

**EFFECT OF FOLIAR APPLICATION OF BIO-REGULATORS AND NUTRIENTS
ON PHYSICO-CHEMICAL PROPERTIES OF LEMON (*CITRUS LIMON* BURMA.)
CV. PANT LEMON-1 UNDER SUBTROPICAL CONDITION
OF GARHWAL REGION**

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Abstract: The present investigation was carried out at Horticultural Research Centre and Department of Horticulture, Chauras campus, H.N.B. Garhwal University, Srinagar Garhwal, Uttarakhand, India during 2008-09 growing seasons to study the effect of foliar application of bio-regulators and nutrients on quality of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1. On the basis of overall performance of treatments on quality characters of fruits, it can be concluded that the values for fruit set, days to maturity, yield of fruits per plant, fruit length, fruit juice, total soluble solids, total sugars, shelf-life of fruits, have been obtained maximum under GA₃ (20 ppm) treatment, while the minimum fruit cracking and the maximum fruit weight, fruit volume, acidity were recorded with NAA (50 ppm). However, the maximum vitamin C was recorded under NAA (10 ppm) foliar application.

Keywords: Foliar application, Nutrients, Bio-regulators, Lemon

INTRODUCTION

Lemon (*C. limon* Burma.) belongs to the family Rutaceae, comes under the category of acid fruits and is used primarily as fresh fruit. The fresh fruits of lemon are also used for the preparation of lemonade, refreshing drinks and for a wide variety of culinary preparations like pies, cakes, dishes of vegetables, fish, meat and salad. It is extensively used with tea in Russia. Lemon is a good source of citric acid which is used for pharmaceutical purposes and for aerated waters. The lemon oil is a stimulant and carminative when given internally as medicine. Lemon juice along with common salt is recommended as a remedy for dysentery, dry bleach, putrid, sore throat and for correcting foetid breath. Lemon squash and pickles are the fine preserves used in India. Lemons are gaining popularity in India because of (i) its multiple utility, (ii) production all the year round and (iii) tolerance against citrus decline and other citrus disorders. To meet the demand of increasing population, its production has to be increased several folds. Lemon is an important fruit crop of Tarai region and valley areas of hill region as well. Among the various cultivars of lemon grown in these regions, Pant Lemon-1 has been found most promising. This variety is becoming popular among the orchardists all over the country. Therefore, modern cultural practices such as use of bio-regulators, integrated nutrient management and integrated insect pest management may be employed for increasing its production and productivity. Among the various practices, the use of bio-regulators have been identified to play an important role in modern crop husbandry for increased production of quality fruits through improving flowering, fruit set, fruit drop control, fruit shape and

size etc. These organic chemical compounds modify the physiological processes of fruit plants when applied in small concentrations (Babu *et al.*, 1982). Therefore, there is a need to study the effect of bio-regulators along with varied concentrations for qualitative characters of lemon fruits. Nutrition is another important factor affecting the health of the plants. The optimum requirement of nutrition of a particular species or variety greatly varies with soil and agro-climatic conditions. Thus, there is a need to standardize the nutritional requirements for lemons under different agro-climatic conditions. Foliar application of nutrients is an ideal way of evading the problems of nutrient availability and supplementing the fertilizers to the soil. In the semi-arid areas of Garhwal region, the foliar application is the alternative and safe way of applying nutrients for quick absorption and maximum availability. In view of the above facts, it is clear that the foliar application of bio-regulators and nutrients is very important not only for increasing yield but also to improve the quality of fruits

MATERIAL AND METHOD

The present study was carried out at Horticultural Research Centre and Department of Horticulture, Chauras campus, H.N.B. Garhwal University, Srinagar Garhwal, Uttarakhand, India during 2008-09 growing season. Six-year-old bearing lemon trees of cultivar Pant Lemon-1 of uniform vigour and size were selected for the present study. All the trees were maintained under uniform cultural schedule during the course of investigation. The experiment consisted of sixteen treatments of two bio-regulators and three nutrients, and each one was applied singly and a spray of plain tap water as control. These were, NAA

