Indian Journal of Agricultural Sciences **83** (6): 678–84, June 2013/Short Communications

Pre-harvest application of iron and zinc influences growth, yield, quality and runner production of strawberry (*Fragaria* × *ananassa*) cv Chandler

PARSHANT BAKSHI[1], AMIT JASROTIA[2], AKASH SHARMA[3], P K RAI[4], V K WALI[5] and RAKESH KUMAR[6]

Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Main Campus, Chatha, Jammu, Jammu & Kashmir 180 009

Received: 12 September 2012; Revised accepted: 1 April 2013

Key words: Growth, Iron, Quality, Runner, Strawberry, Yield, Zinc

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most delicious fruits of the world, which is a rich source of vitamins and minerals, and has fabulous flavour and tantalizing aroma (Kher *et al*. 2010). Consumer demand for high quality strawberry fruit with an appealing red colour, appropriate sweetness, firmness, flavour and adequate storage life drives growers decision with regard to cultivar choice and pre-harvest management practices, viz. agronomic practices, water supply, weather condition and mineral fertilization (Nestby *et al*. 2004). The nutrition status of strawberry plant plays a fundamental importance in determining the growth, yield and quality since it is a very sensitive plant to nutritional balance (Mohamed *et al*. 2011). An optimal fertilization is conductive to obtaining high yield of good quality and high biological value. Thus, for successful cultivation of strawberry, it is essential to supply balanced doses of macro- and micro-nutrients. The requirement of essential nutrients for strawberry has already been standardized by many researchers (Dunn and Able 2006) but very limited information is available on micro-nutrient application to this crop, which is rather very important for its successful cultivation. Micro-elements are known to stimulate various physiological activities when present in very small quantities. The micro-nutrient deficiencies in plants can be corrected by the foliar and/or soil application of these elements; however, foliar application is more economical, efficient, effective and practical because of its quick response. Furthermore, foliar application significantly reduces the quality of nutrients required to rectify such deficiencies (Kumar *et al*. 2010). Among various micro-nutrients, iron and zinc plays an important role in promoting vegetative growth, flowering, yield and quality of guava (Sheriff *et al*. 2000), strawberry (Chaturvedi *et al*. 2005) and kinnow mandarin (Babu *et al*. 2007).

Iron is one of the essential elements required by the plants owing to its vital and indispensable role on plant growth. It takes part in number of plant biochemical processes such as biosynthesis of cytochrome and chlorophyll (Garnick 1970) besides being component of various flavoprotein, peroxidases and catalase, though iron is not a constituent of chlorophyll yet it acts as a catalyst for formation/synthesis and maintenance of chlorophyll. It is also a constituent of enzyme systems and so it plays an important role in plant enzyme reactions (Das 2006).

Zinc has also shown to have an important role in photosynthesis and related enzymes resulting in increasing sugar and decreasing acidity (Abedy 2001). It induces pollen tube growth resulting from its role on tryptophan synthesis as an auxin presursor biosynthesis (Chaplin and Westwood 1980). Moreover, Dixi and Gamdagin (1998) claimed that foliar application of $ZnSO_4$ increased size, TSS and juice of orange. Zinc as a $ZnSO_4$ source had positive effect on leaf area, length and diameter of petiole, fresh and dry shoot ratio, yield, TSS, acidity and Vitamin C of strawberry plant (Mahnaz 2010).

In view of this, the aim of the present investigation was to determine the effects of foliar application of iron and zinc on growth, yield, quality and runner production of Chandler strawberry cultivar.

The studies were conducted at the Research Farm of the Division of Fruit Science at Udheywalla, SKUAST-Jammu, J&K, India during 2010-11. Soil of the experimental field was sandy loam in texture having pH 7.1; organic carbon 0.52 %; available N 216.02 kg/ha; phosphorus 13.68 kg/ha and potassium 135.0 kg/ha. Soil was thoroughly ploughed and raised beds of 25 cm height, 1.5 m in length and 2.0 m width were prepared at a distance of 45 cm. Healthy and disease free runners of Chandler strawberry were planted on

