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Effect of micronutrients on growth, yield and quality of chilli (*Capsicum annuum* L.) cv. pant C-1

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Abstract
The present study was carried out in the Agricultural Research Farm, at Department of Horticulture, School of Agriculture, Jaipur (Rajasthan) during 2022-23. The experiment was laid out in Randomized Block Design which comprises of ten treatment combinations *viz;* Control (T_0), boric acid @ 0.2% (T_1), boric acid @ 0.4% (T_2), boric acid @ 0.6% (T_3), copper sulphate @ 0.2% (T_4), copper sulphate @ 0.4% (T_5), copper sulphate @ 0.6% (T_6), zinc sulphate @ 0.2% (T_7), zinc sulphate @ 0.4% (T_8) and zinc sulphate @ 0.6% (T_9) and treatments were replicated three times. Appraisal of the result indicated that the influence of different concentrations of micronutrients on important parameters like vegetative growth, yield and quality attributes of chilli were significantly influenced by different concentrations of boric acid, copper sulphate and zinc sulphate under local agro-climatic conditions of Jaipur (Rajasthan).
The various concentrations of boric acid, copper sulphate and zinc sulphate had significant effect on various vegetative growth, yield and quality parameters and the (31.64 cm), (49.98 cm) and (75.98 cm) plant height at 45, 60 and 75 DAT, respectively, (14.54) branches per plant, (16.67) flowers per cluster, (45.43) fruits per plant, (2.99 cm) fruit girth, minimum (38.85 days) for and (45.10 days) took for 50% flowering and first harvesting, respectively and longest (8.27 cm) fruit, heaviest (11.25 g) fruit and highest (504.84 g) yield per plant, (12.12 kg) yield per plot, 15.89 t/ha) green chillies and (2.58 t/ha) dry red chillies yield were recorded under foliar application of boric acid @ 0.4% (T_2) treatment. However, the (31.64 cm), (49.98 cm) and (75.98 cm) plant height at 45, 60 and 75 DAT, respectively were recorded under foliar spray of boric acid @ 0.6% (T_3) treatment. Whereas, inferior results were observed under control (T_0) treatment. The foliar application of boric acid @ 0.4% performed significantly superior over control and remaining treatments to get highest green chilli yield per hectare. Results further indicated that the highest B: C ratio (2.90) from green chilli production was recorded under foliar application of boric acid @ 0.4% (T_2).

Keywords: Agricultural, micronutrients, yield, chilli, *Capsicum annuum* L.

Introduction
Chilli also known as hot pepper (*Capsicum annum* L.) is an important warm season vegetable cum spice crop grown throughout the world. It belongs to the family Solanaceae. It is originated in South America and domesticated from last 6000 years (Shoemaker, 1953) [38]. The Capsicum introduced by Portuguese from Brazil to India during 1584 and Christian missionaries introduced *Capsicum* species in the North-eastern states (Thamburaj and Singh, 2003) [44]. It is mostly cultivated in tropical and sub-tropical countries like Africa, USA, Japan, Mexico, India, Turkey, etc. It is grown as a cash crop on commercial scale in India (Anonymous, 2000) [5]. The total area under chilli cultivation is 4.26 million ha in the world with total production of 34.5 million tons (FAO, 2018) [15]. It is 3rd most growing vegetable next to tomato and potato (Naz *et al.*, 2006) [31]. It is a good source of nutrients and, also uses in pharmaceutical industry and has plenty of medicinal properties (Chowdhury, 1976) [11]. Due to its attractive color it is used in curry (Udoh *et al.*, 2005) [46]. It is rich in vitamins, especially in vitamin A and C (Saimbhi *et al.*, 1977 and Sayed and Bagavandoss, 1980) [35, 37].
India is the largest producer, consumer and exporter of chilli. India ranks first in area, and 2nd in production next to china. Chilli is being grown in an area of 3,61,000 ha with a production of 37,61, 000 MT and the productivity is 12.09 t ha^{-1} (Annoymous, 2017) [4]. In hilly areas of Kashmir chilli is sown in the month of April and transplanted in the month of May. Harvesting is done through pickings. Ten to twelve pickings are done within the season from July onwards and continue till September. Productivity could be increased by use of suitable varieties, balanced nutrition, and need based agronomic practices. The micronutrients play a vital role in the plant growth, development and production.

