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Effect of foliar nutrition and growth regulators on nutrient status and fruit quality of Eureka lemon (*Citrus limon*)

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ABSTRACT

Studies were conducted to standardize the doses of nutrients and growth regulators for improving the fruit quality of lemon [*Citrus limon* (L.) Burm.f.] cultivar Eureka while maintaining the plant nutrient status. The experiment comprised twelve foliar applications consisting of 6%, 8% and 10% potassium sulphate; 0.5%, 0.75% and 1.0% calcium chloride; 20 ppm, 30 ppm and 40 ppm 2,4-D and 20 ppm, 30 ppm, 40 ppm naphthalene acetic acid. Potassium and calcium content in leaf and fruit of Eureka lemon was influenced by foliar application of nutrients and growth regulators. Among different nutrients and growth regulators, 10% potassium sulphate and 1.0% calcium chloride reduced fruit cracking and improved the fruit quality of Eureka lemon. Maximum potassium content in leaf and fruit was recorded with foliar application of 10% potassium sulphate and maximum calcium content in leaf and fruit was recorded with the foliar sprays of 1.0% calcium chloride. Two time application of 40 ppm NAA resulted in the most effective treatment for minimizing fruit cracking and improving the fruit quality as compared to the other treatments in Eureka lemon.

Key words: Foliar spray, Fruit cracking, Growth regulators, Lemon, Nutrient status

Among the acidic citrus fruits, lemon [*Citrus limon* (L.) Burm.f.] is a leading premier citrus and is quite popularly grown in the northern plains of India, mainly in the arid-irrigated regions and submontane zone. Lemon has potential to bear in many flushes making it long lasting crop having round the year availability of the fruits and longer shelf-life. It has gained more importance as kitchen garden fruit. Lemon juice is widely used in the preparation of soft drinks and possesses special dietic and medicinal values, associated with its high vitamin C content. However, lemon is confronted with a very serious problem of fruit cracking thereby reducing the yield and quality of the produce. Under field conditions, fruit cracking is usually observed when growing conditions become erratic such as imbalance in nutrients and irrigation. Deficiency of calcium, boron and potassium in plants is also associated with nutritional imbalance leading to fruit cracking. Foliar feeding of nutrients at the most receptive time is the quickest way to augment the depleted nutrients in the plants. Foliar application of growth regulators has been found to reduce fruit cracking by affecting both cell size and the thickness of the flavedo (Garcia-Luis *et al*. 2001) and growth regulator are of utmost importance when targeting quality in lemon fruits. However, selection of proper spraying schedule of nutrients and growth regulators before splitting helps to control cracking. The combination of plant growth regulators and mineral nutrients has been reported to be successful in reducing the severity of citrus fruit splitting (Stander 2013). Reduction in fruit cracking may be attributed to increase in peel thickness with various growth regulators and nutrient sprays. The application of synthetic auxins and gibbrelins has also been recommended to reduce fruit cracking in different fruit crops. Among nutrients, potassium is involved in numerous biochemical and physiological processes which are vital to plant growth, yield, quality and stress tolerance. In addition to stomatal regulation during transpiration and photosynthesis, potassium is also involved in photo-phosphorylation, transportation of photo-assimilates from source tissues via the phloem to sink tissues, enzyme activation, turgor maintenance, and stress tolerance (Pettigrew 2008). Adequate potassium nutrition has also been associated with increased yields, fruit size, increased soluble solids, ascorbic acid concentrations, improved fruit colour, increased shelf-life and shipping quality of many horticultural crops (Kanai *et al*. 2007). Therefore, the present study was carried out to evaluate the impact of different

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foliar application of nutrients and growth regulators on leaf/fruit nutrient status and fruit quality of Eureka lemon.

