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RESEARCH ARTICLE

Optimizing growth, yield and quality of chow chow (*Sechium edule* (Jacq.) Swartz) through foliar micronutrient treatments

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Abstract

Foliar application of micronutrients refers to application of micronutrients directly to plant leaves through spraying. It is a cost-effective method to supply micronutrients to the plants. Chayote (*Sechium edule*) is a Cucurbitaceous perennial vegetable widely grown in tropical and subtropical regions around the world. The plant thrives in warm, humid climates and is appreciated for its versatility and nutritional value Since this crop is cultivated in slightly acidic soil, nutrient fixation is common, leading to micronutrient deficiency symptoms. A field experiment was conducted at the Horticultural Research Station in Thadiyankudisai, following a Randomized Block Design (RBD) with 14 treatments and three replications, using a plot size of 34.56 m^2. Micronutrients such as Boric acid, $ZnSO_4$, $FeSO_4$ and $MnSO_4$ were applied at a 0.5 % concentration through foliar sprays, both individually and in combinations. The treatments were applied three times at 15-day intervals, starting 60 days after planting. Five plants per treatment were randomly selected to assess growth, yield and quality parameters. The recorded data were subjected to statistical analysis. The results showed that the highest vine length (363.14 cm) and shortest time to first female (109 days) and male (91 days) flower emergence were observed in the T_{11} treatment. Yield per plot (155.36 kg) and per hectare (44.95 t/ha) were also highest in T_{11}. Additionally, T_{11} resulted in the highest nutrient content: protein (1.74 g/100 g), calcium (419.37 mg/100 g), antioxidants (1370.22 µg/g), vitamin C (13.81 mg/100 g), boron (0.421 mg/100 g), zinc (1.58 mg/100 g), iron (84.30 mg/100 g), manganese (5.23 mg/100 g), nitrogen (3.61 %), phosphorus (0.461 %) and potassium (1.38 %).

Keywords: chayote; foliar nutrition; microelements; nutritional value; quality; yield

Introduction

The family Cucurbitaceae, includes 118 genera and 825 species and many cucurbits are being cultivated in India, contributing approximately 5.6 % to the nation's total vegetable production. These vegetables are consumed in various forms such as vegetable for cooking, salad (cucumber, gherkin and long melon), dessert (melons), sweet (ash gourd and pointed gourd) and pickle (gherkin). Chow chow (*Sechium edule*) is a Cucurbitaceous perennial vegetable crop that grows as a vigorous creeper. The fruit is typically pear-shaped, somewhat flattened and covered with coarse wrinkles, measuring between 15 and 20 cm in length. Chayote is primarily grown for its edible tuberous roots, young fruits and tender leaves and shoots. It is cultivated worldwide in tropical and subtropical regions. In India, chayote is predominantly grown in Tamil Nadu, Karnataka, West Bengal, Himachal Pradesh and throughout the northeastern hill states. Mizoram stands out as the leading producer, with an estimated cultivation area of 845 hectares and a production of 10985 metric tonnes. The crop thrives at altitudes ranging from 300 to 2000 m above sea level, requiring annual precipitation between 1500 and 2000 mm and a relative humidity of 80-85% (1).

The fruits are viviparous in nature and the whole fruit is used as planting material for commercial cultivation. The ideal temperature for optimal growth is between 20 and 25 ° C. Well-drained soil rich in humus, with a pH between 4.5 and 6.5, is ideal for cultivation. Based on fruit colour, there are two types: white and green. There is no officially named variety of this crop. However, India has yet to release a specific improved or commercial variety for commercial cultivation. Some high yielding genotypes can produce 35 - 40 kg per plant. For better performance, this crop requires well-drained, fertile soil rich in organic matter. While most cucurbits are sensitive to soil pH below 5.5, chayote is slightly tolerant to acidic soils, with a pH range of 5.5 to 6.5. Chayote is highly nutritious, rich in dietary fiber, essential minerals, vitamins and amino acids. Its nutritional profile is influenced by factors such as climate, geographic location, plant age and the processing methods used (2, 3). Young shoots, roots and seeds of chayote provide a good source of calories, carbohydrates and essential macro and micronutrients. Chayote provides the 25 calories, 0.2 g of fat and 2.6 µg of sodium, 6 g of carbohydrates, including 2.2 g of fiber and 2.2 g of sugar. It also has 1.1 g of protein, 122.8

µg of folate and 10.2 mg of vitamin C. Chayote being a crop cultivated in acidic soils where fixation of nutrients to unavailable form to the crops is a common phenomenon in the hilly tracts. Leaching and continuous leaf litter decomposition in hilly areas increase soil acidity, which in turn reduces micronutrient availability for plant physiological activities.

