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GROWTH AND YIELD OF BROCCOLI (*BRASSICA OLERACEA* L. *VAR. ITALICA PLENCK*) AS INFLUENCED BY SOIL APPLICATION OF MICRONUTRIENTS UNDER OPEN CONDITION

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ABSTRACT

A field experiment entitled "Effect of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica* L.) under open condition" was conducted during *rabi* 2024-25 at the Main Agricultural Research Station, UAS, Dharwad, to assess the impact of boron, molybdenum and zinc on broccoli growth and productivity. The study comprised 13 treatments involving individual and combined applications of Borax (5, 10, 15 kg ha^{-1}), Ammonium molybdate (1.0, 1.5, 2.0 kg ha^{-1}) and Zinc sulfate (5, 10, 15 kg ha^{-1}) laid out in a randomized block design with three replications. The results revealed that the combined application of Borax @ 15 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + Zinc sulfate @ 15 kg ha^{-1} (T_{13}) significantly improved growth, yield parameters compared to the control. Treatment T_{13} recorded the highest plant height (70.40 cm), plant spread (65.2 cm), number of leaves (17.07), leaf length (40.20 cm), width of leaf (15.9 cm), leaf area (4.800 dm^2), stalk length (16.09 cm), stalk diameters (25.8 mm), chlorophyll content (76,70), days to curd initiation (58.77 days) and days to curd maturity (77.4 days) and yield parameters like curd weight (2.31 kg), curd length (15.70 cm), curd circumference (22.99 cm), number of sprouts per curd (4.9), marketable curd weight (514 g), net curd weight (462 g), curd yield per plot (10.16 kg) and curd yield per hectare (47.04 t ha^{-1}). The overall improvement may be attributed to the synergistic role of micronutrients in enhancing nutrient uptake, photosynthetic efficiency, enzyme activation and assimilate translocation. Hence, integrated micronutrient management proved effective in enhancing growth and yield of broccoli, demonstrating its potential as a sustainable production strategy under open field conditions.

Keywords **:** Broccoli, Boron, Molybdenum, Zinc, Micronutrients, Yield and Growth.

Introduction

Vegetables constitute an important component of Indian agriculture by contributing to higher productivity, nutritional security and improved farm income. Among the cruciferous vegetables, broccoli (*Brassica oleracea* L. *var. italica Plenck*) has gained prominence as a highly nutritious and economically valuable crop. Native to the Northern Mediterranean region, broccoli is rich in vitamins A, B and C, along with calcium, phosphorus, iron and carotene, making it nutritionally superior to other cole crops such as cabbage and cauliflower (Hazra and Som, 1999; Thamburaj and Singh, 2001). It is also known for its strong antioxidant properties and contains bioactive compounds like glucoraphanin and sulforaphane, which exhibit notable anticancer activity (Kalia, 1995; Aires *et al*., 2006). Broccoli thrives best under cool, moist climatic conditions with an optimum temperature range of 15–23°C and grows well in well-drained loamy soils with a pH of 6.0–7.0 (Rubatzky and Yamaguchi, 1997).

Efficient nutrient management is vital for maximizing broccoli productivity and quality. Although macronutrients are required in larger quantities, micronutrients such as boron (B), molybdenum (Mo) and zinc (Zn) are equally important as they play key roles in physiological and biochemical processes including photosynthesis, chlorophyll formation and enzyme activation (Kaya and Higgs, 2002). Deficiencies of these micronutrients often result

in physiological disorders such as hollow stem, whiptail and poor head compactness, ultimately reducing yield and marketability (Chadha, 2001). Foliar fertilization has emerged as an efficient and environmentally friendly method for micronutrient application, ensuring rapid absorption and improved utilization by plants. However, limited information is available on the combined effects of boron, molybdenum and zinc on broccoli growth and yield under the Northern Transitional Zone of Karnataka. Hence, the present investigation was carried out to evaluate the influence of these micronutrients on the growth, yield and quality of broccoli cultivated under this region.

Material and Methods

A field experiment on "Effect of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea var. italica* L.) under open condition" was carried out during *rabi* 2024-25 at the Main Agricultural Research Station, UAS, Dharwad. The experimental site lies in the Northern Transitional Zone of Karnataka at 15°26′ N latitude, 75°07′ E longitude and 678 mm above mean sea level. The soil was black clay loam, slightly alkaline (pH 7.4), low in nitrogen and phosphorus, medium in potassium and deficient in boron, molybdenum and zinc.

