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Original Research Paper

Response of fruit yield and quality to foliar application of micro-nutrients in lemon [*Citrus limon* (L.) Burm.] cv. Assam lemon

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ABSTRACT

Assam lemon [*Citrus limon* (L.) Burm.], an indigenous lemon cultivar of Assam, is widely cultivated in warm southern slopes of the Himalayas in North-Eastern India. Since this cultivar of lemon is having a prominent trait of bearing fruits in several flushes throughout the year, it is essential to provide sufficient nutrition for obtaining optimum yield with good quality fruits. In the current experiment, a randomized block design having twelve treatments with three replications was followed to find out the response of lemon fruit yield and quality to foliar application of micronutrients during the year 2019. Among all, the treatment $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%) gave the best performance in improving the yield and quality of fruits. The highest number of fruits per plant at the time of harvesting (73), yield per plant (11.5 kg), fruit fresh weight (158 g), fruit length (9.60 cm), fruit diameter (5.80 cm), juice content (152 mL/fruit), TSS (6.40 °B), ascorbic acid (49.10 mg/100g), total sugar (6.30%), reducing sugar (3.90%), non-reducing sugar (2.40%) with lowest titratable acidity (3.13%) were obtained which revealed that the yield and fruit quality of lemon depends on the application of different micronutrients.

Keywords: Assam lemon, fruit quality, micronutrients, nutrition and yield

INTRODUCTION

Citrus is considered as one of the most important fruits widely cultivated in different parts of the world. It belongs to the family Rutaceae. It is very famous for its juice and pulp all over the world. Among the citrus cultivar, Assam lemon [*Citrus limon* (L.) Burm.] is an indigenous lemon cultivar of Assam and is grown all over the North-Eastern region. As this plant is having a prominent trait of bearing fruits in several flushes throughout the year, it is essential to provide sufficient nutrition for obtaining optimum yield with good quality fruits. Micronutrients like zinc, iron, boron and copper are not only essential but they are equally significant like other macronutrients, in spite of their requirement in minute quantities. They also play a vital role in the various enzymatic activities and synthesis. Their acute deficiencies are sometimes incurable in nature (Kumar, 2002). Zinc is required for the synthesis of tryptophan which is the precursor of indole acetic acid synthesis resulting in the growth and development of tissues. Iron is also an important micronutrient necessary for the citrus plants. It has been reported that the application of iron sulphates as foliar spray reduces the leaf chlorosis and consequently increase the yield (Devi *et al.,* 1997). It also helps in a significant increase of fruit yield, fruit volume, ascorbic acid content and leaf iron content in citrus (Aboutalebi and Hassanzadeh, 2013). Similarly, boron also plays a vital role in the growth behaviour and productivity of citrus fruits. It increases the phenolic compound production in the plant system that is responsible for the polar transport of auxin. This increases the auxin activity resulting in increasing the vegetative growth of citrus trees (Gurjar *et al.,* 2015). Boron also helps in pollen grain germination and elongation of pollen tubes that results in increasing the fruit set percentage and ultimately increase in yield (Abd-Allah, 2006). As a micronutrient, copper plays a significant role in plants. It is involved in stimulation activities for lignification of the cell wall of plants, and photosynthesis, and acts as an electron carrier in the plant system (Somasundaram *et al.,* 2011). It is reported that copper helps in production of sugar compounds and leads to more accumulation of total soluble solids (TSS) in the fruit juice (Singh *et al.,* 2018).

Since citrus is a micronutrient loving crop, the more precise management of nutrition is required to meet the nutrient demand for its growth and development. Thus, fulfilling the nutritional requirement is very important for economically profitable citrus fruit production. Assam lemon being a heavy and regular bearing crop which bears throughout the year has to be supplied with adequate nutrients to ensure the yield and quality of the harvest. Most of the time citrus growers are not giving proper emphasis to application of micronutrients, as they are required in minute quantities. This leads to a drastic decrease in the growth and development of plants and it also affects the yield and quality of fruits. So, the current experiment was conducted to study the effect of micronutrients on fruit yield and quality of Assam lemon in the North-Eastern region of India.

MATERIAL AND METHODS

The experiment was laid out with the objectives of evaluating and standardizing the impact of micronutrients on yield and quality of Assam lemon. The research work was executed on three years old Assam lemon plants which were planted at the spacing of 3m x 3m during the year 2019 at the Citrus Fruit Block, Department of Fruit Science of the College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. It is geographically located at 28° 04’ 43" N latitude and 95° 19’ 26" E longitude with an altitude of 153 m above the mean sea level. Pasighat lies under the humid sub-tropical climate. The average annual rainfall and temperature of this area are 32.8 cm and 25.5 ºC, respectively. The rainy season starts from June and it continues till September with maximum rainfall during July. August is the warmest month of the year while December is the coldest month of the year with the average temperature of 31.6^{0}C and 20.5^{0}C P C respectively. The design of the experiment followed was Randomized Block Design (RBD) having twelve treatments and each treatment was replicated thrice. In each replication, there were two plants and the total numbers of plants in the whole experiment were seventy-two. The recommended dose of fertilizer (RDF) for Assam lemon 100: 100: 100 g NPK (Source: N- Urea, P- SSP and K- MOP)/plant/ year (www.kiran.nic.in), was applied to all the plants under the investigation. Half of the dose before flowering during the first week of January and the remaining half dose during the second month of June were applied.

