*Original Research Article*

Impact of zinc and boron on growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench]

**ABSTRACT**

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| A field investigation was carried out during the summer season, 2022-23 at Research Field of Department of Vegetable Science, College of Horticulture, Mandsaur (MP). The experiment was carried on Pusa Bhindi- 5 variety of okra with eight treatments and tested in RBD. The treatments of zinc and boron were T1 -(Control), T2 -(Zinc 2.5 kg/ha) T3 -(Zinc 5.0 kg/ha), T4 -(Zinc 7.5 kg/ha), T5 -(Boron 0.5 kg/ha), T6 -(Boron 1.0 kg/ha), T7 -(Boron 1.5 kg/ha), T8 -(Boron 2.0 kg/ha) used in this field experiment. The results of experiment indicated that the treatment T7 (Boron 1.5 kg/ha) registered with highest of plant height (cm), number of leaves per plant, number of branches per plant, SPAD value, fresh weight and dry weight of plant (g) and minimum days to 50% flowering and days to first picking of okra. Yield attributes *i.e*. number of fruits per plant, fruit length (cm), fruit diameter (cm), average fruit weight (g), fruit yield per plant (g), fruit yield (q/ha) were also recorded maximum. Quality parameters i.e. protein content (%) and fibre content (%) in fruit were also recorded highest. It was followed by treatment T3 (Zinc 5.0 kg/ha) in all the treatments of okra. It can be concluded that the highest result of growth, yield attributing characters, yield and quality attributes were recorded by the treatment T7 (Boron 1.5 kg/ha) followed by treatment T3 (Zinc 5.0 kg/ha) as compared to other treatments. |

**Keywords:** Zinc, boron, okra, growth, yield, quality, net income

**1. INTRODUCTION**

“Okra [*Abelmoschus esculentus* (L.) Moench] commonly known as Bhindi or lady’s finger belongs to family malvaceae with 2n=130 chromosomes. It is one of the most important vegetable crops grown throughout the tropical and subtropical parts of worlds. Okra is said to be a native of South Africa or Asia and has been predominantly vegetable of the Tropics. Okra is commonly grown in almost all parts of the plains and is consumed by the common people in all the states. Okra can be grown over a wide range of soil and climatic conditions. It is a warm season crop and prefers a temperature between 22°C and 35°C. Okra is susceptible to frost damage at temperatures below 12°C. Okra requires a wide range of soils with high in organic matter, provided the internal soil drainage is good.

The green fruits (per 100 g edible portion) of okra contains 88% water, 77% carbohydrates, 2.2% protein, 58.1 IU vitamin A, 633.0 vitamin B. 16 mg vitamin C. 0.7% Ca and 1.2% mineral matter. The dry seed contains 13-22% good edible oil and 20-24% protein” (Premnath and Swamy, 2016).

“Application of fertilizers is one of the most important agronomical practices to increase the crop productivity. The increase in growth and yield and improvement in quality of any crop are linked with physiological activities of the plants for which the micronutrients are equally important. Micronutrients areessentially as important as macronutrients to have better growth, yield and quality in plants. It also plays direct role or indirect role in plant growth and development. Plant absorbs these elements in minor quantity but they are essential for proper growth of the plants” (Kamalakannan*et al.*, 2019). The growth and yield of okra are influenced by the nutrition supplied to the crop. Although zinc and boron are the micronutrients and required by the plant in small quantity but these elements are essential for better growth and development of okra, ultimately affecting the crop yield.

“Zinc mainly functions as the metal component of a series of enzymes. The most important enzymes activate by this element are carbonic anhydrase and a number of dehydrogenases. Zinc is also involved in auxin production as well as flower and fruit setting. Shoots and buds of zinc deficient plants contain very low auxin, which causes dwarfism and growth reproduction. It is also plays an important role in chlorophyll synthesis, cell division, meristematic activity, expansion of cell and formation of cell wall. Zinc application also helps in increasing the uptake of nitrogen and potassium. Zinc is necessary for root cell membrane integrity, and in this function, it prevents excessive potassium uptake by roots and transport of potassium from roots to leaves. Zinc deficiency is thought to restrict RNA synthesis, which in turn inhibits protein synthesis” (Jahan *et al.*, 2020). “Deficiency of zinc produces changes in leaf morphology and cell histology, which causes several-known disorders “little leaf” or “rosette mottled leaf” etc. its deficiency also causes interveinal chlorosis, reduce root growth, blossoming and fruiting” (Sharma *et al.*, 2018).

“Boron is important for the translocation of sugars, root extension and growth of meristematic tissues, the pyrimidine biosynthetic pathway and the ATPase; it is also involved in translocation of sugars, synthesis of amino acid, protein and carbohydrate metabolism. Further, it plays a vital role in pollen enlargement, fertilization and flowering processes of plants” (Rahman *et al*., 2020 and Kumar *et al*., 2023).