The experiment was laid out in a randomized block design with 13 treatments replicated thrice. Treatments included individual and combined applications of Borax (5, 10 and 15 kg ha^{-1}), Ammonium molybdate (1.0, 1.5 and 2.0 kg ha^{-1}) and Zinc sulfate (5, 10 and 15 kg ha^{-1}), along with a control. The hybrid variety 'Saki' (F_1) was transplanted at 60 × 45 cm spacing. The recommended dose of fertilizers (150:80:125 NPK kg ha^{-1}) and 25 t FYM ha^{-1} were applied as basal.

All standard cultural and plant protection practices were followed. Data on growth parameters like plant height, plant spread, number of leaves per plant, length of leaf, width of the leaf, leaf area, stalk length, stalk diameter, days to curd initiation and days to curd maturity and data on yield attributes (curd weight, curd length, curd circumferences, marketable curd weight, net curd weight, number of sprouts per curd, yield per plot and hectare) were recorded. The data were statistically analyzed using analysis of variance (ANOVA) following Panse and Sukhatme (1985).

Result and Discussion

Growth parameters

The application of micronutrients had a significant and consistent influence on the vegetative growth of broccoli, with the combined treatment T13 (Borax 15 kg + Ammonium molybdate 2 kg + Zinc sulfate 15 kg ha^{-1}) recording the highest values for plant height (28.00, 50.50 and 70.40 cm), plant spread (33.60, 47.90 and 65.20 cm), leaf number (10.75, 13.20 and 17.07), leaf length (18.2, 29.0 and 40.2 cm), leaf width (8.3, 12.0 and 15.9 cm), leaf area (1.133, 2.700 and 4.800 dm^2), stalk diameter (11.60, 18.70 and 25.80 mm), and SPAD chlorophyll content (46.80, 55.00 and 76.70) across 30, 45 and 60 DAT. These improvements are attributed to the synergistic roles of boron, molybdenum and zinc in supporting meristem activity, nitrogen metabolism, auxin synthesis and enzymatic functions. The results agree with Thapa *et al*. (2016), Rao *et al*. (1990) and Moniruzzaman *et al*. (2007), who also reported enhanced vegetative growth in Brassica with boron and molybdenum, while Kant Kamal *et al*. (2013) and Sharma *et al*. (2017a) observed improved plant spread and height with boron and zinc application. T_{13} achieved the earliest curd initiation (58.77 days), while T_{12} (Borax 10 kg + Ammonium molybdate 1.5 kg + Zinc sulfate 10 kg ha^{-1}), which recorded similarly high values (e.g., height: 26.50, 47.90 and 67.10 cm, SPAD: 45.00, 48.40 and 74.20), was statistically on par and recorded early curd maturity (77.40 days). These results are consistent with findings from Sharma *et al*. (2018b) and Tiwari and Meena (2010), who reported that balanced micronutrient combinations reduce the time to reproductive initiation in cruciferous crops.

Among individual applications, T_4 (Borax 15 kg ha^{-1}) showed the best performance for plant height (24.00, 43.63 and 61.70 cm), leaf number (9.83, 12.38 and 15.33), and SPAD values (41.60, 44.80 and 66.70), indicating the critical role of boron in promoting cell elongation, auxin activity and sugar translocation. Moderate improvements with zinc and molybdenum alone corroborate the observations of Patel and Patel (2017), Das and Mandal (2021) and Kumar *et al*. (2019), who highlighted their role in leaf expansion and vegetative growth. In contrast, the control (T_1) recorded the lowest values for plant height (18.33, 33.67 and 48.30 cm), plant spread (24.50, 32.70 and 45.60 cm), leaf area (0.502, 1.235 and 1.290 dm^2), SPAD content (35.8, 38.1 and 60.5) and the latest curd initiation (69.47 days) and maturity (86.47 days). These findings are consistent with reports of reduced growth due to micronutrient deficiency, as noted by Ramesh *et al*. (2019), Yadav *et al*. (2017) and Singh *et al*. (2016a). Overall, the study confirms that the integrated application of boron, molybdenum and zinc significantly enhances vegetative growth, physiological efficiency, and early curd development in broccoli, aligning with the general consensus of earlier Brassica

research by Chatterjee & Bandyopadhyay (2013), Pandey & Gupta (2014) and Ghosh *et al*. (2011).