MATERIALS AND METHODS

The present study was carried out at Rainfed Research Sub Station for Subtropical Fruit Crops, Raya, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during 2014-2015. The experiment was laid out on seven year old "Eureka" lemon plants during the month of May, 2014 in randomized block design with thirteen treatments replicated thrice consisting of foliar sprays of 6.0% potassium sulphate (T1), 8.0% potassium sulphate (T2), 10% potassium sulphate (T3), 0.50% calcium sulphate (T4), 0.75% calcium sulphate (T5), 1.0% calcium sulphate (T6), 20 ppm 2,4-D (T7), 30 ppm 2,4-D (T8), 40 ppm 2,4-D (T9), 20 ppm naphthalene acetic acid (T10), 30 ppm naphthalene acetic acid (T11), 40 ppm naphthalene acetic acid (T12) and control as 10 ppm gibberellic acid (T13) which is recommended dose of growth regulator for managing fruit cracking. All the trees were maintained under uniform cultural schedule before and during the course of investigation. Two sprays of nutrients and growth regulators, first on 9 May and second on 29 May were given at an interval of 20 days. Required quantities of NAA, 2,4-D and GA3 were weighed and dissolved in 10 ml of 95% methyl alcohol whereas potassium sulphate and calcium chloride were directly dissolved in distilled water. All the solutions were diluted to a required volume and entire tree was sprayed thoroughly. Leaf nutrient status was analyzed by taking thirty fully matured leaves collected from each treatment from different directions of plant. Washing, cleaning, drying, grinding and storing of samples were carried out as per the method outlined by Chapman (1964). One gram of leaf sample was taken for digestion in a diacid (HNO_3 and $HClO_4$ in ratio of 9:4) for potassium and calcium estimation. Potassium content of leaf was estimated in the digested sample by flame photometer and calcium in leaves was estimated in the digested sample by EDTA methods as described by Piper (1966). Potassium and calcium status of fruit was estimated by digesting 10 of fresh lemon pulp as described by Piper (1966). The percentage of cracked fruits was calculated on the basis of total number of fruits initially present on the tree. A random sample of five fruits taken was hand peeled and weighed on electronic balance. Subsequently, the average peel weight was calculated and expressed in grams. The peel thickness was measured with Vernier calipers and expressed in mm. The quality attributes, viz. total soluble solids, acidity and ascorbic acid were estimated as per standard procedures outlined by AOAC (1994) and subsequently all the data were subjected to statistical analysis as per the procedure suggested by Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

The data presented in Table 1 indicates that all the treatment of nutrients and growth regulators improved the quality characteristics of Eureka lemon. Among all the treatments, maximum fruit weight (71.38 g), rind weight (17.55 g), rind thickness (2.64 mm), TSS (7.9%), acidity (5.77%) and ascorbic acid (50.79 mg/100 g) were recorded with the application of 40 ppm NAA (T12). The fruit weight and rind weight obtained under T12 were significantly higher than rest of the treatments. Total soluble solids resulted with the application of 40 ppm NAA were statistically at par with the total soluble solids recorded as 7.7 and 7.8 under T10 and T11 respectively. The highest titratable acidity (5.77) obtained with 40 ppm NAA was at par with the acidity obtained as 5.67%, 5.70%, 5.73% and 5.67% with the application of T3, T10, T11 and T13 (control) respectively. Vitamin C content recorded highest as 50.74 mg/100g in treatment T12 was again statistically at par with the vitamin C content obtained as 50.68 mg/100g, 50.74 mg/100g and 50.62 mg/100g obtained under T3, T11 and T13 (control). These results are in confirmation with finding of the Sandhu and Bal (2012) in lemon cultivar Baramasi. A generally accepted opinion is that increase in fruit size is due to enlargement of the already existing cells, and auxins are presumed to be responsible for this enlargement. Hence, application of NAA caused fruit enlargement by increase in cell size. Fruit elongation and increase in fruit breadth may be due to cell division initially, and cell enlargement in the later stages. Similar findings have been documented by Singh *et al*. (2007). It may be due to the application of NAA raising endogenous auxin levels in the fruit, which favours development of various parts of the fruit. Thus, increase in fruit size and juice percentage was due to auxin application that led to increase in fruit weight due to cell expansion. It is also possible that a developing fruit is an important metabolic sink into which nutrients and organic substances from leaves and other plant parts flow, thereby

Table 1 Effect of foliar nutrients and growth regulators on quality characteristics of Eureka lemon.