“Boron is required for proper development and differentiation of plant tissues. In its absence, abnormal formation and development of fruit occur. Since boron is relatively immobile in plants, the early casualties of boron deficiency occur in the reproductive process of plants, and its inadequacy is often associated with sterility and malformation of reproductive organs. Boron facilitates the transport of carbohydrates through cell membranes” (Kumar *et al.*, 2009 and Jahan *et al.*, 2020). Keeping in view, the above fact, an experiment was conducted to study the effect of zinc and boron on growth, yield and quality of okra.

**2. MATERIAL AND METHODS**

Field experiment was conducted at Experimental Farm, Department of Vegetable Science, College of Horticulture, Mandsaur (M.P.) during the *Summer* season, 2022-23. The Experimental farm is situated in Malwa plateau agro-climatic zone in the Western part of Madhya Pradesh from 23.450 to 24.130 North latitude and 74.440 to 75.180 East longitudes and at an altitude of 435.02 meters above Mean Sea Level. The topography of the experimental field was plain**.** This region lies under 9th Agro climatic zone of the state. The soil of the experimental field was medium black clay loam in texture with uniform topography.

The experiment was carried on Pusa Bhindi- 5 variety of okra with eight treatments of zinc and boron these treatments were tested in randomized block design. **The treatments of zinc and boron were** T1 -Control, T2 -Zinc 2.5 kg/ha, T3 -Zinc 5.0 kg/ha, T4 -Zinc 7.5 kg/ha, T5 -Boron 0.5 kg/ha, T6 -Boron 1.0 kg/ha, T7 -Boron 1.5 kg/ha and T8 -Boron 2.0 kg/ha used in this field experiment. The calculated quantities zinc and boron as per treatments was applied to the respective plot. Whole quantity of the zinc and born were applied in zinc sulphate mono-hydrate (33%) and Di-sodium octa borate tetra hydrate (20%) as basal application. Fertilizer was applied at the rate of 120 kg N, 80 kg P2O5 and 80 kg K2O/ha. Nitrogen, phosphorus and potassium were provided through urea, DAP and MOP respectively. Half quantity of nitrogen and entire quantity of P and K was applied as basal dose at the time of sowing in the experimental field. Remaining dose of N was given in two split doses at 30 and 45 days after transplanting. The sowing of seeds was done with dibbling method at a spacing of 45 x 30 cm. The irrigation was provided immediately after sowing for better germination. Thereafter, irrigation was given when required. The observations were recorded on growth attributes viz., plant height (cm), number of leaves per plant, number of branches per plant, SPAD value at 30, 45, 60 DAS and at final harvesting stage, fresh of plant (g), dry weight of plant (g) at final harvesting stage, days to first picking and days to 50 % flowering were recorded. As regards yield attributes and yield observations *i. e*., number of fruits per plant, fruit length (cm), fruit diameter (cm), average fruit weight fruit (g), yield per plant (g) and fruit yield (q/ha) were recorded after harvesting in okra. With respect to quality attributes protein content (%) and fibre content (%) in fruit were studied. Economics of different treatments were calculated in terms of gross income, net income and B: C ratio. The data obtained from set of observation for each character were subjected to “Analysis of Variance” as advocated by Panse and Sukhatme (1985).

3. results and discussion

**3.1 Growth Attributes**

**3.1.1 Plant height**

“Plant height had been significantly influenced by zinc and boron treatments. The highest plant height was found in treatment T7 (Boron 1.5 kg/ha) with height of 19.89 cm, 28.93 cm, 39.94 cm and 72.52 cm at 30, 45, 60 DAS and final harvesting stage, correspondingly. The minimum plant height was observed in with the treatment T1 (Control) with height of 15.92, 23.08, 31.99 and 61.15 cm at 30, 45, 60 DAS and final harvesting stage, respectively. Plant might be increased due to fact that boron involved in the various physiological activities in the plants such as, development of cell wall, metabolisms of RNA and protein, transport of sugar from source to sink during flowering and fruiting stage, synthesis of ATP (Adenosine triphosphate) thus, help in improving the growth attributes of the okra plant. Improvement in the growth characters due to application of zinc might be due to zinc involved in various enzymatic and physiological activities inside the cell. It involved in formation of some growth hormones and maintains the accurate level of auxin in the cell in active form” (Satpute et al., 2013, Kumar et al., 2021). Similar results were also reported by Kumar *et al.* (2009), Sharma *et al.* (2018), Jahan *et al.* (2020) and Yamini and Prasad (2023) in okra.

