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Effect of micro nutrients on vegetative growth, flowering and yield related traits of strawberry (*Fragaria x ananassa* Duch.) cv. Sweet Charlie

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Abstract
The field experiment was carried out at Department of Horticulture, National Post Graduate College, Barhalganj, Gorakhpur, U.P., India during 2019-20 on strawberry plant cv. Sweet chaelie. The experiment was designed in RBD to study the effect of micronutrients *viz.* boron, zinc and molybdenum and its combination on plant growth pattern and yield attributing characters of the strawberry. Boric acid (H_3BO_3) (0.2% & 0.4%), zinc sulphate ($ZnSO_4$) (0.2% & 0.4%) and sodium molybdate (Na_2MoO_4) (0.2% & 0.4%) were used as a source of boron, zinc and molybdenum respectively. All the plants fertilized with recommended dose of NPK (150:100:120 as N, P_2O_5 and K_2O). The spraying was done twice; during last week of November at after crown development stage and again at 30 days after the first spraying during years in three replication. Result proved that foliar spraying on strawberry plant with RDF + Zn + Mo + B + @ (0.4%) was the promising treatment for improvement of Plant height, Number of leaves, Plant spread (cm) at harvest, Days to first flowering (days), Days to First harvesting (days), Number of flower per plant, Number of fruit per plant, fruit Yield per plant (g), fruit Yield per plot (kg) and fruit Yield per ha (tn). This treatment was also found best for maximum Fruit length (cm), Fruit diameter (cm), Average Fruit Weight (g), as well as the cost benefit ratio.

Keywords: Strawberry, boron, zinc, molybdenum and fruit yield

Introduction
The modern strawberry, also known as the desert strawberry, or *Fragaria* x *ananassa Duchense,* is a delicious and fascinating fruit. It belongs to the family Rosaceae. It is a perennial, herbaceous, and diminutive plant. Roots reach about 15-30 cm into the ground below the crown and live for several years. Most cultivars have trifoliate, compound leaves arranged in a spiral around the crown (Ozuygur *et al.*, 2000) [18]. Strawberries reproduce sexually via seed; they can also reproduce asexually using their stolons, or runners, which grow several cm away from the 'mother' plant before rooting into the ground at the nodes and developing a new crown. Several weeks later, the stolon deteriorates and the new flowers, leaves, and stolon (Almaliotis *et al.*, 2002) [3].
Micronutrients are vital to the growth of plants, acting as catalyst in promoting various organic reactions taking place within the plant and their deficiencies often limit crop productivity in fruit crops. Application of zinc sulphate and boric acid are increased the fruit yield and use of molybdenum increased fruit quality, higher concentration of zinc sulphate resulted in enhanced shelf life of fruits at ambient temperature and higher concentration of boric acid had toxic effect on the plant and retarded the growth, yield and quality attributes. In the past, there was no need of micronutrients because these trace elements were naturally supplied by soil. But due to intensive cultivation, increase in salinity and soil pH in most of soils, these nutrients are present but are not available to plants (Ahmad *et al.*, 2010) [2].
Mo is a trace element for plant growth. Once molybdate enters the cell, it is subsequently incorporated by complex biosynthetic machinery into Mo co-factors (Moco). Moco, as a prosthetic group, participates in the active site of Mo enzymes, such as nitrate reductase, xanthine dehydrogenase, aldehyde oxidase, sulphite oxidase, and the mitochondrial amidoxime reducing component. These enzymes play an important role in nitrate assimilation, phytohormone biosynthesis, purine metabolism, sulfite detoxification, and the reduction of a broad range of N-hydroxylated compounds (Hille *et al.* 2011) [11]. Mo is involved in nitrogen (N) metabolism of plants (Kaiser *et al.* 2005) [12]. Mo deficiency prevented the transformation

from δ-aminolaevulinic acid to uroporphyrinogen III, and thus inhibited the biosynthesis of chlorophyll, resulting in a decrease in chlorophyll in winter wheat cultivars (Yu *et al.* 2006) [24]. Enhanced chloroplast development and chlorophyll content increases leaf and fruit photosynthetic capacity, which provides more substrate for precursors of sugars, organic acids, and volatile aroma compounds (Nadakuduti *et al.* 2014) [17].

