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EFFECT OF FOLIAR APPLICATION OF BIO-REGULATORS AND NUTRIENTS ON GROWTH AND YIELD CHARACTERS 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 growth and yield of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1. On the basis of overall performance of treatments on growth and yield characters of fruits, it can be concluded that the maximum values for fruit set (3.12%), days to maturity (148.23), yield of fruits (39.25kg) per plant have been obtained maximum with minimum fruit drop (33.58%) under GA_3 (20 ppm), minimum fruit cracking was found under NAA 50 ppm, while minimum number of seeds (10.48) per fruit and minimum seed weight (0.580gm) per fruit under GA_3 (10 ppm) treatment. However, the maximum number of fruits (403.27) per plant and maximum pulp:seed ratio (20.89) was recorded under NAA (10 ppm) foliar application.

Key words : Lemon, bio-regulators, nutrients, growth and yield.

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 above quantitative and qualitative characters of lemon fruits. Nutrition is another important factor affecting the health of the plants. The optimum requirement of nutrition of a

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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.

Materials and Methods

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 seasons. 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 (10 ppm), NAA (25 ppm), NAA (50 ppm), GA_3 (10 ppm), GA_3 (15 ppm), GA_3 (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 Randomized Block Design (RBD). 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 pants 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 field observations have been recorded on experimental trees at Horticultural Research Centre and laboratory analysis was carried out in the laboratory of Department of Horticulture.

Results and Discussion

Under the present study, foliar applications of bio-regulators and nutrients increased the fruit set significantly (table 1). However, the maximum fruit set (3.12%) was obtained with the treatment GA_3 (20 ppm) and minimum (1.54%) with control. The maximum fruit set with treatment GA_3 + BA was found higher due to internal content of GA_3 in the flowers which finally promoted fruit set in citrus fruits (Cottin, 1989; Babu and Lavania, 1985) and in many other fruit crops such as persimmon (Hasegawa and Kakajima, 1990); apple (Singh and Chadha, 1989) and plum (Rangelov *et al*., 1987). All these above findings published by different scientists are justifying the results of present investigation with regard to fruit set in Pant Lemon-1.

The minimum fruit drop (35.27%) was observed under GA_3 (20 ppm) and the maximum (49.31%) under control. Kumar *et al*. (1975) observed that the plant bio-regulator treatments reduced the fruit drop and increased fruit retention in sweet lime. GA_3 (250 and 750 ppm) and 2,4-D (10 ppm) were found be most effective in reducing the total fruit drop. Kaur *et al*. (2000) found that growth regulators, *viz*; GA_3 (15 and 20 ppm); 2,4-D (20 ppm); NAA (20 ppm) and urea (1%) significantly reduced the fruit drop in Kinnow mandarin. The maximum fruit drop (51.23%) was checked by 2,4-D while, the minimum (17.24%) by urea over control. Earlier workers as above observed minimum fruit drop under both GA_3 and NAA in different crops but in present study GA_3 was found most effective in controlling fruit drop in Pant Lemon-1 and confining the earlier findings.

The minimum fruit cracking (16.63%) was observed under treatment NAA (50 ppm) and maximum (21.75%) under control. Josan *et al*. (1995) reported that the sprays of GA_3, NAA and borax in lemon cv. Baramasi resulted into reduction of fruit cracking. However, they found the minimum fruit cracking under with NAA (40 ppm), followed by NAA (20 ppm) and GA_3 (10 ppm) and the cracking of fruits was noticed maximum under control trees, where no spray was done. Bhat *et al*. (2006) observed minimum fruit cracking in Eureka lemon with NAA (20 and 40 ppm), GA_3 (10 and 20 ppm), K_2SO_4 (8 and 10%) and borax (0.5 and 1.0%). They also found the lowest fruit cracking and the highest yield per plant with (40 ppm) NAA, followed by (20 ppm) NAA. Anatomical, climatic and hormonal factors were observed to be responsible for fruit cracking in lemon as reported by Josan and Sandhu (1999). They also reported that the contents of IAA, gibberellin like substances and Zeatin

Table 1 : Effect of foliar application of bio-regulators and nutrients on growth characters of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1 under subtropical conditions of Garhwal region.