**3.1.2 Number of leaves per plant**

“The number of leaves per plant was significantly influenced by the treatments of zinc and boron. The maximum number of leaves per plant were observed with treatment T7 (Boron 1.5 kg/ha) i.e., 5.30, 10.43, 20.53 and 29.02 leaves per plant at 30, 45, 60 DAS and at final harvesting stage correspondingly. The minimum number of leaves was observed in treatment T1 (Control) with 4.27, 7.73, 15.73 and 23.29 leaves at 30, 45, 60 DAS and final harvesting stage correspondingly. The increase in number of leaves could be attributed to inter nodal elongation by cell division and synthesis of higher photosynthesis due to the application of micronutrients cations are involved in enzyme systems as cofactors with the exception of Zn and these are capable of acting as ‘electron carriers’ in the enzyme systems which are responsible for the oxidation-reduction in plant” (Deepika and Pitagi, 2015). “Increase in leaves per plant by application of micronutrients may be due to their involvement in chlorophyll formation, which might have helped to favour cell division, meristematic activity in apical tissue, expansion of cell and formation of new cell wall” (Naga *et al*., 2013). Present findings were collaborated with earlier observations made by Limbachiya *et al*. (2017) and Jahan *et al*. (2020) in okra.

**3.1.3 Number of branches per plant**

“The maximum number of branches were observed in treatment T7 (Boron 1.5 kg/ha) i.e., 2.31 and 4.01 branches at 60 DAS and at final harvesting stage, respectively. The treatment T1 (Control) was observed minimum number of branches per plant *i.e*., 1.66 and 3.02 branches at 60 DAS and at final harvesting stage, respectively. This increase in number of branches per plant may be due to a pronounced effect of boron on plant to increase its vegetative growth since boron is found associated with the development of cell wall and with the process of cell differentiation, helping in the root and shoot growth of the plant” (Kumar *et al*., 2009). The favourable effect of boron on number of branches per plant might also be due to its role in physiological processes such as carbohydrate and protein metabolism and cellular function within the plant. Since boron is mainly involved in the hormone development and stimulation or inhibition of specific metabolism pathways (Bhat *et al*., 2018). Similar findings were also reported by Mehraj*et al*. (2015), Kumar *et al*. (2021) and Maliha *et al*. (2022) in okra.

**3.1.4 SPAD value**

“The SPAD value had been significantly influenced by the treatments of zinc and boron. The highest value of SPAD was found with treatment T7 (Boron 1.5 kg/ha) i.e., 50.02, 55.80, 60.92 and 64.01 at 30, 45, 60 DAS and at final harvesting stage, correspondingly. The minimum value of SPAD recorded by treatment T1 (Control) with values of 40.92, 44.63, 48.89 and 52.17 at 30, 45, 60 DAS and at final harvesting stage. The increase in SPAD value may due to the zinc is essential for several enzyme systems that regulate various metabolic activities in plants and it plays an important role in the formation and the activities of chlorophyll” (Kumar *et al*., 2009). Zn and Mn are involved in the synthesis of chlorophyll and essential for the maintenance of chloroplast structure and function and their omission from the nutrient solution reduced the chlorophyll content and photosynthetic rate of the plants (Narayan *et al*., 2021). Increased in SPAD value after application of zinc and boron has been also reported by Jahan *et al*. (2020)and Singh *et al*. (2022) in okra.

**3.1.5 Fresh weight of plant (g)**

“The fresh weight of plant was significantly affected by treatments of zinc and boron in okra. Maximum fresh weight of plant (184.20 g) was recorded under the treatment T7 (Boron 1.5 kg/ha). The minimum fresh weight of plant (141.38 g) was observed with treatment T1 (Control) at final harvesting stage of okra. This increased in fresh weight of plant may due to boron plays a key role in many metabolic processes such as cell wall differentiation, cell development, N-metabolism, fertilization, fat metabolism, hormone metabolism, active salt absorption and photosynthesis which in turn might have contributed to higher fresh weight” (Nazir *et al*. 2017). These finding are corroborated with the result obtained by Mehraj*et al*. (2015) and Narayan *et al*. (2021) in okra.

**3.1.6 Dry weight of plant (g)**

“In okra, the treatments of zinc and boron had significant influence on the dry weight of plant. The significantly higher dry weight of plant (47.23 g) was recorded by the treatment T7 (Boron 1.5 kg/ha) as compared to other treatments, while the treatment T1 (Control) recorded with minimum dry weight of plant (36.89 g) after harvesting stage of okra. This may be attributed to the effect of zinc which is essential for the carbonic enzyme and photosynthesis, resulting in increase in translocation of photosynthates in fruits; and positive effect on retaining flowers and fruits” (Harris and Mathuma, 2015). Higher dry weight of plant due to the application of B and Zinc have been reported by Mehraj*et al*. (2015), Jahan *et al*. (2020) and Arya *et al*. (2021) in okra.

