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Impact of foliar application of Various micronutrients on broccoli (*Brassica oleracea* Var. Italica) growth and yield-related characteristics

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ABSTRACT
To investigate the " Impact of foliar application of various micronutrients on broccoli (Brassica oleracea Var. Italica) growth and yield-related characteristics", a field experiment was carried out during rabi season of during rabi season of 2020-21 at Horticulture Research Farm, Department of Agriculture, Plantica Agriculture Institute, Dehradun. Three replications and a randomized complete block design were used to set up the experiment. The treatments included three foliar sprays of boric acid @ 100 ppm (T1), manganese sulphate @ 100 ppm (T2), zinc sulphate @ 100 ppm (T3), ammonium molybdate @ 100 ppm (T4), copper sulphate @ 100 ppm (T5), ferrous sulphate @ 100 ppm (T6), combinations of T1 with T2 to T6 (T7 to T11, respectively), mixed T1–T6 (T12), a commercial "Multiplex" formulation at 100 ppm (T13) and a spray-free control (T0). The results of analysis of variance for various quantitative characters showed highly significant mean squares due to treatments for all the characters. The effect of different micronutrient application showed significant increase for number of leaves per plant (10. 80), Polar head diameter (22.50 cm), Equatorial head diameter (24.20 cm), Head compactness (3.80 g/cm^3), Head weight (816.70g) and Head yield (408.30q/ha) in T8, T2 found desirable for Root length (16.90cm) and Days to 50% curd maturity (76.00), significantly increased plant spread (40.01cm) at 60 DAT were observed in T11, maximum stalk length (12.40 cm) at 60 DAT was found in T5 whereas lowest observations for all the traits were found in T0 (control) under agro climatic conditions of Dehradun.

Key words: *foliar sprays, quantitative characters, micronutrient application, growth and yield.*

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INTRODUCTION

The enormous flowering head of the Brassicaceae family member known as broccoli (Brassica oleracea L. var. Italia) is used as a vegetable. Broccoli, sometimes known as sprouting broccoli, is an expensive and rare crop grown for its delicate blooming head and its secondary heads, or spears. It may be broadly divided into three groups: green, purple, and white. Of these, the green form is the richest in nutrients [1]. Around the world, broccoli is commonly produced in temperate, tropical, and subtropical climates. The Mediterranean Sea's coastal regions are where the broccoli crop originated. Italian broccoli was first planted in the country during the Roman era. About 1923, broccoli began to be grown commercially [2]. However, broccoli has been shown to withstand a higher temperature than cauliflower because to its superior environmental adaptation [3].

Broccoli is cultivated in almost every nation these days. Its primary stem sprouts several robust branches, each of which sprouts a robust growing cluster encircled by leaves. China leads the world in broccoli production, with India coming in second. The Nilgiri hills, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, and the northern plains of India are the main hilly regions where it is grown. Broccoli is an important vegetable crop and has high nutritional and good commercial value [1]. It is one of the most nutrient-dense foods known which is a good source of dietary fiber and chock full of vitamins and minerals i.e., Vitamins A, C, K, E (Alpha Tocopherol), B6, Folate, Niacin, Pantothenic Acid, Ca, Fe, Mg, P, K and Zn. Additionally, it contains 3.3% protein, thiamine, and riboflavin Fe [4]. Indole-3-carbinol, which is found in broccoli, aids in the prevention of lung and breast cancer [5]. It may be cooked as a single or

combined vegetable with potato, eaten as a salad, and used in curries, soups, and pickles [6]. Moist, rich soil with a pH of 6.0 to 7.0 and a temperature range of 15.5 to 18 °C (60–65 °F) are suitable for the development of broccoli [7].

Micronutrients are crucial for healthy plant nutrition even though they are utilized in less quantity than other key elements. Broccoli growth and produce are increased by mineral fertilizer because meristematic activity is influenced by nitrogen, phosphorus, and potassium. Micronutrients such as molybdenum, boron, copper, iron, manganese, and zinc are also necessary for plant development and metabolism in addition to the important macronutrients. They play a crucial role in the synthesis of proteins, the production of chlorophyll, and the oxidation-reduction process in biological systems. They also comprise an essential component of the enzyme system [8.9]. Numerous alterations in anatomy, physiology, and biology are brought about by deficiencies. Signs and symptoms of the deficient plant include sword-like leaves (whiptail), browning of the heads, and hollow stems. The aim of the present experiment is to investigate the response of growth attributing traits of broccoli through foliar spray of formulations of different micronutrients individually as well as in combination.