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(10 ppm), NAA (25 ppm), NAA (50 ppm), GA₃ (10 ppm), GA₃ (15 ppm), GA₃ (20 ppm), Urea (0.5%), Urea (1.0%), Urea (2.0%), Zinc Sulphate (0.2%), Zinc Sulphate (0.3%), Zinc Sulphate (0.4%), Borax (0.2%), Borax (0.3%), Borax (0.4%) and Control. All the treatments were applied as a spray at the time of full bloom (when about 75% flowers had opened on the selected shoots). The experiment was laid out in Completely Randomized Block Design (CRD). Forty eight plants of Pant Lemon-1 were selected for the present study and each tree formed as a unit of treatment. All the treatments were replicated thrice. All the plants selected for the experiment were labelled as per layout of experiment and the sprays of treatment solutions were done on experimental plants of Pant Lemon-1 at full bloom stage (when about 75% flowers had opened on the selected shoots) during the spring season. The spray was done in morning around 10 AM with the help of hand sprayer at the rate of three liters per plant to ensure the maximum absorption of bio-regulators and nutrients through the leaves. Each tree was sprayed thoroughly in such a way as to completely drench it with the spray solution. All the chemical analysis of fruits was carried out in the laboratory of Department of Horticulture.

RESULT AND DISCUSSION

It is clear from the data on fruit length and breadth (Table 1.) that various foliar sprays of bio-regulators and nutrients concentrations gave significant variation in fruit length and breadth. The data revealed that the maximum fruit length (5.56 cm) was recorded in treatment GA₃ (20 ppm) and minimum length of fruits (4.64 cm) under control. However, the highest breadth of fruit (5.39 cm) was observed with Borax (0.4%) and the lowest value (4.46 cm) under control. Jackson (1968) reported that the average size of the lemon fruits was increased by spraying GA₃ in late May or early June. Similarly, sprays of (5-40 ppm) GA₃ to Eureka lemon trees increased the size of the fruits (Coggins *et al.*, 1963). Application of NAA (200 ppm) 30 days after full bloom to Unshiu orange trees greatly increased fruit size and the proportion of larger fruits (Nakajima *et al.*, 1969). Babu and Lavania (1985) reported that the maximum length of lemon fruits was recorded with NAA (10 ppm) treatment. Except for the higher concentrations each of NAA and GA₃, all other treatments increased the diameter of the fruits. NAA (10 ppm) gave the maximum response with 9.20% increase in diameter of fruits over control, followed by (4.79%) with 2, 4-D (10 ppm). The maximum number of large fruits was recorded under GA₃ (10 ppm). The lowest concentration, each of 2, 4-D and NAA decreased the proportion of large sized fruits considerably except for the higher concentrations of GA₃ (20 and 40 ppm). The maximum diameter was observed under 2, 4-D (5 ppm), followed by NAA (5

ppm) treatment. As the concentrations of these three growth regulators increased the fruit length and diameter also increased proportionally. In the present investigations GA₃ and Borax in higher concentrations increased the fruit length and diameter significantly. Earlier findings of scientists on fruit length and diameter supported the results for this character under present study.

The maximum increase in fruit weight (110.13g) was observed with the treatment NAA (50 ppm) as compared to the minimum fruit weight (77.46g) obtained under control. In general, sprays of bio-regulators and nutrients increased fruit weight during present investigation. Sprays of 40 ppm 2, 4-D to Washington Navel orange increased the fruit weight by 62% (Keleg and Minessy, 1965). Similarly, Coorg mandarin fruits treated with 25 and 50 ppm 2,4,5-T had 34% and 35% more weight, respectively, over the untreated fruits (Rodrigues and Subramanyam, 1966). An increase in fruit weight with 250-500 ppm NAA was reported by Ali *et al.*, (1973) in kinnow mandarin, when sprayed two weeks after fruit set. Singh and Singh (1981) reported that GA₃ (15 ppm) applied once in August, September and October to Kaula mandarin trees increased fruit weight by 30% over control. Reddy and Prasad (2012) also observed in pomegranate cv. Ganesh that the fruit weight was superior with the application of 2, 4-D (40 ppm), followed by GA₃ (75 ppm) and NAA (40 ppm). All above scientists have reported that NAA and GA₃ were found to increase fruit weight in different fruit crops which also encourage the results of the present investigation for these quality parameters.