**3.1.7 Days to 50% flowering**

“The treatments of zinc and boron had significant impact on days to 50% flowering of okra. The earliest 50 % flowering (43.98 days) was observed under the treatment T7 (Boron 1.5 kg/ha) as compared to all other treatments, whereas, the maximum days to 50% flowering (48.32 days) took with treatment T1 (Control). This might be due to fact that it involved in synthesis of Adenosine Triphosphate (ATP) and translocation of sugars which help in more flowering. Also, boron involved in different enzymatic reaction and help in synthesis of different growth regulators which help in early flowering in okra (Kumar *et al*., 2021). Application of micronutrients may be attributed to progressive increase in absolute amounts of inorganic elements and subsequent storing of sufficient food material leading to early differentiation of buds into flower buds” (Narayan *et al*., 2021). The present findings are in accordance with the results obtained by Kumar and Sen (2004), Satpute*et al*. (2013), Limbachiya*et al*. (2017) and Yamini and Prasad (2023) in okra.

**3.1.8 Days to first picking**

 **“**In okra crop, the treatments of zinc and boron had significant impact on days to first picking of okra. The treatment T7 (Boron 1.5 kg/ha) was found the lowest number of days (46.02 days) to first picking of okra fruits compared to all other treatments. The maximum days to first picking of okra (50.08 days) was taken by the treatment T1 (Control). The improved plant growth and photosynthetic attributes due to the application of micronutrients were reflected as earliness in harvest” (Narayan *et al*., 2021). “Boron regulates the metabolism of carbohydrates and increase carbohydrate supply for formation of flowers and fruit set as well as decrease flower abscission” (Mallick *et al*., 2020). These findings are corroborated with the results obtained by Limbachiya*et al*. (2017) and Yamini and Prasad (2023) in okra.

**3.2 Yield attributes**

**3.2.1 Number of fruits per plant**

In okra, the treatments of zinc and boron had significant impact on the number of fruits per plant of okra. The treatment T7 (Boron 1.5 kg/ha) was recorded maximum number of fruits per plant (15.16) in okra and was followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) which recorded 14.94 and 14.60 number of fruits per plant, respectively. The minimum number of fruits per plant (12.95) was recorded under the treatment T1 (Control). The boron exhibits pronounce effect in improving the yield attribute and yield. It takes part in active photosynthesis, which ultimately helps towards increase in number of fruits per plant (Satpute*et al*., 2013 and Polara *et al*., 2017). Boron and zinc application might be helped balanced absorption of nutrients, increasing the rate of photosynthesis, as a result fruit per plant was highest (Rahman *et al*., 2020). Zinc increases the number of fruits plant per plant by increasing IAA synthesis as well as carbohydrates translocation. Boron regulates the metabolism of carbohydrates and increase carbohydrate supply for formation of flowers and fruit set in tomato as well as decrease flower abscission (Mallick *et al*., 2020). The result of the investigation are in accordance with the finding of Rahman *et al*. (2020) and Singh *et al*. (2022) in okra.

**3.2.2 Fruit length (cm)**

 Zinc and boron showed a significant impact on the fruit length (cm). The maximum fruit length (13.47 cm) was recorded with the treatment T7 (Boron 1.5 kg/ha) which was significantly longer with all other treatments of the trial. This was followed by treatments T3 (Zinc 5.0 kg/ha) with fruit length (13.20 cm), while the minimum fruit length (10.69 cm) was found by the treatment T1 (Control). This increase in fruit length may due to that zinc played an important role in the fundamental processes involved in cellular mechanism. Similarly, boron might have taken part in active photosynthesis and translocation of carbohydrates, which improved the size of fruits (Kumar *et al*., 2009). Increase in fruit length may be attributed to enhanced photosynthetic attributes like leaf area, leaf thickness and leaf chlorophyll content (Narayan *et al*., 2021). The results of the present investigation are accordance with those of Jahan *et al*. (2020), Arya *et al*. (2021), Maliha *et al*. (2022) and Singh *et al*. (2022) in okra.

**3.2.3 Fruit diameter (cm)**

 The fruit diameter (cm) of okra had exerted significant effect of the treatments. The treatment T7 (Boron 1.5 kg/ha) was noticed highest fruit diameter (1.68 cm) after harvest in okra, followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) with fruit diameter of 1.62 and 1.58 cm, respectively. The lowest diameter of fruit (1.37 cm) was measured under the treatment T1 (Control). The increase in fruit diameter by the application of boron and zinc 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 (Khan *et al*., 2022). These findings are in agreement with those obtained by Kumar et al. (2009), Jahan *et al*. (2020), Arya *et al*. (2021) and Narayan *et al.* (2021) in okra.

**3.2.4 Average fruit weight (g)**

 “The average fruit weight varied significantly due to the application of zinc and boron in okra. The treatment T7 (Boron 1.5 kg/ha) was recorded significantly higher fruit weight (12.04 g) than other treatments. It was followed by the treatments T3 (Zinc 5.0 kg/ha) which recorded 11.92 g average fruit weight. The treatment T1 (Control) was noticed minimum fruit weight (10.17 g) among all treatments of okra. The increase in yield attributes due to micronutrients might be due to their role in fundamental processes involved in the cellular mechanism and respiration. Boron exhibits pronounce effect in improving the yield attribute and yield. It takes part in active photosynthesis, which ultimately helps towards increase in average weight of fruits” (Polara *et al*. 2017). Boron and zinc increased cells and cell division, and work in the volume of intercellular space in mesocarpic cells in addition to rapid metabolite translocation and sink fruits and also aid in the preparation of tryptophan, which is an amino acid that aids in the manufacture of proteins, as well as auxins, which are plant growth regulators that result in improved fruit growth in tomato (Gopal and Sarangthem, 2022). These results obtained according to the findings of Kumar *et al*. (2009), Satpute*et al*. (2013), Arya *et al*. (2021), Narayan *et al*. (2021) and Maliha *et al*. (2022) in okra.

