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The impact of micronutrients applied through foliar application on the growth, yield and benefit cost ratio of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa under the polyhouse condition

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Abstract
The present investigation was carried out during 2022-2023 at Experimental Research Farm Chhapang of Dr. Khem Singh Gill, Akal College of Agriculture, Eternal University, Baru Sahib, Sirmour, (Himachal Pradesh) to evaluate the effect of micronutrients through foliar application on growth, yield and benefit cost ratio of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa under the polyhouse condition. It consists of 16 treatments (with 4 different levels of micronutrients) with three replications and one cultivar Camarosa. The outcomes exposed that the maximum plant growth attributes, yield attributes including plant height (30.12 cm), plant spread East-West (40.11 cm), plant spread North-South (40.08 cm), number of leaves/plant (22.73), leaf length (6.83 cm), leaf width (6.73 cm), leaf area (68.87 cm^2), canopy volume (101439.62 cm^3), chlorophyll content A at initial stage (0.92 mg/g) and final stage (1.07 mg/g), chlorophyll content B at initial stage (1.60 mg/g) and final stage (1.86 mg/g), total chlorophyll content at initial stage (2.51 mg/g) and final stage (2.93 mg/g), number of flowers/plant (21.49), number of fruits/plant (21.24), fruit set (98.84%), yield/plant (461.33 g), yield/plot (11.07kg), yield/ha (22.14tonnes) of strawberry were obtained under the treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)}.The cost analysis showed that treatment combination T_{15}{B+ Cu + Fe + Zn (0.5% each)} resulted in highest benefit cost ratio (3.41) and minimum benefit cost ratio (1.53) in the treatment T_0 (control). Hence, the primary objective of the research was to enhance the growth and quality of the fruit production of the Camarosa cultivar with combined foliar application of micronutrients such as {(B+ Cu + Fe + Zn (0.5% each)} under protected conditions. This approach proved to be effective and can be utilized by farmers to enhance yield and generate more income per unit area.

Keywords: Strawberry, cultivar, treatment, yield and micronutrients

Introduction
Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most popular and refreshing horticultural fruit crops. It belongs to the family Rosaceae (subfamily Rosoideae) having chromosome number 2 n = 56 (allo-octaploid) and native to France. Commercially cultivated strawberry is the result of a cross between two American octaploid species, *F. chilonensis* and *F. virginiana*. Strawberry is an herbaceous crop with a prostrate growth habit, which acts as an annual in subtropical regions and as a perennial in temperate regions (Singh *et al*., 2015) [12]. The fruit has gained widespread acceptance as a small fruit with an edible portion of 98% and a fleshy thalamus (Chandrakar *et al*., 2018) [4]. There is a lot of demand for strawberries in the fresh market as well as in the processing industries for making various processed edible products such as juice, chutney, squash, jam, jellies, milkshakes, pie, ice cream, and chocolate. The nutritional profile of this fruit is characterized by its high content of vitamins and antioxidants (Sharma, 2002) [10]. The strawberry is a fruit with a low calorie and carbohydrate content that provides numerous health benefits when consumed (Ayub *et al*., 2010) [1]. The strawberry has gained significant prominence among fruits and is considered as functional food, offering multiple health benefits beyond basic nutrition, with antioxidant and antihypertensive properties (Basu *et al*., 2014) [3]. Strawberry is cultivated in many countries, like Europe, Canada and South America. In India, it is cultivated in Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Karnataka, Tamil Nadu, Rajasthan, Uttarakhand and Himachal Pradesh (Bal, 2018) [2]. The climate of the lower hills in Himachal Pradesh is ideal for production of high-quality fruits, while the climate of the medium and high mountains in the state is perfect for production of high-quality runners.

The strawberry is one of the most nutrient-sensitive fruit crops (Mohamed *et al*., 2011) [7] and a sufficient supply of both macro and micronutrients may enhance the flowering, productivity and quality of this crop. In addition to macronutrients, micronutrients are also essential for the growth, development of plants and played an important role in plant metabolism, including respiration, photosynthesis, chlorophyll synthesis and numerous other enzymatic activities.

Furthermore, the foliar application of micronutrients is the most efficient way to supply essential nutrients they require; it encourages plants to absorb nutrients efficiently through their leaves. Foliar spray can deliver the required amount of nutrients for plant growth and development when it is impossible for roots to absorb and make these nutrients available from the soil. Besides, nutrient absorption through plant foliage is a rapid way as compared to soil nutrition (Kumar *et al*., 2010) [6].