The most important micronutrient is boron which is the vital role for carbohydrate metabolism, nitrogen and cell division as well as help in the water relation of plant growth (Brady and Weil, 1990) [8]. The response of boron on different crops has been studied extensively (Smriti *et al.,* 2002) [42]. Boron plays an important role in cell wall synthesis and structure, membrane stability, growth and development of new cells in plants meristems (Brown *et al.,* 2002 and Iwai *et al.,* 2006) [9, 20]. Boron improves the flowering, fruit sets, fruit formation and fruit quality (Rawaa *et al.,* 2014) [34]. The reproductive organs are developed by boron (Huang *et al*., 2000) [19] and boron increases the yield of fruits (Chen *et al*., 2005 and Nabi *et al*., 2006) [10, 29]. Translocation of sugar, starches, nitrogen, phosphorus, synthesis of amino acids and proteins are also influenced by boron (Rawaa *et al.,* 2014) [34].

Zinc is also one of the most important micro-nutrient which is very necessary for growth and physiological function of plant and also involved in the formation indole acetic acid, enzymatic reactions and a number of enzymes, i.e. dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase (Mousavi, 2011) [28]. Zinc enhances the fruit set by increases the number of flowers. However, excessive application of zinc can adversely affect the ionic homeostatic system which interferes with the uptake, transport and osmotic regulation of essential ions leading to disruption of normal metabolic processes such as photosynthesis, transpiration and enzymatic activities related to metabolism (Sainju *et al.,* 2003) [36]. Zinc promotes yield, due to its role in carbonic enzyme in the biosynthesis particularly in chlorophyll (Ali *et al.,* 2008) [1]. Zinc also serves as co-factor or functional element of different enzymes associated with carbohydrate metabolism, auxin metabolism, formation of anther, pathogens resistance (Alloway, 2008) [2].

Hence, the foliar application of micronutrients increased the uptake of macronutrients in the tissues and organs and improves fruit quality (Anees *et al.,* 2011) [3]. Now-a-days, micronutrients are gradually gaining popularity among the fruit growers because of their beneficial nutritional support. The demand for increasing fruit production will require a thorough knowledge on the relationship between micronutrients and crop growth. Foliar application of micronutrient is one of the tools to enhance plant nutrients and deficiencies can eliminated during the growing season. Foliar fertilization also allows for multiple application timings at post planting.

The available information regarding the impact of micronutrients on vegetable crops is scanty. Keeping this in view, the present investigation was undertaken with the objective to find out best combination of micronutrient for quality chilli production under semi-arid conditions of Jaipur.

Materials and Methods

The present research was carried out in the at Agricultural Research Farm at Suresh Gyan Vihar University, Jaipur (Rajasthan) to study the effect of micronutrients on chilli during the year 2022-23. The experiment was laid down in Randomized Block Design which consisted 10 treatment combinations *viz;* Control (T_0), boric acid @ 0.2% (T_1), boric acid @ 0.4% (T_2), boric acid @ 0.6% (T_3), copper sulphate @ 0.2% (T_4), copper sulphate @ 0.4% (T_5), copper sulphate @ 0.6% (T_6), zinc sulphate @ 0.2% (T_7), zinc sulphate @ 0.4% (T_8) and zinc sulphate @ 0.6% (T_9) and treatments were replicated three times. Appraisal of the result indicated that the influence of plant growth regulators on important parameters like vegetative growth, yield and quality attributes of chilli were significantly influenced by micronutrients under local agro-climatic conditions of Jaipur (Rajasthan). The observations were measured on the five randomly selected and tagged plants in each plot and their mean value was calculated. To test the significance of variation in data obtained from various growth, yield and quality characters. Significance of difference in the treatment effect was tested through 'F' test at 5 percent level of significance and CD (critical difference) was calculated, wherever the results found significant.

