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Influence of micronutrients on yield and quality of broccoli (*Brassica oleracea* L. *var. italica* Plenck) 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 study the influence of boron, molybdenum and zinc on broccoli performance. The experiment consisted of 13 treatments with 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}) arranged in a randomized block design with three replications. Results indicated 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 enhanced growth, yield and quality attributes over the control. T_{13} recorded the maximum curd weight (2.31 kg), curd length (15.70 cm), curd circumference (22.99 cm), number of sprouts per curd (4.9), marketable curd yield (514 g), net curd weight (462 g), curd yield per plot (10.16 kg) and curd yield per ha (47.04 t ha^{-1}) and superior biochemical quality with higher TSS (7.52 °Brix), ascorbic acid (85.30 mg/g), phenol (86.30 mg/100 g), non-reducing sugar (2.16%), total sugar (4.75%), reducing sugar (2.58%), protein (18.31%), carotene (3.44 mg/100 g) and carbohydrate (5.51%). The improvement was attributed to the synergistic role of micronutrients in enhancing nutrient uptake, photosynthesis, enzyme activity and assimilate partitioning. Thus, integrated micronutrient application proved effective in improving both yield and nutritional quality, making it a viable strategy for sustainable broccoli production under open field conditions.

Keywords: Broccoli, boron, molybdenum, zinc, micronutrients, yield and quality

Introduction
Vegetables play an essential role in Indian agriculture by enhancing productivity, providing nutritional security and improving farmers income. Among various cruciferous vegetables, broccoli (*Brassica oleracea* L. *var. italica* Plenck) has emerged as a highly nutritious crop of great economic importance. Originating from the Northern Mediterranean, broccoli is rich in essential nutrients such as vitamins A, B and C, calcium, phosphorus, iron and carotene, making it more nutritious than other cole crops like cabbage and cauliflower (Hazra and Som, 1999; Thamburaj and Singh, 2001) [5, 21]. It possesses strong antioxidant properties and contains bioactive compounds such as glucoraphanin and sulforaphane, which are known for their anticancer potential (Kalia, 1995; Aires *et al.*, 2006) [6, 1]. The crop grows best under cool and moist climatic conditions, with optimal temperatures ranging from 15 °C to 23 °C, and performs well in well-drained loamy soils with a pH of 6.0-7.0 (Rubatzky and Yamaguchi, 1997) [18].

Nutrient management plays a crucial role in determining the productivity and quality of broccoli. While macronutrients are required in larger quantities, micronutrients like boron (B), molybdenum (Mo) and zinc (Zn) are equally essential for various physiological and biochemical processes such as photosynthesis, chlorophyll formation and enzyme activation (Kaya and Higgs, 2002) [8]. Deficiencies of these elements often lead to disorders like hollow stem, whiptail and poor head compactness, resulting in reduced yield and market value (Chadha, 2001) [2]. Among various nutrient application methods, foliar fertilization is considered an effective and eco-friendly approach as it ensures quick nutrient absorption and utilization by plants.

However, limited research has been conducted on the influence of boron, molybdenum and zinc on broccoli growth and productivity under the Northern Transitional Zone of Karnataka. Therefore, the present investigation was undertaken to study the effects of these micronutrients on the yield, quality of broccoli cultivation in this region.

Materials 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 yield attributes (curd weight, curd length, curd circumferences, marketable curd weight, net curd weight, number of sprouts per curd, yield per plot and hectare) and quality traits (TSS, ascorbic acid, reducing non-reducing sugars, total sugar, protein, carbohydrate, carotene and phenols) were recorded. The data were statistically analyzed using analysis of variance (ANOVA) following Panse and Sukhatme (1985) [14].

Results and Discussion

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) [11] and Chaudhary *et al.* (2020) [3], 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) [4] and Mishra and Dashora (2009) [12], 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.* (2017) [20] and Patil *et al.* (2019) [15] 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.