Treatment	Fruit weight (g)	Rind weight (g)	Rind thickness (mm)	TSS (%)	Acidity (%)	Vitamin C (mg/ 100 g)
T1	61.71	16.23	2.36	7.5	5.40	50.46
T2	65.98	16.29	2.50	7.6	5.53	50.57
T3	67.10	16.30	2.54	7.6	5.67	50.68
T4	53.61	16.17	2.24	7.4	5.40	50.11
T5	57.70	16.20	2.29	7.5	5.43	50.25
T6	60.10	16.21	2.30	7.5	5.50	50.29
T7	50.75	15.93	2.06	7.3	5.10	49.67
T8	51.11	15.99	2.11	7.4	5.20	49.92
T9	51.63	16.16	2.23	7.4	5.30	50.07
T10	62.40	15.89	2.39	7.7	5.70	50.55
T11	67.36	16.76	2.61	7.8	5.73	50.74
T12	71.38	17.55	2.64	7.9	5.77	50.79
T13	66.19	16.56	2.53	7.5	5.67	50.62
CD (P=0.05)	2.94	0.23	0.10	0.13	0.18	0.20

accumulating in the fruit. This accumulation of metabolites and water in fruit increases fruit weight. In the present study, the application of nutrients and growth regulators significantly influenced the rind weight of lemon cv. Eureka. Systematic spray of growth regulators before rind splitting helps control fruit cracking as growth regulators influence rind thickness. Treatment T12 also recorded maximum TSS (7.9 %) during the course of present experiment. Auxins have been known to be involved in synthesis of α-amylase which converts starch in sugars and consequently increasing osmotic pressure of the cell which results in accumulation of water and other solutes. Results regarding TSS percentage have been found to be in consonance with that of Huang and Huang (2005) who reported that with the application of growth regulators like auxin and gibberellins, total soluble solid content of citrus species can be significantly increased. The acid content of lemon juice increased significantly under all treatments of growth regulators. However, increase with auxin application was significant which is supported by the result of Nawaz *et al*. (2008). Increase in ascorbic acid content may also be due to the growth regulators increasing osmotic pressure by cell expansion, thus leading to accumulation of this organic acid. Similar results in lemon have been reported by Sandhu and Bal (2013).

The data presented in Table 2 reveaed that the leaf/fruit nutrient status of Eureka lemon was significantly influenced by foliar application of nutrients and growth regulators. The maximum potassium content in leaf (1.68%) and fruit (0.78%) was recorded under treatment T3 (10% potassium sulphate) and highest calcium content in leaf (2.03%) and fruit (1.18%) was recorded with foliar spray of 1.0% calcium chloride. Leaf and fruit potassium content did not differ significantly within three concentrations of potassium sulphate, i.e. 6.0%, 8.0% and 10.0% and resulted in 0.73%, 0.75%, 0.78% leaf potassium content respectively and 1.64, 1.66 and 1.68% fruit potassium content respectively. No significant differences were observed for potassium content of the fruit obtained with the application of different concentrations of potassium sulphate and NAA. The highest leaf and fruit calcium content recorded with the application of 1.0% calcium chloride was statistically at par with that obtained under the application of 0.75% calcium chloride. Similarly, Ahmed *et al.* (2014) reported that calcium chloride at 2% alone or in combination with other nutrients increase the calcium contents in leaves of pomegranate. Gregorz *et al*. (2015) also reported that calcium spraying proved to be an effective way to deliver calcium to the plants, as it increases its content in both the leaves and the fruits of sweet cherry. Application of potassium sulphate might have led to increase in the potassium content of peel. Reduction in the level of calcium was observed under potassium sulphate treatments, while calcium chloride spray increased the calcium content in the peel.

Table 2 Effect of foliar nutrients and growth regulators on leaf/fruit nutrient status of Eureka lemon

Treatment	Leaf potassium content (%)	Fruit potassium content (%)	Leaf calcium content (%)	Fruit calcium content (%)
T1	0.73	1.64	1.63	1.05
T2	0.75	1.66	1.60	1.06
T3	0.78	1.68	1.58	1.08
T4	0.69	1.50	1.91	1.14
T5	0.69	1.51	1.99	1.15
T6	0.70	1.54	2.03	1.18
T7	0.62	1.49	1.50	1.04
T8	0.63	1.50	1.52	1.06
T9	0.65	1.51	1.53	1.07
T10	0.70	1.55	1.55	1.09
T11	0.71	1.62	1.64	1.11
T12	0.72	1.67	1.70	1.06
T13	0.71	1.63	1.62	1.05
CD (P=0.05)	0.05	0.12	0.05	0.03