In most cases farmer fertilize the strawberry with macronutrients only (N, P and K) and neglects micronutrients such as boron, copper, iron and zinc, which hinders strawberry growth and sharply decreases the fruit yield and quality. Keeping in view the significance of micronutrients the study has planned for the better growth and high yield of strawberry fruits.

Materials and Methods

Experimental Site: The present investigation on the effect of micronutrients on growth, yield and benefit cost ratio of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa under the polyhouse condition was carried out at Experimental Research Station Chappang which was located at a distance of approximately 4 km from the main campus of Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, District Sirmour, (Himachal Pradesh). It was located at 30°44'19" latitude in the North and 77° 18'54" longitude in East. The elevation is approximately 907 m above mean sea level (MSL).

Planting material: Strawberry (*Fragaria* × *ananassa* Duch.) cultivar Camarosa was used as the experimental material. The healthy sapling of uniform growth without any diseases and injuries were selected for experiment at Research Station Chappang. All the plants, used in the present investigation were maintained under uniform cultural practices during the entire course of experimentation.

Experimental Details: The present investigation employed two distinct elements with four levels of micronutrients and the strawberry cultivar Camarosa was utilized**.** The experiment was conducted in a randomized block design with three replications and consisted of 16 treatments. The treatment and cultivar were randomly allocated to each plot at a spacing of 60 cm row to row and 30 cm plant to plant. Twenty-four plants are allotted to each plot.

The different treatment combination were used are T_0 (Control), T_1 (Boron 0.2%), T_2 (Boron 0.4%), T_3 (Boron 0.5%), T_4 (Copper 0.2%), T_5 (Copper 0.4%), T_6 (Copper 0.5%), T_7 (Iron 0.2%), T_8 (Iron 0.4%), T_9 (Iron 0.5%), T_{10} (Zinc 0.2%), T_{11} (Zinc 0.4%), T_{12} (Zinc 0.5%), T_{13} (B+ Cu + Fe + Zn (0.2% each)), T_{14} (B+ Cu + Fe + Zn (0.4% each)), T_{15} (B+ Cu + Fe + Zn (0.5% each).

Determination of growth and yield attributes

Plant growth attributes

Plant height (cm): Plant height was determined from ground level of the crown to the tip of photosynthetic tissue, using a measuring scale.

Plant spread (cm): The data on plant spread (East-West and North-South orientations) by using a measuring scale.

Number of leaves/plant: The number of leaves/plant produced on five randomly selected plants in each treatment combination was counted from 60 DAP to 240 DAP at 15 day intervals.

Leaf length (cm): The leaf length was recorded from stalk end to petiole end, with the help of a measuring scale.

Leaf width (cm): The leaf breadth was determined from the centre of the leaf with the help of a measuring scale.

Leaf area (cm^2): The leaf area was calculated by individually collecting five leaves from five randomly marked plants in each treatment combination using graph paper.

Canopy volume (cm^3): The canopy volume was determined by using the data obtained in plant height and plant spread and the formula is given below:

$$\text{Canopy volume (cm}^3\text{)} = \frac{(\text{E-W} + \text{N-S})^2}{4} \times \frac{1}{2} \times \text{Plant height}$$

Chlorophyll content (mg/g) (at initial and at the end ofstudy period): Chlorophyll content was calculated as per the method suggested by Sadasivam and Manickam (1997) [8]. 1 g of fully matured cut leaves were weighed and crushed in a clean mortar with 20 ml of acetone for chlorophyll extraction. The sample was centrifuged for 5 minutes in falcon tubes and the residue was transferred into a 100 ml of volumetric flask. The centrifugal operation was repeated until a colourless residue appeared. To obtain a clear extraction of leaves the mortar and pestle were thoroughly cleaned with 80% acetone. With 80% acetone, the volume was increased to 100 ml. The absorbance of the sample was then measured at 645 and 663 nm in comparison to a blank solution of 80% acetone. The concentration of chlorophyll in the extract was determined by using the given formula:

$$\text{Chlorophyll (a) mg/g tissue} = 12.7(A663) - 2.69\ (A645) \times V/1000 \times W$$

$$\text{Chlorophyll (b) mg/g tissue} = 22.9(A645) - 4.68(A663) \times V/1000 \times W$$

$$\text{Total Chlorophyll mg/g tissue} = 20.2(A645) + 8.02\ (A663) \times V/1000 \times W$$

Where,

A = Absorbance at specific wave length

V = Final volume of chlorophyll extract in 80 per cent acetone

W = Fresh weight of tissue extracted

Yield attributes

Number of flowers/plant: It was counted manually from the beginning of the initial blossoming until the end of the full bloom.