Fig 1: Harvested curds in different treatments

Quality Parameters

Quality parameters such as total soluble solids (TSS), ascorbic acid, sugars, protein, carotene, phenols, and carbohydrate content were significantly influenced by micronutrient treatments. The treatment T_{13} (Borax @ 15 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + Zinc sulfate @ 15 kg ha^{-1}) recorded the highest values for all quality traits like TSS (7.52 °Brix), ascorbic acid (85.30 mg/g), reducing sugar (2.96%), non-reducing sugar (2.61%), total sugar (5.57%), protein (18.31%), carotene (3.44 mg/100 g), phenol (86.3 mg/100 g) and carbohydrate (6.42%). These were followed by T_{12}, while the control recorded the lowest values. The increase in TSS and sugar content under combined micronutrient application can be attributed to improved carbohydrate metabolism and enhanced translocation of sugars from leaves to curds, as influenced by boron and zinc. Similar results were reported by Verma and Bhardwaj (2005) [22] and Rana and Singh (2012) [17], who found increased TSS in cole crops due to balanced micronutrient management. Ascorbic acid content was significantly higher in T_{13} (85.3 mg/g), which may be due to the stimulatory role of molybdenum and zinc in enzymatic reactions enhancing vitamin C synthesis and antioxidant activity. Increased ascorbic acid also improves the nutritional and antioxidant value of broccoli. Comparable results were obtained by

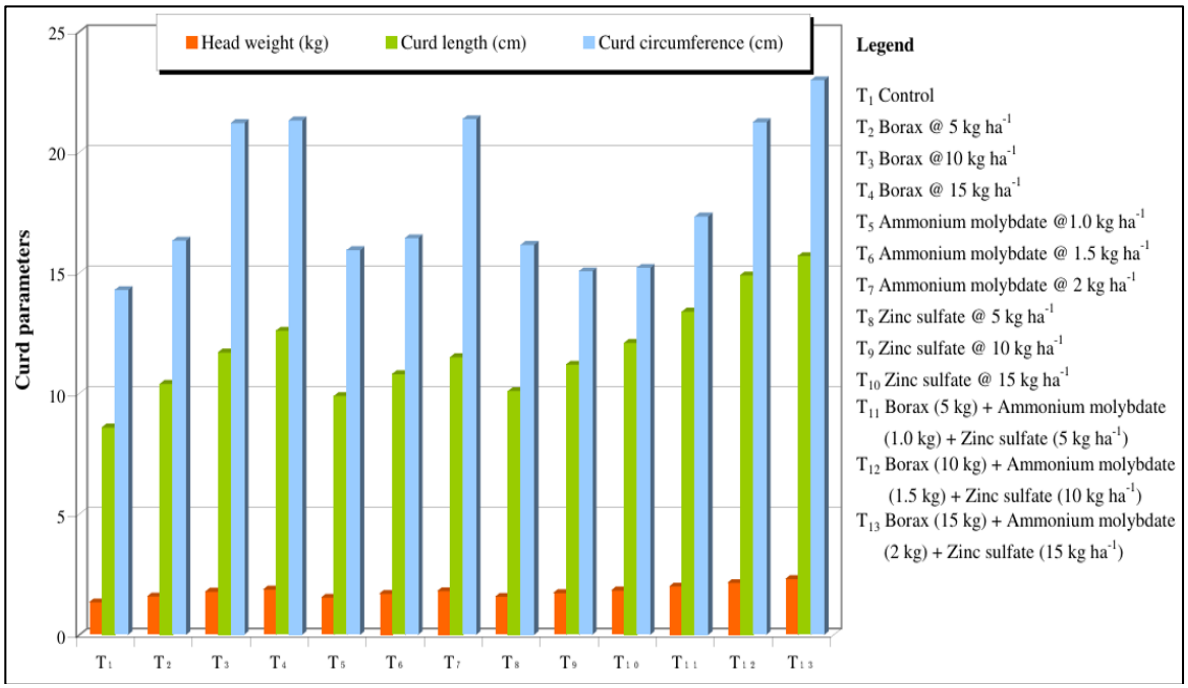

Fig 2: Curd parameter of broccoli as influenced by application of micronutrients under open condition

