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Effect of foliar application of nutrients and growth regulators on fruit cracking and quality of Eureka lemon under rainfed conditions

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ABSTRACT

An experiment was laid out in Randomized Block Design with 13 treatments, consisting of foliar sprays of K_2SO_4 (6.0, 8.0 and 10%), $CaCl_2$ (0.5, 0.75 and 1%), 2,4-D (20, 30 and 40 ppm), NAA (20, 30 and 40 ppm) and control (10 ppm GA_3) and each treatment replicated thrice. Among the various treatments, spray of 40 ppm NAA was found to be most effective for minimizing fruit cracking (13.06%) as compared to other treatments and this treatment also recorded maximum fruit length (5.45 cm), fruit breadth (5.22 cm), fruit weight (71.38 g), pulp weight (37.47 g), rind weight (17.55 g), rind thickness (2.64 mm) specific gravity (1.02), Juice content (50.97%), TSS (7.9°Brix), acidity (5.77%) and ascorbic acid (50.76 mg/100 ml). Among the nutrients, minimum fruit cracking (17.96%) was noticed with the application of 10% K_2SO_4 and this treatment also recorded the maximum fruit length (5.42 cm), fruit breadth (5.09 cm), fruit weight (67.10 g), pulp weight (36.20 g), rind weight (16.30 g), rind thickness (2.54 mm), Juice content (48.94%), TSS (7.6°B), acidity (5.67%) and ascorbic acid (50.68 mg/100 ml).

Key words: Eureka lemon, Fruit splitting, plant growth substances, quality.

INTRODUCTION

Lemon is leading acid citrus fruit because of its very appealing colour, odour and flavour, however, the summer crop has been observed to be prone to severe fruit cracking. Lemon has potential to bear in several flushes making it long lasting crop having round-year availability of the fruits. Fruit cracking is a worldwide problem which affects a number of fruits and losses are sometimes high. Cracking is manifested as a meridian fissure of the peel, usually developing from the stylar end and reaching the equatorial zone or even extending beyond that. It has been explained that citrus fruit splitting as one of the most exasperating problems experienced by the citrus fruit growers. Lemon is confronted with a very serious problem of fruit cracking. The disorder causes considerable losses of the marketable fruit which make it inconsumable leading to heavy losses to the growers. Garcia-Luis *et al.* (6) studied the response of application of growth regulators to fruit cracking and found them relevant to splitting as this application markedly affected the rind structure, affecting both cell size and the thickness of the flavedo. Hoffmann (7) explained citrus fruit splitting as one of the most exasperating problems experienced by the citrus fruit growers. Splitting is usually observed when growing conditions become erratic such as imbalance in nutrients. The optimal growing conditions including reasonable cultural practices along with mineral nutrition can significantly reduce the malady of splitting. Singh *et al.* (14) added that the deficiencies of calcium, boron and potassium causes imbalance leading to fruit cracking. The use of foliar feeding of nutrient and growth regulators is a new and innovative approach to check fruit cracking and enhance quality. Keeping in view the seriousness of the problem the present investigation was conducted to find out the most effective treatment in reducing fruit cracking and improving the quality of Eureka lemon.

MATERIALS AND METHODS

The 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, J&K, India during 2014-2015. The experiment was laid out in randomized block design with 13 treatments, consisting of foliar sprays of K_2SO_4 (6.0, 8.0 and 10%), $CaCl_2$ (0.5, 0.75 and 1%), 2,4-D (20, 30 and 40 ppm), NAA (20, 30 and 40 ppm) and control (10 ppm GA_3) and each treatment was replicated thrice. All the trees were maintained under uniform cultural schedule before and during the course of investigation. Two sprays of nutrients and growth regulators were given in the month of May at 20 day intervals. First spray was given on 9th May and second on 29th May in seven-year-old Eureka lemon trees. The plants were sprayed during forenoon with the help of foot pump sprayer. Total number of fruits present on the tree were counted when observation