[1]Associate Professor (e mail: bakshi_parshant@rediffmail.com; parshantbakshi@krishisandesh.com), [2,6] Junior Scientists (Pomology), [3] Assistant Professor, [5] Professor & Head, Division of Fruit Science; [4] SMS, Soil Science, KVK, R S Pura, SKUAST-J

3 October 2010 at a distance of 30 cm × 45 cm with black polyethylene mulch as standardized by Kher *et al*. (2010) for sub-tropical regions. The experiment was laid out in 3 × 3 RBD factorial with three replications and comprising of 9 treatments, viz. T_1 [F_0Z_0 (0% $FeSO_4$ + 0% $ZnSO_4$)]; T_2 [F_0Z_1 (0% $FeSO_4$ + 0.2% $ZnSO_4$)]; T_3 [F_0Z_2 (0% $FeSO_4$ + 0.4% $ZnSO_4$)]; T_4 [F_1Z_0 (0.2% $FeSO_4$ + 0% $ZnSO_4$)]; T_5 [F_1Z_1 (0.2% $FeSO_4$ + 0.2% $ZnSO_4$)]; T_6 [F_1Z_2 (0.2% $FeSO_4$ + 0.4% $ZnSO_4$)]; T_7 [F_2Z_0 (0.4% $FeSO_4$ + 0% $ZnSO_4$)]; T_8 [F_2Z_1 (0.4% $FeSO_4$ + 0.2% $ZnSO_4$)]; T_9 [F_2Z_2 (0.4% $FeSO_4$ + 0.4% $ZnSO_4$)]. Each treatment consisted of 20 plants in each plot. The spraying of these elements was done after 30 and 80 days of planting. All the necessary cultural operations and plant protection measures were followed uniformly as per the Package of Practices for fruit crops by SKUAST-J for all the treatments during the entire period of experimentation.

Observations were recorded on increase in vegetative growth of plant (plant height, plant spread, number of leaves/plant, number of crowns/plant, leaf area); flowering and fruiting (total number of flowers/plant, total number of fruits/plant, per cent berry set); yield (fruit weight, total yield/plant); quality (fruit length, diameter, volume, total soluble solids, acidity, TSS:acid ratio, ascorbic acid, total sugars, reducing sugars, anthocyanin, crude protein, shelf-life) and runner production/plant. Five fruits/treatment/replication were taken for quality analysis. Plant height (cm) and spread (cm) was recorded by measuring scale, whereas leaf area (cm^2) was determined by leaf area meter (Systronics 211). Fruit weight (g) was calculated by Indosaw digital balance, while length (cm) and diameter (cm) was determined by Mitusyo digital vernier caliper. Fruit volume (cc) was determined by water displacement method. TSS (^{0}B) was recorded by Erma Hand refractometer. Acidity (%), sugars (%) and ascorbic acid (mg/100g pulp) of fruits were determined according to AOAC (1994). Anthocyanin content in fruits was determined as per the method given by Harborne (1973). Crude protein (%) was determined by the method outlined by Rangana (1995). The time of recording runners per plant was mid-May. The data obtained was statistically analyzed by Panse and Sukhatme (2000).

Vegetative growth characteristics

Plant height and plant spread increased with the increase in concentration of iron, zinc and their interaction (Table 1). The plants treated with 0.4% ferrous sulphate showed maximum plant height and plant spread (19.65 cm and 30.12 cm, respectively) followed by those treated with 0.4 % zinc sulphate (18.85 cm and 28.28 cm, respectively). Minimum plant height (16.86 cm) and plant spread (23.24 cm) was recorded in untreated plants. Number of leaves/plant and leaf area increased with the increase in iron and zinc concentrations (Table 1). Both number of leaves/plant as well as leaf area was maximum in plants treated with 0.4 % $FeSO_4$ (19.12 and 64.60 cm^2, respectively).