The treatments studied were: T_1 - Control, T_2 - $ZnSO_4$ (0.2%), T_3 - $FeSO_4$ (0.2%), T_4 - Borax (0.2%), T_5 - $CuSO_4$ (0.2%), T_6 - $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%), T_7 - $ZnSO_4$ (0.2%) + Borax (0.2%), T_8 - $ZnSO_4$ (0.2%) + $CuSO_4$ (0.2%), T_9 - $FeSO_4$ (0.2%) + Borax (0.2%), T_{10} - $FeSO_4$ (0.2%) + $CuSO_4$ (0.2%), T_{11} - Borax (0.2%) + $CuSO_4$ (0.2%) and T_{12} - $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%). For the foliar application of these micronutrients (Sources: $ZnSO_4$- 36.40% Zn, $FeSO_4$- 32.8% Fe, Borax- 10.8% B and $CuSO_4$- 21% Cu), the required amounts of micronutrient sources were dissolved in separate container. Then the pH of the nutrient solutions were checked by using Pen type digital pH meter and it was adjusted by 0.1 N concentrated hydrochloric acid and sodium hydroxide. The application was done on 5th April, 2019 (i.e.) after the complete emergence of spring flush and the onset of fruit setting) on an average of two liters per tree and normal water was used for spraying the plants in control by using Knapsack sprayer. In each spray treatment teepol @ 0.01% was added as sticking gent in prepared solution.

The total numbers of fruits per plant at the time of harvesting (i.e.) during June-July fruits developed attractive green to little yellow colour and they were harvested two times) were recorded. For fruit yield of Assam lemon, fruits from each plant were harvested separately for all treatments and yield per plant was calculated by multiplying total number of fruits per plant with average fruit weight. For recording the readings of physical parameters like fruit weight, fruit length, fruit diameter and juice content, five fruits from each treatment were selected randomly. Then the fruit weight was recorded by using a precision weighing balance and its average weight was expressed in grams (g). For the fruit length and fruit diameter a digital Vernier caliper was used to record the data and their average fruit length and fruit diameter were expressed in centimeters (cm). Fruit juice content was also measured by using a measuring cylinder and its average juice content per fruit was expressed in milliliters (mL).

The TSS in fruit juice was determined using hand held Refractometer (0 ºB–32 ºB). The titratable acidity of the fruit was determined by titrating the fruit juice against 0.1N NaOH solution using phenolphthalein as an indicator (light pink end point) and expressed as percentage in terms of citric acid (AOAC, 2002).

Total sugar content was estimated by anthrone method as described by Hodge and Hofreiter (1962).

Reducing sugar content was estimated by spectrophotometric method as described by Somogyi (1952). The non-reducing sugar content was obtained by the subtraction of the reducing sugar content from the total sugar content.

Non reducing sugars content = total sugar - reducing sugar

The ascorbic acid content of fruits was determined by the method described by Ranganna (1986) using 2, 6-dichlorophenol Indophenol dye. The samples extracted in meta-phosphoric acid solution were titrated with dye to pink end point. The ascorbic acid content was calculated and expressed as mg per 100 g of fruit weight sample.

The observations recorded during field experiment and data obtained from laboratory analysis were subjected to the statistical analysis of variance for RBD. Significance and non-significance of the variance due to different treatments were determined by calculating the respective 'F' values according to the method described by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Yield and its attributing parameters: The data depicted in Table 1 exhibited the significant impact of foliar imposition of micronutrients on yield and its attributing parameters. The highest number of fruits per plant (73) at the time of harvesting and fruit yield (11.52 kg/plant) was recorded in T_{12} [$ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] while the lowest number of fruits per plant (43) at the time of harvesting and fruit yield (5.60 kg/plant) was obtained in T_1 (Control). This might be due to the synergistic effect of different micronutrients as they directly take part in many physiological processes and activity of many enzymes for greater gathering of food materials. Zinc helps in prevention of abscission layer formation and increase the synthesis of tryptophan which is the precursor of auxin synthesis and this facilitates the ovary to remain intact with the shoot, ensuring in minimizing the flower and fruit drop and maximize the retention of fruits in the plants (Gurjar *et al.*, 2015). There is also a correlation between fruit drop and internal hormonal level in the plant system. As the level of internal auxin concentration in the plant system is higher, then the fruit retention capacity will be more leading to increase in number of fruits per plant. Iron also plays a major role in cell division and cell enlargement resulting in increasing the fruit size and fruit weight which ultimately leads to the increase in yield of plants. Ganie *et al.* (2013) reported that boron helps in germination of pollen grains and elongation of pollen tube because of which the fruit set, fruit retention and yield of the guava plants were increased. Copper involves in synthesis and stability of chlorophyll responsible to produce food materials required for the growth and development of fruits. Ilyas *et al.* (2015) observed the significant improvement of photosynthetic and fruit yield in *Citrus reticulata* Blanco var. Kinnow on the foliar imposition of Zn, Cu and B. Similarly, Zoremtluangi *et al.*, (2019) also proved that the foliar application of Zn, Cu and B obtained the maximum number of fruits per plant and yield per tree. The present report is in conformity with the experimental findings revealed by Bhoyar and Ramdevputra (2016) in guava and Jangid *et al.* (2019) in aonla.