Number of fruits/plant: The number of fully mature fruits produced by five randomly tagged plants in each treatment combination was counted at each harvest.

Fruit set (%): The number of fruits set was calculated and then converted into a percentage by using the formula given below:

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruits set}}{\text{Total number of flowers appeared}} \times 100$$

Yield/plant (g): The total fruit yield/plant was recorded at every harvest with the help of a digital analytical balance from randomly selected five plants from each treatment combination.

Yield/plot (kg): The average yield/plot was calculated by multiplying the value of yield/plant (g) by the total number of plants/plot and dividing the result by 1000.

Yield/ha (tonnes): The yield/ha (tonnes) was calculated by multiplying the yield/plot (kg) by the total number of plots/hectare and dividing the result by 1000.

Benefit Cost Ratio: Net returns = Gross returns - Cost of cultivation (Rs/ha).

Results and Discussion

Plant Growth Attributes

The present investigation indicated that the foliar spray of different micronutrients at different concentrations had significant effects on plant growth characteristics of strawberry under the polyhouse condition during the period of investigation i.e. 2022–2023. As the data exhibited in Table 1 showed that the maximum plant height (30.12 cm), plant spread East-West (40.11 cm), plant spread North-South (40.08 cm), number of leaves/plant (22.73), leaf length (6.83 cm), leaf width (6.73 cm), leaf area (68.87 cm^2) and canopy volume (101439.62 cm^3) were observed when plants were treated with treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)}, while the minimum plant height (26.13 cm), plant spread East-West (35.20 cm), plant spread North-South (35.16 cm), number of leaves/plant (15.17), leaf length (5.31 cm), leaf width (5.20 cm), leaf area (52.30 cm^2) and canopy volume (67751.00 cm^3) were recorded under the treatment T_0 (Control). It may be because the crop had more nutrients available for a longer period of time, which led to better photosynthetic activities and high biomass production and ultimately increased all vegetative characteristics of plants. The results are in agreement with the findings of Yadav *et al*., (2021) [15] in strawberry and Saha *et al*., (2019) [9] in Strawbeqrry.

Table 1: Effect of micronutrients on plant height (cm), plant spread East-West (cm), plant spread North- South (cm), number of leaves/plant, leaf length (cm), leaf width (cm) leaf area (cm^2) and canopy volume (cm^3) of strawberry

Treatment notations	Plant height (cm)	Plant spread (E-W) (cm)	Plant spread (N-S) (cm)	Number of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Canopy volume (cm^3)
T_0	26.13	35.20	35.16	15.17	5.31	5.20	52.30	67751.00
T_1	26.19	35.27	35.24	16.31	5.64	5.52	53.60	68196.31
T_2	26.25	35.28	35.26	17.27	6.31	6.14	52.47	68397.91
T_3	26.36	35.51	35.46	15.37	5.98	5.76	52.58	69522.22
T_4	26.38	36.12	36.06	15.42	5.42	5.23	52.87	71974.39
T_5	26.46	36.18	36.15	16.29	5.77	5.60	52.63	72493.11
T_6	26.49	36.29	36.26	17.20	5.54	5.45	53.07	73010.76
T_7	27.16	36.38	36.31	18.30	5.64	5.51	60.83	75160.53
T_8	27.26	36.78	36.68	16.39	6.57	6.54	62.77	77038.51
T_9	27.46	37.87	37.75	18.15	5.82	5.73	68.35	82227.35
T_{10}	28.08	36.26	35.87	19.44	6.32	6.26	54.70	76518.73
T_{11}	28.35	38.09	37.85	19.75	5.83	5.68	55.90	85629.30
T_{12}	29.88	40.03	39.66	22.14	6.29	6.33	68.21	99374.81
T_{13}	29.96	40.04	39.72	22.15	6.66	6.56	68.20	99794.74
T_{14}	30.01	40.09	39.83	22.20	6.74	6.65	68.30	100392.63
T_{15}	30.12	40.11	40.08	22.73	6.83	6.73	68.87	101439.62
SEm	0.06	0.07	0.05	0.24	0.08	0.08	0.24	225.27
$CD_{0.05\%}$	0.19	0.22	0.16	0.69	0.25	0.23	0.72	653.58