MATERIAL AND METHODS

The present investigation was conducted in the temperate Himalaya of Uttarakhand" was carried out at Horticulture Research Farm, Department of Agriculture, Plantica Agriculture Institute, Dehradun, Uttarakhand during rabi season of 2020-21. Three replications and a randomized complete block design were used to set up the experiment. The treatments included three foliar sprays of boric acid @ 100 ppm (T1), manganese sulphate @ 100 ppm (T2), zinc sulphate @ 100 ppm (T3), ammonium molybdate @ 100 ppm (T4), copper sulphate @ 100 ppm (T5), ferrous sulphate @ 100 ppm (T6), combinations of T1 with T2 to T6 (T7 to T11, respectively), mixed T1–T6 (T12), a commercial "Multiplex" formulation at 100 ppm (T13) and a spray-free control (T0), as listed in Table 1. The schedules of foliar spray were at fortnightly interval from 15 days after transplanting. The crop of broccoli hybrid Calabrese (F1) was raised by transplanting 30 days old seedlings in plots of 6.25 m^2 (2.5m x 2.5m) size at 45x45 cm spacing. The crop was supplemented with compost @15.0 t/ha and a fertilizer dose of 120:60:45 kg NPK/ha. The data were recorded on Plant spread (cm) 30 Days, Plant spread (cm) 60 Days, Stalk length (cm) 30 Days, Stalk length (cm) 60 Days, number of leaves per plant, Days to 50 % curd maturity, Root length (cm), polar head diameter (cm) equatorial head diameter (cm), head compactness (g/cm3), head weight (g) and head yield (q/ha).

RESULT AND DISCUSSION

The results of analysis of variance for various quantitative characters showed highly significant mean squares due to treatments for all the characters (Table 1). As a result, the findings demonstrated the existence of significant heterogeneity in the study's experimental materials.

Plant spread (cm):-Table 2 and Figure 1 provide a graphic representation of the results regarding the impact of foliar spraying various micronutrients on the plant spread of broccoli at 30 and 60 days after treatment. At 30 DAT, the plant spread was maximum (21.20 cm) in T7 and T10 (Boric Acid @100ppm + Manganese Sulphate @100ppm and Boric Acid @100ppm + Copper Sulphate @100ppm) followed by 20.70 cm inT8 (Boric Acid @100ppm + Zinc Sulphate @100ppm). The lowest plant spread found in T0 (control) 16.00 cm. Plant spread at 60 DAT is differed significantly due to various treatment combinations. At 60 DAT T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) gave maximum plant spread (39.09 cm). These results are similar recorded by Singh et al [9], Singh *et al* [10] and Singh et al [11]in broccoli and Farag et al. [12] in cauliflower.

Stalk Length (cm): The results revealed the effect of foliar spray of different micronutrient on stalk length of Broccoli at 30 DAT and 60 DAT are tabulated and graphically presented in Table 2 and Fig 2. At 30 DAT the result showed that the stalk length was maximum (6.40 cm) for T4 (Ammonium Molybdate @100ppm) followed by 5.80 cm in T11 (Boric Acid @100ppm + Ferrous Sulphate @100ppm), 5.30 cm in T7 (Boric Acid @100ppm + Manganese Sulphate @100ppm) and T3(Zinc Sulphate @100ppm). The lowest stalk length was observed 3:00 cm in T0 (control). The various treatment combinations showed significant variability in stalk length at 60 DAT. The maximum Stalk length was found 13.40 cm in T2 (Manganese Sulphate @100ppm) followed by 12.40 cm in T5 (Copper Sulphate @100ppm) and 12.20 cm in T6 (Ferrous Sulphate @100ppm). Similar finding has been reported by Agarwal and Ahmed [1], Singh *et al* [9], Singh *et al* [10], Singh *et al* [11] and Dhotra *et al*[13] in broccoli.