Yield parameters

Micronutrient application exerted a significant influence on yield and yield attributes of broccoli. The combined application of boron, molybdenum, and zinc showed superior results compared to their individual applications. The treatment T_{13} (Borax @15 kg ha^{-1} + Ammonium molybdate @2 kg ha^{-1} + Zinc sulfate @15 kg ha^{-1}) recorded the maximum curd weight (2.31 kg), curd length (15.70 cm) and curd circumference (22.99 cm), followed by T_{12}. The lowest values were observed in the control (1.35 kg, 8.60 cm and 14.29 cm). The improvement in these traits could be attributed to the synergistic role of boron, molybdenum and zinc in promoting cell division, meristematic activity and efficient translocation of photosynthates to the developing curd. Boron improved sugar translocation and cell wall strength, molybdenum enhanced nitrogen metabolism through nitrate reductase activity and zinc promoted auxin synthesis and enzyme activation, which together contributed to the formation of compact and heavier curds.

Similar findings were reported by Meena *et al.* (2017) and Chaudhary *et al*. (2020), who observed that combined micronutrient application enhanced curd size and compactness in broccoli. The increased availability of essential micronutrients under T_{13} also improved root activity and photosynthetic efficiency, resulting in enhanced dry matter accumulation and curd development. Marketable and net curd weights were also significantly influenced by micronutrient application. The maximum marketable curd weight (514 g) and net curd weight (462 g) and number of sprouts per curd (4.9) were recorded in T_{13}, followed by T_{12}, while the minimum (312 g, 270 g and 2.49) was recorded in control. The increase in curd weight might be due to improved nutrient uptake and better utilization of assimilates, leading to firmer and more compact curds. Similar observations were made by Chauhan *et al.* (2017) and Mishra and Dashora (2009), who reported that boron, molybdenum and zinc enhanced the marketable yield and curd compactness in broccoli. The highest total yield per plot (10.16 kg) and per hectare (47.04 t ha^{-1}) were observed in T_{13}, followed by T_{12}. The lowest yield (27.50 t ha^{-1}) was recorded in control. The increase in yield under T_{13} may be attributed to the cumulative effect of all three micronutrients on enhancing photosynthetic rate, chlorophyll content, and better assimilate partitioning to economic parts. Molybdenum plays a key role in nitrate reduction, improving protein synthesis, while boron and zinc together enhance carbohydrate metabolism and hormonal regulation. These factors contribute to increased curd size and yield. Sharma *et al*. (2017a) and Patil *et al*. (2019) also reported similar increases in broccoli yield under balanced micronutrient nutrition. Thus, the integrated application of boron, molybdenum and zinc proved beneficial in maximizing yield parameters by improving physiological efficiency and nutrient balance.

Plate 1: Harvested curds in different treatments

Plate 2: Effect of different micronutrients treatments on growth of broccoli.

Table 1: Effect of micronutrients on growth of broccoli under open condition

Tr. No	Treatment details	Plant height (cm)			Plant spread (cm)			Number of leaves per plant		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
T1	Control	18.33	33.67	48.30	24.50	32.70	45.60	9.09	9.50	12.50
T2	Borax @ 5 kg ha^{-1}	21.02	38.73	55.23	27.20	36.70	50.30	9.40	10.87	13.00
T3	Borax @10 kg ha^{-1}	22.78	41.70	58.70	28.60	38.80	53.90	9.73	12.27	14.40
T4	Borax @ 15 kg ha^{-1}	24.00	43.63	61.70	29.80	40.10	56.20	9.83	12.38	15.33
T5	Ammonium molybdate @1.0 kg ha^{-1}	20.50	37.67	53.53	26.10	34.70	48.50	8.79	10.67	13.47
T6	Ammonium molybdate @ 1.5 kg ha^{-1}	22.00	40.23	56.97	27.40	36.90	51.60	9.51	10.93	13.93
T7	Ammonium molybdate @ 2 kg ha^{-1}	23.10	42.63	59.50	28.20	38.10	53.40	9.43	11.50	14.13
T8	Zinc sulfate @ 5 kg ha^{-1}	21.09	37.97	54.70	26.80	35.60	49.80	9.48	10.80	14.07
T9	Zinc sulfate @ 10 kg ha^{-1}	22.50	41.27	57.90	28.10	37.90	52.70	9.49	12.16	14.40
T10	Zinc sulfate @ 15 kg ha^{-1}	23.60	42.90	60.40	29.30	39.50	55.10	9.33	12.21	15.53
T11	Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	24.90	45.50	63.90	30.50	42.60	58.70	9.17	11.13	14.93
T12	Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	26.50	47.90	67.10	32.10	45.80	62.40	10.36	12.47	16.40
T13	Borax (15 kg) + Ammonium molybdate (2 kg) + Zinc sulfate (15 kg ha^{-1})	28.00	50.50	70.40	33.60	47.90	65.20	10.75	13.20	17.07
	Mean	22.9	41.8	59.1	28.80	39.6	54.7	9.42	11.1	14.73
	S.Em(±)	0.59	0.21	0.11	0.96	1.28	1.71	0.31	0.49	0.51
	CD@5%	1.74	0.62	0.34	2.82	3.74	5.01	0.91	1.43	1.49