Results and Discussion

Vegetative Growth Parameters

The foliar application of different concentration of boric acid, copper sulphate and zinc sulphate had significant impact and remarkable increase in growth and yield characteristics of chilli. The significant increase in plant height at periodical growth was observed by all treatment combinations of the exogenous application of various micronutrients. The maximum (31.64 cm), (49.98 cm) and (75.98 cm) plant height were recorded at foliar application of boric acid @ 0.6% (T_3) treatment at 45, 60 and 75 DAT, respectively (Table1). Boron plays an important role in activation of cell division and cell elongation. Therefore, boron enhances the number of metabolites necessary for building plant organs, consequently the vegetative growth of plants increased (Marschner, 1995) [26]. The maximum (162.47) leaves and (14.54) branches per plant were observed in plants foliar sprayed with boric acid @ 0.6% (T_3). The increase in plant height, number of leaves and branches per plant this might be due to enhancing of metabolites necessary for building plant organs by boron and exogenous application of boric acid that increases in cell wall plasticity and elongation in cell wall (Yugandhar *et al*., 2014) [41]. These results are found in agreement with the findings of Suganiya and Kumuthini (2015) [43]. The minimum (38.85 days) and (45.10 days) took for 50% flowering and first harvesting, respectively under foliar spray of boric acid @ 0.4% (T_2) treatment whereas, the maximum (63.65 days) and (69.90 days) took for 50% flowering and first harvesting, respectively under water sprayed plants in control (Table 1). These results are in close conformity with the results of Elankavi *et al.* (2009) [13] who also observed that the exogenous application of boric acid significantly reduces the number of days for flowering and first picking. It might be due to application of boric acid which increases the fruit set and advances the flowering which ultimately reduces the number of days for first harvesting (Kumar *et al.,* 2018) [23]. The results are in conformation with the findings of Osman *et al.* (2019) [33] and Gopal and Sarangtham (2021) [16].

Reproductive structures

Fruit set is one of the most key factors in fruit crops since it impacts the amount of fruit production and the total yield. Several other normal events, including as the formation of male and female parts, pollination, germination of pollen grains on stigmatic surfaces, pollen tube growth, and finally complete fertilization, all influence fruit set. Fruit set increased dramatically with the spraying of low concentration of micronutrient in chilli (Nawaz *et al.,* 2011) [30]. Fruit set is a critical stage in the conversion of a flower into a fruit in order to get a high yield and maximize a grower's profits

(Lovatt, 1999) [24]. The maximum (16.67) flowers per cluster and (45.43) fruits per plant were recorded under foliar spray of boric acid @ 0.4% (T_2) treatment whereas, the minimum (11.38) flowers per cluster and (27.67) fruits per plant under control (Table 1). It might be due to micronutrients application that attributed to enhanced photosynthesis activity and increased production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers. The foliar spray of micronutrients was found to be most effective in reducing premature fruit drop (Chen *et al.*, 2005) [10]. It might be due to the sufficient application and the efficient absorption of foliar sprayed boron that promote the production of more photosynthesis required for good number of chilli fruits. Similar results were also reported by Gopal and Sarangtham (2021) [16] and Umesh *et al.* (2021) [47].

Fruit quality parameters

The micronutrients (H_3BO_3, $CuSO_4$ and $ZnSO_4$) resulted in a considerable increase in fruit length, breadth, weight and volume (Kaur *et al.*, 2016) [22]. The role of boric acid in improving fruit quantity namely, fruit weight and fruit size may be due to its role in increasing cell elongation and cell division (Eman *et al.*, 2007) [14]. The maximum (8.27 cm) fruit length was recorded under foliar spray of boric acid @ 0.4% (T_2) treatment followed by (7.41 cm) in boric acid @ 0.6% (T_3) treatment (Table 2). These results are in close conformity with the findings of Baloch *et al.* (2008) [6] and Singh *et al.* (2019) [39]. The increase in fruit length and fruit diameter might be due to more accumulation of photosynthesis which were synthesized in the leaf and translocated towards the fruit. The increased and accumulation of photosynthesis was probably due to more vigor and growth (Trehan and Grewal, 1981 and Iyenger and Raja, 1988) [45, 21].