Table 1 Effect of foliar applications of iron and zinc on plant height, plant spread, number of leaves/plant and leaf area of strawberry cv Chandler

Treatment	Plant height (cm)				Plant spread (cm)				Number of leaves/plant				Leaf area (cm^2)			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	16.86	17.15	17.60	17.20	23.24	24.76	25.82	24.61	16.52	16.86	17.04	16.82	56.34	57.16	58.02	57.17
F_1	18.14	18.36	18.72	18.41	26.31	27.16	27.81	27.09	17.46	18.02	18.36	17.95	59.13	60.33	61.12	60.19
F_2	19.18	19.52	20.24	19.65	29.02	30.13	31.20	30.12	18.72	19.03	19.61	19.12	63.84	64.72	65.24	64.60
Mean	18.06	18.34	18.85	18.42	26.19	27.35	28.28	27.27	17.57	17.97	18.34	17.96	59.77	60.74	61.46	60.65
	F	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*	
SE (m)	0.04	0.04	0.07		0.02	0.02	0.03		0.06	0.06	0.10		0.12	0.12	0.21	
SE (d)	0.06	0.06	0.11		0.03	0.03	0.05		0.09	0.09	0.15		0.17	0.17	0.30	
CD $_{(0.05)}$	0.13	0.13	NS		0.06	0.06	0.10		0.18	0.18	NS		0.36	0.36	NS	

The number of crown/plant were significantly influenced by various concentrations of iron, zinc and their interaction (Table 2). Maximum number of crown/plant (2.97) was recorded in 0.4 % $FeSO_4$ treated plants, while it was minimum (2.31) in F_0Z_0 (control). This increase in plant height, plant spread, number of leaves/plant, leaf area and number of crown/plant with ferrous sulphate might be attributed to availability of optimum quantity of iron with in the plant system as this element plays an essential role in plant growth.

Flowering and fruiting characteristics

Number of flowers, fruits and fruit set/plant were significantly influenced by various concentrations of iron, zinc and their interaction (Table 2). The maximum number of flowers (28.12), fruits (21.63) and per cent berry set (77.0)/plant were produced with F_2Z_2 (0.4 % $FeSO_4$ and 0.4 % $ZnSO_4$). The plants sprayed with iron showed more number of flowers, fruits and fruit set as compared to those treated with zinc which increased with the increase in concentration and 0.4 % $FeSO_4$ gave maximum number of flowers (27.62), fruits (21.02) and fruit set (76.23 %). Turemis *et al*. (1998) also observed significant increase in flower, fruits and fruit set with 0.2 % $FeSO_4$.

The fruit yield/plant was significantly influenced by various iron and zinc treatments (Table 2). The average fruit yield was more in zinc treated plants and was maximum (158.9 g/plant) in 0.4 % zinc sulphate. Chaturvedi *et al*. (2005) also reported similar results. However, the interaction between iron and zinc was found significantly superior than individual effect. Maximum yield/plant (166.3 g) was recorded in F_2Z_2 (0.4 % iron + 0.4 % zinc), while a minimum fruit yield (98.4 g/plant) was recorded in control (F_0Z_0). These results are in agreement with the findings of Kumar *et al*. (2010) in strawberry.

Physical characteristics

Fruit weight, fruit length, fruit diameter and fruit volume of berries increased with the increase in concentration of iron and zinc (Table 3). The plants treated with zinc showed more weight, length, breadth and volume as compared to those treated with iron. The plants treated with 0.4 % $ZnSO_4$ showed maximum fruit weight (10.56 g), fruit length (3.56 cm), fruit diameter (2.50 cm) and fruit volume (15.06 cc). Increase in fruit weight and size with the application of $ZnSO_4$ was reported by Samant *et al*. (2008) in ber and Babu *et al*. (2007) in mandarin, respectively. Mohamed *et al*. (2011) also observed maximum mean values for most of physical fruit characters of strawberry cv. Sweet Charlie with high rates of zinc.

Chemical characteristics

Total soluble solids (TSS) increased with the increase in concentration of iron, zinc and their interaction (Table 4). The plants treated with 0.4 % zinc sulphate showed maximum

Table 2 Effect of foliar applications of iron and zinc on number of crown/plant, number of flowers/plant, number of fruits/plant, per cent berry set and yield/plant of strawberry cv Chandler