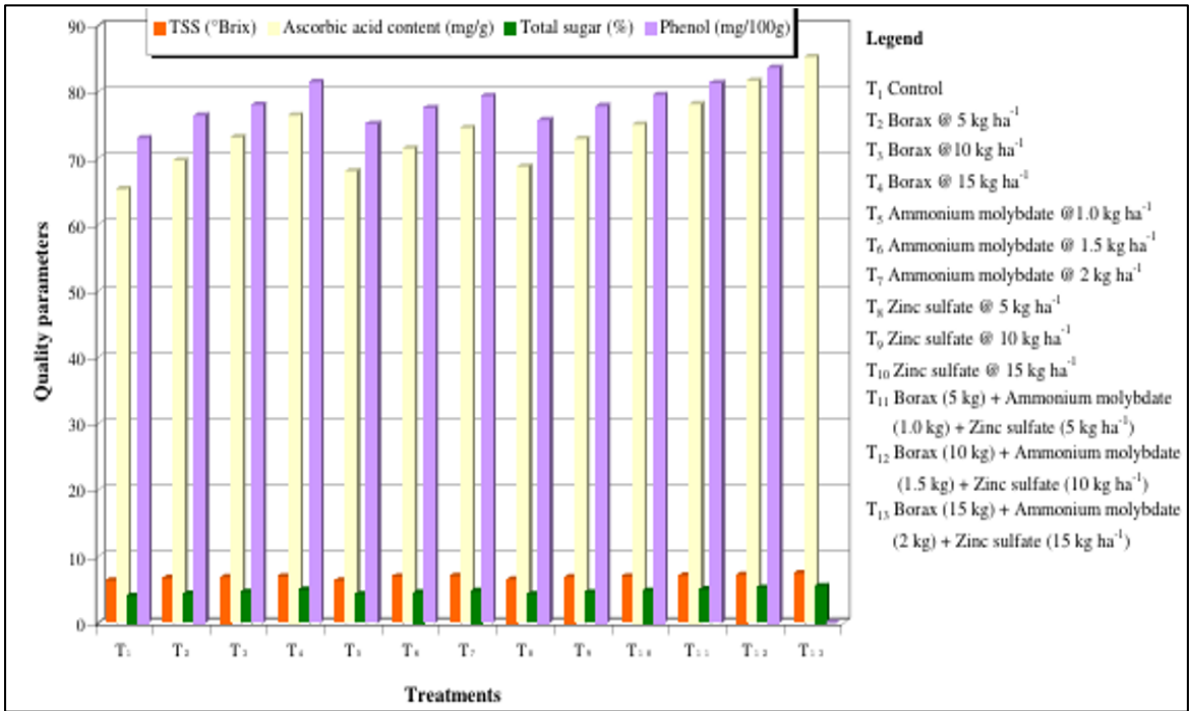

Fig 3: Quality parameters of broccoli as influenced by application of micronutrients under open condition

Kumawat *et al.* (2014) [10] and Pandey and Sengar (2017) [13], who reported increased ascorbic acid and vitamin content in brassicas under integrated micronutrient management. Higher protein content (18.31%) was observed in T_{13}, which may be attributed to improved nitrogen assimilation facilitated by molybdenum through its role in nitrate reduction. Zinc also plays an important role in enzyme activation and protein synthesis. The results are in line with those of Katiyar *et al.* (2018) [7]. The highest phenol content (86.3 mg/100 g) recorded in T_{13} was due to enhanced enzymatic activity, especially of phenylalanine ammonia-lyase, which is stimulated by boron and zinc, leading to increased phenolic compound synthesis. Increased phenol content enhances the antioxidant potential of broccoli, as also reported by Sable *et al.* (2014) [19] and Kumar *et al.* (2014) [9]. Carotene content (3.44 mg/100 g) and carbohydrate (6.42%) were also maximum in T_{13}, which may be due to improved chlorophyll formation, membrane integrity, and photosynthetic activity under balanced micronutrient supply. Similar findings were observed by Raghav *et al.* (2014) [16] in cole crops. The combined action of boron, molybdenum and zinc thus enhanced the biochemical composition and nutritive quality of broccoli, resulting in curds that were superior in flavor, appearance and shelf life compared to those produced under individual or control treatments.

