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Effect of Different Micronutrients on Yield and Quality Traits of Cabbage (*Brassica oleracea* var. *capitata* L.)

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Article

The present study aimed to evaluate the effects of different micronutrients on the growth, yield, and quality parameters of cabbage (*Brassica oleracea* var. *capitata* L.). The experiment was conducted at the Vegetable Research Farm, University, Jaipur, during the Rabi season of 2024-2025. The treatments included various concentrations of boric acid and ammonium molybdate applied as foliar sprays at 30 and 45 days after transplanting. The results showed that the treatment combination of Boric acid (3.0%) + Ammonium Molybdate (0.30%) significantly improved total soluble solids (7.43 °Brix), head firmness (91.21 kg/cm²), chlorophyll content (80.79 SPAD units), and vitamin C content (56.43 mg/100g) compared to the control. The enhanced quality attributes are attributed to the role of boron and molybdenum in enzyme activity, photosynthesis, and nutrient metabolism. The findings suggest that foliar application of these micronutrients can enhance the yield and quality of cabbage, making it a valuable practice for growers.

Key words: Cabbage, *Brassica oleracea*, micronutrients, boric acid, ammonium molybdate

Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) is a widely consumed and commercially significant cole crop, grown in over 90 countries. Cabbage is important leafy vegetables globally, commonly used in salads, slaws, boiled dishes, curries, and processed foods. Cabbage is also preserved as pickles and dehydrated for long-term use. It has a long history of medicinal applications, treating ailments such as gout, diarrhea, stomach issues, and digestive disorders. Notably, cabbage contains indole-3-carbinol, which may protect against bowel cancer (Huo *et al.* 2024). Historically, cabbage juice was used as a gargle for hoarseness and as a treatment for poisoning by mushrooms. The leaves were applied to wounds and ulcers, and it is believed to improve digestion. Fermented cabbage, known as sauerkraut, has been used to prevent scurvy. Cabbage is rich in vitamins A, B, and C, as well as essential minerals, making it useful in enhancing digestion, stimulating appetite, and managing diabetes (Sharma *et al.* 2015; Malek & Rahim, 2011). The name "cabbage" comes from the French word "coboche," meaning "head." Cabbage is well adapted to cool seasons, thriving in temperatures between 15–18°C. It can grow in a variety of soils, though the optimal pH range is 5.5–6.5. This vegetable is highly popular worldwide due to its pleasant flavor, nutritional value, and low fat and calorie content (Birt *et al.* 2018). Cabbage evolved through human selection from wild species such as *Brassica oleracea* var. *oleracea* (wild cabbage or colewort), which originated in the eastern Mediterranean and Asia Minor. It is thought that the Celts brought wild cabbage to Western Europe, and modern cabbage varieties, such as hard-headed white cabbage, were developed in Germany (Anonymous, 2021).

Even though they are only needed in trace amounts, micronutrients are essential for plant development. These include boron (B), copper (Cu), chlorine (Cl), iron (Fe), molybdenum (Mo), manganese (Mn), and zinc (Zn). Micronutrients are important as enzyme activators and growth of cell wall development, chlorophyll formation, and nitrogen fixation. Foliar application is commonly used to provide micronutrients to crops because it ensures better nutrient absorption and reduces costs compared to soil applications (Wallace & Romney, 1970; Yadav *et al.* 2019). Boron, for instance, is essential for new cell growth in plants, particularly in the meristematic regions. A deficiency in boron can lead to stunted growth, poor fruit set, and sterility. Symptoms of boron deficiency in cabbage include thick, twisted, brittle leaves and shortened terminal growth (Poudel *et al.* 2024). Crops like cabbage, cauliflower, and potatoes are particularly sensitive to boron deficiencies, which can be corrected with fertilizers such as borax, boric acid, or sodium octaborate tetrahydrate (Bubarai *et al.* 2017). Molybdenum (Mo) is a critical component of nitrate reductase, which is involved in nitrogen metabolism and fixation. A deficiency in molybdenum can result in stunted growth, chlorosis, and leaf mottling. In cabbage, molybdenum deficiency leads to abnormal leaf development, including elongated and twisted leaves (Kotecha *et al.* 2021).

Materials and Methods

The present study wan conducted on titled "Study of different micronutrients on growth, yield, and quality parameters of cabbage (*Brassica oleracea* var. *capitata* L.)" was carried out with the following methodology.

Experimental Site

During the 2024–2025 rabi season, the experiment was carried out at the Horticulture Research Farm, Nirwan University Jaipur, Jaipur, Rajasthan.

Soil and Climatic Conditions

The experimental field consisted of Sandy Loam soil with good drainage and uniform texture, and it had a medium NPK nutrient status. The research site is geographically situated between 26°49' to 26°51' North latitude and 75°46' to 75°51' East longitude, with an altitude averaging 372 meters above mean sea level. The region experiences a hot, dry summer and cold winter, with occasional showers. The average annual precipitation is approximately 650 mm, mainly occurring between mid-June and early October, with occasional winter rains. The maximum temperature can reach up to 46°C in April-May, while the minimum temperature can drop below 5°C during December-January. The relative humidity averages around 78% during winter, with occasional frost.