Treatment	Number of crown/plant				Number of flowers/plant				Number of fruits/plant				Per cent berry set				Yield (g/plant)			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	2.31	2.46	2.54	2.44	23.25	23.80	24.12	23.72	15.91	16.84	17.52	16.76	69.00	71.00	73.00	71.00	98.4	128.8	150.9	126.1
F_1	2.66	2.74	2.82	2.74	25.84	26.24	26.79	26.29	18.92	19.34	19.92	19.39	74.33	74.00	75.00	74.44	109.2	133.1	159.5	133.9
F_2	2.91	2.97	3.02	2.97	27.06	27.68	28.12	27.62	20.48	20.96	21.63	21.02	76.00	75.70	77.00	76.23	117.4	140.3	166.3	141.3
Mean	2.63	2.72	2.79	2.71	25.38	25.91	26.34	25.88	18.44	19.05	19.69	19.06	73.11	73.57	75.00	73.89	108.3	134.1	158.9	133.8
	F	*Z*	*F × Z*		*F*	*Z*	*F × Z*		*F*	*Z*	*F × Z*		*F*	*Z*	*F × Z*		*F*	*Z*	*F × Z*	
SE (m)	0.00	0.00	0.01		0.05	0.05	0.08		0.04	0.04	0.06		0.15	0.15	0.26		0.41	0.41	0.72	
SE (d)	0.00	0.00	0.01		0.06	0.06	0.11		0.05	0.05	0.09		0.21	0.21	0.36		0.58	0.58	1.01	
CD (0.05)	0.01	0.01	0.20		0.14	0.14	0.23		0.11	0.11	0.19		0.44	0.44	0.77		1.24	1.24	2.15	

Table 3 Effect of foliar applications of iron and zinc on fruit weight, fruit length, fruit diameter and fruit volume of strawberry cv Chandler

Treatment	Fruit weight (g)				Fruit length (cm)				Fruit diameter (cm)				Fruit volume (cc)			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	6.92	8.56	9.74	8.40	3.12	3.38	3.46	3.32	2.06	2.27	2.33	2.22	12.80	13.93	14.45	13.72
F_1	7.26	8.92	10.58	8.92	3.26	3.46	3.51	3.41	2.14	2.36	2.49	2.33	13.21	14.19	14.83	14.07
F_2	7.84	10.64	11.36	9.94	3.31	3.62	3.73	3.55	2.21	2.56	2.68	2.48	13.62	15.32	15.92	14.95
Mean	7.34	9.37	10.56	9.09	3.23	3.48	3.56	3.42	2.13	2.39	2.50	2.34	13.21	14.48	15.06	14.25
	F	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*	
SE (m)	0.04	0.04	0.07		0.01	0.01	0.02		0.02	0.02	0.04		0.10	0.10	0.17	
SE (d)	0.06	0.06	0.11		0.02	0.02	0.03		0.03	0.03	0.06		0.14	0.14	0.25	
$CD_{(0.05)}$	0.13	0.13	0.23		0.04	0.04	0.07		0.07	0.07	NS		0.30	0.30	NS	

Table 4 Effect of foliar applications of iron and zinc on total soluble solids (TSS), acidity, ascorbic acid and TSS/acid ratio of strawberry cv Chandler

Treatment	TSS (^{0}B)				Acidity (%)				Ascorbic acid (mg/100 g of pulp)				TSS/acid ratio			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	6.81	8.56	8.60	7.99	0.87	0.81	0.77	0.81	51.84	55.16	57.29	54.76	7.88	10.57	11.17	9.87
F_1	8.03	8.68	8.85	8.52	0.85	0.75	0.71	0.77	53.76	58.86	60.12	57.58	9.45	11.57	12.46	11.16
F_2	8.21	9.03	9.34	8.86	0.83	0.69	0.65	0.72	53.74	61.80	62.21	59.25	9.89	13.09	14.37	12.45
Mean	7.68	8.75	8.93	8.45	0.85	0.75	0.71	0.77	53.11	58.60	59.87	57.19	9.07	11.74	12.67	11.16
	F	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*	
SE (m)	0.07	0.07	0.12		0.01	0.01	0.02		0.08	0.08	0.14		0.04	0.04	0.07	
SE (d)	0.09	0.09	0.16		0.02	0.02	0.03		0.12	0.12	0.20		0.06	0.06	0.09	
$CD_{(0.05)}$	0.20	0.20	NS		0.03	0.03	NS		0.25	0.25	0.43		0.12	0.12	0.20	