Numbers of leaves per Plant: The results of this experiment indicate that there was significant effect of foliar spray of micronutrient on the numbers of leaves per plant of broccoli over the unsprayed controlled. The maximum numbers of leaves per plant was found 10.80 in T8 (Boric Acid @100ppm +

Zinc Sulphate @100ppm) followed by 9.60 in T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm)and 9.20 in T12 (Mixture of B, Zn, Mo, Cu, Fe & Mn salt solutions (T1 to T6)) while the lowest number of leavers per plant was observed in Control (T0) i.e. 7.60 cm Fig 3.Similar findings had been observed by Dhotra *et al*. [13] in broccoli, Chaudhari *et al* [14], Singh et al. [9], Farag *et al*. [12] in cauliflower.

Table no. 1: Analysis of variance for the effect of foliar spray of micronutrients at different characters in Broccoli.

S.V.	d.f.	Mean of squares											
		PS 30 DAT	PS 60 DAT	SL 30 DAT	SL 60 DAT	NL/P	50 % CM	RL	PHD	EHD	HC	HW	HY
Replication	2	0.79	0.92	0.02	0.00	0.02	2.27	0.19	0.40	0.02	0.00	235.84	12.58
Treatment	13	8.377**	7.755**	3.091**	4.930**	2.410**	64.476**	7.771**	9.974**	9.274**	0.648**	54796.073**	11057.467**
Error	26	0.19	1.04	0.01	0.06	0.05	5.03	0.98	0.17	0.39	0.01	322.82	63.65
SEm±		0.25	0.59	0.06	0.14	0.12	1.30	0.181	0.24	0.36	0.04	10.37	4.61
CD (at 5%)		0.74	1.72	0.16	0.40	0.36	3.79	0.53	0.70	1.05	0.13	30.32	13.46
CV (%)		2.30	2.74	2.11	2.15	2.54	2.72	2.34	2.20	3.03	2.73	3.13	2.74

Table no. 2: Effect of different micronutrient application on various characters in Broccoli.

Treatments	PS 30 DAT	PS 60 DAT	SL 30 DAT	SL 60 DAT	NL/P	50 % CM	RL	PHD	EHD	HC	HW	HY
T0	16.00	35.29	3.00	9.00	7.60	90.00	11.00	16.40	18.60	2.40	289.00	174.50
T1	17.00	34.46	4.20	9.60	7.90	79.00	12.40	17.90	19.40	2.80	652.30	311.20
T2	17.60	35.98	5.10	13.40	8.30	76.00	16.90	18.50	19.70	2.30	487.30	243.70
T3	17.50	34.69	5.30	10.20	7.70	81.00	13.20	16.90	19.20	2.60	573.30	281.70
T4	18.20	38.63	6.40	11.20	8.20	89.00	14.20	18.10	20.40	2.70	575.00	287.50
T5	19.60	36.81	4.20	12.40	8.60	79.00	13.20	17.50	20.10	2.30	508.30	284.20
T6	19.00	37.82	3.10	12.20	7.80	84.00	15.40	18.20	20.50	2.70	480.00	240.00
T7	**21.20**	36.59	5.30	12.30	7.50	85.00	13.50	18.30	19.80	2.40	544.30	272.20
T8	20.70	39.09	5.00	10.20	10.80	87.00	14.50	22.50	24.20	3.80	816.70	408.30
T9	18.30	37.43	4.10	11.20	9.60	82.00	13.20	21.80	23.50	3.50	766.70	383.30
T10	**21.20**	38.89	3.40	10.50	8.30	81.00	11.20	18.60	20.30	2.90	566.70	283.30
T11	21.00	40.01	5.80	9.40	8.50	77.00	12.40	17.80	19.20	2.40	476.00	258.00
T12	18.00	34.03	3.90	11.50	9.20	78.00	14.20	21.20	23.10	3.30	725.00	362.50
T13	19.40	36.93	4.20	10.60	8.40	88.00	11.90	19.60	19.40	2.90	566.70	283.30
SEm±	0.25	0.59	0.06	0.14	0.12	1.30	0.181	0.24	0.36	0.04	10.37	4.61
CD (at 5%)	0.74	1.72	0.16	0.40	0.36	3.79	0.53	0.70	1.05	0.13	30.32	13.46

Fig 1. : Effect of different micronutrient application on Plant Spread in Broccoli.