The application boric acid had significant influenced on the fruit growth rate like fruit length, girth and diameter. The maximum (2.99 cm) fruit girth was recorded under foliar spray of boric acid @ 0.2% (T_1) treatment followed by (2.92 cm), (2.79 cm) and (2.68 cm) fruit girth in boric acid @ 0.4% (T_2), Copper sulphate @ 0.4% (T_5) and boric acid @ 0.6% (T_3) treatment, respectively whereas, the minimum (1.13 cm) fruit girth was recorded in control (Table 2). It might be due to boron that promotes the photosynthesis rate and cell divisions that increase the fruit diameter (Singh and Tiwari, 2013) [40]. Boron and Zinc also help in the preparing tryptophan that is amino acids which helps in the biosynthesis of proteins and auxins that is plant growth regulators which result in the improving of fruit growth (Wojcik and Wojcik, 2003) [48]. These results are in accordance with the findings of Singh *et al.* (2019) [39] and Gopal and Sarangtham (2021) [16].

The role of boric acid in improving the fruit weight and fruit size may be due to its role in increasing cell division and cell elongation (Eman *et al.*, 2007) [14]. The highest (11.25 g) fruit weight was recorded under foliar application of boric acid @ 0.4% (T_2) treatment, whereas, the lowest (6.51 g) fruit weight was recorded under control (Table 2). It may also be stated that the application of optimum dose of calcium and boron were promote the production of more photosynthesis required for good fruit weight and its components. These results are in close conformity with the findings of These results are in close conformity with the findings of Osman *et al.* (2019) [33] and Umesh *et al.* (2021) [47].

Yield parameters

Among the different concentrations of boric acid, copper sulphate and zinc sulphate and the highest (504.84 g) fruits per plant was recorded under foliar spray of boric acid @ 0.4% (T_2) treatment. Similar trend was also reported on green chilli yield per plot and the treatment boric acid @ 0.4% (T_2) produced the highest (12.12 kg) fruits per plot (Table 2). The boric acid @ 0.4% (T_2) produced the highest (15.89 t/ha) green chillies, whereas, the lowest (5.62 t/ha) green chilliies were produced under in control (T_0). Hence, the foliar application of boric acid @ 0.4% performed significantly superior over control and remaining treatments to get highest green chilli yield per hectare. Hence, the foliar application of boric acid @ 0.4% had significant impact on yield and yield components (Table 2). Similarly, the highest (2.58 t/ha) dry red chillies yield was recorded under foliar spray of boric acid @ 0.4% (T_2), whereas, the lowest (0.90 t/ha) dry red chilliies yield was recorded under water sprayed plants in control (Table 2). Micronutrient foliar application improves photosynthesis and other metabolic activities, which help in increasing of cell division and elongation (Hatwar *et al.*, 2003) [18]. Foliar application of B and Zn increased the yield of chilli significantly as it enhanced the vegetative growth, retention of flowers and fruits, speeds up the process of photosynthesis which resultantly increased the photosynthates (CH_2O) by the result of which it increased the no. and weight of fruits and ultimately increased the yield. Almost similar results were also clarified by (Davis *et al*., 2003 and Basavarajeswari *et al*., 2008) [12, 7] in vary vegetable crops (Hatwar *et al.*, 2003) [18]. These results are in close conformity with the findings of Gopal and Sarangtham (2021) [16] and Umesh *et al.* (2021) [47].

The maximum highest B: C ratio (2.90) chilli production was recorded in boric acid @ 0.4% (T_2) treatment followed by (2.41) and (2.15) in boric acid @ 0.6% (T_3) and boric acid @ 0.2% (T_1), respectively (Table 2).