Increased demand for high-quality fruit with unique colour, high nutritional value, and good flavour has leads to a proliferation in research on fresh fruit quality, including physicochemical and flavor characteristics. Strawberry flavor is derived from a combination of its taste and aroma. The taste of strawberry primarily depends on sugars and organic acids, whereas its aroma depends on numerous volatiles. Over 360 volatile compounds have thus far been reported in ripe strawberry (Raab *et al.* 2006) [20], including esters, organic acids, alcohols, ketones, phenols, terpenes, furan ones, aldehydes, lactones, sulfur compounds, and epoxides. Other micronutrients are also key factors in strawberry fruit quality. However, while the effect of N (Ancín-Azpilicueta *et al.* 2013) [4], Zinc and Boron (Motesharezade *et al*. 2001) [16], Molybdenum (Li *et al*., 2017) [13], phosphorus and potassium (Topalović *et al.* 2011) [23] on fruit yield and fruit quality have been described, the effects of micronutrients on flavor and nutritional quality have not been reported.

Materials and Methods

The present work was conducted at experimental farm of Department of Horticultural, National Post Graduate College, Barhalganj, Gorakhpur (U.P.), India during 2019-20. The experimental area was not used for any agricultural activity before setting up the experiment. The experimental site was established under a Randomized Block Design with 12 treatments under open condition and each treatment replicated thrice.

The treatments used were Control (RDF) (T_0), RDF + B (0.2%) (T_1), RDF + Mo (0.2%) (T_2), RDF + Zn (0.2%) (T_3), RDF + B (0.4%) (T_4), RDF + Mo (0.4%) (T_5), RDF + Zn (0.4%) (T_6), RDF + B + Mo @ (0.2%) (T_7), RDF + B + Mo @ (0.4%) (T_8), RDF + Zn + Mo + B + @ (0.4%) (T_9), RDF + Zn + Mo @ (0.4%) (T_{10}) and RDF + Zn + Mo @ (0.2%) (T_{11}). Boric acid (H_3BO_3) (0.2% & 0.4%), zinc sulphate ($ZnSO_4$) (0.2% & 0.4%) and sodium molybdate (Na_2MoO_4) (0.2% & 0.4%) were used as a source of boron, zinc and molybdenum respectively. The spraying was done twice; during last week of November at after crown development stage and again at 30 days after the first spraying during years in three replication. All the plants fertilized with recommended dose of NPK (150:100:120 as N, P_2O_5 and K_2O). The RDF were applied in the form of urea (N-46%), SSP (P-16%) and MOP (K-60%). Full dose of P and K along with half of N were applied as basal and rest half of N were applied as side dressed during the growth season (one month after transplanting). The runners of strawberry were planted in the month of November with the spacing of 45 x 45 cm. All the other cultural practices were applied as per normal packages of practices. The observations were recorded on growth parameters and yield attributes by using standard procedure. Data were analysed as per the statistical methods given by Panse and Sukhatme (1995) [19]. After harvest, Fruit length (cm), Fruit diameter (cm), Average Fruit Weight (g) and total yield was recorded as well as the cost benefit ratio and expressed as t ha^{-1}.

Results and Discussion

The perusal of table-1, reveals that the growth related traits of strawberry plant significantly affected by the use of micronutrients and resulted maximum with treatment T_9 (RDF + Zn + Mo + B + @ (0.4%)) in terms of plant height (17.23 cm), Number of leaves (12.73), Plant spread (cm) (24.70 cm), whereas minimum values for growth traits were noted with T_0 (Control).

The increase in plant growth during research may be due to used of micronuitrients. The enhancement of plant height with the application of RDF + Zn + Mo + B + @ (0.4%) may be due to improved nutrient availability for longer period throughout the crop growth which resulted in better photosynthetic activities and ultimately high biomass production (Singh *et al*., 2015) [22]. The results of present investigation in terms of plant growth are in concordance with the findings reported earlier by Ekka *et al.* (2003) [10], Chaturvedi *et al.* (2005) [7] and Li *et al*. (2017) [13] in strawberry.