The maximum increase in fruit volume (108.18 ml) was exhibited by the treatment NAA (50 ppm) against the minimum fruit volume (76.63 ml) recorded under control. Babu and Lavania (1985) reported that the highest fruit volume was recorded under NAA (10 ppm), followed by 2,4-D (20 ppm) and NAA (5 ppm). Among all treatment NAA (10 ppm) gave the maximum response (9.20% increase) over control. Reddy and Prasad (2012) reported that the fruit volume was found superior with the application of 2,4-D (40 ppm), followed by GA₃ (75 ppm) and NAA (40 ppm) in pomegranate cv. Ganesh. Rawat *et al.*, (2011) recorded the maximum fruit volume when guava trees of L-49 were sprayed with 0.4% zinc sulphate. As the concentrations of these three growth regulators increased the fruit volume also increased considerably. The results obtained for fruit volume under present study are in conformity with the results of earlier workers as mentioned above.

Data pertaining to specific gravity showed the non-significant difference between all treatments and control. The minimum specific gravity (0.96) was found with urea (1.0%) as compared to the maximum specific gravity (0.98) recorded under control. The minimum specific gravity of fruits was obtained under urea treatment presumably, because of the

effect of urea on the internal quality of the fruits, which affects the weight and volume of the fruits. Guava fruits showed minimum specific gravity when trees were sprayed with zinc sulphate at the rate of 0.4% concentration (Rawat *et al.*, 2010).

The maximum increase in fruit juice (46.87%) was recorded with the treatment GA₃ (20 ppm) as compared to minimum fruit volume (38.40%) found under control. Babu *et al.*, (1982) investigated the effects of zinc, 2, 4-D and GA₃ alone or in combination on the fruit quality of kagzi lime fruits. Zinc and 2, 4-D treatments were found to increase the physical traits and chemical composition of juice. GA₃ treatments increased the fresh weight and percentage of juice. Singh *et al.*, (1989) found significant effect of zinc spray (0.4%) and (0.5%) on juice percentage in kinnow and kagzi lime. Juice per cent was found maximum (48.3%) in fruits sprayed with (0.75%) ZnSO₄. Zinc sulphate (1.0%) increased juice content of Kinnow mandarin (Dixit *et al.*, 1977). Singh and Singh (1981) found that the juice content was increased with GA₃ (15 ppm) spray in Kaula mandarin. The maximum juice content was found in fruits from the trees sprayed with 1.0 and 0.8% urea and zinc sulphate but ascorbic acid content of fruits was decreased with increasing concentration of urea and zinc sulphate in Kinnow (Malik *et al.*, 2000). Sharma *et al.*, (2003) reported that maximum juice content was obtained with 0.5% zinc sulphate + 50 ppm gibberellic acid in kagzi lime. Plants of Eureka lemon sprayed with NAA (20 and 40 ppm), GA₃ (10 and 20 ppm), K₂SO₄ (8 and 10%) and borax (0.5 and 1.0%) twice in the month of May showed the highest juice percentage with GA₃ sprays (Bhat *et al.*, 2006). With the present investigation, GA₃ and NAA concentrations increased fruit juice significantly over control. The findings of earlier workers with regards the fruit juice as described above are almost similar to the results obtained under present study.

Significant gradual reduction on peel thickness was shown by foliar sprays of bio-regulators and nutrients over control (Table 2). The minimum peel thickness (2.13 mm) was found with GA₃ 15 ppm as compared to the maximum peel thickness (2.70 mm) found under control. Singh and Singh (1984) reported that the peel thickness increased with rising nitrogen rates in Pant Lemon-1. Nitrogen and potassium elements increased peel thickness whereas; phosphorus reduced it significantly in lemon crops (Dilipbabu, 1984; Ahmed *et al.*, 1988; and Deshraj, 1989). Sharma *et al.*, (2003) reported that the maximum juice content and the minimum peel thickness was obtained with 0.5% zinc sulphate + 50 ppm gibberellic acid in kagzi lime. Bhat *et al.*, (2006) also observed the maximum juice content and the minimum peel thickness in Eureka lemon when sprayed with GA₃ in different concentrations. These findings of above scientists with respect to peel thickness match with the results of present study.

