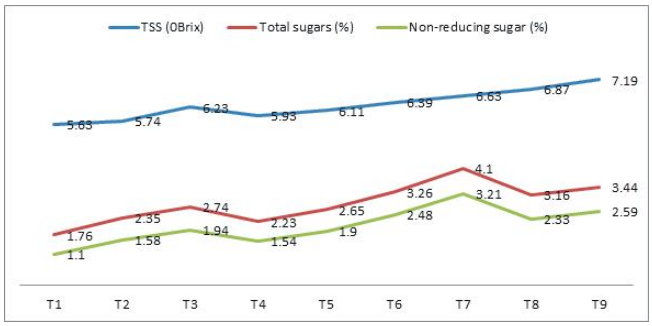



**Fig. 1 :** Effect of Foliar application of Boron and Zinc on Total, Reducing and non-Reducing Sugar content in Cauliflower curd.

**Reducing sugar (%)**

Foliar application of boron and zinc significantly influenced the reducing sugar content of cauliflower curds. The highest reducing sugar content (0.89%) was recorded in $T_7$ (Boron @ 0.2% + Zinc @ 0.5%), followed by 0.85% in $T_9$ (Zinc @ 0.4%) and $T_6$ (Boron @ 0.5%). In contrast, the lowest reducing sugar content was recorded in the control ($T_1$).

**Non-reducing Sugar (%)**

The data presented in Table 1 revealed that foliar application of boron and zinc significantly influenced the non-reducing sugar content of cauliflower curds. The highest non-reducing sugar content (3.05%) was recorded in $T_7$ (boron @ 0.2% + zinc @ 0.5%), followed by $T_9$ (boron @ 0.4% + zinc @ 0.5%) and $T_6$ (boron @ 0.2% + zinc @ 0.3%), which recorded 2.46 and 2.36%, respectively. Among the individual micronutrient treatments, $T_3$ (boron @ 0.4%) recorded 1.84%, followed by $T_5$ (zinc @ 0.5%) with 1.81%. The lowest non-reducing sugar content (1.05%) was recorded in the control ($T_1$).

**Ascorbic acid (mg 100 g$^{-1}$)**

The results presented in Table 1 indicated a significant influence of boron and zinc application on ascorbic acid content. The maximum ascorbic acid content (67.17 mg 100 g$^{-1}$) was recorded in $T_7$ (boron @ 0.2% + zinc @ 0.5%), followed by $T_9$ (66.61 mg 100 g$^{-1}$). The minimum content (62.53 mg 100 g$^{-1}$) was observed in the control ($T_1$).

**Table 1 :** Influence of Foliar Application of Boron and Zinc on Biochemical Sugar attributes of Cauliflower curd.

| Treatment | TSS ($^0$Brix) | Total sugars (%) | Reducing sugar (%) | Non-reducing sugar (%) | Ascorbic acid (mg/100g) | Acidity (%) | TSS: Acidity ratio |
|---|---|---|---|---|---|---|---|
| $T_1$ | 5.63 | 1.76 | 0.66 | 1.05 | 62.53 | 0.39 | 14.29 |
| $T_2$ | 5.74 | 2.35 | 0.77 | 1.50 | 63.66 | 0.39 | 14.68 |
| $T_3$ | 6.23 | 2.74 | 0.80 | 1.84 | 65.05 | 0.37 | 16.75 |
| $T_4$ | 5.93 | 2.23 | 0.69 | 1.46 | 64.26 | 0.38 | 15.44 |
| $T_5$ | 6.11 | 2.65 | 0.75 | 1.81 | 64.16 | 0.37 | 16.12 |
| $T_6$ | 6.39 | 3.26 | 0.78 | 2.36 | 65.35 | 0.37 | 17.13 |
| $T_7$ | 6.63 | 4.10 | 0.89 | 3.05 | 67.17 | 0.36 | 18.07 |
| $T_8$ | 6.87 | 3.16 | 0.83 | 2.21 | 65.94 | 0.35 | 19.35 |
| $T_9$ | 7.19 | 3.44 | 0.85 | 2.46 | 66.61 | 0.34 | 20.78 |
| **SEm (±)** | **0.052** | **0.034** | **0.009** | **0.038** | **0.689** | **0.004** | **0.190** |
| **C.D. (p=0.05)** | **0.156** | **0.103** | **0.026** | **0.116** | **2.082** | **0.011** | **0.574** |

**Note -** $T_1$ – Control; $T_2$ – Boron @ 0.2%; $T_3$ – Boron @ 0.4%; $T_4$ – Zinc @ 0.3%; $T_5$ – Zinc @ 0.5%; $T_6$ – Boron @ 0.2% + Zinc @ 0.3%; $T_7$ – Boron @ 0.2% + Zinc @ 0.5%; $T_8$ – Boron @ 0.4% + Zinc @ 0.3% and $T_9$ – Boron @ 0.4% + Zinc @ 0.5%.