From the table-1, In the terms of flowering, fruiting and yield related traits, the minimum Days to First flowering (days) (52.30 days) and Days to First harvesting (days) (64.23 days) was recorded with treatment T_9 (RDF + Zn + Mo + B + @ (0.4%)), while the maximum values was recorded with treatment T_0 (Control (RDF)), whereas the maximum Number of flower per plant (35.95), Number of fruit per plant (26.56), fruit yield per plant (g) (618.84 g), fruit yield per plot (kg) (2.78 kg) and fruit yield per ha (tn) (20.02 tn) was recorded with treatment T_9 (RDF + Zn + Mo + B + @ (0.4%)) while the treatment T_0 (Control (RDF)) reflected as poor performer for these traits due to the lack of essential fertilizer.

The present study suggested that physiological behavior of strawberry is highly influenced by micronutrients. In the same way, rise in the flower cluster on plant was recorded by the application of micronutrients (Mohamed *et al.,* 2011) [14]. Our findings were also in agreement with the earlier report by Singh *et al.* (2015) [22] who inferred that precocious amount of boron and Zinc, and also their synergism improved vegetative growth, fruit quality as well as yield of strawberry. In a previous research study, Ekka *et al*. (2018) [10] demonstrated that boron, zinc, iron and copper application prior to flower initiation of strawberry plant boosted vegetative growth which ultimately enhanced quality and shelf life in cv. "Chandler". Micronutrients are popular for their role in increasing plant yield (Rehm and Sims, 2006) [21]. Higher count of total fruit on single plant was documented by Mohsen (2013) [15] in tomatoes by the usage of micronutrients through foliar dose. Similar outcomes were mentioned by Bakshi *et al*. (2013) [5] who reported efficient number of fruit per plant applying calcium, iron and zinc in combinations. Increased yield with good individual fruit weight were achieved in mango by the application of micronutrients (Bhatt *et al.*, 2012) [6].

From the table-1, In the terms of quality related traits the maximum Average Fruit Weight (g) (23.30 g), Fruit diameter (cm) (3.85 cm) and Fruit length (cm) (4.14 cm) was recorded with treatment T_9 (RDF + Zn + Mo + B + @ (0.4%)) while the treatment T_0 (Control (RDF)) reflected as poor performer for these traits due to the lack of essential fertilizer.

The outcomes of this study are parallel to the conclusions of Mohamed *et al.* (2011) [14], who recommended that increase in fruit size could be achieved by the spraying of Zinc and phosphorus in a combination after flower initiation. Davis *et al*. (2003) [8] revealed similar outcomes about fruit size boosted through the foliar application of boron in tomato.

From the table-2, reveals that the Maximum cost of cultivation (Rs. 4, 90,160), gross return (Rs. 25, 02,500) and benefit cost ratio (5.10:1) was observed in treatments T_9 (RDF + Zn + Mo + B + @ (0.4%)) and minimum cost of cultivation (Rs. 4, 89,980), gross return (Rs. 4, 90,000) and benefit cost ratio (1.00:1) was recorded in treatment T_0- (Control (RDF)). Results of this study was also supported by Singh *et al.* (2015) [22], who found significant increase in benefit cost ratio by foliar application of micronutrients along with ASPA-80.

Table 1: Effect of micro nutrients on vegetative growth, flowering and yield related traits of strawberry (*Fragaria x ananassa* Duch.) cv. Sweet Charlie

