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Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria* × *ananassa* Duch.) cv. winter dawn

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Abstract
An experiment was carried out during October, 2020 to March, 2021 at Horticulture Farm, Rajasthan College of Agriculture, Udaipur, Rajasthan during to work out the most suitable foliar spray of micronutrient (Fe, Zn and B) in different concentration to obtain better growth, yield and quality of strawberry. The experiment was laid out in randomized block design with a total of eleven treatments replicated thrice. Result showed that the treatment combination (S_{10}) comprising RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) recorded highest values in terms of petiole length (8.57 cm), number of leaves (25.07), plant spread i.e. E-W (28.37 cm) and N-S (27.37 cm), runner per plant (5.87), days to final harvest (115.07 days), number of picking (17.07), fruit length (36.03 mm), fruit width (27.17 mm), length diameter ratio (1.24), fresh weight of fruit (12.32 g), fruit per plant (16.20), fruit yield per plant (198 g) and recorded lowest in term of days to first flower initiation (56.47 days), days to initiation of fruit set (59.40 days), days to first harvest (73.07 days).

Keywords: strawberry, foliar application, growth, yield, micro-nutrients like iron, zinc, boron, runners and treatments

1. Introduction
Strawberry (*Fragaria* × *ananassa*) is one of the most delicious fruit of the world which attained a prime position in the world fruit market as fresh fruit with in the processing industries. All the cultivated varieties of strawberry are octaploid (2n=8×=56) in nature and belongs to the family Rosaceae. It is short day plant, native from France in 17th century and the two American diploids *Fragaria* × *chiloensis* and *Fragaria* × *virginiana* are considered as its progenitors. Strawberry is perennial, stoliniferous herbs which spread via stolons or runners. The strawberry have a type of aggregate fruit botanically. In India, many strawberry cultivars were introduced in early 1960. Primarily strawberry was growing in temperate zone of the country. However, it can also be cultivated under sub-tropical climate, even at higher altitudes of tropical climate. In India its main centers of cultivation are Nainital (district) and Dehradun in Uttrakhand, Mahabaleshwer (Maharashtra), Kashmir Valley, Bangalore and Kalimpong (West Bengal). In recent years, strawberry is being cultivated successfully in plains of Maharashtra around Pune, Nashik and Sangli towns. In Rajasthan strawberry is getting popularity for the cultivation in Jhadol and Mavali (Udaipur), Nimbaheda (Chittorgarh), Mandalgarh (Bhilwara) and Jhalawar. The strawberry plants are strongly affected by the environmental factors like temperature, photoperiod and light intensity. It requires optimum day temperature of 22 °C to 25 °C and night temperature of 7 °C to 13 °C. Photoperiod has a marked effect on strawberry vegetative growth, plant morphology and yield. Stolon formation, petiole length, leaf area and yield increases with the increase in photoperiod. It is a short day plant which requires exposure to about 10 days of less than 8 hours sunshine for initiation of flowering. In cold climate the soil is covered with mulch in winter to protect the root from chilling injury. The mulch keep the fruits free from soil, reduces decay of fruits, conserves the soil moisture, lowers soil temperature in hot weather, protects flower from frost in mild climates and protect plants from freezing injury in cold climates. Several kinds of mulches are used but the commonest one is straw mulch. The name strawberry has been derived from this fact. Black alkathene mulch (40 micron) is also used to cover the soil it saves irrigation water, prevents the growth of weed and keeps the soil temperature high. Strawberry plant grows best in sandy loam soil but in case of light soil frequent irrigation needed for establishment of

runners. The heavier soil with adequate soil moisture is better than lighter soil. Strawberry prefers soil reasonably rich in humus because of 70-90% of its roots were found in the top 15 cm soil. It grows well in soil with pH 5.0- 7.5. However the plant thrives best in slightly acidic soil (pH 5.5-6.5). The availability of micronutrient like iron, zinc and boron to the plant at less than pH 6.5. Boron is absorbed in H_3BO_4 form. Next to zinc, boron is widely deficient nutrient. It is a micronutrient mobile in soil and immobile in the plant. Availability of boron in soil is reduced on account of calcareousness, salinity or sodicity, over liming. Very little is known about mineral of B in soils. Boron plays many important roles in plant metabolism. Zn absorbed by the plant in Zn^{2+} form. Zn is very most important micro-nutrient of global concern, and highly deficient micro-nutrient of equal magnitude on both acid as well as alkaline soils. zinc is an immobile micro-nutrient in the plants. The availability of zinc in soil is adversely affected by soil calcareousness, high phosphorus content, salinity or sodicity, over liming *etc.* Iron absorbed by plant in Fe^{2+} form. It is one of the micronutrients becomes extremely mobile under waterlogged conditions and it is highly immobile in the plant. In acid soils, soluble iron could fix phosphates which are aggravated further by high water table and water logging. Whereas on alkaline calcareous soils, lime induced Fe chlorosis is perhaps the most researched nutritional disorder in citrus. Availability of iron becomes less available in soils having beyond pH 7.8. High available iron could induce manganese-deficiency. Chandrakar *et al*., 2019 [5] studies on nutritionally, strawberry contains low calorie carbohydrate and a potential source of vitamin-C and fibers. It contains more vitamin-C than oranges. The chemical composition of strawberry is ascorbic acid (64.0 mg), water (91.75 g), protein (0.61 g), fat (0.37 g), carbohydrate (7.02 g), fiber (2.3 g), calcium (14.0 mg), potassium (166 mg/100 g) and vitamin-A (27 IU). Ellagic acid is a naturally occurring plant phenol. It has been found to inhibit the cancer disease and asthma by the regular consumption of the fruit. Currently, the production of strawberry in more than 63 countries, the global production of strawberry in 2012 about 4516810 tons and planted area of 2.41 Mha and the United States ranks first in the list of producing countries with a total of 1.36 MT, more than a quarter of the world production (FAO, 2014) [9].

