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Growth, yield and quality improvement in strawberry through foliar application of calcium, iron and zinc: A review

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Abstract
This review is partly based on complete articles and partly on abstracts. The nutrition status in the strawberry plants plays a vital role in determining the growth, yield and quality of fruits since it is a very sensitive plant to nutritional balance. An optimal fertilization is contributive in obtaining high yield of good quality and high biological value. Both macro and micro-nutrients are well known to ameliorate plant growth, yield and quality of fruits. Foliar fertilization of micronutrients is one of the most important methods of fertilizer application in horticulture practices in order to increase the plant growth, yield and quality of fruits. Foliar application of Iron, Zinc and Calcium either single or along with other micronutrients can help to achieve favorable results on growth parameters, yield components and quality of strawberry fruits. The available literature on effect of foliar application of Fe, Zn and Ca on growth, yield and quality of strawberry and other fruit crops are reviewed and presented below.

Keywords: Calcium, iron, zinc, foliar application, growth, yield, quality, strawberry etc.

Introduction
Strawberry (*Fragaria* x *ananassa* Duch.) is one of the most important temperate fruit belongs to the family Rosaceae. It is an octoploid (8x) in nature having (x=7) basic chromosome number. Botanically it is an aggregate fruit which is highly perishable in nature. Basically, it is herbaceous, perennial and short-day plant. Among all the berries, strawberry gives the quickest return in a shortest possible time (Boriss *et al*., 2006) [7]. Strawberry has gained the status of being one of the most important soft fruits in the world. Nutritionally, strawberry is a low calorific carbohydrate fruit. It is a rich source of Vit. A (60 IU/100 g of edible portion), Vit. C (30-120mg/100 g of edible portion), fiber and also has high pectin content (0.55%) available in the form of calcium pectate. Water is a major constituent of strawberry fruit. It contains 90% water. Ellagic acid is a naturally occurring plant phenol in its fruit.

Strawberry fruits have great demand in fresh market, in processing industries as well as in preserve and confectionaries industries. It's phenomenal increases in production during the recent years show the popularity of strawberry fruit cultivation. In India, the total area of strawberry is 1000 Ha with production of 5000 MT (Anonymous, 2015-16) [2]. Here, Maharashtra is the leading State in production of strawberry fruits. It is also commercially grown in Haryana, Punjab, Uttar Pradesh, Jammu and Kashmir, Uttarakhand and lower hills of Himachal Pradesh.

The nutrition status in the strawberry plant plays a vital role in determining the growth, yield and quality of fruits since it is a very sensitive plant to nutritional balance (Mohamed *et al*., 2011) [33]. An optimal fertilization is contributive in obtaining high yield of good quality and high biological value. Both macro and micro-nutrients are well known to ameliorate plant growth, yield and quality of fruit plants.

Ca is one of the most important macro nutrients. The beneficial effects of Ca on maintaining fruit quality and increasing shelf life are well documented by many researchers (Bakshi *et al*., 2005) [3]. Pre and post-harvest application of Calcium have been practiced commercially in many fruits for improving quality, delaying senescence, reducing post-harvest decay and controlling the physiological disorders (Poovaiah, 1986 and Conway *et al*., 1994) [36, 15]. Foliar applications of Calcium during the vegetative growth have been reported to delay ripening and mold development in strawberries (Cheour *et al*., 1991, Chung *et al*., 1995) [13, 14].

Among various micro-nutrients, iron (Fe) and zinc (Zn) plays an important role in promoting vegetative growth, flowering, yield and quality of strawberry fruits (Chaturvedi *et al*., 2005) [12]. Iron has many important functions in plant growth and development, such as involvement in the biosynthesis of chlorophyll, respiration, chloroplast development and improves the

performance of photosystems. It is an essential part of many enzymes. Iron also participates in the oxidation process that releases energy from sugars and starches and in responses that convert nitrate to ammonium in plant. It plays an essential role in nucleic acid metabolism (Romheld and Marschner, 1991; Miller *et al*., 1995; Eskandari, 2011; Havlin *et al*., 2014) [39, 31, 19, 21]. Zinc also plays an important role in photosynthesis and related enzymes resulting in increasing sugar and decreasing acidity. Mahnaz *et al*., 2010 [29] claimed that $ZnSO_4$ as a source of zinc had a positive effect in increasing leaf area, length and diameter of petiole, fresh and dry shoot ratio, yield, TSS, acidity and Vitamin-C of strawberry plant.