The maximum total soluble solids (6.58%) was observed with the treatment GA₃ (20 ppm) as compared to the minimum total soluble solids (5.22%) recorded under control. Significant increase in TSS over control was recorded with the sprays of GA₃ (250-1000 ppm) at full bloom stage in Sweet lime Kumar *et al.*, (1975), and sprays of GA₃ (50-100 ppm) in Washington Naval orange (Deidda, 1971). Similarly, sprays of 2,4-D or 2,4,5-T have been reported to increase the TSS in Lahore local (Singh and Randhawa, 1961) and Kinnow mandarins (Chundawat *et al.*, 1975). Application of zinc sulphate 0.4% has resulted into increased total soluble solids (5.19%) in Assam lemon as reported by Langthasa and Bhattacharya (1991). Hafeez *et al.* (1999) reported that foliar spray of zinc significantly increased TSS content in orange juice. Ram and Bose (1994) reported that the mandarin orange treated with 600g urea as soil application + 1.5% foliar application, and spray of ZnSO₄ (0.5%) contained more juice and total soluble solids as compared to control plants. Malik *et al.*, (2000) found the significant increase in total soluble solids with receiving 1% urea spray and 0.8% zinc sulphate separately or in combination in mandarin hybrid trees. All these findings of different workers and scientist are justifying the results obtained for total soluble solids under present investigation.

The maximum acidity (6.69%) was observed with the treatment NAA (50 ppm) as compared to the minimum acidity (4.95%) obtained under control. Zidan *et al.*, (1965) reported a reduction in titratable acidity in Balady orange with 20 ppm 2,4-D when sprayed one or two months after full bloom. Similarly, a significant decrease in acidity was reported in Satsuma with NAA sprays (Hirose *et al.*, 1974). On the other hand, Phillips and Meagher (1967) observed an increase in acidity with sprays of 20 ppm 2,4-D or 2,4,5-T in pineapple orange, when sprayed three months before harvest. Similarly, in Unshiu orange, an application of NAA (200 ppm), 30 days after full bloom has been reported to increase the acidity of the juice (Nakajima *et al.*, 1969). Likewise, post bloom sprays of GA slightly increased the acidity in Orlando tangelo and Navel orange (Krezdorn and Cohen, 1963). The nutrient treatments did not cause any significant variation in acidity of fruit of mandarin orange. Although treatments with zinc (0.5%) resulted in slightly higher acidity (1.06) over control (Ram and Bose, 1994). Joshan *et al.* (1995) also reported that the acid content was maximum under 6% and 8% K₂SO₄ treatments in lemon. The results of present study with respect to acidity are more or less similar to the findings of above scientists and little variation in acidity content might be due to the difference in climatic conditions, species and cultivars.

The maximum increase in vitamin C content (21.32 mg/100g of fruit juice) was observed in NAA (10 ppm) and the minimum increase in vitamin C content under