2. Material and Methods

The experiment was conducted from October, 2020 to March, 2021 at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. This is situated at 24º 34′ N latitude and 73º 42′ E longitude at an elevation of 582.17 meter above mean sea level. Soil of this region is Sand (32.40%), Silt (28.65%), Clay (38.95%), Bulk density (1.35%), Particle density (2.64%), Porosity (28.21%, Organic carbon (0.68%), Available N kg ha^{-1} (194.8), Available P_2O_5 kg ha^{-1} (17.1) and Available K_2O kg ha^{-1} (255.3). Planting material of the cultivar Winter Dawn (Strawberry) was procured from Kimya Biotech Pvt. Ltd. Kasaba, Pune. The experiment was laid out in randomized block design with 11 treatments *viz.* S_1 i.e. RDF + Control (Water spray), S_2 i.e. RDF + Borax (0.1%), S_3 i.e. RDF + $ZnSO_4$ (0.2%), S_4 i.e. RDF + $FeSO_4$ (0.2%), S_5 i.e. RDF + Borax (0.2%), S_6 i.e. RDF + $ZnSO_4$ (0.4%), S_7 i.e. RDF + $FeSO_4$ (0.4%), S_8 i.e. RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%), S_9 i.e. RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%), S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%), S_{11} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%). Boron application, 1g and 2g of borax were weighed and solutions were made in one litre of distilled water for making 0.1 per cent and 0.2 per cent concentrations, respectively. Iron and zinc solution was prepared from same procedure. Petiole length (cm) of the leaves was recorded with meter scale from five tagged plant in each replication. After harvesting period, total number of leaves were counted, Meter scale was used to determine the plant spread, After harvesting period that total number of runner were counted, Data were recorded on the basis of average number of days taken from planting date to start flowering after planting, same procedure follow to determined for days to initiation of fruit set, days to first harvest and final harvest, Fruit length and width was determined with digital Vernier Caliper in mm from 20 strawberry fruit from each treatment. The ratio (length: diameter) was also calculated of 20 fruits, After ripening, average fruit weight of fruit was calculated from each tagged plants with the help of electronic balance and the mean five of fruit was express in grams, Digital hand refractometer was used to calculate total soluble solid, Standard N/10 NaOH solution and phenolphthalein as an indicator were used to determine the titratable acidity of strawberry fruit juice until faint pink color appeared, The ripe strawberry fruits were crushed and pass through muslin cloth. The weight of strawberry juice was measured with electronic balance and the percentage of juice was worked out on the basis of total weight of fruit taken for juice extraction, calculation of ascorbic acid/100 ml juice by using below formula (Sadasivam and Theymoli, 1987.

3. Results and Discussion

The data recorded for various parameters are statistically analyzed, their mean value are presented in Table 4.1 to 4.3. It is clear that maximum petiole length (8.57 cm) was noted in treatment S_{10} i.e. RDF (100: 80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded minimum petiole length (7.10 cm). This change might be due to that iron, zinc and boron help in cell division, elongation and growth of meristamatic tissue and also due to enhanced photosynthetes which forced plant to produce higher petiole length. Similar findings were observed by Saadati and Moallemi (2012) [17], Bakshi *et al*. (2013) [3], Qureshi *et al*. (2013) [15], Gurjar *et al*. (2015) [10] (Bhanukar *et al*., 2021) [4] in sweet orange, (Chandrakar *et al*., 2019) [5] in strawberry, Pawar *et al.* (2019) [14] in mandarin, Tagad *et al*. (2018) [20] in acid lime. Similarly highest leaves per plant (25.07), plant spread i.e. E-W (28.37 cm) and N-S (24.37 cm) and runner per plant (5.87) was recorded in the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas treatment S_1 i.e. RDF + Control (Water spray) recorded minimum leaves per plant (20.0), plant spread i.e. E-W (24.60 cm) and N-S (20.63 cm) and runner per plant (3.27). This change might be due to Zn is necessary for the production of tryptophan which is the precursor of indole acetic acid synthesis resulting in the growth and development of tissues which leads to vegetative growth of plant. It added cell membrane integrity, stabilizes sulflahydryl groups in membrane proteins involved in ion transport. The increase in vegetative growth has been reported by Ram and Bose (2000) [16] in mandarin, Pawar *et al.* (2019) [14] in mandarin, Haque *et al.* (2000) [11] in mandarin orange, Ahmad *et al.* (2012) [2] in tangerine, Gurjar *et al.* (2015) [10] in kinnow and Choudhary *et al.* (2016) [7] in kinnow mandarin, Chandrakar *et al*., 2018 [6],

