



Influence of pre-harvest application of calcium and micro-nutrients on growth, yield, quality and shelf-life of strawberry cv Chandler

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ABSTRACT

Studies were carried out in Chandler cultivar of strawberry (*Fragaria × ananassa* Duch.) to assess whether pre-harvest foliar application of calcium (Ca), iron (Fe) and zinc (Zn) influences vegetative growth, flowering, fruit yield and quality during 2010 and 2011. Treatments consisted of CaCl₂ (0.2%, 0.4% and 0.6%), FeSO₄ (0.2%, 0.4% and 0.6%), ZnSO₄ (0.2%, 0.4% and 0.6%), while the plants sprayed with water served as the control. Results indicated that plants treated with 0.6% FeSO₄ showed maximum plant height (20.34 cm), plant spread (31.02 cm), number of leaves/plant (19.63), leaf area (64.74 cm²), number of flowers/plant (27.65), number of fruits/plant (21.02), yield/ha (24.32 tonnes) and per cent berry set (75.82). However, the plants treated with 0.6% ZnSO₄ showed highest fruit weight (12.00 g), fruit length (3.68 cm), fruit diameter (2.62 cm), fruit volume (15.74 cc), TSS (8.31 °B), ascorbic acid (60.88 mg/100g pulp), TSS:acid ratio (11.70) and lowest acidity (0.716 %). Highest shelf-life of fruits (2.50 days) and maximum crude protein (10.79 %) were recorded in 0.6 % CaCl₂ treated plants. Studies indicated that pre-harvest foliar application of calcium, iron and zinc are quiet useful for improving vegetative growth, quality and shelf-life of strawberry cv. Chandler and getting higher marketable value in subtropical region.

Key words: Calcium, Growth, Iron, Quality, Shelf-life, Strawberry, Yield, Zinc

The modern cultivated strawberry (*Fragaria × ananassa* Duch.) is one of the most delicious and refreshing soft fruits of the world. It is the most widely distributed fruit crop due to its genotype diversity, highly heterozygous nature and broad range of environment adaptations (Larson 1994, Childers *et al.* 1995). It is a profitable fruit crop in the shortest possible time as compared to the other fruits. It is also nutritious and beneficial to anemic patients. Strawberry consumption can reduce the risk of developing cancer by 50% due to high levels of Vitamin C (30-100 mg/100g of fruit) as well as foliate and photochemical compound such as the ellagic acid present in the fruit. Besides this, it is also a fairly good source of Vitamin-A (60 IU/100g of edible portion). Now, strawberries are available as fresh fruit throughout the year rather than being a traditional season crop. The world area and production of strawberry is 244 283 hectares and 459 4540 tonnes, respectively (FAO 2011). The nutrition status of strawberry plays a vital role 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 conducive in obtaining high yield of good quality and high biological value. Both calcium and micro-nutrients are well known to improve plant growth, yield and quality. The beneficial effects of Ca on maintaining fruit quality are well documented by many researchers (Bakshi *et al.* 2005). Pre- and postharvest application of Ca have been practised commercially in many fruits for improving quality, delaying senescence, reducing postharvest decay and controlling the physiological disorder (Poovaiah 1986, Conway *et al.* 1994). Foliar applications of Ca during the growing season have been reported to delay ripening and mold development in strawberries (Cheour *et al.* 1991, Chung *et al.* 1995). The preharvest sprays of 200 ppm Ca-chelate in strawberries during the fruit growth and development certainly increased fruit firmness and decreased rate of softening during storage for 2 days at 20°C (Naphun *et al.* 1997).

Among various micro-nutrients, iron and zinc plays an important role in promoting vegetative growth, flowering, yield and quality of 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

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and indispensable role on plant growth. It takes part in number of plant biochemical processes such as biosynthesis of cytochrome and chlorophyll 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 also plays an important role in photosynthesis and related enzymes resulting in increasing sugar and decreasing acidity (Abedy 2001). Mahnaz *et al.* (2010) claimed that zinc as a ZnSO₄ source had a positive effect on leaf area, length and diameter of petiole, fresh and dry shoot ratio, yield, TSS, acidity and Vitamin-C of strawberry plant. Foliar application of ZnSO₄ increased size, TSS and juice of orange (Dixi and Gamdagin 1998).

Keeping this into consideration, the present investigation was conducted to determine the effects of foliar application of calcium, iron and zinc on growth, yield, quality and shelf-life of strawberry cv. Chandler.