**3.2.5 Fruit yield per plant (g)**

The different treatments of zinc and boron had significant effect on the fruit yield per plant (g) of okra. The treatment T7 (Boron 1.5 kg/ha) was recorded significantly maximum fruit yield per plant (182.61 g), followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) with 177.66 g and 170.80 g fruit yield per plant, respectively. While the minimum fruit yield per plant (131.57 g) was recorded under the treatment T1 (Control) of okra. Increase in yield due to micronutrients application may be attributed to enhanced photosynthesis activity and increased in production and accumulation of carbohydrates and favorable effect on vegetative growth, and retention of flowers and fruits (Satpute*et al*., 2013). Greater availability of nutrients in the soil that resulted in better growth and development which might be attributed to better mobilization of phosphorus and increased allocation of photosynthesis towards the economic parts and also hormonal balance on the plant system (Limbachiya*et al*., 2017). Boron facilitates the reduction of male sterility and increase normal fruit. Zinc involved in the biochemical synthesis of phytohormone, Indole Acetic Acid through the pathway of conversion of tryptophan to IAA, which also improved yield and its attributes (Rahman et al., 2020). These findings are confirms the results reported by Kumar and Sen (2004), Sharma *et al.* (2018) and Arya *et al.* (2021) in okra.

**3.2.6 Fruit yield (q/ha)**

“The significant difference for fruit yield (q/ha) was registered due to the application of zinc and boron in okra. Application of treatment T7 (Boron 1.5 kg/ha) had registered significantly higher fruit yield (135.27 q/ha) and was followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) which were observed 131.60 q/ha and 126.54 q/ha fruit yield of okra, respectively. The minimum fruit yield (97.46 q/ha) was recorded with treatment T1 (Control). The increased yield per hectare due to the application of micronutrients might be attributed to the favorable effect on flower retention, which might have increased the number of fruits per plant” (Kumar *et al*. 2009). “Increased yield of okra due to micronutrients application may be attributed to enhanced photosynthesis activity and increased in production and accumulation of carbohydrates and favorable effect on vegetative growth, and retention of flowers and fruits” (Limbachiya*et al*., 2017 and Polara *et al*., 2017). The present findings are in accordance with same type of results obtained by Kamalakannan*et al*. (2019) and Singh *et al*. (2022) in okra.

**3.3 Quality attributes**

**3.3.1 Protein content (%) in fruit**

The treatments of zinc and boron had a significant influence on the protein content (%) in fruit. The treatment T7 (Boron 1.5 kg/ha) was observed significantly higher protein content in fruit (13.80 %) of okra as compared to other treatments. It was followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) which was registered 13.44 and 13.09 % protein content in fruits of okra, respectively. The minimum protein content in fruit (11.33 %) was recorded in treatment T1 (Control). The boron and zinc, an essential component of many enzymes are known to be directly involved in the synthesis of protein in plants (Kumar *et al*., 2009). Increase in protein content due to application of zinc might be due to fact that zinc is an important structural component of protein and required in different enzymatic activities for normal growth and development of plant (Kumar *et al*., 2021). The results of present investigation are in close confirmation with the findings of Limbachiya *et al.* (2017), Sharma *et al.* (2018) and Rahman *et al*. (2020) in okra.

**3.3.2 Fiber content (%) in fruit**

“In okra, the treatments of zinc and boron had significant impact on the fiber content (%). The treatment T7 (Boron 1.5 kg/ha) was observed significantly higher fibre content in fruit (12.97 %) of okra. It was followed by treatments T3 (Zinc 5.0 kg/ha) and T8 (Boron 2.0 kg/ha) with 12.78 and 12.35 % fibre content in fruits of okra, respectively. The lowest fibre content in fruit (10.69 %) was recorded under treatment T1 (Control). The beneficial role of zinc in increasing cation exchange capacity (CEC) of roots helped in increasing absorption of nutrients from the soil. Futher, the beneficial role of zinc in chlorophyll formation, regulating auxin concentration and its stimulatory effect on most of the physiological and metabolic processes of plant, might have helped plants in absorption of greater amount of nutrients from soil. Thus, the favorable effect of zinc on photosynthesis and metabolic process augmented the production of photosynthates and their translocation to different plant parts, which ultimately increased the concentration of nutrients in the plant” (Sharma *et al*., 2018).