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on total number fruits per tree was recorded. The percentage of cracked fruits was calculated on the basis of total number of fruits initially present on the tree. The observations on fruit length, breadth and peel thickness were measured with Vernier calipers. The weight of ten fruits from each replication of all the treatments was measured with electronic balance. Subsequently, the average fruit weight was calculated and expressed in grams. A random sample of five fruits already taken for weight was hand peeled and weighed with electronic balance. Subsequently, the average rind weight was calculated and expressed in grams. Specific gravity of fruits was measured with water displacement method. Juice percentage was calculated on the weight basis. The chemical characters like TSS, acidity and ascorbic acid were estimated as per standard procedures outlined by Ranganna (11) and AOAC (1) and all the data were subjected to statistical analysis.

RESULTS AND DISCUSSION

The statistical analysis of the data presented in Table 1 showed that there was significant difference between the treatments of nutrients and growth regulators in terms of fruit cracking. Among the growth regulators, the minimum fruit cracking was recorded under treatment T_{12} (NAA 40 ppm), *i.e.* 13.06 percent, which is statistically at par with the treatment T_{11} (NAA 30 ppm), *i.e.* 14.10 per cent and maximum fruit cracking was noticed under the treatment T_7 (2,4-D 20 ppm), *i.e.* 36.21 percent. All the treatments had a profound effect on the fruit cracking percentage and the elastic and plastic properties of the citrus rind are thought to be involved in resistance to puncture. Application of auxins caused enlargement of cells by increasing the elasticity or permeability of cell wall (Cline and Trought, 4). Reduction in fruit cracking may be due to the auxin causing enlargement of cells by increasing elasticity and plasticity of the cell wall. Thus, peripheral tissues of the fruit would have kept pace with growth of cortex resulting in the reduction of fruit cracking, since; one reason for cracking in fruits is differential growth rates of the peripheral and cortex tissues. Peripheral tissues, being senescent and weak, are highly prone to mechanical stress and cracking. The results are in close conformity with the findings of Sandhu and Bal (13) who reported that the treatment NAA is effective for the managing fruit cracking and improving fruit quality. Similar results have been reported by Sandhu and Bal (12) in lemon cv. Baramasi substantially reduced the cracking losses by (94.5%) and resulted in impressive impact on fruit quality. Singh *et al.* (14) also opined that systematic spray of growth regulators before rind splitting helps control cracking as growth regulators influence rind thickness. Garcia-Luis *et al.* (6) found that application of growth regulators markedly influenced rind structure, affecting both cell size and thickness of flavedo, as it is relevant to cracking. Moreover, growth regulators play a

Table 1. Effect of foliar application of nutrients and growth regulators on fruit cracking and quality of Eureka lemon under rainfed conditions.

Treatment	Cracking (%)	Fruit length (cm)	Fruit breadth (cm)	Fruit wt. (g)	Pulp wt. (g)	Rind wt. (g)	Rind thickness (mm)
T_1 = K_2SO_4(6%)	26.05	5.30	4.42	61.71	34.75	16.23	2.36
T_2 = K_2SO_4 (8%)	21.99	5.37	5.02	65.98	35.34	16.29	2.50
T_3 = K_2SO_4 (10%)	17.96	5.42	5.09	67.10	36.20	16.30	2.54
T_4 = $CaCl_2$ (0.5%)	30.11	4.69	4.38	53.61	34.15	16.17	2.24
T_5 = $CaCl_2$ (0.75%)	28.08	4.70	4.41	57.70	35.37	16.20	2.29
T_6 = $CaCl_2$ (1.0%)	24.02	5.20	4.45	60.10	36.41	16.21	2.30
T_7 = 2,4-D (20 ppm)	36.21	4.60	4.26	50.75	32.27	15.93	2.06
T_8 = 2,4-D (30ppm)	34.17	4.61	4.28	51.11	33.25	15.99	2.11
T_9 = 2,4-D (40 ppm)	32.15	4.67	4.35	51.63	33.98	16.16	2.23
T_{10} = NAA (20 ppm)	19.98	4.57	5.06	62.40	35.45	15.89	2.39
T_{11} = NAA (30 ppm)	14.10	5.43	5.19	67.36	36.30	17.38	2.61
T_{12} = NAA (40 ppm)	13.06	5.45	5.22	71.38	37.47	17.55	2.64
T_{13} = GA_3 (10 ppm) (control)	15.93	5.35	5.13	66.19	35.47	16.26	2.53
$CD_{0.05}$	2.00	0.51	0.11	2.94	2.70	0.03	0.10