MATERIALS AND METHODS

The studies were conducted at the Research Farm of the Division of Fruit Science at Main Campus, Chatha, SKUAST-Jammu, J&K, India during 2010 and 2011. The soil of experimental field was sandy loam in texture, thoroughly ploughed and raised beds of 25 cm height, 1.5 m length and 2.0 m width were prepared at a distance of 45 cm. Healthy and disease free runners of Chandler strawberry were planted in first week of October during both 2010 and 2011 at a distance of 30 cm × 45 cm with black polyethylene mulch. The experiment was laid out in RBD factorial with three replications and comprising of 10 treatments, viz. T₁, 0.2 % CaCl₂; T₂, 0.4 % CaCl₂; T₃, 0.6 % CaCl₂; T₄, 0.2 % FeSO₄; T₅, 0.4 % FeSO₄; T₆, 0.6 % FeSO₄; T₇, 0.2 % ZnSO₄; T₈, 0.4 % ZnSO₄; T₉, 0.6 % ZnSO₄ and T₁₀, control (water spray). Each treatment consisted of 20 plants in each plot. The prepared fertilizer solutions of calcium chloride, zinc sulphate

and ferrous sulphate sprayed on the foliage of the plants with the help of a hand sprayer (atomizer). The spraying was done thrice at 30, 60 and 75 days after planting during evening hours. Spraying was preformed carefully by covering the adjacent bed with polyethylene sheets. Wetting agent Tween-20 was added to all the treatments. As per the Package of Practices for fruit crops by SKUAST-J, all the necessary cultural operations and plant protection measures were followed uniformly 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, leaf area); flowering and fruiting (total number of flowers/plant, total number of fruits/plant, per cent berry set); yield (fruit weight, total yield/ha); quality (fruit length, diameter, volume, total soluble solids, acidity, TSS:acid ratio, ascorbic acid, total sugars, anthocyanin, crude protein) and shelf-life under ambient condition (20 ± 2 °C). Plant height (cm) and spread (cm) was recorded by measuring scale, whereas leaf area (cm²) was determined by leaf area meter (Systronics 211). Five uniform berries with medium size, similar colour and free of visual defects /treatment/replication were taken for quality analysis. 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 (⁰B) 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 Ranganna (1995). The data obtained was statistically analyzed by Panse and Sukhatme (2000).

RESULTS AND DISCUSSION

Plant height and plant spread increased with the increase in concentration of calcium, iron and zinc (Table 1). The

Table 1 Effect of calcium, iron and zinc on vegetative growth and floral development of strawberry cv. Chandler (pooled data of 2 years)

Treatment	Plant height (cm)	Plant spread (cm)	Number of leaves/plant	Leaf area (cm ²)	No. of flowers/plant	No. of fruit/plant
CaCl ₂ (0.2%)	17.75	23.70	17.76	60.02	23.36	17.23
CaCl ₂ (0.4%)	18.58	27.24	18.62	61.56	24.98	18.97
CaCl ₂ (0.6%)	19.40	29.80	19.22	64.05	26.33	20.06
FeSO ₄ (0.2%)	18.04	24.40	18.39	60.68	23.78	17.84
FeSO ₄ (0.4%)	19.18	28.86	19.15	62.16	25.62	19.76
FeSO ₄ (0.6%)	20.34	31.02	19.63	64.74	27.65	21.02
ZnSO ₄ (0.2%)	17.93	24.20	18.04	59.26	23.51	17.72
ZnSO ₄ (0.4%)	18.81	28.61	18.63	61.72	25.26	19.32
ZnSO ₄ (0.6%)	20.11	30.81	19.38	63.98	26.92	20.40
Control	16.72	21.78	16.29	55.63	22.73	15.06
CD (P = 0.05)	0.91	0.83	0.47	0.55	0.74	0.56

plants treated with 0.6 % ferrous sulphate showed maximum plant height and plant spread (20.34 cm and 31.02 cm, respectively) followed by those treated with 0.6 % zinc sulphate (20.11 cm and 30.81 cm, respectively). Minimum plant height (16.72 cm) and plant spread (21.78 cm) was recorded in untreated plants. Number of leaves/plant and leaf area increased with the increase in calcium and micro-nutrients (Fe and Zn) concentrations (Table 1). Both number of leaves/plant as well as leaf area were maximum in plants treated with 0.6 % FeSO₄ (19.63 and 64.74 cm², respectively). This increase in plant height, plant spread, number of leaves/plant, and leaf area with ferrous sulphate might be attributed to availability of optimum quantity of iron within the plant system as this element plays an essential role in plant growth.