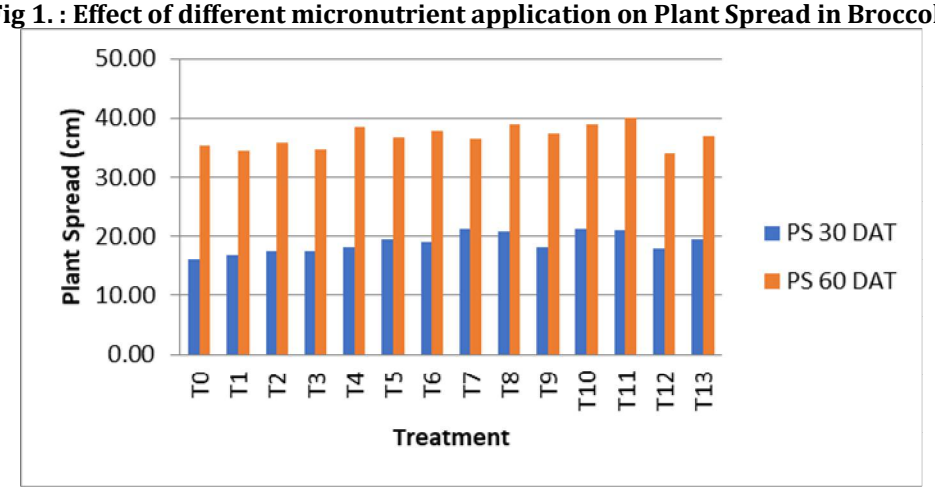


Fig 2. : Effect of different micronutrient application on Stalk Length in Broccoli.

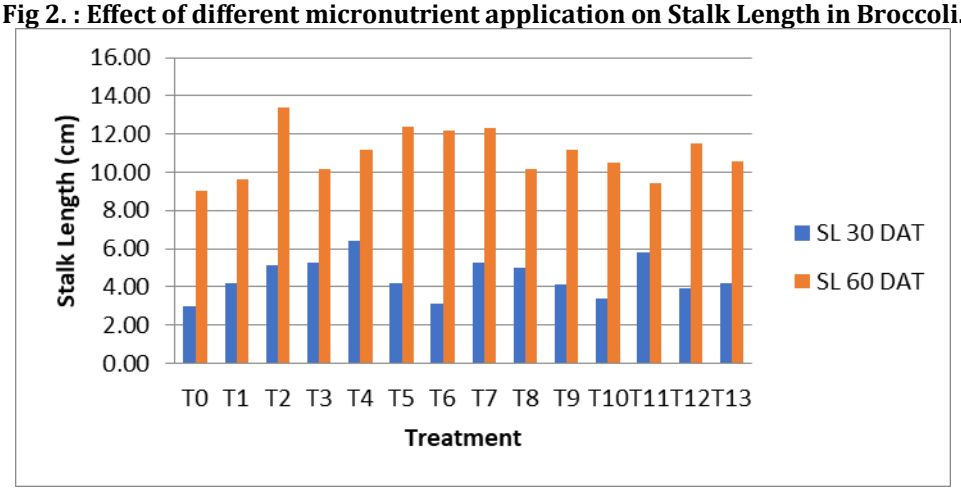


Fig 3. : Effect of different micronutrient application on Number of leaves per plant in Broccoli.