Critical plant growth stages influence yield and timely foliar nutrition enhances growth, leading to higher yields and improved quality. Foliar nutrition can accelerate plant growth, increase crop yields by 15-19 % under stressful conditions and reduce the impact of environmental factors. Foliar nutrients like magnesium, iron and manganese help to form chlorophyll, which is essential for photosynthesis and energy production. Foliar feeding also improves nutrient absorption and helps the plant to uptake more nutrients from the soil. Additionally, Foliar nutrition can impact reproductive processes, with nutrients like boron playing a critical role in pollination, fruit set and seed development, ultimately influencing crop yield and quality. Under such circumstances the foliar application of micronutrients is an alternative method to provide nutrients to the crops.

Materials and Methods

An experiment on "Effect of foliar application of micronutrients on growth, flowering, yield and quality in chow chow *Sechium edule* (Jacq.) Swartz" was undertaken at Horticultural Research Station, Thadiyankudisai, Kodaikanal Block, Dindigul District, Tamil Nadu, India. The research work has been carried out during June 2023 to September 2024. The experimental plot is located at 10°N and 77°E, at an elevation of 1300 m above sea level. The micronutrients used were boric acid (H_3BO_3), zinc sulphate ($ZnSO_4$), ferrous sulphate ($FeSO_4$), manganese sulphate ($MnSO_4$) and Arka Vegetable Special (a micronutrient formulation) were used in this research. The field experimental design consisted of a Randomized Block Design (RBD) with three replications and 14 treatments. The plot size was 34.56 m^2, the spacing was 2.4 m × 1.8 m. As per the treatment details, 5 g of each nutrient was dissolved in 1 L of water (0.5 %) and applied as a foliar spray on a two-month-old chow chow crop at 15-day intervals using a knapsack sprayer (low - drift nozzle, 16 L/ha).

The treatment consists of T_1 (boric acid - 0.5 %), T_2 ($ZnSO_4$ - 0.5 %), T_3 ($FeSO_4$ - 0.5 %), T_4 ($MnSO_4$ - 0.5 %), T_5 (boric acid - 0.5 % + $ZnSO_4$ - 0.5 %), T_6 (boric acid - 0.5 % + $FeSO_4$ - 0.5 %), T_7 (boric acid - 0.5 % + $MnSO_4$ - 0.5 %), T_8 ($ZnSO_4$ - 0.5 % + $FeSO_4$ - 0.5 %), T_9 ($ZnSO_4$ - 0.5 % + $MnSO_4$ - 0.5 %), T_{10} ($FeSO_4$ - 0.5 % + $MnSO_4$ - 0.5 %), T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %), T_{12} (arka vegetable special - 0.5 %), T_{13} (water spray - control), T_{14} (absolute control). After the treatment was applied, growth, yield and quality parameters were measured from the tagged plants. Observation was recorded on growth yield and biometrical characters *viz.*, vine length, days taken for the first male flower, yield per plot and yield per hectare, quality parameter *viz.*, protein, calcium, antioxidants, vitamin C, N, P, K, B, Zn, Fe, Mn. The protein content of the fruit was measured and expressed in grams per 100 grams (4). Calcium content was estimated using the EDTA method (5) and reported in milligrams per 100 grams. vitamin C was determined by the 2,6-dichlorophenol indophenol titration method (6) and expressed in milligrams per 100 grams. Nitrogen content was assessed using the Micro-Kjeldahl method (7) and reported as a percentage. Phosphorus content was measured using the vanado-molybate method (5) and expressed as a percentage. Potassium was quantified using a flame photometer (5) and reported as a percentage. Boron content was analyzed using mass spectrometry (8) and expressed in milligrams per 100 grams. Zinc, iron and manganese contents were measured using a spectrophotometer (5) and reported in milligrams per 100 grams. The recorded data were then analysed using AGRES software to determine the statistical differences among the treatments (9).

Results

The data regarding growth, yield and quality parameters are presented below.

Growth parameters

Micronutrients have a better impact on plant growth and development. They carry out specific functions that are crucial for the plant's growth (10). The key indicators of a plant's vigour are its vegetative characteristics such as plant height, number of branches, leaf area and number of flowers (11). The average mean analysis shows that the foliar application of micronutrients had significant difference on vine length. Vine length ranged from 151.01 to 363.21 cm (Table 1). The outcome from the mixture of all micronutrients tested T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) recorded the highest vine length (363.21 cm) (Table 1). Boron contributes for the structural integrity of cell walls and it is also essential for cell division and cell elongation. Boron is also one of the components of cell wall and reproductive structures in plants. The above result was highly in accordance with the findings in cabbage (12). This could be because of the application of micronutrient mixture in sufficient quantity, improves the biochemical processes such as respiration, photosynthesis and protein synthesis. The similar results were also reported with the application of micronutrient mixture through the foliar spray in broccoli and bitter gourd (13, 14). The number of days required for the appearance of the first female and male flowers of chow chow was significantly reduced by foliar micronutrient application at different intervals. Among the foliar micronutrient treatments, T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) recorded the shortest time (109 days) for the first female flower to appear (Fig. 1). Significantly, treatment T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) recorded the lowest number of days taken for the appearance of first male flower (91) than other treatments (Table 1). The minimum (38.13 days), days were taken for appearance of first female flower was observed in cucumber crop fertilized at the fertigation level of 120 % RDF through fertigation along with the foliar application of boron at the concentration level of 0.2 % (15, 16).