The data presented in Table 3 show that maximum fruit cracking (8.55%) was recorded on 8 July 2014 in T7 (20 ppm 2,4-D) and the minimum fruit cracking (1.11%) was recorded in T12 (40 ppm NAA) on 14 June 2014. The T12 (40 ppm NAA) proved to be most effective for minimizing the fruit cracking in lemon, where it was recorded to be 2.86% which is followed by percent fruit cracking with the application 10 ppm GA_3, 30 ppm NAA and 20 ppm NAA treatments. The data pertaining to the effect of NAA and nutrient sprays on the periodical incidence of fruit cracking as presented in table 3 clearly indicates that the fruit cracking started from second week of June when some of the fruits showed initial symptoms of cracking which continued till harvest. The intensity of fruit cracking was maximum (8.55%) in first week of July. The cracking recorded during this week was significantly higher than the other dates of observations. The growth regulator and nutrient sprays significantly reduced the fruit cracking. Amiri *et al.* (2012) reported that sprays of synthetic auxins decreased fruit splitting and increased rind thickness. Similar results have been reported by Sandhu and Bal (2013) in lemon cultivar Baramasi that NAA substantially reduced the cracking losses by 94.5% and resulted in impressive improvement on fruit quality**.** Application of auxins causes enlargement of cells by increasing the elasticity or permeability of cell wall (Cline and Trought 2007). Thus, peripheral tissues of fruit would keep pace in growth with that of cortex resulting in the control of fruit cracking, since one of the reasons for cracking of fruits is thought to be the differential growth rates of the peripheral and cortex tissues. Among the nutrient application, minimum fruit cracking on 8 July 2014 was reported in treatment T3 (10% potassium sulphate) and T2 (8% potassium sulphate). Low level of potassium is also been found to be responsible for splitting of Washington Navel orange (Rahman *et al.* 2012). Morgan *et al.* (2005) reported that imbalances in potassium can contribute to thin or weak rind and can therefore, indirectly increase the likelihood of splitting. The results are in close

Table 3 Influence of nutrients and growth regulators on time and duration of fruit cracking in Eureka lemon

Treatment	Fruit cracking recorded on different days						Total fruit cracking (%)
	14th June	22th June	30th June	8th July	16th July	24th July	
T1	1.80 (7.50)	2.70 (9.37)	3.60 (10.89)	6.70 (14.92)	6.08 (14.23)	5.10 (13.06)	25.98
T2	1.70 (6.54)	2.40 (8.79)	3.10 (10.11)	5.40 (13.41)	4.21 (11.82)	4.19 (11.80)	21.00
T3	1.60 (6.36)	2.20 (8.43)	3.10 (10.13)	3.20 (10.26)	3.9 (11.38)	3.6 (7.23)	17.96
T4	3.40 (10.25)	3.80 (11.21)	4.13 (11.69)	7.11 (15.46)	6.22 (14.43)	5.50 (13.55)	30.16
T5	2.10 (8.08)	3.10 (10.07)	4.80 (12.64)	6.50 (14.75)	5.80 (13.92)	5.8 (13.92)	28.1
T6	1.12 (5.39)	2.12 (8.35)	4.66 (12.44)	6.00 (14.13)	5.44 (13.47)	4.60 (12.37)	23.94
T7	4.60 (12.31)	4.11 (11.68)	5.36 (13.36)	8.55 (16.99)	7.1 (15.44)	6.51(14.75)	36.23
T8	3.20 (10.30)	4.01 (11.54)	4.98 (12.88)	7.98 (16.40)	8.02 (16.44)	6.01 (14.18)	34.2
T9	4.01 (11.55)	3.90 (11.38)	5.21 (13.19)	6.82 (15.13)	6.9 (15.21)	5.31 (13.31)	32.5
T10	2.09 (8.18)	2.90 (9.79)	3.04 (10.03)	3.80 (11.23)	4.68 (12.48)	3.48 (10.73)	19.99
T11	1.22 (5.57)	1.80 (7.69)	2.10 (8.33)	3.80 (11.22)	3.12 (10.16)	2.06 (8.24)	14.10
T12	1.11 (5.36)	1.84 (7.69)	2.50 (9.04)	2.86 (9.68)	2.38 (8.85)	2.42 (8.03)	13.11
T13	1.30 (5.77)	2.80 (9.62)	3.27 (10.37)	3.30 (10.45)	3.00 (9.67)	2.33 (8.435)	16.0
CD (P=0.05)	Treatments :				0.67		2.01
	Days/Time interval :				0.99		
	Treatment × Days/Time interval :				NS		