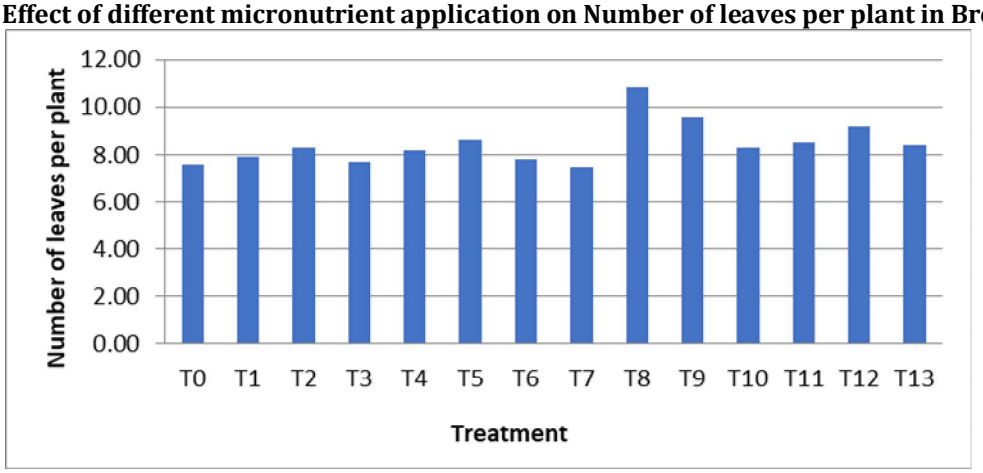


Fig 4. : Effect of different micronutrient application on Days to 50% curd maturity in Broccoli.

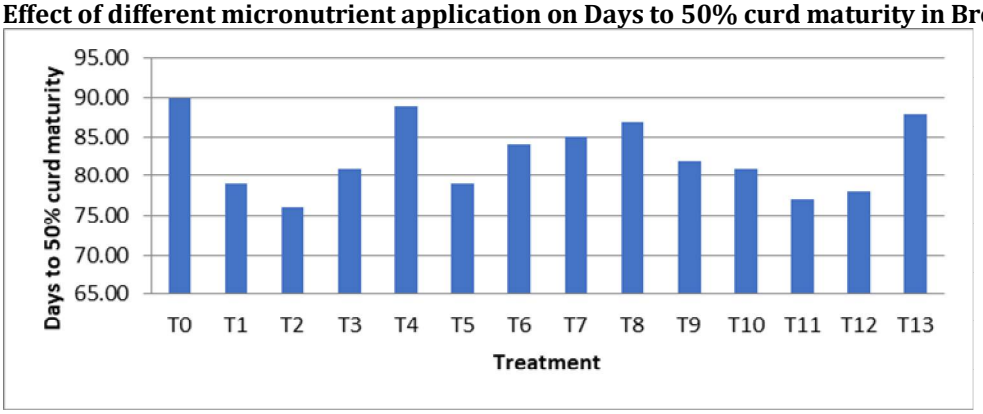


Fig 5. : Effect of different micronutrient application on Root Length in Broccoli.

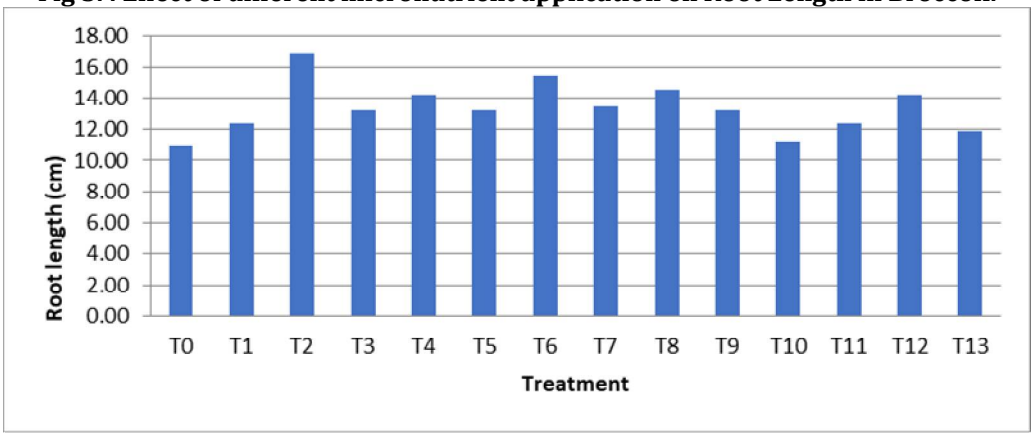


Fig 6. : Effect of different micronutrient application on Polar head diameter in Broccoli.