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

Tr. No	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)
T_1	Control	1.35	8.60	14.29	2.49	312	270	5.94	27.50
T_2	Borax @ 5 kg ha^{-1}	1.59	10.40	16.34	3.53	365	318	7.00	32.41
T_3	Borax @ 10 kg ha^{-1}	1.79	11.70	21.21	4.46	402	352	7.74	35.83
T_4	Borax @ 15 kg ha^{-1}	1.88	12.60	21.32	4.51	428	375	8.25	38.19
T_5	Ammonium molybdate @ 1.0 kg ha^{-1}	1.54	9.90	15.94	2.93	348	308	6.78	31.39
T_6	Ammonium molybdate @ 1.5 kg ha^{-1}	1.70	10.80	16.44	2.96	388	340	7.48	34.63
T_7	Ammonium molybdate @ 2 kg ha^{-1}	1.81	11.50	21.37	3.08	412	362	7.96	36.85
T_8	Zinc sulfate @ 5 kg ha^{-1}	1.58	10.10	16.17	3.20	355	315	6.93	32.08
T_9	Zinc sulfate @ 10 kg ha^{-1}	1.73	11.20	15.07	3.21	390	345	7.59	35.14
T_{10}	Zinc sulfate @ 15 kg ha^{-1}	1.84	12.10	15.21	3.43	420	368	8.10	37.50
T_{11}	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
T_{12}	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
T_{13}	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 2: Effect of micronutrients on quality of broccoli under open condition

Tr. No	Treatment details	TSS (^{o}Brix)	Ascorbic acid content (mg/g)	Phenol (mg/100 g)	Non-Reducing sugar (%)	Total sugar (%)	Reducing sugar (%)	Protein (%)	Carotene (mg/100 g)	Carbohydrate (%)
T_1	Control	6.42	65.40	73.05	1.82	4.12	2.30	14.25	2.45	4.82
T_2	Borax @ 5 kg ha^{-1}	6.79	69.70	76.50	2.01	4.43	2.42	14.94	2.68	5.04
T_3	Borax @ 10 kg ha^{-1}	6.88	73.20	78.10	2.15	4.71	2.56	16.00	2.86	5.38
T_4	Borax @ 15 kg ha^{-1}	7.02	76.50	81.50	2.28	4.97	2.69	15.38	3.02	5.60
T_5	Ammonium molybdate @ 1.0 kg ha^{-1}	6.42	68.10	75.20	1.94	4.32	2.38	16.00	2.62	5.10
T_6	Ammonium molybdate @ 1.5 kg ha^{-1}	6.98	71.50	77.60	2.08	4.57	2.49	16.44	2.80	5.44
T_7	Ammonium molybdate @ 2 kg ha^{-1}	7.10	74.60	79.40	2.21	4.82	2.61	16.75	2.95	5.61
T_8	Zinc sulfate @ 5 kg ha^{-1}	6.59	68.80	75.80	1.96	4.36	2.40	15.38	2.64	5.20
T_9	Zinc sulfate @ 10 kg ha^{-1}	6.89	73.00	77.90	2.10	4.63	2.53	15.75	2.84	5.49
T_{10}	Zinc sulfate @ 15 kg ha^{-1}	7.04	75.10	79.60	2.24	4.90	2.66	16.19	3.03	5.65
T_{11}	Borax (5 kg) + Ammonium molybdate (1.0 kg) + Zinc sulfate (5 kg ha^{-1})	7.20	78.20	81.40	2.33	5.08	2.75	17.00	3.14	5.81
T_{12}	Borax (10 kg) + Ammonium molybdate (1.5 kg) + Zinc sulfate (10 kg ha^{-1})	7.28	81.70	83.70	2.46	5.30	2.84	17.94	3.26	6.14
T_{13}	Borax (15 kg) + Ammonium molybdate (2 kg) + Zinc sulfate (15 kg ha^{-1})	7.52	85.30	86.30	2.61	5.57	2.96	18.31	3.44	6.42
	Mean	6.83	73.90	79.03	2.16	4.75	2.58	16.17	2.90	5.51
	S.Em(±)	0.24	2.35	1.38	0.05	0.08	0.035	0.28	0.05	0.09
	CD @ 5%	0.95	9.31	5.77	0.20	0.33	0.140	1.13	0.20	0.38

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 yield and quality of broccoli under open field conditions. This treatment recorded the highest curd weight, yield, and superior quality parameters such as TSS, ascorbic acid, sugars, protein, carotene, and phenols. 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.

