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# Interaction effect of boron and zinc on growth, yield and quality of chilli (*Capsicum annuum* L.) cv. 'Pant C-1'

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**Abstract**
The present investigation was carried out in the Agricultural Research Farm, at Horticulture Department, School of Agriculture, Jaipur (Rajasthan) during 2022-23. The experiment was laid out in Factorial Randomized Block Design which comprises of ten treatment combinations *viz;* Control ($T_0$), boron @ 0.2% ($T_1$), boron @ 0.4% ($T_2$), zinc @ 0.2% ($T_3$), zinc @ 0.4% ($T_4$), Boron @ 0.2% + Zinc @ 0.2% ($T_5$), Boron @ 0.2% + Zinc @ 0.4% ($T_6$), Boron @ 0.4% + Zinc @ 0.2% ($T_7$) and Boron @ 0.4% + Zinc @ 0.4% @ 0.4% ($T_8$) 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 boron and zinc under local agro-climatic conditions of Jaipur (Rajasthan).
The various concentrations of boron and zinc had significant effect on various vegetative growth, yield and quality and the maximum (31.64 cm) and (49.98 cm) plant height was recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment at 45 DAT and 60 DAT, respectively, (162.47) leaves per plant, (14.54) branches per plant, (16.67) flower clusters per plant, (50.10) fruits per plant, (2.66 cm) fruit girth, minimum (45.10 days) for and (50.03 days) took for 50% flowering and first harvesting, respectively and longest (8.15 cm) fruit length, heaviest (11.79 g) fruit and highest (468.73 g) yield per plant, (11.68 kg) yield per plot, 18.03 t/ha) green chillies and (3.20 t/ha) dry red chillies yield were recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% 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 perusal that the highest B: C ratio (3.25) from green chilli production was recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment followed by (2.95) and (2.57) B: C ratio in Boron @ 0.2% + Zinc @ 0.2% and Boron @ 0.4% + Zinc @ 0.2%, respectively. Whereas, the lowest B: C ratio (1.04) was recorded under control ($T_0$).

**Keywords:** Boron, zinc on growth, yield, *Capsicum annuum* L.

## Introduction
Chilli (*Capsicum annuum* L.) is an important vegetable and spice crop in the family of Solanaceae. It has diploid chromosome number i.e. 2n=24, originated in Mexico, Southern Peru and Bolivia (Villalon, 1981) [47]. It is herbaceous, profusely branching and bushy in nature. It was introduced in India by the Britishers in the 19$^{th}$ century in Shimla hills. It was introduced by Portuguese from Brazil to India during 1584 and in the North-eastern regions by Christian missionaries (Thamburaj and Singh, 2003) [43]. It is mainly grown in Africa, USA, Japan, Mexico, India, Turkey, etc. It is commercially cultivated as a cash crop in India (Anonymous, 2000) [4].
India is the leading country in production, consumption and export of Chilli in the world (Anonymous, 2021) [5]. It contributes 4.26 million ha area and 34.5 million tones production in the world (FAO, 2018) [13]. It is third important vegetable crop after tomato and potato (Naz *et al.*, 2006) [32]. India is accounting 7.43 lakh ha area and 19.14 lakh MT production with 2576 kg/ha productivity (Anonymous, 2021) [5]. Chilli is cultivated under 13812 ha area with 13649 MT production in Rajasthan. It is mainly consumed as culinary supplement to add flavour, colour, vitamin and pungency.

It is rich in nutrients and has plenty of medicinal properties (Chowdhury, 1976) [10]. It is used in curry due to its appealing color (Udoh *et al.,* 2005) [45]. Chillies contains good amount of vitamin A and C (Saimbhi *et al.,* 1977 and Sayed and Bagavandoss, 1980) [35, 38].

Boron is the most important micronutrient and play major role for carbohydrate metabolism, nitrogen and cell division and also helpful in the water relation (Brady and Weil, 1990 and Smriti *et al.,* 2002) [7, 42]. It plays an important for cell wall synthesis and membrane stability (Goldbach *et al.,* 2001; Brown *et al.,* 2002 and Iwai *et al.,* 2006) [14, 8, 19]. It enhances the flowering and fruit sets in chilli (Rawaa *et al.,* 2014) [34]. It plays prime role in reproductive organs development (Huang *et al*., 2000) [18] and increases the fruit yield (Chen *et al*., 2005 and Nabi *et al*., 2006) [9, 30].