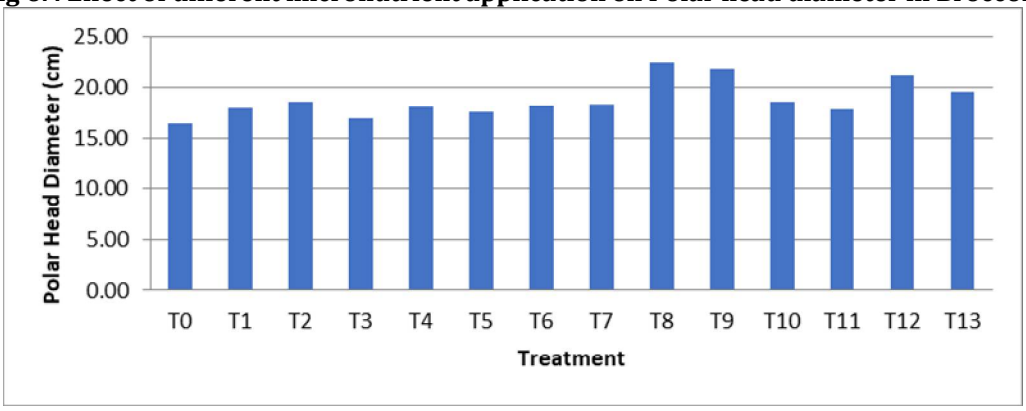


Fig 7. : Effect of different micronutrient application on Equatorial head diameter in Broccoli.

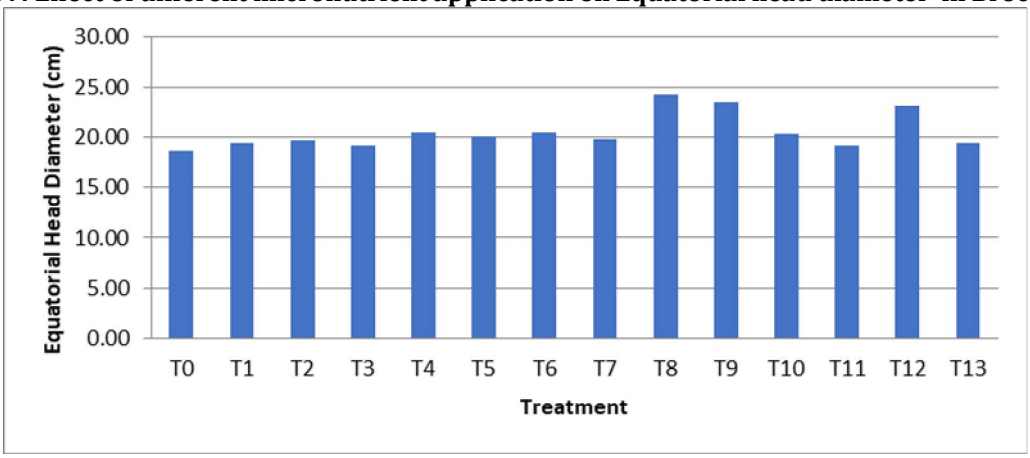


Fig 8. : Effect of different micronutrient application on Head compactness in Broccoli.