Table 1: Effect of micronutrients on vegetative and phenology characters

Treatments	Plant height (cm)			Number of leaves per plant	Number of branches per plant	Days to 50% flowering	Number of flowers per cluster	Number of days to first harvesting	Number of fruits per plant
	45 DAT	60 DAT	75 DAT						
Control (T_0)	14.70	33.04	59.04	128.37	9.94	63.65	11.38	69.90	27.67
Boric Acid @ 0.2% (T_1)	26.55	44.89	70.89	150.73	10.40	47.69	11.91	53.94	38.83
Boric Acid @ 0.4% (T_2)	28.66	47.00	73.00	162.47	14.54	38.85	16.67	45.10	45.43
Boric Acid @ 0.6% (T_3)	31.64	49.98	75.98	158.57	12.84	44.19	14.71	50.44	42.17
Copper sulphate @ 0.2% (T_4)	23.46	41.80	67.80	140.73	10.34	53.99	11.79	60.24	31.83
Copper sulphate @ 0.4% (T_5)	25.86	44.20	70.20	144.27	12.60	50.10	14.39	56.35	36.76
Copper sulphate @ 0.6% (T_6)	24.71	43.05	69.05	142.57	11.03	51.65	12.63	57.90	35.17
Zinc sulphate @ 0.2% (T_7)	16.34	34.68	60.85	137.73	9.94	49.99	11.37	56.24	32.83
Zinc sulphate @ 0.4% (T_8)	17.94	36.27	62.27	144.27	12.70	52.65	14.53	58.90	40.23

Zinc sulphate @ 0.6% (T_9)	17.06	35.40	61.40	140.57	11.64	54.99	13.30	61.24	36.17
S.Em±	0.97	1.26	3.05	5.24	0.43	1.93	0.50	2.65	1.13
C.D. (p=0.05)	2.90	3.77	9.13	15.68	1.30	5.78	1.48	7.94	3.38
CV (%)	7.39	5.31	7.88	6.25	6.46	6.58	6.47	8.06	5.36

Table 2: Effect of micronutrients on yield and quality parameters

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Green Chilli Yield			Dry chilli yield (t/ha)	B:C Ratio
				(g/plant)	(kg/plot)	(t/ha)		
Control (T_0)	4.81	1.13	6.51	178.63	4.29	5.62	0.90	1.03
Boric Acid @ 0.2% (T_1)	7.17	2.99	9.74	373.63	8.97	11.76	1.90	2.15
Boric Acid @ 0.4% (T_2)	8.27	2.92	11.25	504.84	12.12	15.89	2.58	2.90
Boric Acid @ 0.6% (T_3)	7.41	2.68	10.07	419.70	10.07	13.21	2.14	2.41
Copper sulphate @ 0.2% (T_4)	5.89	2.18	7.99	251.37	6.03	7.91	1.27	1.45
Copper sulphate @ 0.4% (T_5)	6.47	2.79	8.79	325.06	7.80	10.24	1.65	1.87
Copper sulphate @ 0.6% (T_6)	5.71	2.03	7.74	269.63	6.47	8.49	1.37	1.55
Zinc sulphate @ 0.2% (T_7)	5.39	1.71	7.31	237.55	5.70	7.48	1.21	1.37
Zinc sulphate @ 0.4% (T_8)	6.27	2.59	8.51	338.91	8.13	10.67	1.73	1.95
Zinc sulphate @ 0.6% (T_9)	5.71	2.03	7.74	277.38	6.66	8.73	1.41	1.59
S.Em±	0.30	0.13	0.39	14.19	0.25	0.53	0.06	
C.D. (p=0.05)	0.89	0.38	1.15	42.50	0.73	1.58	0.18	
CV (%)	8.18	9.43	7.79	7.74	5.56	9.12	6.41	

Conclusion

The application of micronutrients significantly influenced the vegetative growth parameters of chilli. The highest (504.84 g per plant), (12.12 kg per plot), (15.89 t/ha) green¬ chillies and (2.58 t/ha) dry red chillies yield and highest B: C ratio (2.90) was recorded under foliar spray of boric acid @ 0.4% (T2) treatment.

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