Table 1. Effect of foliar application of micronutrients on vine length (cm). Days taken for the emergence of first male flower and female flower in chow chow

Treatments	Vine length (cm) at 105 DAP	Days taken for the emergence of first male flower	Days taken for the emergence of first female flower
T_1 - Boric acid 0.5 %	229.81 ± 6.63	101.00 ± 2.92	115.00 ± 3.32
T_2 - $ZnSO_4$ 0.5 %	209.72 ± 6.05	100.00 ± 2.89	114.00 ± 3.29
T_3 - $FeSO_4$ 0.5 %	186.52 ± 5.38	102.00 ± 2.94	121.00 ± 3.49
T_4 - $MnSO_4$ 0.5 %	171.66 ± 4.96	103.00 ± 2.97	120.00 ± 3.46
T_5 - Boric acid 0.5 % + $ZnSO_4$ 0.5 %	332.14 ± 9.59	95.00 ± 2.74	118.00 ± 3.41
T_6 - Boric acid 0.5 % + $FeSO_4$ 0.5 %	318.03 ± 9.18	94.00 ± 2.71	115.00 ± 3.32
T_7 - Boric acid 0.5 % + $MnSO_4$ 0.5 %	294.82 ± 8.51	94.00 ± 2.71	114.00 ± 3.29
T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %	279.09 ± 8.06	96.00 ± 2.77	113.00 ± 3.26
T_9 - $ZnSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	264.88 ± 7.65	97.00 ± 2.80	116.00 ± 3.35
T_{10} - $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	242.03 ± 6.99	98.00 ± 2.83	117.00 ± 3.38
T_{11} -Boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	363.21 ± 10.48	91.00 ± 2.63	109.00 ± 3.15
T_{12} - Arka vegetable special 0.5 %	347.35 ± 10.03	93.00 ± 2.68	112.00 ± 3.23
T_{13} - Water spray (Control)	160.31 ± 4.63	105.00 ± 3.03	123.00 ± 3.55
T_{14} - Absolute control	151.01 ± 4.36	103.00 ± 2.97	125.00 ± 3.61
Mean	**252.87**	**98.00**	**116.30**
SD	**54.40**	**3.33**	**2.67**
SE(d)	**24.33**	**1.49**	**1.19**
SE (M)	**17.20**	**1.05**	**0.84**
CD(p = 0.05)	**55.03****	**3.37****	**2.70****

NS - non significant; ** - significant.

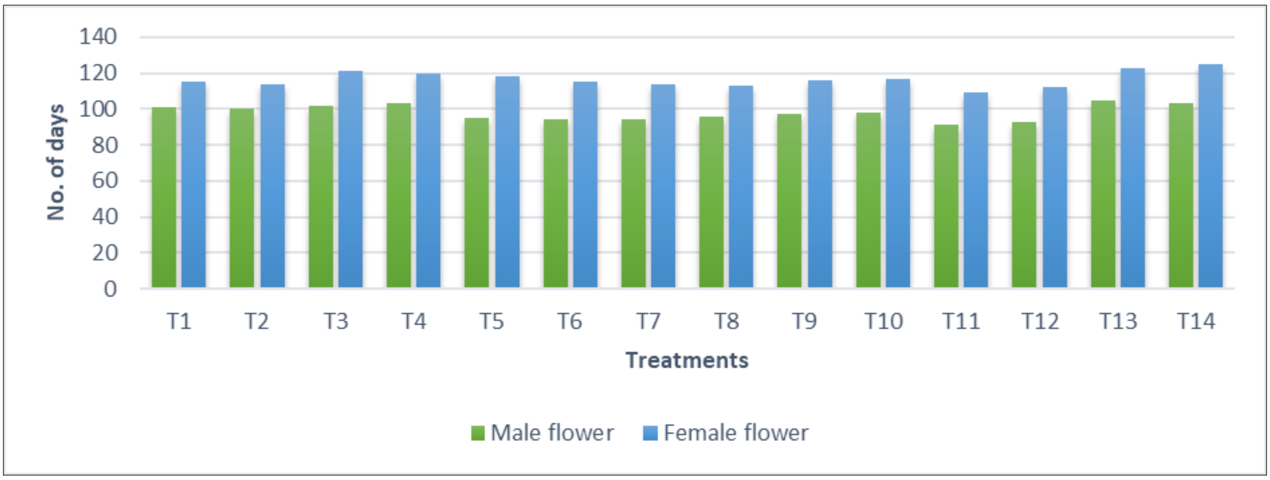

Fig. 1. Effect of foliar application of micronutrients on days taken for the emergence of first male flower and female flower in chow chow (*Sechium edule*).