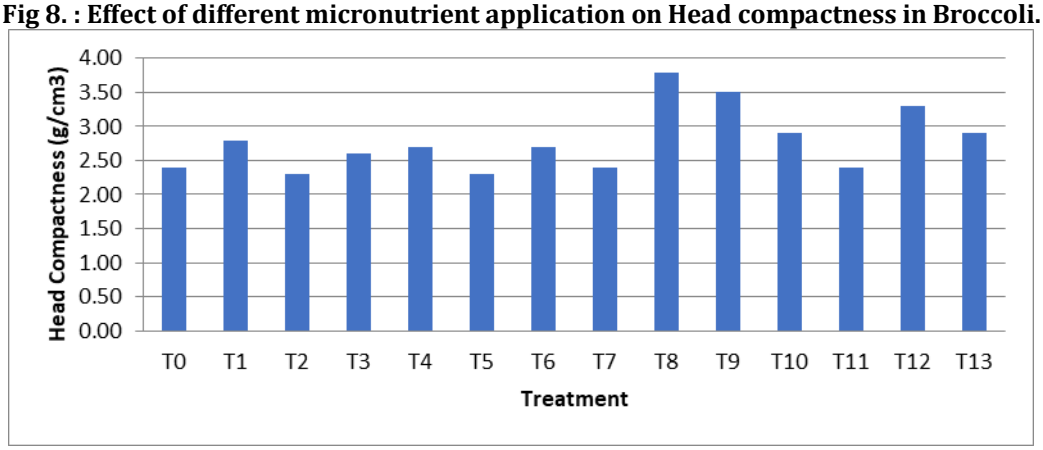


Fig 9. : Effect of different micronutrient application on Head weight in Broccoli.

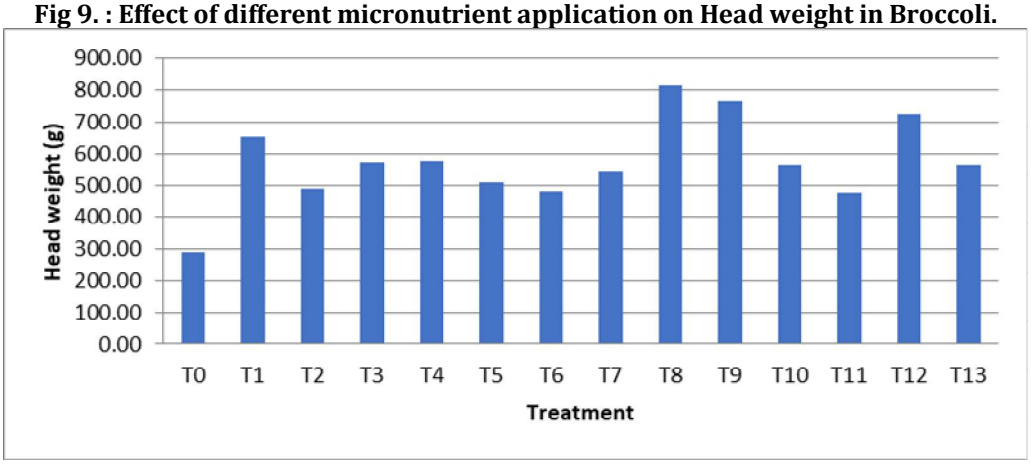
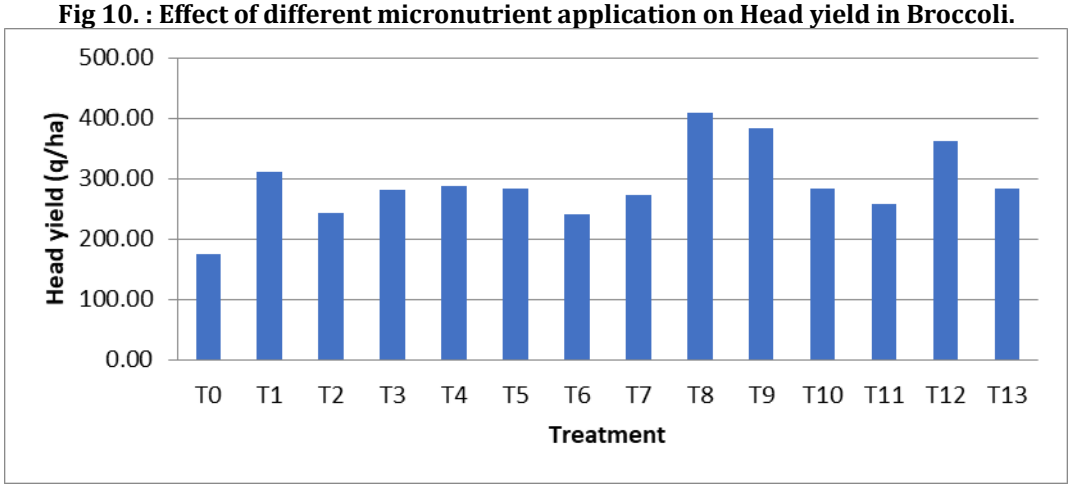


Fig 10. : Effect of different micronutrient application on Head yield in Broccoli.