Tr. No	Treatment details	Length of leaf (cm)			Width of leaf (cm)			Leaf area (dm^2)		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
T1	Control	12.40	20.30	28.60	5.40	8.10	10.70	0.502	1.235	2.300
T2	Borax @ 5 kg ha^{-1}	14.10	22.80	31.70	6.10	9.00	11.90	0.639	1.539	2.893
T3	Borax @10 kg ha^{-1}	15.20	24.50	34.10	6.60	9.80	12.90	0.752	1.799	3.291
T4	Borax @ 15 kg ha^{-1}	16.00	25.80	35.90	7.00	10.40	13.70	0.840	2.014	3.692
T5	Ammonium molybdate @1.0 kg ha^{-1}	13.70	22.00	30.80	5.90	8.70	11.50	0.607	1.431	2.661
T6	Ammonium molybdate @ 1.5 kg ha^{-1}	14.80	23.60	33.00	6.40	9.50	12.50	0.711	1.677	3.094
T7	Ammonium molybdate @ 2 kg ha^{-1}	15.60	24.90	34.60	6.80	10.10	13.20	0.795	1.887	3.423
T8	Zinc sulfate @ 5 kg ha^{-1}	14.00	22.50	31.30	6.00	8.80	11.70	0.603	1.491	2.743
T9	Zinc sulfate @ 10 kg ha^{-1}	15.10	24.20	33.70	6.70	9.70	12.80	0.760	1.770	3.246
T10	Zinc sulfate @ 15 kg ha^{-1}	15.90	25.60	35.40	7.10	10.30	13.60	0.846	1.981	3.628
T11	Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	16.50	26.40	36.80	7.40	10.80	14.20	0.917	2.124	3.933
T12	Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	17.40	27.80	38.50	7.80	11.40	15.00	1.016	2.379	4.331
T13	Borax (15 kg) + Ammonium molybdate (2 kg) + Zinc sulfate (15 kg ha^{-1})	18.20	29.00	40.20	8.30	12.00	15.90	1.133	2.700	4.800
	Mean	15.3	24.5	34.2	6.7	9.8	13.0	0.77	1.84	3.42
	S.Em(±)	0.48	0.78	1.08	0.21	0.31	0.41	0.014	0.03	0.06
	CD@5%	1.41	2.27	3.16	0.62	0.91	1.20	0.043	0.10	0.18

Tr. No	Treatment details	Stalk length (cm)			Stalk diameter (mm)			SPAD reading		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
T1	Control	5.20	9.64	14.07	7.50	12.10	16.3	35.80	38.10	60.50
T2	Borax @ 5 kg ha^{-1}	5.60	10.68	14.18	8.60	13.80	18.5	38.40	41.50	62.50
T3	Borax @10 kg ha^{-1}	5.67	11.78	15.82	9.20	14.90	20.3	40.10	43.20	65.60
T4	Borax @ 15 kg ha^{-1}	5.77	11.82	15.95	9.80	15.80	21.6	41.60	44.80	66.70
T5	Ammonium molybdate @1.0 kg ha^{-1}	5.53	10.91	14.1	8.20	13.30	17.9	37.20	40.20	64.70
T6	Ammonium molybdate @ 1.5 kg ha^{-1}	5.30	11.13	14.5	8.90	14.40	19.6	39.00	42.00	67.60
T7	Ammonium molybdate @ 2 kg ha^{-1}	5.40	11.21	14.85	9.60	15.50	20.9	40.40	43.70	68.50
T8	Zinc sulfate @ 5 kg ha^{-1}	5.53	11.23	14.9	8.40	13.60	18.30	37.60	40.60	63.60
T9	Zinc sulfate @ 10 kg ha^{-1}	5.57	11.37	15.73	9.10	14.80	20.00	39.30	42.30	65.80
T10	Zinc sulfate @ 15 kg ha^{-1}	5.77	11.41	15.85	9.70	15.70	21.40	40.80	44.10	66.40
T11	Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	6.20	11.65	16.07	10.20	16.30	22.70	43.20	46.30	73.90
T12	Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	6.50	12.68	16.78	10.90	17.50	24.10	45.00	48.40	74.20
T13	Borax (15 kg) + Ammonium molybdate (2 kg) + Zinc sulfate (15 kg ha^{-1})	6.20	12.51	16. 69	11.60	18.70	25.80	46.80	50.10	76.70
	Mean	5.77	11.82	15.40	9.3	15.1	20.5	40.5	43.4	67.4
	S.Em(±)	0.21	0.40	0.35	0.06	0.09	0.10	1.05	1.11	1.60
	CD@5%	0.61	1.16	1.35	0.17	0.27	0.29	3.05	3.25	4.67