**4.Economics of different treatments for okra production**

In okra, the treatments of zinc and boron exerted significant effect on gross income, net income and B:C ratio. Significantly maximum gross income (202904.72 Rs/ha), net income (136204.72 Rs/ha) and B:C ratio (2.04) was recorded with treatment T7 (Boron 1.5 kg/ha) of okra. The minimum gross income (146191.26 Rs/ha), net income (81366.26 Rs/ha) and B:C ratio (1.26) was observed under the treatment T1 (Control). The increase in B: C ratio and other crop economic parameters might be due to increase in yield which fetched more prices in market. These results are in accordance with the findings of Kumar and Sen (2004), Polara *et al*. (2017), Sharma *et al.* (2018), Arya *et al*. (2021) and Yamini and Prasad (2023) in okra.

**5.CONCLUSIONS**

On the basis of experimental results of present investigation, It can be concluded that the highest result of growth, yield attributing characters, yield and quality attributes were recorded by the treatment T7 (Boron 1.5 kg/ha) followed by treatment T3 (Zinc 5.0 kg/ha) as compared to other treatments.Highest gross income, net income and B:C ratio (1:2.04) was obtained with treatment T7 (Boron 1.5 kg/ha).

**Disclaimer (Artificial intelligence)**

**Option 1:**

**Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.**

**REFERENCE**

Arya, P., Anitha, S., Menon, M. V.; Bhindhu, P. S. and Antony, S. (2021). Foliar application of micronutrients on growth and yield of okra under different irrigated conditions. *J. Tropical Agric.* 59(1).

Bhat, T. A., Chattoo, M. A., Mushtaq, F., Akhter, F., Mir, S. A., Zargar, M. Y.; Wani, K. P., Shah, M. D., and Parry, E. A. (2018). Effect of zinc and boron on growth and yield of onion under temperate conditions. *Int. J. Curr. Microbiol. App. Sci.,*7(4), 3776-3783.

Deepika, C., and Pitagi, A. (2015). Effect of zinc and boron on growth, seed yield and quality of radish (*Raphanus sativus* L.) cv. Arka Nishanth. *Cur. Agri. Res. J.,* 3(1), 85-89.

Gopal, D., andSarangthem, I. (2022). Interaction Effect of zinc and boron on the growth, yield and yield attributes of tomato in acid soils of Manipur. Int. J. Env. Clim. Change*,* 12(11), 2693-2699.

Harris, K.D., andMathuma, V. (2015). Effect of foliar application of boron and zinc on growth and yield of tomato (*Lycopersiconesculentum* L.). *Asian J. Pharma. Sci. Tech*., 5(2), 74-78.

Jahan, N., Hoque, M. A., Rasal-Monir, M., Fatima, S., Islam, M. N., and Hossain, M. B. (2020). Effect of zinc and boron on growth and yield of okra (*Abelmoschus esculentus* L.). Asi. J. Adv. Agril Re., 12(1), 41-47.

Kamalakannan, S., Manikandan, R., Haripriya, K., Sudhagar, R. and Kumar, S. (2019). Effect of zinc sulphate and biofertilizers on yield attributes and yield of okra [*Abelmoschus esculentus* (L.) Moench]. *Res. on Crops,* 20(4), 742-747.

Khan, M. N., Rab, A., Khan, M. W., ud Din, I., Khan, M. A., Khan, M. A. and Ahmad, M. (2022). Effect of zinc and boron on the growth and yield of chilli under the agro climatic condition of Swat. *Pure Appl. Biol*.,**11**(3), 835-842.

Kumar, M., and Sen, N. L. (2004). Interaction effect of zinc and boron on okra (*Abelmoschus esculentus*L. moench) cv. Prabhani Kranti. *Agric. Sci. Digest,* 24 (4), 307-308.

Kumar, M., Chaudhary, S. K., Kumar, R., Singh, S. K., Prabhakar, M. K., and Singh, P. K. (2023). Effect of boron and zinc on growth and yield attributes in early cauliflower (*Brassica oleracea* var*. botrytis* L.). *Int. J. Plant Soil Sci.,* 35(6), 104-110.

Kumar, S., Chankhar, S. K., and Rana, M. K. (2009). Response of okra to zinc and boron micronutrients. *Veg. Sci.,* 36(3), 327-331.

Kumar, V., Deo, C., Sarma, P., Wangchu, L., Debnath, P., Singh, A. K., and Hazarika, B. N. (2021). Effect of foliar application zinc and boron on vegetative growth characters of okra. *J. Pharmacognosy and Phytochemistry,* 10(1), 2084-2086.

Limbachiya, T., Vadodaria, J., Patel, H., and Vaghela, K. (2017). Assessment some micronutrients and biofertilizers on growth, yield and quality of okra (*Abelmoschus esculentus* L. Moench) cv. Gao-5. *The Bioscan,* 12(3), 1491-1496.