The faster growth of the vine observed with higher fertilizer and boron levels may be attributed to the enhanced production of flower-forming hormones, leading to an increased number of female flowers. These results align with the findings in cucumber crops (17). The improvement in vegetative growth can be explained by the role of boron in regulating auxin concentration in vines, which in turn boosts the absorption of essential nutrients by enhancing the cation exchange capacity of the roots. Similar observations were reported in bitter gourd (14).

Fruit characters

The resultant data pertaining to the yield per plot and yield per hectare was influenced by the foliar application of micronutrient in chow chow are tabulated in Table 2. Among the foliar application of micronutrients, the highest yield per plot (155.36 kg) was found in the treatment T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) whereas the lowest yield per plot (66.72 kg) was found in the treatment T_{14} (absolute control). The faster growth of the vine observed with higher fertilizer and boron levels may be attributed to the enhanced production of flower-forming hormones, leading to an increased number of female flowers. Applying combined nutrients through foliar may have accelerated and stimulated the physiological forms and functions of cells, tissues and entire plants leading to an increase in yield per plant, yield per plot and yield per hectare. Micronutrient application may have increased the yield due to improved photosynthesis activity and accumulated more carbohydrates that have a positive effect on vegetative development and fruit retention, which not only increased the size but also increased the number of fruits per plant (18).

A significant difference regarding yield per ha which was greatly influenced by the foliar application of micronutrient on chow chow (Table 2). The averaged mean yield per ha was observed to be 29.40 t/ha. Among the foliar application of micronutrients highest yield per ha (44.95 t/ha) was found in the treatment T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) followed by the treatment T_{12} (Arka vegetable special 0.5 %) (40.09 t/ha) whereas lowest yield per ha (19.30 t/ ha) was found in the treatment T_{14} (Absolute control) (Fig. 2). Overall yield is directly correlated with vegetative growth, which increases fruit and flower production (19, 20). One of the most crucial components in the metabolism of carbohydrates

Table 2. Effect of foliar application of micronutrients on fruit yield per plot and on fruit yield in chow chow

Treatments	Yield per plot (kg)	Yield (t/ha)
T_1 - Boric acid 0.5 %	100.24 ± 3.75	29.12 ± 1.09
T_2 - $ZnSO_4$ 0.5 %	91.28 ± 3.42	26.41 ± 0.99
T_3 - $FeSO_4$ 0.5 %	85.52 ± 3.21	24.74 ± 0.93
T_4 - $MnSO_4$ 0.5 %	81.04 ± 3.04	23.44 ± 0.88
T_5 - Boric acid 0.5 % + $ZnSO_4$ 0.5 %	100.88 ± 3.78	29.18 ± 1.09
T_6 - Boric acid 0.5 % + $FeSO_4$ 0.5 %	107.63 ± 4.04	31.13 ± 1.17
T_7 - Boric acid 0.5 % + $MnSO_4$ 0.5 %	121.84 ± 4.57	35.25 ± 1.33
T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %	101.84 ± 3.81	29.46 ± 1.10
T_9 - $ZnSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	98.08 ± 3.67	28.37 ± 1.06
T_{10} - $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	97.04 ± 3.63	28.07 ± 1.05
T_{11} -Boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	155.36 ± 5.83	44.95 ± 1.69
T_{12} - Arka vegetable special 0.5 %	138.56 ± 5.20	40.09 ± 1.51
T_{13} - Water spray (Control)	76.48 ± 2.87	22.12 ± 0.83
T_{14} - Absolute control	66.72 ± 2.51	19.30 ± 0.73
Mean	**98.54**	**28.52**
SD	**11.43**	**3.31**
SE(d)	**5.11**	**1.48**
SE (M)	**3.61**	**1.05**
CD (p = 0.05)	**11.56****	**3.35****

NS - non significant; ** - significant.