Zinc is the key micronutrient for the growth, development and physiological function of plant. It synthesized IAA and played catalytic role in enzymatic reactions (Mousavi, 2011) [29]. It interfere the uptake, transport and osmotic regulation of essential ions that leads the disruption of normal metabolic processes (Sainju *et al.,* 2003) [36]. Zinc increases yield, due to its role in carbonic enzyme in the biosynthesis in chlorophyll (Ali *et al.,* 2008) [1]. It plays important role in anther formation and diseases resistance (Alloway, 2008) [2].

The foliar feeding of boron and zinc quickly enhanced the uptake of macronutrients in the tissues (Anees *et al.,* 2011) [3]. Nowadays, micronutrients are gradually gaining popularity among the growers for getting better returns. Foliar feeding of micronutrients is one tool to enhance the productivity. It should be quickly corrected quality losses occur in chilli.

The work on impact of micronutrients on chilli is scanty. Keeping in view, the present study was undertaken with the objective to find out best combination of micronutrients with optimum concentration for quality chilli production under semi-arid conditions of Jaipur.

## Materials and Methods

The present research was carried out in at Agricultural Research Farm at Suresh Gyan Vihar University, Jaipur (Rajasthan) to study the effect of different boron and zinc on chilli during the year 2022-23. The experiment was laid out in Factorial Randomized Block Design which comprises of ten treatment combinations *viz;* Control ($T_0$), boron @ 0.2% ($T_1$), boron @ 0.4% ($T_2$), zinc @ 0.2% ($T_3$), zinc @ 0.4% ($T_4$), Boron @ 0.2% + Zinc @ 0.2% ($T_5$), Boron @ 0.2% + Zinc @ 0.4% ($T_6$), Boron @ 0.4% + Zinc @ 0.2% ($T_7$) and Boron @ 0.4% + Zinc @ 0.4% @ 0.4% ($T_8$) and treatments were replicated three times. Appraisal of the result indicated that the influence of micronutrients and their interaction effect on important parameters like vegetative growth, yield and quality attributes of chilli were significantly influenced by boron and zinc 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. The significance of variation was tested on data obtained from various growth, yield and quality characters. The 'F' test at 5 per cent level of significance and critical difference was calculated to study the difference in the treatments, wherever the results were found significant.

## Results and Discussion

The experimental findings computed on the basis of the observations recorded and statistical analyses are presented precisely in this chapter under the following heads:

### 1. Vegetative Growth Parameters

The different concentration of boric acid and zinc sulphate had significant impact on remarkable increase in growth and yield characteristics of chilli. The plant height at periodical growth was significantly increased by foliar feeding of various micronutrients. Amongst the treatment, the maximum (26.55 cm), (44.89 cm) and (70.89 cm) plant height was recorded under foliar spray of boron @ 0.2% treatment at 45 DAT, 60 DAT and 75 DAT, respectively (Table 1). It might be due to boron application and it plays an important role in activation of cell division and cell elongation. The boron strengthens the number of metabolic activities for building plant organs that consequently increased the plant height (Marschner, 1995) [26]. Maximum (17.94 cm), (36.27 cm) and (62.27 cm) plant height was recorded under foliar spray of zinc @ 0.4% treatment at 45 DAT, 60 DAT and 75 DAT, respectively. This attribute might be due to active synthesis of tryptophane; a precursor of auxin, besides the synergistic effect of zinc which may serve as a source of energy for the synthesis of auxin. It could be attributed as one of the key factor for the growth of plant (Raghav and Singh, 2004) [33]. In case of interaction effect, the maximum (31.64 cm) and (49.98 cm) plant height was recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment at 45 DAT and 60 DAT. At 75 DAT, the maximum (75.98 cm) plant height was recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment followed by (73.00 cm), (70.20 cm) and (69.05 cm) plant height under Boron @ 0.2% + Zinc @ 0.2%, Boron @ 0.4% + Zinc @ 0.2% and Boron @ 0.4% + Zinc @ 0.4% but all treatments were performed at par with Boron @ 0.2% + Zinc @ 0.4% treatment and had significant effect over control. It might be due to synergistic effect of boron and zinc on vegetative parameters. The produced auxine promote the apical dominance that ultimately enhances the tree height.