Maliha, M. B. J.; Nuruzzaman, M.; Hossain, B.; Trina, F. A.; Uddin, N. and Sarkar, S. (2022). Assessment of varietal attributes of okra under foliar application of zinc and boron. *Int. J. Hort. Sci. Technol.,*  9(2), 143-149.

Mallick, S., Zakir, H. M., and Alam, M. S. (2020). Optimization of zinc and boron levels for better growth and yield of tomato (*Lycopersiconesculentum* Mill.). *J. Exp. Agri. Int.,* 42(2), 87-96.

Mehraj, H., Taufique, T., Mandal, M. S. H., Sikder, R. K., and Uddin, A. J. (2015). Foliar feeding of micronutrient mixtures on growth and yield of okra (*Abelmoschus esculentus*). *American Eurasian J. Agric. Environ. Sci.,* 15(11), 2124-2129.

Naga, S.K., Swain, S.K., Verma, S., and Raju, B. (2013). Effect of foliar application of micronutrients on growth parameters in tomato (*Lycopersiconesculentum* Mill.). *Discourse J. Agric. Food Sci.,* 1(10), 146-151.

Narayan, S., Javeed, I., Hussain, K., Khan, F. A., Mir, S. A., Bangroo, S. A., and Malik, A. A. (2021). Response of okra (*Abelmoschus esculentus* L.) to foliar application of micronutrients. *Ind. J. Agri. Sci.,* 91(5), 749-752.

Nazir, G., Kumar, P., Shukla, A., and Sharma, U. (2017). Cauliflower (*Brassica oleracea* var. *botrytis*) growth yield and quality as influenced by variable rates of boron*. J. Env. Bio-sci*.,31(1), 33-39.

Panse, V. G. and Sukhatme, P. V. (1985). Statistical Methods for Agricultural Workers. Fourth edition. *ICAR Publication*, New Delhi.

Polara, K. B., Ponkia, H. P., Sakarvadia, H. L., Vekaria, L. C., and Babariya, N. B. (2017). Effect of multi-micronutrients fertilizers on yield and micronutrients uptake by okra (*Abelmoschus esculentus* L.) grown on medium black calcareous soils of Saurashtra Region of Gujarat. *Int. J. Pure App. Biosci.*, 5(6), 258-264.

Premnath, and Swamy, K. R. M. (2016). Textbook of Vegetable Crops. Directorate of Knowledge Management in Agriculture, ICAR pp, 427-433.

Rahman, M. H., Quddus, M. A., Satter, M. A., Ali, R., Sarker, M. H., and Trina, T. N. (2020). Impact of foliar application of boron and zinc on growth, quality and seed yield of okra. *J. Energy Natural Resources,* 9(1), 1-9.

Satpute, N.R., Suryawanshi, L.B., Waghmare, J.M., and Jagtap, P.B. (2013). Response of summer okra (cv. Phule Utkarsha) to iron, zinc and boron in inceptisol. Asian J. Hort*.,* 8(2), 541-546.

Sharma, R., Bairwa, L. N., Ola, A. L., Lata, K., and Meena, A. R. (2018). Effect of zinc on growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench]. *J.Pharma. Phyto*., 7(1), 2519-2521.

Singh, D., Bahadur, A., Singh, A. K., Singh H., Yadav, S., and Singh, D. (2022). Effect of zinc and boron foliar application on growth, biomass production and yields of spring-summer okra: Zinc and boron foliar yields of spring-summer okra. *J. Agri Search*, 9(1), 46-49.

Yamini, P., and Prasad, V. M. (2023). Effect of boron and zinc on growth, yield and quality of okra (*Abelmoschus esculentus* L.) F1 Hybrid. *Int. J. Environ. Clim. Change*, 13(8), 722-727.

**Table 1: Effect of zinc and boron on growth attributes of okra**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment** | **Plant height (cm)** | **No. of leaves per plant** | **Number of branches** |
| **30 DAS** | **45 DAS** | **60 DAS** | **At final harvest** | **30 DAS** | **45 DAS** | **60 DAS** | **At final****harvest** | **60 DAS** | **At final harvest** |
| **T1** | 15.92 | 23.08 | 31.99 | 61.15 | 4.27 | 7.73 | 15.73 | 23.29 | 1.66 | 3.02 |
| **T2** | 16.15 | 24.23 | 33.14 | 63.82 | 4.37 | 7.93 | 16.10 | 24.17 | 1.71 | 3.30 |
| **T3** | 18.78 | 27.90 | 37.89 | 74.20 | 5.13 | 9.87 | 20.59 | 28.61 | 2.21 | 3.91 |
| **T4** | 17.25 | 26.60 | 35.43 | 71.24 | 4.60 | 9.03 | 18.50 | 26.23 | 1.97 | 3.73 |
| **T5** | 16.38 | 24.41 | 33.96 | 66.10 | 4.43 | 8.13 | 17.07 | 24.53 | 1.77 | 3.43 |
| **T6** | 16.84 | 25.39 | 34.39 | 68.17 | 4.60 | 8.80 | 17.53 | 25.28 | 1.81 | 3.58 |
| **T7** | 19.89 | 28.93 | 39.14 | 76.52 | 5.30 | 10.43 | 20.53 | 29.02 | 2.31 | 4.01 |
| **T8** | 17.56 | 26.92 | 36.94 | 72.11 | 4.83 | 9.53 | 19.15 | 27.44 | 2.05 | 3.82 |
| **SEm±** | **0.78** | **1.20** | **1.47** | **3.03** | **0.20** | **0.41** | **0.96** | **1.23** | **0.10** | **0.17** |
| **CD at 5%** | **2.39** | **3.64** | **4.48** | **9.08** | **0.62** | **1.26** | **2.93** | **3.75** | **0.30** | **0.53** |