Treatments	Fruit set (%)	Fruit drop (%)	Fruit cracking (%)	Days to maturity
NAA (10 ppm)	2.10	38.12	8.89	145.53
NAA (25 ppm)	2.19	36.87	8.67	144.11
NAA (50 ppm)	2.23	35.78	8.32	144.87
GA_3 (10 ppm)	2.56	35.25	9.12	143.35
GA_3 (15 ppm)	2.87	34.89	9.89	146.14
GA_3 (20 ppm)	3.12	33.58	8.45	148.23
Urea (0.5%)	1.56	48.24	9.47	135.64
Urea (1.0%)	1.69	47.02	9.87	137.45
Urea (2.0%)	1.81	46.52	10.20	138.24
Zinc Sulphate (0.2%)	1.76	44.65	10.23	140.25
Zinc Sulphate (0.3%)	1.86	44.01	9.87	139.47
Zinc Sulphate (0.4%)	1.94	43.65	9.24	141.22
Borax (0.2%)	2.02	43.26	8.99	138.41
Borax (0.3%)	2.08	43.01	9.23	140.86
Borax (0.4%)	2.12	42.87	9.45	137.22
Control	1.54	56.21	13.24	130.42
S.Em.±	**0.071**	**1.50**	**0.284**	**1.92**
CD at 5%	**0.206**	**4.35**	**0.820**	**5.54**

Table 2 : Effect of foliar application of bio-regulators and nutrients on yield characters of lemon (*Citrus limon* Burma.) cv. Pant Lemon-1 under subtropical conditions of Garhwal region.

Treatments	No. of fruits/ plant	Yield of fruits/ plant (kg)	No. of seeds/ fruit	Weight of seeds/ fruit (gm)	Pulp and seed ratio
NAA (10 ppm)	350.69	32.15	11.21	0.667	15.18
NAA (25 ppm)	369.79	34.56	11.69	0.685	15.99
NAA (50 ppm)	395.71	38.24	12.06	0.753	15.10
GA_3 (10 ppm)	394.89	34.25	10.48	0.580	17.20
GA_3 (15 ppm)	403.27	37.45	10.98	0.636	17.71
GA_3 (20 ppm)	388.42	39.25	11.35	0.673	16.79
Urea (0.5%)	319.91	29.78	12.35	0.766	18.79
Urea (1.0%)	325.49	30.56	13.21	0.828	17.89
Urea (2.0%)	330.16	31.25	13.67	0.881	17.74
Zinc Sulphate (0.2%)	331.82	30.24	11.69	0.714	20.89
Zinc Sulphate (0.3%)	325.30	31.75	12.56	0.766	20.25
Zinc Sulphate (0.4%)	346.85	36.54	13.01	0.798	20.46
Borax (0.2%)	355.59	31.56	12.23	0.720	17.44
Borax (0.3%)	369.95	33.25	12.87	0.781	18.62
Borax (0.4%)	382.70	32.41	13.06	0.831	17.09
Control	303.30	23.56	14.13	0.902	20.06
S.Em.±	**13.03**	**0.82**	**0.22**	**0.015**	**0.42**
CD at 5%	**37.64**	**2.36**	**0.64**	**0.045**	**1.21**

were higher in the pulp than in the peel of the cracked fruits, whereas the level of ABA was higher in the peel than that of pulp of the cracked fruit of lemon. Thus, the results of present study for fruit cracking, in Pant Lemon-1 are almost similar to the results reported by other scientists.

The maximum increase in day to maturity (148.45 day) was observed with the treatment GA_3 (20 ppm), whereas minimum days to maturity (130.16 days) was found under control. In lemon, GA_3 frequently delays the maturity and the delay is beneficial and also appears to be of economic value. Coggins *et al*. (1968) found delay in maturation of Lisbon lemon when trees were sprayed in the spring with high concentrations of gibberellins. Thus, results of present study match with the study of earlier workers for this character.