Treatment No.	Plant height (cm)	Number of leaves	Plant spread (cm)	Days to First flowering (days)	Days to First harvesting (days)	Number of flower per plant	Number of fruit per plant	Yield per plant (g)	Yield per plot (kg)	Yield per ha (tn)	Average Fruit Weight (g)	Fruit diameter (cm)	Fruit length (cm)
T_0	8.14	6.38	13.00	65.39	75.66	23.70	14.20	116.44	0.52	3.92	8.20	1.40	1.91
T_1	11.67	10.63	16.33	60.36	66.66	25.73	17.98	184.30	0.83	5.96	10.25	3.52	2.58
T_2	10.10	6.90	15.81	51.30	65.52	24.90	16.30	155.90	0.70	5.05	9.57	1.64	2.37
T_3	13.90	10.92	17.18	59.81	68.00	28.52	18.21	266.23	1.20	8.62	14.62	2.67	2.06
T_4	16.25	8.05	18.64	60.22	69.20	27.50	19.87	322.49	1.45	10.43	16.23	2.25	3.15
T_5	14.40	8.91	21.25	60.74	69.58	30.97	21.32	396.55	1.78	12.83	18.60	1.51	3.64
T_6	12.13	10.03	18.20	62.11	70.13	29.10	20.56	404.01	1.82	13.09	19.65	2.38	2.73
T_7	14.95	9.47	19.40	57.80	71.30	32.44	22.30	458.04	2.06	14.84	20.54	2.95	2.18
T_8	15.78	11.08	16.85	61.58	70.75	33.19	24.12	517.37	2.32	16.72	21.75	3.19	2.96
T_9	17.23	12.73	24.70	52.30	64.23	35.95	26.56	618.84	2.78	20.02	23.30	3.85	4.14
T_{10}	13.36	11.86	21.63	58.49	71.51	33.89	25.40	571.75	2.57	18.47	22.51	1.83	3.41
T_{11}	14.52	10.44	20.48	57.55	70.27	31.98	23.80	504.08	2.27	16.33	21.18	2.07	3.86
F-test	S	S	S	S	S	S	S	S	S	S	S	S	S
C. D. at 0.05%	1.51	1.09	2.10	2.71	2.79	1.38	0.97	2.48	0.22	1.56	2.02	0.27	0.34
S.Ed (+)	0.73	0.53	1.01	1.31	1.35	0.66	0.47	1.19	0.10	0.75	0.98	0.13	0.17

Table 2: Economics of different treatments and benefit cost ratio for strawberry

Treatment No.	Treatment	Cost of cultivation (Rs. ha^{-1})	Fruit yield (t ha^{-1})	Selling rate (Rs. t^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit cost ratio
T_0	Control (RDF)	4,89,980	3.92	1,25,000	4,90,000	20	1.00:1
T_1	RDF + B (0.2%)	4,90,000	5.96	1,25,000	7,45,000	2,55,000	1.52:1
T_2	RDF + Mo (0.2%)	4,90,020	5.05	1,25,000	6,31,250	1,41,230	1.28:1
T_3	RDF + Zn (0.2%)	4,90,010	8.62	1,25,000	10,77,500	5,87,490	2.19:1
T_4	RDF + B (0.4%)	4,90,020	10.43	1,25,000	13,03,750	8,13,730	2.66:1
T_5	RDF + Mo (0.4%)	4,90,060	12.83	1,25,000	16,03,750	11,13,690	3.27:1
T_6	RDF + Zn (0.4%)	4,90,040	13.09	1,25,000	16,36,250	11,46,210	3.33:1
T_7	RDF + B + Mo @ (0.2%)	4,90,040	14.84	1,25,000	18,55,000	13,64,960	3.78:1
T_8	RDF + B + Mo @ (0.4%)	4,90,100	16.72	1,25,000	20,90,000	15,99,900	4.26:1
T_9	RDF + Zn + Mo + B + @ (0.4%)	4,90,160	20.02	1,25,000	25,02,500	20,12,340	5.10:1
T_{10}	RDF + Zn + Mo @ (0.4%)	4,90,120	18.47	1,25,000	23,08,750	18,18,630	4.71:1
T_{11}	RDF + Zn + Mo @ (0.2%)	4,90,050	16.33	1,25,000	20,41,250	15,51,200	4.16:1

Conclusion

By considering the findings of present investigation, it is concluded that the application of treatment T_9 (RDF + Zn + Mo + B + @ (0.4%)) was found the best micronutrients combination for exhaustive yield per ha (20.02 tn) of strawberry which returned maximum benefit: cost ratio (5.10:1). So it can be recommend to growers by few more conjunctive trials.

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