Many researchers have shown that plants absorb nutrients not only through roots (by soil application) but also through the foliage (by foliar spray). In fact, it has efficient organ of absorption of nutrients through foliage. The foliar spray of micro-nutrients has been very popular means of correcting micro-nutrients deficiencies in many fruit crops. Foliar feeding of micro-nutrients also plays an important role in influencing the plant growth characters, yield and yield attributing parameters and quality characters in strawberry. Application of micro-nutrients through foliar feeding is an effectual way of controlling the timing and emplacement of nutrients. This also ameliorates the micronutrient use efficiency by reducing nutrients losses from leaching, volatilization and from fixation in the soil to less available forms. For getting higher yield as well as quality produce, it is very important to bring changes in the method of nutrient management in strawberry. Some literatures are available on foliar feeding of micro-nutrients in strawberry; however, attempts are made to collect related on the aforesaid aspects.

The works on effect of foliar spray of calcium, iron and zinc on strawberry and other fruit crops have been summarized under following heads:

Effect on growth attributing parameters

Foliar application of ferrous sulphate alone @ 0.4-0.6% or in combination with zinc sulphate @ 0.4% on strawberry gave best result regarding growth parameters *i.e.* increased number of leaves per plant, leaf area, runners per plant and plant height, plant spread in strawberry. [Chaturvedi *et al.* (2005) [12], Bakshi *et al.* (2013 a) [4], Bakshi *et al*. (2013 b) [5], Singh *et al*. (2015) [44] Mehraj *et al*. (2015) [30], Mishra *et al.* (2016) [32], Chandrakar *et al.* (2018 b) [9]

Effect on flowering, fruiting, fruit maturity and crop duration

Application of ferrous sulphate at 0.2 percent with zinc sulphate at 0.4 per cent through foliar feeding in strawberry significantly increased the number of flowers, fruit set, fruits and fruit yield per plant. [Chaturvedi *et al.* (2005)] [12]

Pre-harvest foliar application of 0.4-0.6% $FeSO_4$ on Chandler cultivar of strawberry showed maximum number of flowers/plants, number of fruits/plants, yield/ha and per cent berry set. However, the plants treated with 0.4-0.6% $ZnSO_4$ showed highest fruit weight (12.00 g), fruit length (3.68 cm), fruit diameter (2.62 cm), fruit volume (15.74 cc). [Bakshi *et al.* (2013 a) [4], Bakshi *et al*. (2013 b) [5], Singh *et al*. (2015) [44], Chandrakar *et al.* (2018 b) [9]

Foliar spray of zinc sulfate on strawberry plant at 150 mg l^{-1}, iron at 1000 mg l^{-1} and calcium at 10 mM improved number of flowers, weight of primary and secondary fruit. [Kazemi M. (2014)] [24]

The early flowering (72.7 days) and fruit harvesting (97.0 days), maximum number of flowers/plant (25.3), maximum number of fruits/plant (23.3), fruit length (3.3 cm), fruit diameter (31.6 mm), single fruit weight (15.0 g), fruit yield/plant (354.5 g) and degree of brix (11.3%) were found from the foliar application of boron-zinc three times spraying at 30, 45 and 60 DAT on strawberry.[Mehraj *et al*. (2015) [30]

Effect of Calcium, Iron and Zinc spray on yield and yield-attributing characters

The number of fruits per plant, mean fruit weight, diameter and volume of fruit significantly increased with the application of Zinc (0.6%) alone or with Iron (0.4%) in fruit plants. [Bhambota *et al.* (1962) [6] in citrus, Dixit *et al.* (1977) [17], Sarkar *et al.* (1984) [40], Kumar and Pathak (1992) [25] in grapes, Sharma and Bhattacharyya (1994) in guava, Kamble *et al.* (1994) [22] in ber, Durgadevi *et al.* (1997) [18] in citrus, Veena and Lavania (1998) [50] in Papaya, Afria *et al.* (1999) [1] in pomegranate, Haque *et al.* (2000) [20] in mandarin orange, Lal *et al.* (2000) [28] in guava, Chaturvedi *et al.* (2005) [12] in strawberry, Kumar *et al*. (2010) [27] in strawberry, Bakshi *et al.* (2013 a) [4], Bakshi *et al.* (2013 b) [5], Singh *et al*. (2015) [44], Mishra *et al.* (2016) [32] in strawberry, Rahman *et al.* (2016) [37], Yadav *et al.* (2017) [52], Chandrakar *et al.* (2019 a) [8], Chandrakar *et al.* (2019 b) [9] in strawberry]