average TSS (8.93 ^{0}B) followed by those treated with 0.4 % $FeSO_4$ (8.86 ^{0}B). However, the plants receiving both 0.4 % ferrous sulphate + 0.4 % zinc sulphate (F_2Z_2) showed highest TSS (9.34 ^{0}B). Minimum TSS (6.81 ^{0}B) was recorded in F_0Z_0. The quality of fruit in terms of TSS was improved with different iron, zinc and their interaction. Both iron and zinc sprays proved highly beneficial in the process of photosynthesis which ultimately improved fruit quality. Zinc also regulates the enzymatic activity and enzymes mobilize the carbon compounds into glucose. Chaturvedi *et al*. (2005) also reported similar results in strawberry.

Acidity content decreased with iron, zinc and their interaction (Table 4). The plants receiving 0.4 % iron in combination with 0.4 % zinc (F_2Z_2) resulted in minimum acidity (0.65 %). Maximum acidity (0.87 %) was recorded in control (F_0Z_0). The acidity content of fruit decreased with the different levels of iron, zinc and their interaction. Iron and zinc application decrease the acid content which ascribed an increase in total soluble solids and ultimately reduced the acidity of fruit. Similar results were reported by Ahlawat *et al*. (1985) in grapes.

The data showed significant effect with respect to different levels of iron, zinc and their interaction on ascorbic acid content (Table 4). The interaction between iron and zinc was found to be significant and maximum ascorbic acid content (62.21 mg/100 g) was recorded in F_2Z_2 (0.4 % iron in combination with 0.4 % zinc) which was at par with F_2Z_1 (0.4 % iron and 0.2 % zinc). Minimum ascorbic acid (51.84 mg/100 g) was reported in F_0Z_0 (control). The ascorbic acid content also showed an increase with different levels of iron, zinc and their interaction. The iron and zinc application increased the ascorbic acid synthesis. These results are in confirmation with the findings of Kumar *et al*. (2010).

Reducing sugars as well as total sugars increased with the increase in iron and zinc concentration (Table 5). The plants treated with zinc showed more sugar content in their fruits as compared to those treated with iron. Highest reducing sugars (4.26 %) and total sugars (6.98 %) was recorded in strawberry fruits taken from plants treated with 0.4 % $ZnSO_4$. The increase in total sugars was found to be associated with increasing reducing and non-reducing sugar. These results are in consonance with the findings of Kumar *et al*. (2010).

Anthocyanin content increased with the increase in iron and zinc concentration (Table 5). The plants treated with iron showed more anthocyanin content as compared to those treated with zinc. Maximum content of anthocyanin (0.20 OD) was recorded in 0.4 % $FeSO_4$ followed by (0.18 OD) in 0.4 % $ZnSO_4$. Increase in anthocyanin content in iron treated fruits might be due to its role in biosynthesis of chlorophyll.

The data showed significant effect with respect to different levels of iron, zinc and their interaction on per cent crude protein (Table 5). The interaction between iron and zinc was found to be significant and maximum crude protein content (13.78 %) was recorded in F_2Z_2 (0.4 % iron in

Table 5 Effect of foliar applications of iron and zinc on reducing sugars, total sugars, anthocyanin and crude protein of strawberry cv Chandler

Treatment	Reducing sugars (%)				Total sugars (%)				Anthocyanin (OD at 535 nm)				Crude protein (%)			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	2.72	4.05	4.21	3.66	5.18	6.64	6.72	6.18	0.14	0.15	0.15	0.14	7.21	9.48	10.31	9.00
F_1	3.94	4.26	4.19	4.13	6.31	7.01	6.88	6.73	0.16	0.18	0.19	0.17	9.56	12.40	13.24	11.73
F_2	3.96	4.29	4.38	4.21	6.48	7.12	7.34	6.98	0.20	0.20	0.21	0.20	10.53	13.15	13.78	12.49
Mean	3.54	4.20	4.26	4.0	5.99	6.92	6.98	6.63	0.16	0.17	0.18	0.17	9.10	11.68	12.44	11.07
	F	*Z*	*F × Z*		*F*	*Z*	*F × Z*		*F*	*Z*	*F × Z*		*F*	*Z*	*F × Z*	
SE (m)	0.12	0.12	0.20		0.04	0.04	0.07		0.01	0.01	0.02		0.05	0.05	0.09	
SE (d)	0.16	0.16	0.28		0.06	0.06	0.10		0.01	0.01	0.02		0.07	0.07	0.13	
CD $_{(0.05)}$	NS	NS	NS		0.12	0.12	NS		0.03	NS	NS		0.16	0.16	0.27	