control. Kumar *et al.*, (1975) also reported that the ascorbic acid content was increased significantly in all the sprayed fruits. However, the maximum increase was obtained in fruits treated with PCPA at 100 ppm and 2,4-D at 7.5 ppm in Sweet lime. Singh *et al.*, (1989) reported that both zinc and potash fertilization applied through foliage or soil increased the ascorbic acid content significantly when compared with control in Kagzi lime. The maximum ascorbic acid content was observed in the fruits under 4% K₂SO₄, followed by borax and CaCl₂ treatments in lemon (Josan *et al.*, 1995). The ascorbic acid content in fruits was estimated to be highest in fruits treated with NAA (20 ppm), which was closely followed by Mumaur and the lowest under control in aonla cv. NA-10 (Ghosh *et al.*, 2009). Singh *et al.*, (2007) also observed higher ascorbic acid content in aonla fruits treated with micronutrients 0.5% ZnSO₄ and 0.4% CuSO₄ and plant growth regulators as 10 ppm NAA and 25 ppm GA₃. All sprayed compounds increased vitamin C contents as compared with all other treatments in both seasons, whereas phosphoric acid and activated dry yeast gave the highest vitamin C as compared with all other chemicals in both seasons. Application of NAA (0.001%) during full bloom and at 0.002% during fruit set increased the ascorbic acid content in lemon juice (Arslanov, 1979). Kumar *et al.*, (1975) reported an increase in ascorbic acid content in Sweet lime with sprays of 2,4-D (5-20 ppm) or 2,4,5-T (5-20 ppm) or 250-1000 ppm GA₃ applied at full bloom. On the other hand, sprays of 2,4-D were reported to reduce the same in Balady oranges (Zidan *et al.*, 1965). Application of boron 0.4% concentration significantly increased the vitamin C content of guava fruits as reported by Rawat *et al.*, (2010). Findings of earlier works carried out by various scientists with respect to vitamin C completely match with the results of the present study.

The maximum total sugars (0.30%) were observed with the treatment GA₃ (20 ppm) and the minimum (0.11%) under control. In lemon, application of NAA (0.001%) during full bloom and (0.002%) during fruit set increased the sugar content of the juice (Arslanov, 1979). Similarly, increase in the total

sugar content was also reported with 2, 4-D (15 ppm) in Duncan grapefruit (Chundawat and Randhawa, 1973) and (Singh and Randhawa, 1961). On the other hand, in Pineapple orange (Phillips and Meagher, 1967) sprays of 2,4,5-T (20 ppm) were reported to reduce the total sugar content. Singh and Singh (1981) observed in Kaula mandarin that sprays of 15 ppm GA₃ in August, September and October increased the total sugar content by 23.5% over control. Ram and Bose (1994) reported that the mandarin orange treated with 600 g urea as soil application + 1.5% foliar application and spray of ZnSO₄ (0.5%) contained more total sugars as compared to control plants. Micronutrient spray with 0.4% zinc sulphate and boric acid are beneficial for improvement in fruit quality of guava (Rawat *et al.*, 2010). All these findings of different scientists are justifying the results of present investigation with regard to total sugars

GA₃ (20 ppm) gave the maximum shelf-life (26.57 days) and the minimum shelf-life (19.36 days) was found in control. Ahlawat *et al.* (1984) reported that the spray of different concentrations of GA₃ alone and in combination with captan fungicide showed the least loss in fruit weight under GA₃ (75 ppm) treatment in kinnow fruits. Kumar and Nagpal (1996) also reported that the fruits dipped in calcium nitrate, calcium chloride and gibberellic acid in mango cv. Dashehari, decreased the firmness of fruits with the increase in storage period but the decrease was much slower in fruits treated with chemicals. Brahmachari *et al.*, (1999) reported that the spray of GA₃ (50 and 100 ppm), Kinetin (20 and 40 ppm), CCC (500 and 1000 ppm) MH (500 and 1000 ppm), calcium nitrate (1 and 2%) and borax (0.4 and 0.8%) 15 days before harvest extended the shelf-life of Purbi litchi fruits as compared to control. Choudhary and Dhaka (2005) reported that gibberellic acid and their combinations were found to prolong the shelf-life of kinnow fruits. All above earlier findings reported by different scientists are almost similar to the results obtained under present study with regards the shelf-life of fruits of Pant Lemon-1.