The banana plant treated with 25 kg $ZnSO_4$ / ha + FYM @ 25 kg / plant + neem cake @ 0.5 kg/plant produced maximum number of hands per bunch, number of fingers per hand, bunch length and bunch yield per hectare. [Subramanina and Pillai (1997) [48]

Foliar spray of Zn (0.5%), Fe (0.2%), Cu (0.2%), or H_3BO_4 (0.1%) at 3rd, 5th and 7th months after planting on banana cv. Robusta significantly increased number of fingers per hand and other yield attributing characters. [Kumar and Jeyakumar (1999) [26]

Foliar spray of Zn (0.5%) + B (0.1%) at 4th, 8th, 12th and 16th month after planting improved total number of fruits per tree, fruit characters, and latex yield in papaya. [Kavitha *et al.* (2000)] [23]

Repeated foliar application of boron-zinc (100 ppm) on strawberry significantly increased number of fruits/plant (23.3), fruit length (3.3 cm), fruit diameter (31.6 mm), single fruit weight (15.0 g), fruit were found from the foliar application of boron-zinc three times spraying at 30, 45 and 60 DAT. [Mehraj *et al*. (2015) [30]

Effect of Calcium, Iron and Zinc spray on quality-parameters

The total sugars, TSS and sugar/acid ratio were improved with the application of 2 ppm zinc or 1 ppm boron, while non-reducing sugars and acidity were found maximum under the 4-ppm zinc concentration in pineapple. [Shrivastava (1969) [42], Shrivastava (1970) [43] in pineapple, Singh and Brahmachari (1999) [47] in guava cv. Allahabad Safeda]

Total soluble solids and total sugars were recorded maximum in guava by foliar spray of 0.2% $ZnSO_4$. [Singh and Chhonkar (1983)] [45]. Rai *et al.* (1988) [38] also recorded that plant treated with borax at 0.6% and Zn & Cu in combined form produced fruits with increased TSS, total sugar and ascorbic acid content.

Foliar application of B + Zn + Cu applied at 3rd and 5th months after planting reported significant increase in the total soluble solids. [Das (1995)] [16]

Foliar application of Zn (0.5%), Fe (0.2%), Cu (0.2%), or H_3BO_4 (0.1%) sprayed at 3, 5 and 7 months after planting

registered the highest total soluble solids content in ripen fruit of banana. [Kumar and Jayakumar (1999), Thangasel vabai *et al.* (2009)] [49]

Foliar application of micronutrient mixture (1%) on banana cv. Grand Naine recorded maximum percentage of reducing sugar (12.97%), non- reducing sugar (3.58) and highest amount of ascorbic acid (0.70 mg/100 g). [Yadlod and Kadam (2003)] [51]

Foliar application of ferrous sulphate at 0.2-0.6 per cent alone or with zinc sulphate at 0.4 per cent in strawberry gave best result in increased ascorbic acid content, decreased acidity, increased TSS content, total sugar, reducing sugar and also enhanced shelf life of fruits. [Chaturvedi *et al.* (2005) [12], Kumar *et al.* (2010) [27], Patel *et al.* (2010) [34] in banana, Pathak *et al.* (2011) [35] in banana, Bakshi *et al.* (2013 a) [4], Bakshi *et al.* (2013 b) [5], Kazemi M. (2014) [24], Mishra *et al.* (2016) [32] and Chandrakar *et al.* (2018 a) [9] in strawberry]

Pre-harvest foliar application of Ca + B is quite useful for reducing the incidence of disorders and getting higher marketable yield in 'Chandler' variety of strawberry. [Singh *et al.* (2007) [46]

Conclusion

Regarding the above review of research articles and abstracts it can be concluded that the foliar application of iron, zinc and calcium, single or in mixture with other micronutrients has a positive effect on growth, yield and quality parameters of fruit crops. In addition, it is very practical when plants are not able to absorb the micro-nutrients like iron and zinc from soil due to many soil physical and chemical properties such as soil texture, very high or low soil temperature, poor soil aeration, high humidity, compaction, soil pH, calcium carbonate, organic matter content etc. As a result, foliar application of them improve plant growth, development, yield and quality of strawberry and other fruit crops.

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