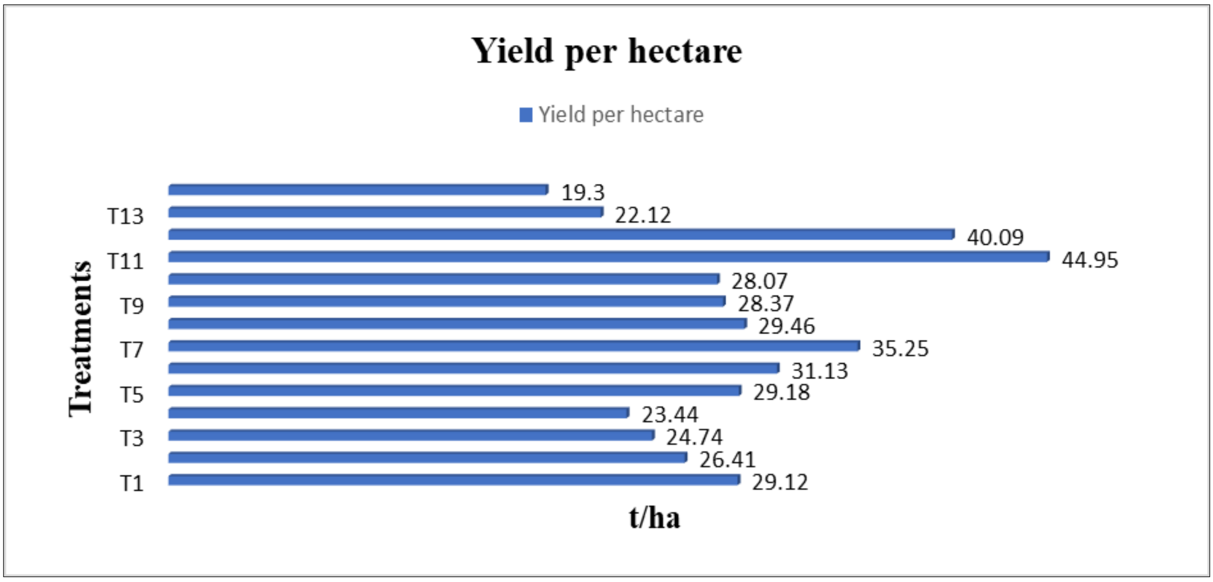

Fig. 2. Effect of foliar application of micronutrients on yield per hectare in chow chow (*Sechium edule*).

is zinc. Zinc activates most of the enzymes involved in the metabolism of carbohydrates which is ultimately responsible for the increase in yield (21). The foliar treatment of micronutrients and the soil application of organic manures may have increased the amount of nutrients and organic matter available in the soil, which could be the cause for the improvement in yield characteristics observed after applying micronutrients externally (12).

Biochemical parameters

Micronutrients applied through foliar treatment are more effective than those applied to the soil because, since they are absorbed and used by the plant more quickly. Soil application takes longer time for the plant to take up and use the nutrients (22).

Adding micronutrients like iron, zinc, boron and manganese to vegetable crops helps to improve their growth, yield and quality (23). The analysis showed that the foliar application of micronutrients had significantly improves the protein content in chow chow (Table 3). The mean value of protein ranges from 0.41 to 1.74 g/100 g. Among the various treatments combined foliar application of micronutrient treatment T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) noted highest protein content (1.74 g/100 g) and lowest protein content was noted in T_{14} control. Foliar application of micronutrients like boron, zinc, iron and manganese enhances protein content in fruits by improving photosynthesis, enzyme activity and nitrogen assimilation. These nutrients activate enzymes involved in protein synthesis and help regulate plant growth hormones. They also reduce stress, allowing the plant to allocate more resources to growth and protein production. Ultimately, the micronutrients support higher protein levels by optimizing metabolic processes and nutrient availability.

This is in line with the findings in mung bean plants with micronutrients led to a significant increase in the levels of total carbohydrates and total protein (24). The results are in conformity with the results obtained in broccoli (25).

Quality parameters are significantly influenced by foliar application of micronutrients like iron, zinc, boron and manganese. Foliar application of micronutrients showed significant positive effect on calcium content on chow chow. Among all treatments, the highest calcium content (419.37 mg/100 g) was recorded in T_{11}.

Table 3. Effect of foliar application of micronutrients on protein, calcium, antioxidants and vitamin C in chow chow

Treatments	Protein (g/100 g)	Calcium (mg/100 g)	Antioxidants (µg/g)	Vitamin C (mg/100 g)
T_1 - Boric acid 0.5 %	0.96 ± 0.05	258.41 ± 9.42	871.02 ± 31.73	10.13 ± 0.37
T_2 - $ZnSO_4$ 0.5 %	0.85 ± 0.04	236.54 ± 8.63	806.37 ± 29.39	9.86 ± 0.36
T_3 - $FeSO_4$ 0.5 %	0.74 ± 0.04	213.67 ± 7.80	740.72 ± 27.02	9.52 ± 0.35
T_4 - $MnSO_4$ 0.5 %	0.68 ± 0.03	189.82 ± 6.93	674.70 ± 24.61	9.07 ± 0.33
T_5 - Boric acid 0.5 % + $ZnSO_4$ 0.5 %	1.51 ± 0.06	378.63 ± 13.82	1245.92 ± 45.46	12.71 ± 0.46
T_6 - Boric acid 0.5 % + $FeSO_4$ 0.5 %	1.44 ± 0.06	356.76 ± 13.02	1182.27 ± 43.12	12.19 ± 0.44
T_7 - Boric acid 0.5 % + $MnSO_4$ 0.5 %	1.35 ± 0.05	333.89 ± 12.18	1117.62 ± 40.73	11.71 ± 0.43
T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %	1.26 ± 0.05	316.02 ± 11.53	1056.97 ± 38.54	11.34 ± 0.41
T_9 - $ZnSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	1.14 ± 0.04	299.15 ± 10.91	997.32 ± 36.40	10.92 ± 0.40
T_{10} - $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	1.08 ± 0.04	279.28 ± 10.19	934.67 ± 34.13	10.64 ± 0.38
T_{11} -Boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	1.74 ± 0.07	419.37 ± 15.33	1370.22 ± 50.01	13.81 ± 0.50
T_{12} - Arka vegetable special 0.5 %	1.59 ± 0.06	399.54 ± 14.61	1308.57 ±47.74	13.25 ± 0.48
T_{13} - Water spray (Control)	0.57 ± 0.03	164.93 ± 6.03	606.42 ± 22.14	8.52 ± 0.31
T_{14} - Absolute control	0.41 ± 0.02	145.06 ± 5.31	543.77 ± 19.86	7.87 ± 0.29
Mean	**1.10**	**286.22**	**962.76**	**10.78**
SD	**0.29**	**62.08**	**191.01**	**3.49**
SE(d)	**0.13**	**27.76**	**85.42**	**0.190**
SE (M)	**0.09**	**19.63**	**60.40**	**0.084**
CD (p = 0.05)	**0.29****	**62.81****	**193.24****	**0.390****