References

1. Aires A, Rosa EAS, Carvalho R. Effect of nitrogen and sulfur fertilization on glucosinolates in broccoli (*Brassica oleracea* var. *italica*) sprouts. J Sci Food Agric. 2006;86(10):1512-1516.
2. Chadha KL. Handbook of horticulture. New Delhi: Indian Council of Agricultural Research; 2001.
3. Chaudhary RC, Yadav DS, Kumari R. Effect of micronutrient application on growth and yield of broccoli (*Brassica oleracea* var. *italica*). Int J Chem Stud. 2020;8(2):1916-1919.
4. Chauhan DVS, Singh P, Yadav RK. Influence of micronutrient fertilization on growth and yield of broccoli (*Brassica oleracea* var. *italica*). J Pharmacogn Phytochem. 2017;6(4):369-372.
5. Hazra P, Som MG. Technology for vegetable crops production and improvement. Calcutta: Naya Prokash; 1999.
6. Kalia P. Biochemical assays and yield performances of sprouting broccoli genotypes of Himachal Himalayas. Cruciferae Newsl. 1995;17:90-91.
7. Katiyar D, Singh VB, Singh DK. Effect of micronutrients on yield and quality of cole crops. Int J Chem Stud. 2018;6(2):672-676.
8. Kaya C, Higgs D. Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. J Plant Nutr. 2002;25(10):2229-2240.
9. Kumar R, Singh JP, Singh R. Effect of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*). Veg Sci. 2014;41(1):42-45.
10. Kumawat RN, Singh RP, Choudhary R. Effect of micronutrients on growth and yield of cabbage (*Brassica oleracea* var. *capitata*). Int J Agric Sci. 2014;10(2):652-655.
11. Meena ML, Maurya BR, Meena VS. Effect of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*). J Pharmacogn Phytochem. 2017;6(5):1642-1646.
12. Mishra BN, Dashora LK. Effect of micronutrient mixture on quality and yield of broccoli. Indian J Hortic. 2009;66(2):246-248.
13. Pandey RK, Sengar RS. Influence of foliar application of micronutrients on growth and yield of broccoli. Plant Arch. 2017;17(2):1365-1368.
14. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: Indian Council of Agricultural Research; 1985.
15. Patil RB, Deshmukh MS, Pawar SR. Micronutrient management in broccoli for better yield. Veg Sci. 2019;46(3):312-316.
16. Raghav M, Sharma R, Singh JP. Influence of micronutrients on pigment content and yield attributes of leafy vegetables. Veg Sci. 2014;41(1):47-50.
17. Rana DK, Singh V. Effect of micronutrients on growth, yield and quality of broccoli. Haryana J Hortic Sci. 2012;41(1-2):90-92.
18. Rubatzky VE, Yamaguchi M. World vegetables: principles, production and nutritive values. 2nd ed. New York: Chapman and Hall; 1997.
19. Sable RN, Patil HB, Patil DN. Effect of micronutrients on yield and quality of broccoli (*Brassica oleracea* var. *italica*). Int J Agric Sci. 2014;10(1):193-195.
20. Sharma A, Meena ML, Singh R, Kumar S. Impact of micronutrients on broccoli yield and quality. J Hortic Sci. 2017;12(2):125-130.
21. Thamburaj S, Singh N. Vegetables, tuber crops and spices. New Delhi: Directorate of Information and Publications of Agriculture, ICAR; 2001.
22. Verma TS, Bhardwaj AK. Influence of micronutrients on quality parameters of cole crops. Indian J Agric Sci. 2005;75(4):240-243.