Experimental Materials

The cabbage variety used was Golden Acre, an early-maturing, open-pollinated cultivar developed through selection at the Copenhagen Market. The cultivar matures 60-75 days after transplantation, with small, cup-shaped outer leaves, compact plants, and short stems. The heads are small, spherical, and compact, weighing around 1.0–1.5 kg with an average yield of 200–250 q ha^{-1}. This variety is ideal for spring and summer planting. The seeds were obtained from ICAR-Indian Institute of Vegetable Research, Varanasi (UP).The experiment followed a Randomized Block Design (FRBD) with three replications. Each replication consisted of 16 treatments, and the treatments were randomized separately for each replication. The experimental plot measured 3 × 3 meters. The study included 15 different concentrations of growth regulator solutions and a control treatment. Each plot was marked with symbols to represent the different treatments in each replication, as shown below:

Nursery Preparation and Seedling Raising

The nursery was raised in open field conditions. Nursery beds of 3 x 1 x 0.15 meters were prepared with pulverized soil, decomposed leaf mold, and compost. Phosphate dust was applied at 25 kg ha^{-1}, along with Bavistin (0.01%). Seeds were sown on October 16, 2024, and the beds were covered with dried grass for five days to aid germination. Regular watering was done using a sprinkler. After 30 days, seedlings were transplanted at the 3-4 leaf stage.

Cultural Practices

During the 2024–2025 rabi season, the experiment was carried out at the Horticulture Research Farm, Nirwan University Jaipur, Jaipur, Rajasthan.It was cross-ploughed and laddered to achieve proper tilth, and 2 kg/m² of farmyard manure was applied. Furadon (10 kg ha^{-1}) was used for soil treatment to protect against soil-inhabiting insects. The recommended fertilizer doses were 120 kg N, 60 kg P2O5, and 60 kg K2O per hectare. Urea, Single Super Phosphate, and Muriate of Potash were used. Half the nitrogen and all of the phosphorus and potassium were applied as basal doses. The remaining nitrogen was top-dressed 40 days after transplanting. Uniform, healthy, green seedlings were transplanted on November 16, 2023, at a spacing of 50 cm between rows and 40 cm within rows. Seedlings were watered immediately after transplanting and left exposed to dew at night. Micronutrients (boric acid and ammonium molybdate) were applied as foliar sprays at 30 and 45 days after transplanting (DAT).

Solution Preparation

The required quantities of boric acid and ammonium molybdate were weighed, dissolved in distilled water, and diluted to make 4 liters of solution for foliar spray. A fresh solution was prepared for each spray.Foliar spraying was done using a Knapsack sprayer. The first spray was applied 30 days after transplanting, and the second at 45 days after transplanting. A sticker was added to improve solution absorption.

Observation recorded Qualitative Characters

Total soluble solids (TSS) in cabbage were assessed using a hand refractometer by placing a drop of juice from crushed cabbage head pieces on the glass prism for readings. Head firmness was measured with a pocket penetrometer, where pressure was recorded at two puncture points on each head. Chlorophyll content was evaluated using a SPAD chlorophyll meter, calculating the average of five measurements. Vitami C content (ascorbic acid) was determined by titrating a known weight of cabbage sample with 2,4,6 dichloro-indophenol dye, employing metaphosphoric acid as a stabilizing agent, following the method described by Ranganna (1997).

Statistical Analysis

A Factorial Complete Randomized Design (FCRD) was used to perform the experiment on low and high cold peach seeds in a lab setting, with three replications of each treatment. Microsoft Excel (Microsoft Corporation, USA) programs were used for statistical analysis and analysis of variance (ANOVA) of the data.

Observation recorded Qualitative Characters

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Statistical analysis

The experiment was conducted under lab conditions on low and high chill peaches seeds by using a Factorial Complete Randomized Design (FRRD), with each treatment replicated three times. The data underwent analysis of variance (ANOVA) and statistical analysis was done using R software (2.2.0.)

Result and Discussions

Yield $plot^{-1}$ (kg)

Maximizing yield is the main objective of cultivation in order to maximize revenues. One of the most crucial elements that receives the most attention during the whole research phase is yield, which determines a variety's economic viability. Micronutrients significantly affected cabbage production per plot (kg) during the trial, according to a detailed analysis of the data. Among all the treatments, (T11) B2 Boric acid @ 3.0% + Ammonium Molybdate @ 0.30% recorded a maximum yield plot-1 of (30.07 kg), which was statistically comparable to treatment (T10) Boric acid @ 3.0% + Ammonium Molybdate @ 0.15%, i.e., (28.39 kg). These treatments were followed by (T9) Boric acid @ 3.0% and (T3) Ammonium Molybdate @ 0.30%, with treatment Control showing the lowest yield (15.92 kg) (Chaudhary *et al.* 2024).

Table 1 Yield plot-1 (kg) of cabbage as influenced by different micronutrients.