The maximum (162.47) leaves per plant was observed under foliar sprayed plants with boric acid @ 0.6% ($T_3$), whereas, the maximum (14.54) branches per plant was observed under Boric acid @ 0.2% + Zinc sulphate @ 0.4% and it showed the significant effect (Table 1). The maximum (16.67) flower clusters per plant also observed on same treatment. The increase of leaves and branches might be due to enhancing of metabolic reaction for building of plant organs, it helps increasing plasticity and cell wall elongation (Yugandhar *et al*., 2014) [49]. The plant height augmented with foliar application of boric acid. It might be due to production of more branches and more available space and photosynthate. These results are found in agreement with the findings of Kavvadias *et al.* (2012) [21]. 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 (38.51 days) took for 50% flowering and (46.03 days) took for first picking under foliar spray of Boron @ 0.2% + Zinc @ 0.4% followed by (51.70 days) under foliar spray of Boron @ 0.2% + Zinc @ 0.2% treatment (Table 1). These results are in line of Elankavi *et al.* (2009) [11] who also obtained similar results by foliar application of boric acid that significantly reduced the days to 50% 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 (Khatri *et al.,* 2022) [23]. The results are in conformation with the findings of Gopal and Sarangtham (2021) [15] and Khan *et al.* (2023) [22].

**2. Reproductive Structures**

The key factors in fruit crops is maximum fruit set since it had impacts on fruit production and total yield. Several other factors such as formation of perfect flowers, germination of pollen grains and complete fertilization that influences fruit set. With the spraying of low concentration of micronutrient on chilli, the fruit set increased dramatically (Nawaz *et al.,* 2008) [31]. The conversion of a flower into a fruit is prime factor in order to maximize yield for profit maximization (Lovatt, 1999) [24]. It is apparent from the data presented in Table 2 revealed that the maximum (16.67) flower clusters per plant, (48.10) fruits per plant, minimum (38.51 days) took for 50% flowering and (46.03 days) took for first picking were recorded under foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment whereas, the minimum (11.38) flower clusters per plant and (29.67) fruits per plant under control ($T_0$). It might be due to foliar feeding of micronutrients that strengthen the photosynthetic activity. The accumulation of carbohydrates favors the flower retention in fruit vegetables.

Fruit drop is a main constraint in chilli and it can be caused by abiotic stresses and these aspects can cause plant hormonal disparities (Modise *et al.,* 2009) [28]. The foliar spray of micronutrients was found the most efficient in controlling premature fruit drop (Chen *et al.,* 2005) [9]. It might be due to absorption of boron that promotes the production of more photosynthates required for good number of chilli fruits. Similar results were also reported by Singh *et al.* (2019) [41]; Gopal and Sarangtham (2021) [15] and Meriño-Gergichevich *et al.* (2021) [27].

**3. Yield Attributing Parameters**

Fruit size is key factor in productivity and it also ascendancy the customer demand of chilli (Guardiola and García-Luis, 2000) [16]. The boric acid and zinc sulphate spray significantly increase in length, breadth, weight and volume (Kaur *et al.*, 2016) [20]. It may be due to boron improves fruit quantity and quality of chilli. The boron increases cell elongation and cell division (Eman *et al*., 2007) [12]. The maximum (8.15 cm) fruit length was observed in foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment followed by (7.41 cm) under Boron @ 0.2% + Zinc @ 0.2% treatment (Table 2). These results are in close conformity with the findings of Shil *et al.* (2013) [39]; Singh *et al.* (2019) [41] and Mallick (2021) [25]. The enlarging of fruit might be due to accumulation of more food which were synthesized during photosynthesis and translocated towards the fruit. The accumulated food material probably increased the fruit size (Trehan and Grewal, 1981and Singh *et al.* (2019) [44, 41].

The application boric acid had significant influenced on the fruit growth rate like fruit length, girth and diameter. The maximum (2.66 cm) fruit girth was observed in foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment followed by (2.47 cm) under foliar spray of Boron @ 0.2% + Zinc @ 0.2% treatment whereas, the minimum (1.20 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] and Meriño-Gergichevich *et al.* (2021) [27]. Boron encourages tryptophan formation which helps in the biosynthesis of proteins and auxins which results in the improving of fruit size (Wojcik and Wojcik, 2003) [48]. Similar results were also reported by Singh *et al.* (2019) [41] and Khan *et al.* (2023) [22].