As the data indicated in Table 2 showed that the maximum chlorophyll content A (0.92 mg/g), chlorophyll content B (1.60 mg/g), total chlorophyll content (2.51 mg/g) at initial stage and chlorophyll content A (1.07 mg/g), chlorophyll content B (1.86 mg/g) and total chlorophyll content (2.93 mg/g) at final stage were recorded under the treatment T_{15}{B+ Cu + Fe + Zn (0.5% each)}, whereas the minimum chlorophyll content A (0.63 mg/g), chlorophyll content B (1.10 mg/g), total chlorophyll content (1.73 mg/g) at initial stage and chlorophyll content A (0.74 mg/g), chlorophyll content B (1.32 mg/g), total chlorophyll content (2.06 mg/g) at final stage were observed in the treatment T_0 (Control). It might be due to the role of micronutrients in the regulation of cytoplasmic concentrations of nutrients and the enhancement of secondary metabolite concentrations. The results of this research concurred with those of Singh *et al*. (2015) [12] in strawberry cv. Chandler.

Table 2: Effect of micronutrients on chlorophyll content A (mg/g), chlorophyll content B (mg/g) and total chlorophyll content (mg/g) (at initial stage and final stage) of strawberry

Treatment notations	Chlorophyll content A		Chlorophyll content B		Total Chlorophyll content	
	(At initial stage) (mg/g)	(At final stage) (mg/g)	(At initial stage) (mg/g)	(At final stage) (mg/g)	(At initial stage) (mg/g)	(At final stage) (mg/g)
T_0	0.63	0.74	1.10	1.32	1.73	2.06
T_1	0.65	0.77	1.12	1.34	1.78	2.11
T_2	0.69	0.78	1.19	1.36	1.88	2.13
T_3	0.68	0.81	1.15	1.38	1.83	2.19
T_4	0.76	0.83	1.28	1.39	2.04	2.22
T_5	0.74	0.85	1.26	1.43	2.00	2.27
T_6	0.78	0.86	1.41	1.44	2.19	2.30
T_7	0.79	0.88	1.35	1.51	2.14	2.39
T_8	0.80	0.91	1.36	1.53	2.15	2.44
T_9	0.81	0.92	1.38	1.60	2.19	2.52
T_{10}	0.82	0.93	1.43	1.66	2.25	2.60
T_{11}	0.85	0.95	1.49	1.70	2.34	2.65
T_{12}	0.86	0.97	1.51	1.74	2.37	2.71
T_{13}	0.88	1.02	1.54	1.76	2.41	2.78
T_{14}	0.90	1.06	1.55	1.84	2.44	2.89
T_{15}	0.92	1.07	1.60	1.86	2.51	2.93
SEm	0.01	0.03	0.03	0.07	0.03	0.10
$CD_{0.05\%}$	0.03	0.10	0.08	0.21	0.10	0.31

Yield Attributes

The present investigation indicated that the foliar application of different micronutrients at different concentrations had a significant impact on yield characteristics. As the data showed in the Table 3 revealed that the maximum number of flowers/plant (21.49), number of fruits/plant (21.24), fruit set (98.84%), yield/plant (461.33 g), yield/plot (11.07 kg) and yield/hectare (22.14 tonnes) were observed in the treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)} while the minimum number of flowers/plant (17.18), number of fruits/plant (15.52), fruit set (90.32%), yield/plant (262.61 g), yield/plot (6.30 kg) and yield/hectare (12.61 tonnes). This might be because zinc is important for starch formation and other activities in the plant, such as the transportation of carbohydrates. Zinc in the plant helps to load and move photoassimilates to the fruits faster and is involved in cell division and cell growth. Similar findings were also obtained by Tagad *et al*., (2018) [13] in acid lime and Thorat *et al*., (2018) [14] in strawberry. Furthermore, boron and copper are beneficial for stimulating enzymatic action in peripheral tissue, which would otherwise be ineffective due to their deficiency in the area. The utilization of boron and zinc may contribute to the transfer of carbohydrates and the formation of the cell wall, which in turn may enhance the yield, as reported by Sheikh and Manjula (2012) [11] in pomegranate. Moreover, iron and copper may play a role in the enhancement of the chlorophyll content of leaves, the improvement of photosynthetic efficiency, and the translocation of metabolites from the source to the sink as needed by the crop. This may lead to an increase in the number of fruits and, ultimately, an increase in the yield of fruit crops. The results were similar to those reported by Kazi *et al*., (2012) [5] in sweet orange.