Table 6 Effect of foliar applications of iron and zinc on shelf-life and runner production of strawberry cv Chandler

Treatment	Shelf-life (days)				Number of runners/ plant			
	Z_0	Z_1	Z_2	Mean	Z_0	Z_1	Z_2	Mean
F_0	1.87	2.21	2.44	2.17	1.92	2.16	2.47	2.18
F_1	2.10	2.30	2.51	2.30	1.99	2.24	2.56	2.26
F_2	2.15	2.40	2.53	2.36	2.10	2.46	2.83	2.46
Mean	2.04	2.30	2.49	2.28	2.00	2.28	2.62	2.30
	F	*Z*	*F* × *Z*		*F*	*Z*	*F* × *Z*	
SE (m)	0.00	0.00	0.01		0.01	0.01	0.01	
SE (d)	0.01	0.01	0.01		0.01	0.01	0.02	
CD $_{(0.05)}$	0.01	0.01	0.02		0.02	0.02	0.03	

combination with 0.4 % zinc) which was followed by F_2Z_1 (13.15 %). Minimum crude protein content (7.21 %) was reported in F_0Z_0 (control). The crude protein content also showed an increase with different levels of iron, zinc and their interaction.

Shelf-life and runner production

The data showed significant effect with respect to different levels of iron, zinc and their interaction on shelf-life and number of runners/plant (Table 6). The plants treated with 0.4 % $ZnSO_4$ showed highest shelf-life (2.49 days) followed by those treated with 0.4 % $FeSO_4$ (2.36 days). The shelf-life was minimum in control (F_0Z_0), while the strawberry fruits from plants treated with 0.4 % $FeSO_4$ in combination with 0.4 % $ZnSO_4$ (F_2Z_2) showed maximum shelf-life of (2.53 days) at ambient condition. These results are similar to the findings of Chaturvedi *et al*. (2005) who reported maximum shelf-life at higher concentration of $ZnSO_4$.

The plants treated with zinc showed more number of runners as compared to those treated with iron. The plants treated with 0.4 % $FeSO_4$ in combination with 0.4 % $ZnSO_4$ (F_2Z_2) showed maximum number of runners (2.83), while it was minimum in F_0Z_0 (1.92). The enhancing effect of applied zinc on runner production may be attributed to its beneficial effect on stimulating the meristametic activity for producing more tissues and organs via its role in activation of cell division and cell elongation (Mohamed *et al*. 2011).

SUMMARY

This work was carried out to study the influence of foliar application of iron (0, 0.2 and 0.4 %) and zinc (0, 0.2 and 0.4%) on vegetative growth, flowering, yield and fruit quality of strawberry (*Fragaria* × *ananassa* Duch.) cv Chandler during 2010-11. The results indicated that plants treated with 0.4 % $FeSO_4$ showed maximum plant height (19.65 cm), plant spread (30.12 cm), number of leaves/plant (19.12), leaf area (64.60 cm^2), number of crowns/plant (2.97), number of flowers/plant (27.62), number of fruits/plant (21.02) and per cent berry set (76.23 %). However, the plants treated with 0.4 % $ZnSO_4$ showed highest yield/plant (158.90 g), fruit weight (10.56 g), fruit length (3.56 cm), fruit diameter (2.50 cm), fruit volume (15.06 cc), TSS (8.93 ^{0}B), ascorbic acid (59.87 mg/100g pulp), TSS:acid ratio (12.67), total sugars (6.98 %) and lowest acidity (0.71 %). Highest shelf-life of fruits (2.49 days) and maximum number of runner/plant (2.62) were recorded in 0.4 % $ZnSO_4$ treated plants.