The boric acid in improves the size and weight of fruit. It may be due to multiplication of cell and cell elongation (Eman *et al*., 2007) [12]. Data presented in Table 2 also revealed that the micronutrients significantly increased the fruit weight. The highest (11.79 g) fruit weight was recorded in foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment, whereas, the lowest (6.51 g) fruit weight was recorded under control ($T_0$). It may also be stated that the application of optimum dose boron and zinc were encourage the photosynthesis rate that required for gaining fruit weight. These results are in line of Umesh *et al.* (2021) 46] and Khan *et al.* (2023) [22].

**4. Yield Parameters**

Among the different concentrations of boric acid, copper sulphate and zinc sulphate and the highest (468.73 g) fruit yield was observed under Boron @ 0.2% + Zinc @ 0.4% treatment presented in Table 2. Similar trend was also reported on green chilli yield and the highest (11.68 kg/plot) green chilli fruits were produced in Boron @ 0.2% + Zinc @ 0.4% treatment (Table 2). The highest (18.03 t/ha) green chilli yield was obtained in foliar sprayed plants of Boron @ 0.2% + Zinc @ 0.4% treatment. Hence, Boron @ 0.2% + Zinc @ 0.4% treatment performed significantly superior over foliar spray of different concentrations of Boron, Zinc individually and their interaction treatments on green chilli yield per hectare (Table 2). Similarly, the interaction of boron and zinc had significant effect on dry red chilli yield per hectare. The highest (3.20 t/ha) dry red chillies yield was recorded in foliar spray of Boron @ 0.2% + Zinc @ 0.4% treatment, whereas, the lowest (1.25 t/ha) dry red chillies yield was recorded under water sprayed plants in control (Table 2). The micronutrients improve the photosynthesis rate and other metabolites which help in rapid cell division and elongation (Hatwar *et al.*, 2003) [17]. 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 (Basavarajeswari *et al*., 2008) [6] in vary vegetable crops (Hatwar *et al*., 2003) [17]. These results are in close conformity with the findings of Shil *et al.* (2013) [39]; Singh *et al.* (2019) [41]; Umesh *et al.* (2021) [46]; Khatri *et al.* (2022) [23] and Khan *et al.* (2023) [22].

**5. Economic Parameters**

The highest B: C ratio (3.25) chilli production was recorded in Boron @ 0.2% + Zinc @ 0.4% treatment followed by (2.95) in Boron @ 0.2% + Zinc @ 0.2% and (2.57) B: C ratio in Boron @ 0.4% + Zinc @ 0.2% as compared to lowest B: C ratio (1.04) in control (Table 2). It might be due to increase fruit set, higher fruit retention and minimized the fruit drop by boron treatment that ultimately increased the yield per hectare. Similar results were obtained by Sathiyamurthy *et al.* (2017) [37]; Singh *et al.* (2019) [41]; Gopal and Sarangtham (2021) [15] and Khan *et al*. (2023) [22].

**Table 1:** Effect of plant growth regulators on vegetative growth parameters.

| Treatments | Plant height (cm) | | | Number of leaves per plant | Number of branches per plant | Number of days to 50% flowering |
|---|---|---|---|---|---|---|
| | 45 DAT | 60 DAT | 75 DAT | | | |
| Control | 14.70 | 33.04 | 59.04 | 128.37 | 9.94 | 63.65 |
| Boron | | | | | | |
| Boron @ 0.2% | 26.55 | 44.89 | 70.89 | 144.27 | 11.64 | 50.10 |
| Boron @ 0.4% | 23.46 | 41.80 | 67.80 | 140.57 | 10.40 | 52.31 |
| S.Em± | 0.59 | 0.63 | 5.56 | 3.17 | 0.26 | 1.25 |
| C.D. (p=0.05) | 1.77 | 1.91 | N.S. | 9.58 | 0.79 | 3.78 |
| | | | | | | |
| Zinc | | | | | | |
| Zinc @ 0.2% | 16.34 | 34.68 | 60.85 | 140.73 | 10.34 | 53.98 |
| Zinc @ 0.4% | 17.94 | 36.27 | 62.27 | 142.57 | 11.04 | 53.19 |
| S.Em± | 0.59 | 0.63 | 5.56 | 03.17 | 0.26 | 1.25 |
| C.D. (p=0.05) | 1.77 | 1.91 | 8.93 | N.S. | N.S. | 3.78 |
| Interaction between boron and zinc | | | | | | |
| Boron @ 0.2% + Zinc @ 0.2% | 28.66 | 47.00 | 73.00 | 158.57 | 12.70 | 44.19 |
| Boron @ 0.2% + Zinc @ 0.4% | 31.64 | 49.98 | 75.98 | 162.47 | 14.54 | 38.51 |
| Boron @ 0.4% + Zinc @ 0.2% | 25.86 | 44.20 | 70.20 | 150.73 | 12.84 | 46.69 |
| Boron @ 0.4% + Zinc @ 0.4% | 24.71 | 43.05 | 69.05 | 144.27 | 12.60 | 49.99 |
| S.Em± | 1.01 | 1.91 | 2.96 | 5.49 | 0.45 | 2.17 |
| C.D. (p=0.05) | 3.06 | 3.32 | 8.93 | 15.59 | 1.37 | 6.55 |