significant role in peel resistance and plasticity that determine intensity of cracking.

It is clear from the data presented in the Tables 1 and 2 that there were significant differences between the treatments of nutrients and growth regulators on quality of Eureka lemon. The maximum fruit length (5.45 cm) and fruit breadth (5.22 cm) were recorded with application of NAA (40 ppm) as compared to all the treatments. A generally accepted opinion is that increase in fruit size is due to enlargement of the already existing cells, and auxin is 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. The result are in close conformity with the findings of Sandhu and Bal (12) who reported that foliar application of NAA at 40 ppm resulted in comparatively large sized fruits. Similar findings have been documented by Babu *et al*. (3) in Kagzi lime, who also reported increase in fruit size with NAA and GA treatments. Auxin is considered to be responsible for enlargement of cells, thus increase in size of fruit.

In the present study the maximum fruit weight (71.38 g), pulp weight (37.47 g) and rind weight (17.55 g) were noticed with the application of 40 ppm NAA, *i.e.* T_{12} treatment. There are many reports suggesting that application of NAA may raise endogenous auxins levels in the fruit, which favours development of various tissues of the fruit. Thus, increase in fruit size due to auxins application perhaps 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 accumulating in the fruit. This accumulation of metabolites and water in fruit increases fruit weight. A direct relationship between endogenous gibberellin content in developing fruits of orange with their growth rate has been established. The results obtained in the present investigation are also in consonance with the findings of Babu *et al.* (3), Josan *et al.* (9) and Sandhu and Bal (13). The application of NAA might have favoured the development of various parts of fruit due to increase in endogenous auxin levels. Maximum rind thickness (2.64 mm) was recorded with 40 ppm NAA followed by GA_3, while minimum rind thickness was registered in 20ppm 2,4-D. Singh *et al.* (14) also opined that systematic spray of growth regulators before rind splitting helps control cracking as growth regulators influence rind thickness.The treatments of nutrients and growth regulators had non significant effect on specific gravity of Eureka lemon in the present study.All the treatments of nutrients and growth regulators applied in the presentexperiment produced significant effect on juice content of Eureka lemon. Data clearly depict that fruits harvested from trees sprayed with 40 ppm NAA showed maximum juice content (50.97%), which is statistically at par with 30 ppm NAA and 10 ppm GA_3. Higher moisture content in fruits resulted in higher juice content.

Table 2. Effect of Foliar application of nutrients and growth regulators on quality of Eureka lemon under rainfed conditions.