Physical parameters of fruits: Most of the physical parameters of the Assam lemon fruit had consequential effect due to the application of different micronutrients and they are presented in Table 1. The highest fruit fresh weight (157.77 g), juice content (152 mL/fruit), fruit length (9.60 cm) and fruit diameter (5.80 cm) were obtained in treatment T_{12}[$ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] while the lowest fruit fresh weight (130.20 g), juice content (120 mL/fruit), fruit length (7.43 cm) and fruit diameter (4.10 cm) were obtained in treatment T_1 (Control).

The overall amelioration in the physical parameters of the Assam lemon fruit might be because of benefaction of different micronutrients in the growth and development of fruits. Zinc facilitates in the

Table 1. Effect of micronutrients on yield and physical parameters of Assam lemon

Treatments	Number of fruits/plant	Fruit yield (kg/plant)	Fruit Fresh weight (g)	Fruit length (cm)	Fruit diameter (cm)	Juice content (mL/fruit)
T_1	43	5.60	130.2	7.43	4.10	120
T_2	58	8.40	144.60	8.57	5.00	135
T_3	48	6.64	138.40	7.87	4.67	129
T_4	54	7.68	142.10	8.33	4.90	134
T_5	45	6.00	133.30	7.60	4.27	123
T_6	70	10.84	155.00	9.43	5.73	149
T_7	67	10.11	150.80	9.27	5.50	145
T_8	63	9.34	148.13	8.90	5.33	141
T_9	52	7.29	140.23	8.13	4.73	131
T_{10}	47	6.38	135.70	7.77	4.43	127
T_{11}	61	8.95	146.60	8.73	5.13	137
T_{12}	73	11.52	157.77	9.60	5.80	152
C.D. (0.05)	7.22	1.17	5.02	0.85	0.54	4.01
SEm±	2.44	0.39	1.70	0.28	0.18	1.36

synthesis of tryptophan, the precursor of auxin synthesis and consequently the auxin level in the fruit increases. This lead to the higher enlargement of cell because of cell vacuolization resulting in increased size of vesicles, dimension of locules and eventually the weight and size of fruit. Therefore, the significant influence of Zn in increasing the fruit fresh weight was revealed by Ghosh and Besra (2000) in sweet orange. Iron and zinc also play a vital role in the enlargement of cell, division of cell and formation of starch. Thus, the additive effect of these micronutrients resulted in increased fruit fresh weight. The rise in fruit fresh weight might be because of the higher translocation of photosynthates to fruits. Similar findings were revealed by Waskela *et al*. (2013) in guava.

Boron also plays a vital role in cell division and cell elongation, thereby increasing the fresh weight of fruit. The increase in fruit fresh weight owing to the combined imposition of Zn and B may be the result of stimulation influence on plant metabolic process. In addition to this, B also activates the sugar and water mobilization in the fruits resulted in increasing the fruit weight as reported by Lakshmipathi *et al*. (2015). Similarly, Ilyas *et al*. (2015) also reported that the foliar imposition of Zn, Cu and B had significant effect on fruit yield with regard to number and fresh weight of fruit.

Trivedi *et al*. (2012) reported that zinc controls the semi-permeability of cell wall through which the movement of water into fruits increases, that results in obtaining the highest juice content in guava. Sajid *et al*. (2012) also revealed that the foliar spray of Zn and B had consequential influence on juice content in fruits of sweet orange. The imposition of micronutrients might have ameliorated the plant health by improving the sugar metabolism and conduction of assimilates as a result of which the fruit juice content increase. Similar outcomes were revealed by the findings of Singh *et al*. (2018) in sweet orange cv. Mosambi. Increase in fruit length might be because of the direct effect of B and Zn in increasing the cell division and cell elongation process. Similarly, the fruit diameter was notably influenced by the imposition of zinc sulphate and borax. Dutta and Banik (2005) reported that the increase in fruit length and fruit diameter may be due to the improvement in internal physiology of developing fruit with regard to proper supply of water, mineral nutrients and other compounds essential for normal growth and development of fruit and the present result is in conformity with the reports of Yadav *et al*. (2013).