REFERENCES

Abedy A. 2001. 'Effect of zinc sulfate and citric acid spray on fruit characteristics of tomato cultivar Urbana'. M Sc thesis, Shiraz University.

Ahlawat V P, Sharma S, Dahia SS and Yamdagni R. 1985. Effect of iron sprays on physico-chemical characteristics of grapes cv. Beauty Seedless. *Progressive Horticulture* **17**: 100–2.

AOAC. 1994. *Official methods of Analysis,* 15th edn, pp 125–39. Association of Official Analytical Chemists. Washington DC.

Babu K D, Dubey A K and Yadav D S. 2007. Effect of micro-nutrients on enhancing the productivity and quality of kinnow mandarin. *Indian Journal of Horticulture* **64** (3): 353–6.

Chaplin M H and Westwood M N. 1980. Relationship of nutritional factors to fruit set. *Journal of Plant Nutrition* **2**: 477–505.

Chaturvedi O P, Singh A K, Tripathi V K and Dixit A K. 2005. Effect of zinc and iron on growth, yield and quality of strawberry cv. Chandler. *Acta Horticulturae* **696**: 237–40.

Das D K. 2006. *Introductory Soil Science*, pp 299–300. Kalyani Publishers.

Dixi C X and Gamdagin R. 1998. Effect of foliar application of zinc and iron chlorosis and yield of kinnow. *Proceedings of Horticultural Science* **10**: 13–9.

Dunn J L and Able A J. 2006. Pre-harvest calcium effects on sensory quality and calcium mobility of strawberry fruit. *Acta Horticulturae* **708**: 307–12.

Garnick S. 1970. Iron metabolism in animals and plants. *Harvey Lectures Series* **44**: 220.

Harborne J B. 1973. *Phytochemical Methods*, p 256. Toppan Company Limited, Tokyo, Japan.

Kher R, Baba J A and Bakshi P. 2010. Influence of planting time and mulching material on growth and fruit yield of strawberry cv. Chandler. *Indian Journal of Horticulture* **67**(4): 441–4.

Kumar S, Yadav M and Singh G K. 2010. Effect of iron and zinc on fruit yield and quality of strawberry (*Fragaria ananassa*). *Indian Journal of Agricultural Science* **80**(2): 171–3.

Mahnaz A, Saeid E and Enayat T. 2010. Interaction of paclobutrazol, boron and zinc on vegetative growth, yield and fruit quality of strawberry (*Fragaria* x *ananassa* Duch. cv Selva). *Journal of Biology and Environment Science* **4**: 67–75.

Mohamed R A, Abd El-Aal H A and Abd El-Aziz M G. 2011. Effect of phosphorus, zinc and their interactions on vegetative growth characters, yield and fruit quality of strawberry. *Journal of Horticultural Science and Ornamental Plants* **3**(2): 106–14.

Nestby R, Lieten F, Pivot D, Raynal Lacroix C, Tagliavini M and Evenhuis B. 2004. Influence of mineral nutrients on strawberry fruit quality and their accumulation in plant organs. *Acta Horticulturae* **649**: 201–5.

Panse V G and Sukhatme P V. 2000. *Statistical Methods for Agricultural Workers*. Publication and Information Division, Indian Council of Agricultural Research, New Delhi.

Ranganna S. 1995. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, pp 24. Tata McGraw Hill Publishing Company Limited, New Delhi.

Samant D, Mishra N K, Singh A K and Lal R L. 2008. Effect of micronutrient sprays on fruit yield and quality during storage in ber cv Umran under ambient conditions. *Indian Journal of Horticulture* **65**(4): 399–404.

Sheriff A A, Saeed W T and Noumon T T. 2000. Effect of foliar application of potassium and zinc on behavior of Montakhab El-Kanater guava trees. *Bulletin Faculty of Agriculture University Cairo* **50**: 73–84.

Turemis N, Ozguven A I, Paydas S, Idem G, Kundan A B and Dennis F G. 1998. Effect of sequestrone EF-138 foliar and/or soil application on yield and earliness of some strawberry cultivars in the sub-tropics. *Acta Horticulturae* **441**: 369–74.