*Figures in parenthesis are angular transformed values

conformity with the findings of Sandhu and Bal (2013) who reported that potassium sulphate reduces the fruit cracking in lemon. Reduction in fruit cracking with the spray of calcium chloride application may be due to strengthening of rind. Results from the present investigation also revealed that the control treatment, i.e. 10 ppm GA_3 (University recommendation) was also effective in minimizing fruit cracking in lemon cultivar Eureka. Moreover, growth regulators play a significant role in peel resistance and plasticity that determine intensity of cracking. Thus it was concluded from the present study that application of 10% potassium sulphate was superior in improving the leaf/fruit nutrient status, reduced fruit cracking with improved quality characteristics and among the growth regulators 40 ppm NAA recorded least fruit cracking and this treatment also enhanced the quality of Eureka lemon.

REFERENCES

Amiri N A, Kangarshahi A A and Arzani K. 2012. Reducing of citrus losses by spraying of synthetic auxins. *International Journal of Agriculture and Crop Sciences* **4**(22): 1720–4.

AOAC. 1994. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, DC.

Ahmed W, Tahir F M, Rajwana I A, Raza S A and Asad H U. 2014. Comparative evaluation of plant growth regulators for preventing premature fruit drop and improving fruit quality parameters in Dushehri mango. *International Journal of Fruit Science* **12**: 372–89.

Chapman H D. 1964. Suggested foliar sampling and handling techniques for the determining the nutrient status of some field, horticulture and plantation crop. *Indian Journal of Horticulture* **21**: 97–119.

Cline J A and Trought M. 2007. Effect of gibberellic acid on fruit cracking and quality of Bing and Sam sweet cherries. *Canandian Journal of Plant Science* **87**: 545–50.

Garcia – Luis A, Duarte A M M, Kanduser M and Guardiola J L. 2001. The anatomy of the fruit in relation to the properties of citrus species to split. *Scientia Horticulturae* **87**: 33–52.

Gregorz M, Małgorzata M, Ewa M, Małgorzata S and Urszula C. 2015. The effects of foliar nutrition with inca fertilizer on the chemical composition of leaves and fruits of sweet cherry. *Journal of Ecological Engineering* **16**(2): 116–9.

Huang J H and Huang L. 2005. The application of GA_3 in citrus orchards. *South China Fruits* **3**: 32–6.

Kanai S, Ohkura K, Adu-Gyamfi J J, Mohapatra P K, Nguyen N T, Saneoka H and Fujita K. 2007. Depression of sink activity precedes the inhibition of biomass production in tomato plants subjected to potassium deficiency stress. *Journal of Experimental Botany* **58:** 2917–28.

Morgan K T, Rouse R E, Roka F M, Futch S H and Zekri M. 2005. Leaf and fruit mineral content and peel thickness of 'Hamlin' orange. *Proceedings of the Flordia State Horticultural Society* **118**: 19–21.

Nawaz M A, Ahmad W, Ahmad S and Khan M M. 2008. Role of growth regulators on pre-harvest fruit drop, yield and quality of Kinnow mandarin. *Pakistan Journal of Botany* **40**(5): 1971–81.

Panse V G and Sukhatme P V. 1995. *Statistical Methods for Agricultural Workers*, p 385. Indian Council of Agricultural Research, New Delhi.

Piper C S. 1966. *Soil and Plant Analysis*, p 367. Hans Publication, Bombay.

Pettigrew W T. 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Plant Physiology* **133**(4): 670–81.

Rahman A E, Hoda G F, Mohamed M and Tayh E A T. 2012. Effect of GA_3 and potassium nitrate in different dates on fruit set, yield and splitting of Washington Navel Orange. *Nature and Science* **10**(1): 148–57.

Sandhu S and Bal J S. 2012. Response of lemon cv. Baramasi to foliar feeding of nutrients. *Indian Journal of Horticulture* **69(**2): 281–3.

Sandhu S and Bal J S. 2013. Quality improvement in lemon (*Citrus limon* (L.) Burm.) through integrated management of fruit cracking. *African Journal of Agricultural Research* **8**(27)**:** 3552–7.

Singh J K, Parsad J and Singh H K. 2007. Effect of micronutrients and plant growth regulators on yield and physio-chemical characteristics of aonla fruits in cv. Narendra Aonla-10. *Indian Journal of Horticulture* **64**: 216–8.

Stander O P J. 2013. 'Fruit split and fruit size studies on citrus'. MSc thesis, Faculty of Agricultural Sciences, Stellenbosch University.