NS - non significant; ** - significant.

The averaged mean on vitamin C content ranges from 7.87 to 13.81 mg/100 g (Fig. 3) and the highest vitamin C content (13.81 mg/100 g) was observed in T_{11} and lowest as found in T_{14} (Table 3). This study showed that the combined foliar application of micronutrients significantly improved quality parameter when compared to the control. The ascorbic acid content of moringa was raised by spraying a mixture of all micronutrients (23). The application of boron with other micronutrients acts as active carriers for enzymatic activities and biochemical processes which paved way for plant ascorbate production pathways which raise the amount of vitamin C content in cabbage heads (26). Similar results were also reported in most of the research articles (27-29). Micronutrients like zinc, copper and manganese are crucial cofactors to produce antioxidant enzymes. Among all the treatments evaluated, the highest antioxidant content (1370.22 µg/g) was found in the treatment T_{11} which was followed by the treatment T_{12} (1308.57µg/g). Foliar application of micronutrients to the leaves, the plant can produce more enzymes which in turn improves the overall antioxidant capacity of the plant. This results in higher levels of antioxidants in the harvested fruits and vegetables (30).

This study showed that the combined foliar application of micronutrients significantly improved nitrogen, phosphorus and potassium content in chow chow when compared to the control (Table 4). Among the combinations, the highest nitrogen content (3.61 %), phosphorus content (0.461 %) and potassium content (1.38 %) was found in the treatment T_{11} (boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + $MnSO_4$ 0.5 %) in chow chow fruit (Fig. 4). The impact of B, Zn, Fe and Mn in various combinations had increased the amount of N, P and K has been reported in ginger. Manganese plays a role in the enzymes that regulate phosphorus uptake and utilization (31). Spraying zinc (Zn) increases the potassium (K) levels in both the leaves and heads of broccoli, while zinc (Zn) and boron (B) together enhance the potassium content in the broccoli head (32).

Highest boron content (0.421 mg/100 g) was noted in T_{11} this could be because of as the foliar spray of boron increases the boron content as reported in onion bulb (31). Zinc helps in various physiological and biochemical process related to carbohydrate, protein, auxins and is also important for the structure of cellular membrane (33). The average zinc content in chow chow fruit ranges between 0.34 and 1.58

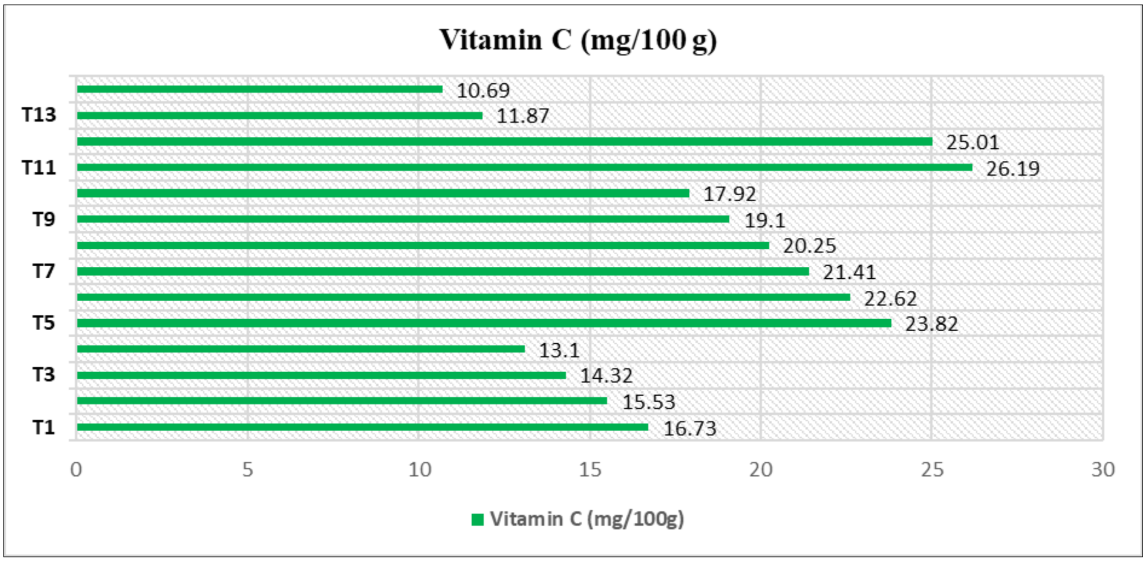

Fig. 3. Effect of foliar application of micronutrients on vitamin C content in chow chow (*Sechium edule*).