The maximum number of fruits per plant (401.72) was obtained under GA_3 (15 ppm) treatment and the minimum number of fruits per plant (299.13) under control. Moss (1972) reported that 20% increase in the number of fruits was obtained when plants were treated with GA_3 (50 ppm) at petal fall in sweet orange. Kumar *et al*. (1975) reported in sweet lime that the highest number of fruits (50.65%) were noticed with GA_3 (1000 ppm) and the least number under control. Among all the treatments, GA_3 (1000, 750 and 500 ppm) gave the maximum number of fruits. These earlier findings are also in conformity with the trend of present study for number of fruits per plant.

The maximum fruit yield (39.19 kg/plant) was obtained under GA_3 (20 ppm) treatment and the minimum (23.17 kg/plant) under control. Plant bio-regulator sprays generally result in increased yield of citrus fruit either by increasing the total number of fruits harvested or by their direct effect on increased fruit size. Abd El-Rahman *et al*. (2012) found that the foliar sprays of Washington Navel orange trees with GA_3 (50 ppm) with or without (0.5%) urea were superior for inducing the highest fruit set and yield, in addition to KNO_3 at 4% comparing with 2% and 6%. The best treatment for increasing yield and fruit quality is GA_3 (50 ppm) with or without (0.5%) urea at full bloom stage. The results of present study in Pant Lemon-1 are in line with the findings of other workers in several fruit crops as above.

The minimum number of seeds/fruit (10.48) was recorded with the treatment GA_3 (10 ppm) and the maximum number of seeds/fruit (14.35) with control. Application of various concentrations of GA_3 to emasculated flowers of three mandarin varieties, viz; Kaula, Lahore Local and Nagpuri induced parthenocarpic fruit set and the fruits were completely seedless (Randhawa *et al*., 1964). Kumar *et al*. (1975) also reported in Sweet lime that the number of seeds were reduced in all GA_3 (250, 500, 750 and 1000 ppm) treated fruits significantly. Under the present study total numbers of seeds per fruit were decreased significantly with GA_3 treatments. Earlier workers also have proved the lesser number of seeds per fruit with GA_3 and NAA applications and thus, the trend of decreasing seeds per fruit also gets true under the present study.

The minimum seed weight (0.58 g) was recorded with treatment GA_3 (10 ppm) and the maximum seed weight (0.90 g) under control. Application of 10 or 20 (ppm) GA_3 to the Clementine trees at the time of 80% petal fall significantly reduced the seed weight as compared to control (Russo, 1980). Only a few workers have suggested the less seed number and weight of seeds per fruit from the plants treated with bio-regulator and nutrient treatments. Above few findings and suggestions with regards this character satisfy the findings of the present investigation.

It is revealed from the study of data that the pulp and seed ratio was maximum (21.17) with $ZnSO_4$ (0.2%) treatment. However, the minimum pulp and seed ratio (15.11) was recorded with NAA (50 ppm) treatment. Khayyat *et al.* (2007) reported in date palm that the higher and lower pulp and seed ratio were resulted from H_3BO_3 (1500 ppm) and control. Under the present study, zinc sulphate with gradual low concentrations seems to be effective in enhancing pulp and seed ratio. Earlier workers have proved the significant increase in ratio with treatments like H_3BO_3, GA_3 and KNO_3 which confirmed the positive effect of this character under present study.

Conclusion

On the basis of overall performance of treatments on growth and yield characters of fruits, it can be concluded that the maximum values for fruit set (3.12%), days to maturity (148.23), yield of fruits (39.25kg) per plant have been obtained maximum with minimum fruit drop (33.58%) under GA_3 (20 ppm), minimum fruit cracking was found under NAA 50 ppm, while minimum number of seeds (10.48) per fruit and minimum seed weight (0.580gm) per fruit under GA_3 (10 ppm) treatment. However, the maximum number of fruits (403.27) per plant and maximum pulp:seed ratio (20.89)was recorded under NAA (10 ppm) foliar application.

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