Table 1. Effect of Foliar Application of Bio-regulators and Nutrients on Physical Characters of Lemon (*Citrus limon* Burma.) cv. Pant Lemon-1 under Subtropical Conditions of Garhwal Region

Treatments	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (gm)	Fruit volume (ml)	Specific gravity of fruits	Peel thickness (mm)
NAA (10 ppm)	5.12	4.89	96.89	97.23	0.975	2.23
NAA (25 ppm)	5.21	5.03	106.24	107.23	0.972	2.27
NAA (50 ppm)	5.31	5.19	110.25	108.25	0.967	2.25
GA ₃ (10 ppm)	5.27	5.17	96.32	97.22	0.973	2.16
GA ₃ (15 ppm)	5.31	5.21	101.23	100.35	0.977	2.10
GA ₃ (20 ppm)	5.57	5.31	102.56	101.98	0.973	2.16
Urea (0.5%)	4.89	4.72	93.09	94.25	0.965	2.38
Urea (1.0%)	5.13	5.06	93.89	94.89	0.960	2.29
Urea (2.0%)	4.98	4.68	94.65	95.41	0.968	2.54
Zinc Sulphate	5.19	4.98	86.23	87.53	0.976	2.67

(0.2%)						
Zinc Sulphate (0.3%)	5.23	5.01	85.86	84.21	0.968	2.48
Zinc Sulphate (0.4%)	5.37	5.04	92.34	93.25	0.966	2.41
Borax (0.2%)	5.14	4.87	79.92	81.02	0.965	2.36
Borax (0.3%)	5.39	5.06	82.45	83.25	0.967	2.42
Borax (0.4%)	5.08	4.86	83.44	81.97	0.964	2.31
Control	4.65	4.46	77.68	76.58	0.986	2.68
S.Em.±	0.110	0.106	4.03	4.47	0.007	0.106
CD at 5%	0.318	0.308	11.64	12.93	0.021	0.306

Table 2. Effect of Foliar Application of Bio-regulators and Nutrients on Chemical Characters of Lemon (*Citrus limon* Burma.) cv. Pant Lemon-1 under Subtropical Conditions of Garhwal Region

Treatments	Fruit juice (%)	Total soluble solids (%)	Acidity (%)	Vitamin C (mg/100gm)	Total Sugars (%)	Shelf-life of fruits (Days)
NAA (10 ppm)	41.90	6.35	5.19	21.06	0.169	24.58
NAA (25 ppm)	42.15	6.42	5.52	19.17	0.174	25.12
NAA (50 ppm)	45.87	6.43	6.70	19.04	0.270	25.32
GA ₃ (10 ppm)	44.27	6.40	5.73	19.58	0.168	25.78
GA ₃ (15 ppm)	45.67	6.50	5.33	19.85	0.282	26.23
GA ₃ (20 ppm)	46.40	6.56	5.38	18.90	0.302	26.39
Urea (0.5%)	42.03	6.47	5.73	20.93	0.116	23.21
Urea (1.0%)	42.91	6.33	5.70	20.52	0.125	23.56
Urea (2.0%)	41.59	6.12	5.69	19.98	0.152	23.87
Zinc Sulphate (0.2%)	43.09	6.27	5.28	18.77	0.143	23.89
Zinc Sulphate (0.3%)	42.16	5.98	5.66	18.90	0.157	24.13
Zinc Sulphate (0.4%)	41.09	5.80	5.59	18.63	0.180	24.31
Borax (0.2%)	43.12	6.01	5.57	19.17	0.133	23.11
Borax (0.3%)	40.79	5.60	5.69	19.44	0.148	23.25
Borax (0.4%)	43.71	5.73	5.49	19.04	0.150	23.27
Control	38.11	5.23	4.94	18.77	0.111	19.34
S.Em.±	0.92	0.165	0.127	0.680	0.010	0.60
CD at 5%	2.68	0.477	0.369	1.966	0.031	1.75

CONCLUSION

The findings of present study as summarized above are indicative of beneficial effects of bio-regulators and nutrients applied singly at full bloom stage (about 75% flowers opened) on lemon cv. Pant Lemon-1 under subtropical conditions of Garhwal Region. On the basis of overall performance of treatments on quality characters of fruits, it can be concluded that the values for fruit length, fruit juice, total soluble solids, total sugars, shelf-life of fruits, have been obtained maximum with minimum fruit drop under GA₃ (20 ppm) treatment, while the minimum fruit cracking and the maximum fruit weight, fruit volume, acidity were recorded with NAA (50 ppm). However, the maximum vitamin C was recorded under NAA (10 ppm) foliar application.

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