in strawberry, Tagad *et al*. (2018) [20] in acid lime. The foliar application of iron, zinc and boron exhibited significant effect on yield parameter of strawberry. Treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) recorded minimum days to first flower initiation (56.47 days) which was found to be better over the S_{1}- control as RDF + water spray (64.27 days). This change might be due to foliar spray of micronutrient mainly boron Fe promotes the formation of florigin (hypothetical hormone) from leaf to the leaf axils thus produces early flowering and fruiting. This findings are close conformity with the findings by the Yadlod and Kadam (2003) in banana and Mehraj *et al*. (2015) in strawberry crop, Similar results about days to fruit setting were also observed by Tagad *et al*. (2018) [20] in acid lime, Ashoori *et al*., 2013 [1], Mohammed *et al*., 2018 in lemon, Chandrakar *et al*., 2018 [6] in strawberry, Pawar *et al*. (2019) [14] in mandarin. Similarly minimum days to initiation of fruit set (59.40 days) and days to first harvest (73.07 days) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas treatment S_1 i.e. RDF + Control (Water spray) recorded maximum days to initiation of fruit set (68.80 days) and days to first harvest (77.07 days). It is clear that maximum fruit length (36.03 mm) and fruit width (27.17 mm) was noted in treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas, S_1 i.e. RDF + Control (Water spray) recorded minimum fruit length (34.07 mm) and fruit width (25.53 mm). it might be due to the effect of zinc, as zinc plays a vital role in the promote of starch formation and other activity involve in the plant is transportation of carbohydrate and another function of zinc in plant is faster loading and mobilization of photo assimilates to the fruits and involvement in cell division, cell expansion, ultimately reflected into more length of the fruits in treated plants. Related results were also obtained by Bakshi *et al.* (2013) [3] and Mehraj *et al.* (2015) in strawberry, Chandrakar *et al*. (2019) [5] in strawberry, Soni *et al*., 2017, Etehadnejad and Aboutalebi (2014) [8], Pawar *et al.* (2019) [14] in mandarin, Tagad *et al*. (2018) [20] in acid lime found that foliar application of zinc increased diameter of fruits. The maximum fresh weight of fruit, fruit per plant and fruit yield per plant (12.32 g, 16.20 and 198 g respectively) was recorded under the treatment S_{10} i.e. RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) whereas S_1 i.e. RDF + Control (Water spray) recorded minimum fresh weight of fruit, fruit per plant and fruit yield per plant (10.88 g, 14.93 and 162 g respectively). It might be due to higher number of fruit might be due to the effect of zinc, as zinc plays a vital role in the promote of starch formation and other activity involve in the plant is transportation of carbohydrate and another function of zinc in plant is faster loading and mobilization of photo assimilates to the fruits and involvement in cell division, cell expansion similar findings were also obtained by Tagad *et al*. (2018) [20] in acid lime, Thorat *et al*. (2018) [21] Kazemi (2014), Bakshi *et al.* (2013) [3] and Mehraj *et al.* (2015) in strawberry, Chandrakar *et al*., 2019 [5] in strawberry, Pawar *et al.* (2019) [14] in mandarin. The reason behind that increase in fresh weight of the fruits might be due to more growth of the fruit by accelerate rate of cell enlargement (increase in cell size) & cell division (increase in number of the cells) and larger intercellular space and another reason for that due to increase the photosynthetic activities & accumulation of more carbohydrate. The increase in number of fruit per plant could be attributed to increased fruit size, diameter and fruit weight. Furthermore, probably there was a larger diversion of photosynthates to sink (Fruit), which was ultimately added to the number of fruits. Related results were also obtained by, Chandrakar *et al*. (2018) [6] in strawberry Cakici and Arslan (2012), Bakshi *et al.* (2013) [3] and Mehraj *et al.* (2015) in strawberry, Tagad *et al*. (2018) [20] in acid lime.