Days to 50% Curd Maturity: Different micronutrient application significantly influenced the Days to 50% curd maturity over control. Table 2 and fig 4 reveals that the minimum number of days to 50% curd maturity(76.00) was recorded with T2 (Manganese Sulphate @100ppm) followed by 77.00 in T11 (Boric Acid @100ppm + Ferrous Sulphate @100ppm) and T12 (Mixture of B, Zn, Mo, Cu, Fe & Mn salt solutions (T1 to T6)) i.e. 78.00, which were significantly lower than other treatment. The maximum days to 50% curd maturity (90.00) was observed in treatment T0(control). This result is in conformity with the finding of Patel et al. [15]in cabbage, Singh et al. [9] in broccoli and Chandni et al. [16] in cauliflower.

Root Length (cm): The treatmentT2 (Manganese Sulphate @100ppm) showed maximum root length (16.90 cm) followed by 15.40 cm in T6 (Ferrous Sulphate @100ppm) and 14.50 cm in T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) which was significant over the unsprayed control having root

length of 11:00 cm fig 5. Similar result was in agreement with finding of Kumar [17] and Sharma [18], Singh etal. [9] in broccoli.

Polar head diameter: Table 2 and fig. 6 shows that the polar head diameter was significantly influenced by the different treatment combination tried. The treatment T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) had significantly the highest polar head diameter (22.50 cm) followed by T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm) is 21.80 cm. Lowest polar head diameter16.40 cm was observed in T0 (control). These results are closely recorded by Lashkari et al. 2008 in cauliflower, Naher *et. al* [19]in cabbage, Singh et al [10] and Singh *et.al* [11] in broccoli.

Equatorial head diameter: On observing the data, table 2 and fig. 7 shows that there was significant difference among various treatment combinations regarding equatorial head diameter. Maximum equatorial head diameter (24.20 cm) was observed in T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) followed by 23.50 cm T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm) and minimum (18.60) were found in T0 (control). These results are closely recorded by Lashkari et al. [20] in cauliflower, Naher *et.al*[19]in cabbage, Singh *et al*[10] and Singh *et al*[11] in broccoli.

Head compactness: The table 2 and fig 8 shows that the treatment T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) and T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm) had significantly more head compactness than other treatment (3.80 g/cm3and 3.50 g/cm3).The treatment T0 (control) recorded lowest head compactness (2.40 g/cm3).These results are closely recorded by Lashkari *et.al*[20] in cauliflower, Naher *et.al* [19]in cabbage.

Head weight: The data respect of mean head weight observed are presented in table 2 and fig 9. It‟s seen from results that, there was highest head weight in T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) 816.70g followed by 766.70g in T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm) and lowest head weight was found in T0 (control) is 289.00. These results are similar to the finding of Singh *et.al* [10], Singh *et.al*[11] and Singh *et.al*[8] in broccoli**.**

Head yield: The table 2 and fig 10 shows that the treatment T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) and T9 (Boric Acid @100ppm + Ammonium Molybdate @100ppm) had significantly more yield per hectare than other treatment (408.30 q/ha and 383.30 q/ha). The treatment T0 (control) recorded lowest yield per hectare (174.50 q/ha). Similar finding was observed by Singh *et.al [8]*, Singh *et.al [10],* Singh *et.al*[11] in broccoli and Chaudhari *et.al*[14]in cauliflower.

CONCLUSION

From the present studies it can be concluded that the treatment T8 (Boric Acid @100ppm + Zinc Sulphate @100ppm) was found to be the best treatment combination yield and flower bud quality parameters of Broccoli. Among 14 treatments, it has been concluded that the combined levels of optimum dose of micronutrients showed the best results in vegetative growth and yield parameters of broccoli. Micronutrients also increased the availability of other nutrients which are essential for plant growth. Micronutrients was involved in the protein synthesis, carbohydrate metabolism, synthesis of plant growth hormones which helped in better vegetative growth of broccoli.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Authors Contribution

Naveen Chandra: Investigation, Conceptualization, Writing - Original Draft preparation, **Kulveer Yadav:**Validation, Supervision, **Anoop Badoni:** Validation, Supervision **& Shantosh Bali:** Writing – Review, Editing &Proof reading,

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