Number of flowers and fruits/plant also increased with the increase in concentration of calcium, iron and zinc (Table 1). The plants sprayed with iron showed more number of flowers and fruits as compared to those treated with calcium and zinc. The maximum number of flowers (27.65) and fruits (21.02)/plant were produced with 0.6 % FeSO₄, while these were minimum (22.73 and 15.06, respectively) in control. Turemis *et al.* (1998) also observed a significant increase in flowers and fruits with FeSO₄.

The berry set and fruit yield was influenced by various calcium, iron and zinc concentrations (Fig 1). Berry set was maximum (75.82 %) in plants treated with 0.6 % FeSO₄ closely followed by those treated with 0.6 % ZnSO₄ (75.76 %), whereas untreated showed minimum fruit set (68.24 %). The average fruit yield was more in iron treated plants and was maximum (24.32 tonnes/ha) in 0.6 % ferrous sulphate followed by those treated with 0.6 % zinc sulphate (23.68 tonnes/ha). Minimum fruit yield (17.82 tonnes/ha) was recorded in control. Chaturvedi *et al.* (2005) also reported similar results.

Fruit weight, fruit length, fruit diameter and fruit volume of berries increased with the increase in concentration of calcium, iron and zinc (Table 2). The plants treated with zinc showed more weight, length, breadth and volume of fruits as

Table 2 Effect of calcium, iron and zinc on physical characteristics of strawberry cv. Chandler (pooled data of 2 years)

Treatment	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Fruit volume (cc)
CaCl ₂ (0.2%)	9.90	3.34	2.32	13.64
CaCl ₂ (0.4%)	10.75	3.38	2.37	14.44
CaCl ₂ (0.6%)	11.42	3.44	2.43	15.09
FeSO ₄ (0.2%)	9.46	3.17	2.23	13.38
FeSO ₄ (0.4%)	10.14	3.26	2.31	13.85
FeSO ₄ (0.6%)	11.19	3.36	2.40	14.68
ZnSO ₄ (0.2%)	11.03	3.54	2.48	14.08
ZnSO ₄ (0.4%)	11.49	3.59	2.56	14.89
ZnSO ₄ (0.6%)	12.00	3.68	2.62	15.74
Control	7.12	3.11	2.12	12.42
CD (P = 0.05)	0.28	0.11	0.22	0.45

compared to those treated with iron. The plants treated with 0.6 % ZnSO₄ showed maximum fruit weight (12.00 g), fruit length (3.68 cm), fruit diameter (2.62 cm) and fruit volume (15.74 cc). Increase in fruit weight and size with the application of ZnSO₄ 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.

Total soluble solids (TSS) increased with the increase in concentration of calcium, iron and zinc (Table 3). The plants treated with 0.6 % zinc sulphate showed maximum average TSS (8.31 °B) followed by those treated with 0.6 % FeSO₄ (8.03 °B). Minimum TSS (7.42 °B) was recorded in fruits of untreated plants. The quality of fruits in terms of TSS was improved with different nutrient application. 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.

The acidity content of fruit decreased with the increase in different levels of calcium, iron and zinc (Table 3). The plants receiving 0.6% zinc resulted in minimum acidity (0.716%). Maximum acidity (0.740%) was recorded in control. Calcium, 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.

Total sugars increased in all the different concentrations of calcium, iron and zinc (Table 3). The plants treated with zinc showed more sugar content in their fruits as compared to those treated with iron. Highest total sugars (6.34 %) was recorded in strawberry fruits taken from plants treated with 0.4 % ZnSO₄ closely followed by those treated with 0.4 %