Table 1: Response of micronutrients foliar spray on growth and flowering parameters in Strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

Notations	Treatments	Petiole length (cm)	Leaves plant^{-1}	Plant spread (cm) E-W, N-S		Runner plant^{-1}	Days to First Flower Initiation
S_1	RDF + Control (Water spray)	7.10	20.00	24.60	3.27	3.27	64.27
S_2	RDF + Borax (0.1%)	7.17	21.60	25.03	3.80	3.80	60.87
S_3	RDF + $ZnSO_4$ (0.2%)	8.27	22.07	26.03	4.13	4.13	61.13
S_4	RDF + $FeSO_4$ (0.2%)	7.23	21.87	25.83	3.87	3.87	63.13
S_5	RDF + Borax (0.2%)	8.27	22.13	26.00	4.27	4.27	61.07
S_6	RDF + $ZnSO_4$ (0.4%)	8.17	23.07	26.83	4.53	4.53	61.07
S_7	RDF + $FeSO_4$ (0.4%)	8.27	22.87	25.63	3.87	3.87	62.33
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	8.30	23.80	26.87	5.20	5.20	60.33
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	8.37	24.47	27.10	5.47	5.47	58.60
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	8.57	25.07	28.37	5.87	5.87	56.47
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	8.50	24.93	27.87	5.53	5.53	57.67
	SEm±	0.32	0.66	0.71	0.25	0.25	1.50
	CD @5%	0.95	1.96	2.08	0.75	0.75	4.44

Table 2: Response of micronutrients foliar spray on fruit yield and quality parameters in Strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

Notations	Treatments	Days to initiation of fruit set	Days to first harvest	Days to final harvest	Number of picking	Fruit length (mm)
S_1	RDF + Control (Water spray)	68.80	77.07	107.07	15.07	34.07
S_2	RDF + Borax (0.1%)	65.27	76.93	108.67	15.33	34.17
S_3	RDF + $ZnSO_4$ (0.2%)	65.20	76.80	109.00	15.53	34.20
S_4	RDF + $FeSO_4$ (0.2%)	67.27	76.47	109.73	15.73	34.50
S_5	RDF + Borax (0.2%)	64.13	76.33	110.53	15.80	34.83
S_6	RDF + $ZnSO_4$ (0.4%)	64.47	75.93	111.93	15.93	35.13
S_7	RDF + $FeSO_4$ (0.4%)	65.60	75.60	112.40	16.13	35.27
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	64.07	75.00	113.60	16.33	35.43
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	61.80	74.60	114.60	16.60	35.53
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	59.40	73.07	115.07	17.07	36.03
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	60.73	74.20	114.47	16.93	35.87
	SEm±	1.77	0.88	1.76	0.49	0.36
	CD @5%	5.24	2.60	5.20	1.44	1.06

Table 3: Response of micronutrients foliar spray on fruit yield and quality parameters in Strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

Notations	Treatments	Fruit width (mm)	Length : Diameter	Fresh weight of fruit (g)	Number of fruit plant^{-1}	Fruit yield plant^{-1} (g)
S_1	RDF + Control (Water spray)	25.53	1.15	10.88	14.93	162.00
S_2	RDF + Borax (0.1%)	26.00	1.16	10.95	15.00	164.00
S_3	RDF + $ZnSO_4$ (0.2%)	26.10	1.18	11.12	15.13	168.33
S_4	RDF + $FeSO_4$ (0.2%)	26.20	1.17	11.26	15.33	172.67
S_5	RDF + Borax (0.2%)	26.27	1.16	11.39	15.47	176.00
S_6	RDF + $ZnSO_4$ (0.4%)	26.30	1.19	11.56	15.60	180.00
S_7	RDF + $FeSO_4$ (0.4%)	26.40	1.17	11.73	15.60	183.33
S_8	RDF + Borax (0.1%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	26.50	1.16	11.87	15.67	186.00
S_9	RDF + Borax (0.1%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	26.67	1.20	12.02	15.80	190.00
S_{10}	RDF + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%)	27.17	1.24	12.32	16.20	198.00
S_{11}	RDF + Borax (0.2%) + $ZnSO_4$ (0.4%) + $FeSO_4$ (0.4%)	26.83	1.23	12.20	16.00	194.67
	SEm±	0.34	0.02	0.12	0.26	7.82
	CD @5%	*NS*	0.06	0.34	0.76	23.07

4. Conclusion

It can be concluded that among the various treatment S_{10} i.e. RDF (100: 80: 80 NPK) + Borax (0.2%) + $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) was found the superior treatment in petiole length, leaves per plant, plant spread (E-W and N-S), runner per plant, days to first flower initiation, days to initiation of fruit set, days to first harvest, days to final harvest, number of picking, fruit length, fruit width, length diameter ratio, fresh weight of fruit, fruit per plant and fruit yield per plant.

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