**Table 2:** Effect of plant growth regulators on yield and yield attributing characters.

| Treatments | Number of flowers per plant | Number of days to first picking | Number of fruits per plant | 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 | 11.38 | 71.16 | 29.67 | 4.81 | 1.20 | 6.62 | 191.70 | 4.60 | 7.10 | 1.25 | 1.04 |
| Boron | | | | | | | | | | | |
| Boron @ 0.2% | 13.30 | 57.61 | 39.10 | 6.39 | 2.15 | 8.68 | 322.85 | 7.75 | 11.96 | 2.12 | 2.18 |
| Boron @ 0.4% | 12.63 | 59.83 | 38.50 | 5.86 | 2.03 | 8.12 | 318.49 | 7.64 | 11.80 | 2.08 | 1.87 |
| S.Em± | 0.30 | 1.55 | 0.59 | 0.20 | 0.11 | 0.12 | 12.48 | 0.30 | 0.46 | 0.08 | |
| C.D. (p=0.05) | 0.90 | 4.68 | 1.79 | 0.60 | 0.32 | 0.36 | 37.73 | 0.91 | 1.40 | 0.23 | |
| Zinc | | | | | | | | | | | |
| Zinc @ 0.2% | 11.79 | 61.50 | 35.50 | 5.37 | 1.71 | 7.47 | 253.01 | 6.06 | 9.38 | 1.67 | 1.83 |
| Zinc @ 0.4% | 11.91 | 60.70 | 37.17 | 6.01 | 2.18 | 8.08 | 290.76 | 6.98 | 10.79 | 1.91 | 1.87 |
| S.Em± | 0.30 | 1.55 | 0.59 | 0.20 | 0.11 | 0.12 | 12.48 | 0.30 | 0.46 | 0.08 | |
| C.D. (p=0.05) | 0.90 | N.S. | 1.79 | 0.60 | 0.32 | 0.36 | 37.73 | 0.91 | 1.40 | 0.23 | |
| | | | | | | | | | | | |
| Interaction between boron and zinc | | | | | | | | | | | |
| Boron @ 0.2% + Zinc @ 0.2% | 16.67 | 51.70 | 43.50 | 7.41 | 2.47 | 10.84 | 417.27 | 10.01 | 15.45 | 2.74 | 2.95 |
| Boron @ 0.2% + Zinc @ 0.4% | 14.71 | 46.03 | 48.10 | 8.15 | 2.66 | 11.79 | 486.73 | 11.68 | 18.03 | 3.20 | 3.25 |
| Boron @ 0.4% + Zinc @ 0.2% | 14.53 | 54.20 | 41.90 | 7.17 | 2.42 | 9.91 | 369.22 | 8.86 | 13.67 | 2.42 | 2.57 |
| Boron @ 0.4% + Zinc @ 0.4% | 14.39 | 57.50 | 39.50 | 6.47 | 2.39 | 8.72 | 324.60 | 7.79 | 12.02 | 2.14 | 2.51 |
| S.Em± | 0.52 | 2.68 | 1.03 | 0.35 | 0.18 | 0.21 | 21.35 | 0.52 | 0.80 | 0.13 | |
| C.D. (p=0.05) | 1.56 | 8.10 | 3.10 | 1.04 | 0.55 | 0.62 | 65.35 | 1.57 | 2.42 | 0.39 | |

## Conclusion

Based on the results obtained from the present study, it may be concluded that the Boron @ 0.2% + Zinc @ 0.4% was found the best treatment followed by Boron @ 0.2% + Zinc @ 0.4% treatment.

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