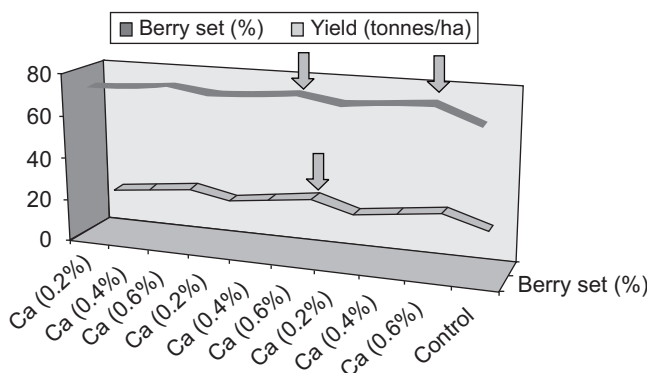


Fig 1 Effect of calcium, iron and zinc on fruit set and yield of strawberry cv. Chandler (pooled data of 2 years)

Table 3 Effect of calcium, iron and zinc on chemical characteristics of strawberry cv Chandler (pooled data of 2 years)

Treatment	TSS (°B)	Acidity (%)	TSS:Acid ratio	Total sugar (%)	Ascorbic acid (mg/100 g fresh weight)	Crude protein (%)	Anthocyanin OD at 535 nm
CaCl ₂ (0.2%)	7.58	0.730	10.46	6.18	60.72	9.56	0.16
CaCl ₂ (0.4%)	7.72	0.728	10.60	6.23	60.24	10.64	0.18
CaCl ₂ (0.6%)	7.91	0.725	11.15	6.28	59.16	10.79	0.19
FeSO ₄ (0.2%)	7.63	0.734	10.43	6.24	60.03	9.36	0.15
FeSO ₄ (0.4%)	7.83	0.731	10.71	6.32	59.82	10.36	0.18
FeSO ₄ (0.6%)	8.03	0.728	11.32	6.27	59.64	10.58	0.20
ZnSO ₄ (0.2%)	7.68	0.736	10.43	6.31	59.84	8.98	0.16
ZnSO ₄ (0.4%)	7.94	0.728	10.91	6.34	60.46	9.92	0.17
ZnSO ₄ (0.6%)	8.31	0.716	11.70	6.29	60.88	10.28	0.20
Control	7.42	0.740	10.03	5.14	58.26	8.21	0.14
CD (P = 0.05)	0.47	N.S.	0.38	0.22	0.06	0.62	0.01

FeSO₄. 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).

The data showed significant effect with respect to different level of calcium, iron and zinc on ascorbic acid content (Table 3). The maximum ascorbic acid content (60.88 mg/100 g) was recorded in 0.6 % zinc sulphate treated plants which was at par with 0.2 % calcium chloride. Minimum ascorbic acid (58.26 mg/100 g) was reported in control. The ascorbic acid content also showed an increase with different levels of calcium, iron and zinc. These results are in confirmation with the findings of Kumar *et al.* (2010) who also reported an increase in ascorbic acid synthesis with iron and zinc application.

The data showed an increase with respect to different levels of calcium, iron and zinc on per cent crude protein (Table 3). This increase was more in plants treated with calcium followed by iron and zinc. The fruits of plant treated with 0.6 % calcium chloride showed maximum crude protein content (10.79 %) which was followed by 0.4 % calcium chloride (10.64 %). Minimum crude protein content (8.21%) was reported in untreated fruits.

Anthocyanin content increased with the increase in calcium, iron and zinc concentration (Table 3). The plants treated with iron and zinc showed more anthocyanin content as compared to those treated with calcium. Maximum content of anthocyanin (0.20 OD) was recorded both in 0.6 % FeSO₄ and 0.6 % ZnSO₄ followed by (0.18 OD) in 0.4 % FeSO₄. Increase in anthocyanin content in iron treated fruits might be due to its role in the biosynthesis of chlorophyll.

The data showed significant effect with respect to different levels of calcium, iron and zinc on shelf-life of strawberry. The fruits taken from plants treated with calcium showed highest shelf-life which increased with the increase in calcium concentration. The shelf-life was minimum (1.58

days) in control, while the strawberry fruits from plants treated with 0.6 % CaCl₂ showed highest shelf-life (2.50 days) followed by those treated with 0.4 % ZnSO₄ (2.33 days) at ambient condition. These results are similar to the findings of Amiria (2009) who stated that calcium treatment showed an increase in berry firmness and also extended shelf-life in grapes.

It is thus concluded that pre-harvest foliar application of 0.6 % FeSO₄ resulted maximum vegetative growth, whereas 0.6 % ZnSO₄ application improved quality of Chandler strawberry. The shelf-life of fruit increased up to 2.50 days with 0.6 % CaCl₂ as compared to 1.58 days in control.

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