Table 4. Effect of foliar application of micronutrients on nitrogen, phosphorus and potassium content in chow chow

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1 - Boric acid 0.5 %	2.23 ± 0.05	0.292 ± 0.004	0.87 ± 0.03
T_2 - $ZnSO_4$ 0.5 %	2.04 ± 0.08	0.271 ± 0.004	0.80 ± 0.01
T_3 - $FeSO_4$ 0.5 %	1.87 ± 0.07	0.246 ± 0.005	0.73 ± 0.03
T_4 - $MnSO_4$ 0.5 %	1.67 ± 0.06	0.221 ± 0.006	0.67 ± 0.02
T_5 - Boric acid 0.5 % + $ZnSO_4$ 0.5 %	3.26 ± 0.04	0.417 ± 0.005	1.25 ± 0.01
T_6 - Boric acid 0.5 % + $FeSO_4$ 0.5 %	3.07 ± 0.04	0.391 ± 0.005	1.18 ± 0.04
T_7 - Boric acid 0.5 % + $MnSO_4$ 0.5 %	2.87 ± 0.03	0.372 ± 0.006	1.12 ± 0.04
T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %	2.72 ± 0.08	0.353 ± 0.004	1.05 ± 0.04
T_9 - $ZnSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	2.58 ± 0.06	0.335 ± 0.005	0.99 ± 0.02
T_{10} - $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	2.41 ± 0.07	0.313 ± 0.005	0.93 ± 0.01
T_{11} -Boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	3.61 ± 0.03	0.461 ± 0.006	1.38 ± 0.04
T_{12} - Arka vegetable special 0.5 %	3.44 ± 0.08	0.432 ± 0.007	1.31 ± 0.03
T_{13} - Water spray (Control)	1.49 ± 0.08	0.197 ± 0.004	0.60 ± 0.02
T_{14} - Absolute control	1.32 ± 0.04	0.176 ± 0.006	0.54 ± 0.03
Mean	**2.47**	**0.32**	**0.96**
SD	**0.52**	**0.06**	**0.19**
SE(d)	**0.23**	**0.03**	**0.09**
SE (M)	**0.17**	**0.02**	**0.06**
CD (p = 0.05)	**0.53****	**0.06****	**0.20****

NS - non significant; ** - significant.

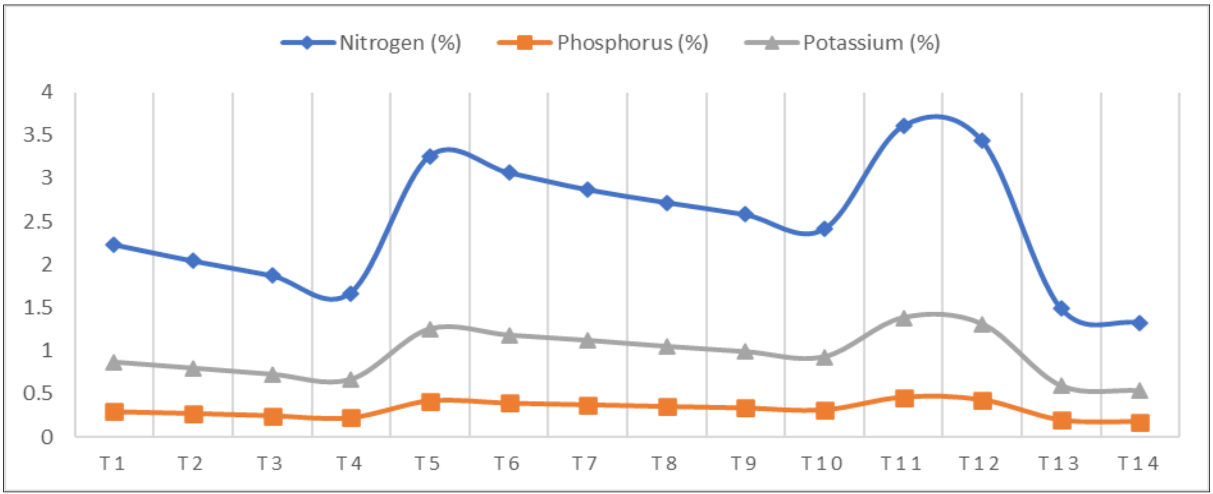

Fig. 4. Effect of foliar application of micronutrients on N, P and K content in chow chow (*Sechium edule*).