**Table 2: Effect of zinc and boron on growth attributes of okra**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **SPAD Value** | **Fresh weight of plant (g)** | **Dry weight****of plant (g)** | **Days to 50%****flowering** | **Days to first picking** |
| **30 DAS** | **45 DAS** | **60 DAS** | **At final****harvest** |
| **T1** | 40.92 | 44.63 | 48.89 | 52.17 | 141.38 | 36.89 | 48.32 | 50.08 |
| **T2** | 42.25 | 46.35 | 50.30 | 54.54 | 147.27 | 38.37 | 47.80 | 49.86 |
| **T3** | 48.83 | 53.57 | 58.75 | 62.89 | 178.44 | 45.92 | 44.19 | 47.47 |
| **T4** | 46.33 | 50.67 | 55.88 | 58.64 | 162.69 | 42.25 | 46.18 | 48.71 |
| **T5** | 43.07 | 47.80 | 51.96 | 56.10 | 153.68 | 39.32 | 46.84 | 49.45 |
| **T6** | 44.21 | 48.78 | 53.20 | 56.69 | 157.37 | 40.44 | 46.37 | 49.12 |
| **T7** | 50.02 | 55.80 | 60.92 | 64.01 | 184.20 | 47.23 | 43.98 | 46.02 |
| **T8** | 46.94 | 51.21 | 56.32 | 60.15 | 169.31 | 43.17 | 45.28 | 48.04 |
| **SEm±** | **1.88** | **2.14** | **2.32** | **2.42** | **8.80** | **1.91** | **0.92** | **0.79** |
| **CD at 5%** | **5.70** | **6.50** | **7.05** | **7.36** | **26.69** | **5.79** | **2.80** | **2.40** |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Number of fruits per plant** | **Fruit length (cm)** | **Fruit diameter (cm)** | **Average fruit weight** | **Fruit Yield per plant (g)** | **Fruit yield (q/ha)** | **Protein content (%) in fruit** | **Fiber content (%) in fruit** | **Gross income (Rs./ha)** | **Net income (Rs./ha)** | **B: C Ratio** |
| **T1** | 12.95 | 10.69 | 1.37 | 10.17 | 131.57 | 97.46 | 11.33 | 10.69 | 146191.26 | 81366.26 | 1.26 |
| **T2** | 13.26 | 11.37 | 1.40 | 10.31 | 136.66 | 101.23 | 11.57 | 11.19 | 151843.14 | 86033.14 | 1.31 |
| **T3** | 14.94 | 13.20 | 1.62 | 11.92 | 177.66 | 131.60 | 13.44 | 12.78 | 197394.80 | 130600.80 | 1.96 |
| **T4** | 14.36 | 12.61 | 1.53 | 11.44 | 163.80 | 121.34 | 12.82 | 12.02 | 182003.82 | 114224.82 | 1.69 |
| **T5** | 13.32 | 11.85 | 1.43 | 10.62 | 141.10 | 104.52 | 11.95 | 11.42 | 156780.44 | 91330.44 | 1.40 |
| **T6** | 13.82 | 12.28 | 1.48 | 10.86 | 149.78 | 110.95 | 12.28 | 11.74 | 166417.54 | 100342.54 | 1.52 |
| **T7** | 15.16 | 13.47 | 1.68 | 12.04 | 182.61 | 135.27 | 13.90 | 12.97 | 202904.72 | 136204.72 | 2.04 |
| **T8** | 14.60 | 12.90 | 1.58 | 11.68 | 170.84 | 126.54 | 13.09 | 12.35 | 189816.92 | 122491.92 | 1.82 |
| **SEm±** | **0.49** | **0.55** | **0.06** | **0.44** | **6.06** | **4.48** | **0.54** | **0.45** | **6734.06** | **6734.06** | **0.10** |
| **CD at 5%** | **1.51** | **1.67** | **0.19** | **1.33** | **18.38** | **13.61** | **1.63** | **1.37** | **20425.66** | **20425.66** | **0.30** |

**Table 3: Effect of zinc and boron on yield, quality and economics of okra**