Table 2: Effect of micronutrients on yield of broccoli under open condition

Treatment details	Curd weight (kg)	Curd length (cm)	Curd circumference (cm)	Number of sprouts per curd	Marketable curd weight (g)	Net curd weight (g)	Curd yield per plot (kg plot)	Curd yield per ha (t ha^{-1})
Control	1.35	8.60	14.29	2.49	312	270	5.94	27.50
Borax @ 5 kg ha^{-1}	1.59	10.40	16.34	3.53	365	318	7.00	32.41
Borax @10 kg ha^{-1}	1.79	11.70	21.21	4.46	402	352	7.74	35.83
Borax @ 15 kg ha^{-1}	1.88	12.60	21.32	4.51	428	375	8.25	38.19
Ammonium molybdate @1.0 kg ha^{-1}	1.54	9.90	15.94	2.93	348	308	6.78	31.39
Ammonium molybdate @ 1.5 kg ha^{-1}	1.70	10.80	16.44	2.96	388	340	7.48	34.63
Ammonium molybdate @ 2 kg ha^{-1}	1.81	11.50	21.37	3.08	412	362	7.96	36.85
Zinc sulfate @ 5 kg ha^{-1}	1.58	10.10	16.17	3.20	355	315	6.93	32.08
Zinc sulfate @ 10 kg ha^{-1}	1.73	11.20	15.07	3.21	390	345	7.59	35.14
Zinc sulfate @ 15 kg ha^{-1}	1.84	12.10	15.21	3.43	420	368	8.10	37.50
Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	2.00	13.40	17.34	3.97	452	400	8.80	40.74
Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	2.15	14.90	21.25	4.6	483	430	9.46	43.80
Borax (15 kg) + Ammonium molybdate (2 kg) + Zinc sulfate (15 kg ha^{-1})	2.31	15.70	22.99	4.9	514	462	10.16	47.04
Mean	1.79	11.7	18.07	3.63	405.3	357.3	7.8	36.3
S.Em(±)	0.05	0.06	0.62	0.11	18.63	17.32	0.38	0.66
CD@5%	0.16	0.16	1.83	0.34	54.39	50.54	1.11	1.92

Table 3: Effect of micronutrients on days to curd initiation and days to curd maturity of broccoli

Tr. No	Treatment details	Days to curd initiation	Days to curd maturity
T_1	Control	69.47	86.47
T_2	Borax @ 5 kg ha^{-1}	64.37	83.07
T_3	Borax @10 kg ha^{-1}	63.43	82.00
T_4	Borax @ 15 kg ha^{-1}	67.13	82.13
T_5	Ammonium molybdate @1.0 kg ha^{-1}	66.70	85.27
T_6	Ammonium molybdate @ 1.5 kg ha^{-1}	66.93	84.13
T_7	Ammonium molybdate @ 2.0 kg ha^{-1}	66.43	84.87
T_8	Zinc sulfate @ 5 kg ha^{-1}	64.73	84.53
T_9	Zinc sulfate @ 10 kg ha^{-1}	64.77	83.00
T_{10}	Zinc sulfate @ 15 kg ha^{-1}	62.97	83.20
T_{11}	Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	60.30	80.27
T_{12}	Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	59.47	77.40
T_{13}	Borax (15 kg) + Ammonium molybdate (2.0 kg) + Zinc sulfate (15 kg ha^{-1})	58.77	79.33
	Mean	64.2	82.7
	S.Em(±)	2.15	3.02
	CD@5%	6.3	8.82

Conclusion

The study revealed that the combined foliar application of Borax @15 kg ha^{-1} + Ammonium molybdate @2 kg ha^{-1} + Zinc sulfate @15 kg ha^{-1} (T_{13}) significantly enhanced the growth and yield of broccoli under open field conditions. This treatment recorded the highest plant height, plant spread, number of leaves per plant, curd weight, yield, and superior quality parameters. The synergistic effect of boron, molybdenum and zinc improved nutrient uptake, enzyme activity and assimilate translocation, leading to compact, nutritious and marketable curds. Hence, integrated micronutrient management is vital for achieving higher productivity, profitability and quality in broccoli cultivation.

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