Treatment	Specific gravity	Juice (%)	Total soluble solids (°Brix)	Titreable acidity (%)	TSS:acid ratio	Ascorbic acid (mg/ ml)
T_1 = K_2SO_4(6%)	1.10	43.63	7.5	5.40	1.38	50.46
T_2 = K_2SO_4 (8%)	1.01	45.71	7.6	5.53	1.38	50.57
T_3 = K_2SO_4 (10%)	1.00	48.94	7.6	5.67	1.36	50.68
T_4 = $CaCl_2$ (0.5%)	1.00	44.78	7.4	5.40	1.37	50.11
T_5 = $CaCl_2$ (0.75%)	1.01	45.69	7.5	5.43	1.34	50.25
T_6 = $CaCl_2$ (1.0%)	1.01	46.25	7.5	5.50	1.37	50.29
T_7 = 2,4-D (20 ppm)	0.99	40.36	7.3	5.10	1.41	49.67
T_8 = 2,4-D (30ppm)	1.00	41.15	7.4	5.20	1.42	49.92
T_9 = 2,4-D (40 ppm)	1.00	43.79	7.4	5.30	1.42	50.07
T_{10} = NAA (20 ppm)	1.01	49.11	7.7	5.70	1.33	50.55
T_{11} = NAA (30 ppm)	1.00	44.20	7.8	5.73	1.35	50.74
T_{12} = NAA (40 ppm)	1.02	50.97	7.9	5.77	1.38	50.79
T_{13} = GA_3 (10 ppm) (control)	1.01	49.11	7.5	5.67	1.43	50.62
$CD_{0.05}$	NS	3.27	0.13	0.18	NS	0.20

Josan *et al* (9) in lemon elucidated similar results. The results are in consonance with the findings of Sandhu and Bal (12) who also reported that 40 ppm NAA yielded highest juice percentage.

The data depicted in Table 2 revealed that the treatments of nutrients and growth regulators had significant effect on total soluble solid, acidity and ascorbic acid of Eureka lemon under rainfed conditions. The Maximum TSS (7.9°B), acidity (5.77%), and ascorbic acid (50.76 mg/ 100 ml) were recorded under treatment T_{12}, *i.e.* 40 ppm NAA. 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. Another reason may be that sugars get accumulated, or, some insoluble substances like starch are rendered soluble by hydrolysis, and thus increase total soluble solids. Results regarding TSS percentage were found to be in consonance with that of Atawia and El-Desouky (2) and Huang and Huang (8) who reported that by application of growth regulators like auxin and gibberellins, TSS content of citrus species can be significantly increased. Babu *et al*. (3) found an increase in total soluble solids by application of NAA. An increase in TSS could be attributed to higher solutes as a result of enhanced mobilization of carbohydrates in these treatments. It is well known that activity of cytoplasmic sucrose phosphate synthase, a key enzyme regulating the pool size of sucrose in the leaf, had been shown to be stimulated by foliar applications of plant growth regulators and promotes phloem loading.The acid content of juice increased significantly under all treatments of growth regulators. However, maximum acidity (5.77%) in case of growth regulators was found under T_{12} (40 ppm NAA) and the least acidity was found under T_7 (20 ppm 2,4-D). The results of acidity are in close conformity with the findings of Nawaz *et al.* (10) who also reported that 15 ppm NAA results in increase in acidity in Kinnow mandarin. Babu *et al.* (3) reported significant increase in acidity of Pant-lemon with 5 to 10 ppm NAA. The treatments of nutrients and growth regulators had non-significant effect on TSS:acid ratio of Eureka lemon.

It is clear from the data presented in Table 2 that maximum ascorbic acid (50.76 mg/ 100 ml) was recorded under the treatment T_{12} (40 ppm NAA) and minimum under T_7 (20 pm 2,4-D). The 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 are documented by Sandhu and Bal (14) who observed that the 40 ppm NAA increases the ascorbic content of lemon. Nawaz *et al.* (10) also observed that 15 ppm NAA showed highest vitamin-C content in Kinnow mandarin. Results regarding this parameter of study were also found to be in agreement with that of Xiao *et al.* (15) who also observed that preharvest application of growth regulators increased vitamin-C contents of the citrus fruits. Farag and Nagy (5) also reported that the application of NAA led to a significant increase in vitamin C relative to the control.

It is concluded from the present investigation that application of nutrients and growth regulators reduce the fruit cracking and enhanced the quality of Eureka lemon. The treatment T_{12} (NAA 40 ppm) recorded least fruit cracking and this treatment also enhanced the fruit quality of lemon cv. Eureka. Among the nutrients 10% K_2SO_4 was found superior in reduction of fruit cracking with improved fruit quality.

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