mg/100 g. Highest zinc content was found in the treatment T_{11} (Table 5). Photosynthesis and metabolic activities may have enhanced photosynthates production and its translocation to various plant sections, ultimately leading to a rise in the concentration of zinc in the fruit (31). Combined foliar application of micronutrients shows increased iron content in fruit and the average ranges between 34.71 and 84.30 mg/100 g. Highest iron content in the chow chow fruit was found to be 84.30 mg/100 g in the treatment T_{11}. Iron is a part of the electron transport of protein ferredoxin and is linked to chloroplasts, it plays a significant function in boosting growth characteristics (34). Manganese is a major component of chlorophyll, making up 15-20 % of the total Mn content in plants. Manganese activates enzymes that are involved in

Table 5. Effect of foliar application of micronutrients and its concentration in fruit

Treatments	B (mg/100 g)	Zn (mg/100 g)	Fe (mg/100 g)	Mn (mg/100 g)
T_1 - Boric acid 0.5 %	0.296 ± 0.005	0.84 ± 0.02	53.83 ± 1.23	2.46 ± 0.07
T_2 - $ZnSO_4$ 0.5 %	0.283 ± 0.004	1.05 ± 0.03	50.21 ± 1.37	2.97 ± 0.06
T_3 - $FeSO_4$ 0.5 %	0.268 ± 0.006	0.67 ± 0.02	76.19 ± 1.44	2.75 ± 0.05
T_4 - $MnSO_4$ 0.5 %	0.254 ± 0.005	0.57 ± 0.01	42.37 ± 1.19	3.21 ± 0.08
T_5 - Boric acid 0.5 % + $ZnSO_4$ 0.5 %	0.381 ± 0.007	1.41 ± 0.04	76.69 ± 1.51	3.99 ± 0.09
T_6 - Boric acid 0.5 % + $FeSO_4$ 0.5 %	0.367 ± 0.006	0.88 ± 0.03	72.87 ± 1.32	3.78 ± 0.08
T_7 - Boric acid 0.5 % + $MnSO_4$ 0.5 %	0.351 ± 0.005	0.87 ± 0.02	69.04 ± 1.28	3.56 ± 0.07
T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %	0.339 ± 0.004	1.14 ± 0.03	65.26 ± 1.47	4.74 ± 0.06
T_9 - $ZnSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	0.325 ± 0.006	1.09 ± 0.02	61.49 ± 1.36	4.48 ± 0.07
T_{10} - $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	0.312 ± 0.005	0.97 ± 0.03	57.65 ± 1.26	4.21 ± 0.08
T_{11} -Boric acid 0.5 % + $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %+ $MnSO_4$ 0.5 %	0.421 ± 0.007	1.58 ± 0.04	84.30 ± 1.69	5.23 ± 0.09
T_{12} - Arka vegetable special 0.5 %	0.395 ± 0.006	1.49 ± 0.03	80.52 ± 1.61	4.99 ± 0.07
T_{13} - Water spray (Control)	0.235 ± 0.004	0.46 ± 0.01	38.54 ± 1.08	2.19 ± 0.06
T_{14} - Absolute control	0.197 ± 0.005	0.34 ± 0.01	34.71 ± 1.02	1.91 ± 0.05
Mean	**0.316**	**0.954**	**61.69**	**3.61**
SD	**0.063**	**0.368**	**15.73**	**1.04**
SE(d)	**0.017**	**0.098**	**4.20**	**0.28**
SE (M)	**0.012**	**0.069**	**2.97**	**0.20**
CD (p = 0.05)	**0.035****	**0.202****	**8.63****	**0.57****

NS - non significant; ** - significant.

reactions like oxidation, carboxylation and carbohydrate metabolism because it can easily change from Mn^{2+} to Mn^{3+} or Mn^{4+}. The data in relevance to the effect of foliar application of micronutrients on manganese content was tabulated in Table 5. The micronutrient manganese content in fruit ranges between 1.91 and 5.23 mg/100 g. Manganese content was found to be the highest in the treatment T_{11} (5.23 mg/100 g). Applying Mn through foliar spray enhanced the movement of photosynthates from the leaf to the fruit (35).

Conclusion

The findings of the current study indicate that treatments with micronutrients boron (B), zinc (Zn), iron (Fe) and manganese (Mn) applied through combined foliar sprays resulted in a significantly better response compared to the control. Applying foliar fertilizers at the correct concentration and growth stage maximizes benefits. Foliar application of micronutrients enhances crop yield, offering a sustainable approach for farmers to improve productivity of chow chow.

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Authors' contributions

RB, RRR and KN assisted in writing original drafts and conceptualization. RB, RRR, KN and MK revised the draft, inclusion of tables and DMRT analysis. All the authors contributed in revision, formatting, supervision, read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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