Quality parameters of fruit: The quality parameters of fruits were significantly improved by the foliar application of micronutrients and they are presented in Table 2. In this, the treatment T_{12}[$ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] offered maximum TSS (6.40 ºB), ascorbic acid (49.10 mg/100 g), total sugars (6.30%), reducing sugars (3.90%) and non-reducing sugars (2.40%) content of fruits while the minimum TSS (5.30 ºB), ascorbic acid (34.37 mg/100 g), total sugars (3.73%), reducing sugars (2.53%) and non-reducing sugars (1.20%) were obtained in T_1 (Control).

Table 2. Effect of micronutrients on quality parameters of Assam lemon

Treatments	TSS (°Brix)	Ascorbic acid (mg/100g)	Titratable acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)
T_1	5.30	34.37	4.93	3.73	2.53	1.20
T_2	5.93	40.43	4.57	4.80	2.90	1.90
T_3	5.50	35.27	4.63	5.13	3.17	1.97
T_4	5.60	39.55	4.47	4.37	2.70	1.67
T_5	5.83	37.09	4.33	4.63	2.83	1.80
T_6	6.13	42.33	3.90	6.00	3.80	1.20
T_7	6.00	46.83	3.73	5.53	3.43	2.10
T_8	6.20	48.30	3.57	5.73	3.70	2.03
T_9	5.90	45.13	3.47	5.67	3.57	2.10
T_{10}	5.97	41.06	3.23	5.37	3.13	2.23
T_{11}	5.80	47.70	3.67	5.47	3.27	2.20
T_{12}	6.40	49.10	3.13	6.30	3.90	2.40
C.D. (0.05)	0.44	3.31	0.39	0.27	0.24	0.40
SEm±	0.15	1.12	0.13	0.09	0.08	0.13

Zinc is required in enzymatic reactions namely hexokinase, carbohydrate and protein synthesis. In addition to this, Boron helps in the transportation of sugar in the form of boron-sugar complex and it also intensifies hydrolysis of carbohydrates into simple sugar. Copper also helps in elevating the photosynthetic efficiency that results in higher rate of photosynthesis. The main product of photosynthesis is sugar, thus increase in the photosynthesis by the additive action of zinc, boron and copper results in more sugar compounds and this led to the accumulation of more total soluble solids in fruit juice. The results of the current investigation are in line with the results obtained by Babu and Yadav (2005) in Khasi mandarin and Singh *et al*. (2018) in Sweet orange cv. Mosambi. Kumari *et al*. (2009) also reported that the foliar fertilization of Fe, Zn and Cu had significant effect in increasing the TSS of Kinnow mandarin.

Zinc helps in the synthesis of auxin that leads to the increase in ascorbic acid content as reported by Nawaz *et al*. (2008). Similarly, foliar imposition of Zn, B and Cu also helps in increasing the ascorbic acid content in the fruit juice of Sweet orange cv. Mosambi as reported by Singh *et al*. (2018). Increase in sugar content (total sugar, reducing sugar and non-reducing sugar) in the fruit juice of Assam lemon might be because of the active participation of Zn, Cu and B in photosynthesis and faster translocation of sugars from the site of synthesis to the developing fruits. The other reason might be due to the decrease in starch content during deterioration of acid and quick transfer of sugars in the fruit. Thus, the present findings are in line with the outcomes obtained by El-Rahman (2003) in Naval Orange and Bhatt *et al*. (2012) in mango.

Although, the lowest value of titratable acidity (3.13%) of fruit juice was observed in T_{12}[$ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%)] while the highest titratable acidity (4.93%) was recorded in T_1 (Control). The reduction of titratable acidity might be because of more synthesis of nucleic acids due to more availability of plant metabolites as reported by Ullah *et al*. (2012) in Kinnow mandarin. The other reason might be because of their utilization in respiration and quick transformation of organic acid into sugars as disclosed by Brahmachari *et al*. (1997) in litchi. Similarly, the outcomes are in agreement with the results obtained by Sau *et al*. (2018) in guava.

On the basis of the experimental evidence obtained from the current research work, it is concluded that the imposition of recommended dose of N, P and K fertilizers (100g: 100g: 100g NPK/plant/year) together with foliar spray of $ZnSO_4$ (0.2%) + $FeSO_4$ (0.2%) + Borax (0.2%) + $CuSO_4$ (0.2%) once (two weeks after fruit setting) can be advocated to Assam lemon growers as the most potent measures to enhance the number of fruits per plant, yield per plant and fruit quality that will eventually increase the productivity.

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