	B_0	B_1	B_2	B_3	Mean A
M_0	17.92	19.11	26.99	16.34	20.09
M_1	18.10	22.02	28.40	23.59	23.03
M_2	27.98	16.83	30.07	23.98	24.72
M_3	16.24	25.99	16.34	17.10	18.92
Mean B	20.06	20.99	25.45	20.25	
Factors		**C.D.**		**SE(m)±**	
Factor (A)		0.49		0.17	
Factor (B)		0.49		0.17	
Factor (A X B)		.98		0.34	

TSS (oBrix)

Data on the effects of different micronutrients on the TSS of cabbage are presented in Figure 1. From the data, it is evident that different treatments had a significant effect on the TSS of cabbage. Among all the treatments, (T11) B2 Boric acid @ 3.0 %+ Ammonium Molybdate @ 0.30% recorded a maximum total soluble solids (oBrix) of (7.43) which was statistically at par with treatment (T10) Boric acid @ 3.0 %+ Ammonium Molybdate @ 0.15% viz., (6.60) and these were followed by treatment (T15) Boric acid @ 4.5 %+ Ammonium Molybdate @ 0.30% (6.4). While, lowest total soluble solids (oBrix) was observed in control (3.15) (Ali *et al.* 2024). Increased total soluble solids content clearly demonstrated that the stored food materials undergo partial or complete hydrolysis and serve as substrates for respiration. As an essential component involved in the respiratory process in the cell and plant systems, this could have naturally resulted in the conversion of reserved food material to soluble simple sugar. Lashkari *et al.* (2008) found that combined foliar sprays of zinc and iron @ 0.5 per cent concentrations each increased T.S.S. (7.20° Brix) (Souza *et al.* 2025).

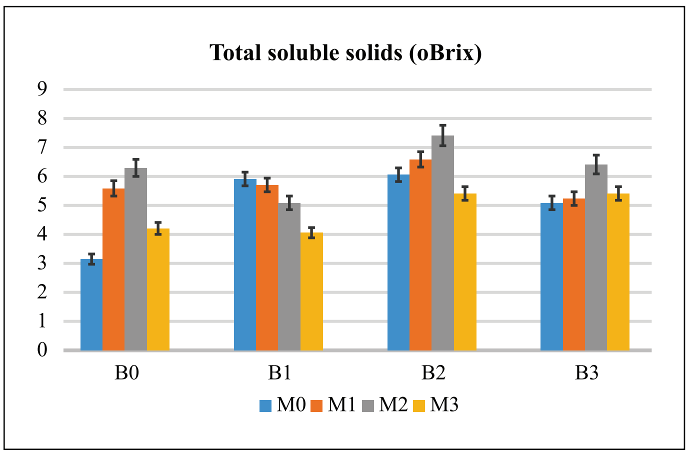

Figure 1 Total soluble solids (oBrix) of cabbage as influenced by different micronutrients

1.1 Vitamin - C content (mg/100 g)

One of the most crucial quality factors in cabbage is its ascorbic acid (Vitamin-C) concentration, which enhances the head's nutritional value. Micronutrients significantly impacted the vitamin-C content (mg/100 g) of cabbage during the trial, according to an analysis of the data in Table 2. Vitamin-c was recorded at 56.43 kg/cm2 for treatment (T11) B2 Boric acid @ 3.0% + Ammonium Molybdate @ 0.30%, which was statistically comparable to treatment (T10) Boric acid @ 3.0% + Ammonium Molybdate @ 0.15%, or 50.42 kg/cm2. Treatment (T3) Ammonium Molybdate @ 0.30%, or 48.03 kg/cm2, came next. The control group had the least amount of head stiffness (35.05 kg/cm2) (Parvin *et al.* 2025). The use of boron and molybdenum, which serve as active carriers for a variety of enzymatic activities and enzymes catalyzing a wide range of biochemical reactions, including those that neutralize the effects of reactive oxygen species and various pathways of ascorbate synthesis in plants, may be the reason for the higher vitamin-C content in cabbage heads. Similar outcomes for cabbage were reported by Kotecha *et al.* (2011) (Romanovski 2025).

Table 2 Vitamin - C content (mg/100 g) of cabbage as influenced by different micronutrients

	B_0	B_1	B_2	B_3	Mean A
M_0	35.05	45.21	48.65	45.42	43.58
M_1	45.62	45.48	50.42	45.62	46.79
M_2	47.36	46.21	56.43	48.03	49.51
M_3	42.96	43.42	41.62	42.62	42.59
Mean B	42.75	45.08	49.28	45.36	
Factors		C.D.		SE(m)±	
Factor (A)		0.93		0.32	
Factor (B)		0.93		0.32	
Factor (A X B)		1.87		0.64	

Conclusion

The study concludes that the application of micronutrients, specifically Boric acid (3.0%) and Ammonium Molybdate (0.30%), significantly enhances the quality parameters of cabbage, including total soluble solids, and vitamin C content. These improvements are due to the essential roles of boron and molybdenum in various physiological and biochemical processes, such as enzyme activity, chlorophyll formation, and nutrient metabolism. The treatment T11 was most effective, making it a recommended practice for improving both yield and quality of cabbage. The findings align with previous studies, reinforcing the importance of micronutrient supplementation in cabbage cultivation for enhanced nutritional value and marketability

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