Table 3 Effect of micronutrients number of flowers/plant, number of fruits/plant, fruit set (%), yield/plant (g), yield/plot (kg) and yield/hectare (tonnes) of strawberry

Treatment notations	Number of flowers/plant	Number of fruits/plant	Fruit set (%)	Yield/plant (g)	Yield/plot (kg)	Yield/ha (tonnes)
T_0	17.18	15.52	90.32	262.61	6.30	12.61
T_1	17.26	15.86	91.87	272.27	6.53	13.07
T_2	17.17	15.80	92.07	272.61	6.54	13.09
T_3	17.49	16.14	92.27	280.40	6.73	13.46
T_4	17.68	16.48	93.21	285.43	6.85	13.70
T_5	18.13	16.81	92.70	306.16	7.35	14.70
T_6	18.24	17.31	94.88	315.90	7.58	15.16
T_7	18.28	17.28	94.51	316.11	7.59	15.17
T_8	18.69	17.80	95.28	338.91	8.13	16.27
T_9	19.08	18.26	95.68	349.07	8.38	16.76
T_{10}	19.28	18.68	96.85	359.14	8.62	17.24
T_{11}	19.77	19.34	97.86	390.67	9.38	18.75
T_{12}	20.37	20.10	98.70	434.09	10.42	20.84
T_{13}	21.34	21.07	98.75	455.67	10.94	21.87
T_{14}	21.37	21.11	98.80	456.54	10.96	21.91
T_{15}	21.49	21.24	98.84	461.33	11.07	22.14
SEm	0.07	0.12	0.75	2.39	0.05	0.11
$CD_{0.05\%}$	0.20	0.35	2.19	6.93	0.16	0.33

Benefit Cost Ratio

Data regarding the total benefit cost ratio shown in Table 4 and revealed that the treatment combination T_{15} {B+ Cu + Fe + Zn (0.5% each)} against the cost of cultivation (Rs. 601900.00/ha) had the highest benefit cost ratio (3.41), followed by the treatment combination T_{14} {B+ Cu + Fe + Zn (0.5% each)} against the cost of cultivation (Rs. 601725.00/ha). Additionally, treatment combination T_0 (control) showed the lowest benefit cost ratio (1.53).

On the basis of the results obtained in the present investigation, the inference can be drawn that different levels of micronutrients had a considerable effect on the growth, yield, and fruit quality of strawberry. Among the various treatment combinations, the treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)}has been found to be superior in giving the maximum net return, mostly because of the larger production and more uniform-sized fruits with better fruit quality and yield. This attracted the consumer and gave it a good market price. However, the treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)} was found greatest benefit: cost ratio (3:41). This fact might be due the foliar application of different micronutrients at different levels significantly increased strawberry plant growth, yield and fruit quality.

Table 4: Effect of micronutrients on total benefit cost ratio

Treatment notations	Total Cost of Cultivation (Rs)	Gross Return (Rs)	Net Return (Rs)	B:C Ratio
T_0	599000.00	1512639.36	913639.36	1.53
T_1	599430.00	1568297.47	968867.47	1.62
T_2	599575.00	1570208.06	970633.06	1.62
T_3	599600.00	1615129.73	1015529.73	1.69
T_4	599900.00	1644064.32	1044164.32	1.74
T_5	599950.00	1763495.42	1163545.42	1.94
T_6	600000.00	1819602.24	1219602.24	2.03
T_7	599300.00	1820819.52	1221519.52	2.04
T_8	599350.00	1952139.46	1352789.46	2.26
T_9	599400.00	2010614.78	1411214.78	2.35
T_{10}	599800.00	2068674.24	1468874.24	2.45
T_{11}	599850.00	2250242.30	1650392.30	2.75
T_{12}	599900.00	2500372.22	1900472.22	3.17
T_{13}	601430.00	2624678.78	2023248.78	3.36
T_{14}	601725.00	2629695.55	2027970.55	3.37
T_{15}	601900.00	2657269.44	2055369.44	3.41

Conclusion

The conclusion can be drawn that foliar application of micronutrients contributes significantly to the alteration of plant growth characteristics, yield and also gave the maximum benefit returns in strawberry. In order to achieve a higher yield, it is imperative to implement modifications in the approach of nutrient management in strawberry. Hence the application of treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)} is highly recommended for the improved plant growth characteristics, yield characteristics of strawberry. The cost analysis of the study revealed that the treatment T_{15} {B+ Cu + Fe + Zn (0.5% each)} against the cost of cultivation (Rs. 601900.00/ha) had the highest benefit cost ratio (3.41).

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