**Titratable acidity (%)**

The titratable acidity of cauliflower curds was significantly influenced by foliar application of boron and zinc. The highest acidity (0.39%) was recorded in the control ($T_1$) and $T_2$ (boron @ 0.2%). This was followed by $T_4$ (zinc @ 0.3%), which recorded 0.38% acidity. The acidity decreased with combined application of boron and zinc, with the lowest acidity (0.34%) recorded in $T_9$ (boron @ 0.4% + zinc @ 0.5%), followed by $T_8$ (boron @ 0.4% + zinc @ 0.3%) with 0.35%.

**TSS: Acidity ratio**

The TSS:acidity ratio was significantly influenced by foliar application of boron and zinc. The highest ratio (20.78) was recorded in $T_9$ (boron @ 0.4% + zinc @ 0.5%), followed by $T_8$ (19.35), $T_7$ (18.07) and $T_6$ (17.13). The lowest TSS:Acidity ratio (14.29) was recorded in the control ($T_1$). These results indicate that combined application of boron and zinc improved the overall biochemical quality of cauliflower curd.

## Discussion

The results obtained for various biochemical and quality parameters were critically evaluated and discussed in relation to available literature. The findings revealed that foliar application of boron and zinc improved the TSS, total sugars, reducing sugars, non-reducing sugars and ascorbic acid content, while reducing titratable acidity compared with the control. The response varied with the concentration and combination of the micronutrients.

The improvement in quality attributes may be attributed to the complementary roles of boron and zinc in carbohydrate metabolism, enzyme activation, sugar translocation and other physiological processes involved in quality development.

Zinc plays an important role in several physiological and biochemical processes, including enzyme activation, carbohydrate metabolism, and translocation of sugars and proteins (Yang *et al.*, 2020). The present findings are in agreement with Singh *et al*. (2017), who reported improved vitamin C and TSS in broccoli following boron application. Similarly, Moklikar *et al.* (2015) observed that boron application at 0.2% improved TSS and vitamin C content in cauliflower. Kumar *et al.* (2012) also reported an increase in ascorbic acid concentration following foliar application of zinc sulphate and boric acid.

The present results are further supported by Gajendra *et al*. (2014), who reported improved TSS and vitamin C content in broccoli with combined application of boron, manganese, and zinc. Shivram *et al.* (2017) also observed enhanced TSS, ascorbic acid, total sugars, reducing sugars, and non-reducing sugars in sprouting broccoli following zinc application. Likewise, Raj *et al*. (2012), Salam *et al*. (2011) and Meena *et al*. (2015) reported that foliar application of zinc and boron, either individually or in combination, improved the quality characteristics of vegetable crops.

The improvement in quality attributes observed in the present investigation may therefore be attributed to the synergistic effect of boron and zinc, which enhances nutrient utilization, enzymatic activity, carbohydrate metabolism and the accumulation of soluble sugars and vitamin C in cauliflower curds. Overall, the findings demonstrate that appropriate foliar application of boron and zinc can effectively improve the biochemical and nutritional quality of cauliflower under the agro-climatic conditions of Lucknow.

## Conclusion

The present study clearly demonstrated that foliar application of boron and zinc significantly improved the biochemical and quality attributes of cauliflower cv. Pusa Snowball K-1 compared to the untreated control. Combined application of the two micronutrients proved more effective than their individual application, confirming a synergistic effect between boron and zinc on curd quality. Among all treatments, $T_7$ (boron @ 0.2% + zinc @ 0.5%) recorded the highest total sugars (4.10%), reducing sugars (0.89%), non-reducing sugars (3.21%), and ascorbic acid content (67.17 mg 100 $g^{-1}$ edible curd), while $T_9$ (boron @ 0.4% + zinc @ 0.5%) produced the highest TSS (7.19 °Brix) and TSS:acidity ratio (20.78). The lowest quality parameters, along with the highest acidity (0.394%) were recorded in the control, reinforcing the positive role of boron and zinc in enhancing curd biochemical.

Based on the overall performance across sugar content, ascorbic acid, and other quality parameters, foliar application of boron @ 0.2% + zinc @ 0.5% ($T_7$) can be recommended as the most suitable treatment for improving the biochemical quality of cauliflower cv. Pusa Snowball K-1 under the experimental conditions.

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