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Effect of Plant Growth Regulators on Yield and Quality Parameters of Summer Crop in Acid Lime (*Citrus aurantifolia* Swingle) cv. Balaji

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A B S T R A C T

A field study was conducted at AICRP on Citrus, Citrus Research Station, Tirupati, Andhra Pradesh during the year 2015 under Dr. YSR Horticultural University, to find out Effect of Plant growth Regulators on yield and quality parameters of summer crop in acid lime (*Citrus aurantifolia* Swingle) cv. Balaji. Trees were sprayed with treatments *viz* Spraying GA_3 @ 50 ppm during June + CCC @1000 ppm during September + KNO_3 2% during October, Spraying CCC @ 200 ppm (Chloromequat chloride) 1st in August, 2nd in September followed by light pruning in September and heavy irrigation in mid-October, Application of Paclobutrazol @ 5 ml per meter canopy 4 times at 45 days interval starting from July to December, Spraying NAA @ 200 ppm during December, Spraying 2, 4-D @ 40 ppm during November + 20 ppm during February, Imposition of 30 days of soil moisture stress during October followed by 50 ppm Ascorbic acid spray at release of stress, Spraying ethephon @ 200 ppm during the month of October, With holding irrigation (Bahar) for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November and along with control (Not spray). The data recorded from the results concluded that maximum number of fruits per tree was (234.78) with the treatment application of Paclobutrazol @ 5 ml four times starting from July to December (T_3), maximum fruit yield per tree was recorded with Spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1), Highest juice percent (53.59) recorded in the treatment spraying GA_3 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 2% during October, Highest TSS (8.42 ^{0}Brix) was recorded with spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1), highest ascorbic acid content (61.09 mg) was noticed in spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 2 % during October (T_1) and the differences for acidity among the treatments was non-significant.

Introduction

Citrus is one of the largest and most important groups of fruit crops in tropical and subtropical regions. In India, among the fruit crops citrus species covers an area of major fruit crops is 10.4% with an area of 953.40 thousand ha, with production of 1, 17, 42, 000 MT, giving rise to Productivity of 8.7 MT per ha estimated data NHB 2015-2016. As per the data available (AP Horticulture online 2015-16), in Andhra Pradesh oranges and Batavia

are being cultivated in 1, 21, 716 hectares with the production of 1, 40, 78, 216 MT and limes and lemons are grown an area of 111.09 thousand ha with production of 1717.34 thousand MT and productivity of 16.8 MT per hectares during 2015-2016 (NHB, 2016.). Acid lime (*Citrus aurantifolia Swingle)* is considered as most important fruit crop (Ghosh, 1990). It is considered to be native of Malayan peninsula. It belongs to the family Rutaceae, with chromosome number (2n=18). It is mainly cultivated for its multi - fold nutritional and medicinal values which made acid lime more important among the fruits. Its attractive appearance, penetrating aroma of peel and excellent taste gives a remarkable position to acid lime which is grown widely throughout the world (Babu, 2001). Acid lime fruits have great medicinal value. Being acidic in nature, acid lime fruits have great medicinal value. Acid lime is good appetizer, anti helmentic and it checks biliousness and stomach ache. Lime is used in making candy, chocolate, ice cream, pastries and 100 grams of fruit juice contains 80 percent of water, carotene, 26 IU, Vitamin A, Vitamin B_1 20 mg, Riboflavin 0.1 mg, Vitamin C 63 mg, Iron (Fe) 1.83 mg, Copper (Cu) 0.16 mg, Oxalo-acetic acid 0.30%, Malic acid and alkaline salt 8.2% therefore it is very essential for human health (Rangel, 2010).

The major constraints faced by the growers of acid lime are the peak and lean production in consecutive years. Flowering in acid lime is recurrent under tropical and sub-tropical conditions unless synchronized into well-defined period of extreme stress. Since the demand for the fruit remains very high during summer it is very essential to regulate flowering that gives fruiting in the months of April and May which fetches higher returns to the grower compared to the income receive during other seasons. There is difficulty in fruit set because of incomplete pollination, hence plant growth regulators may be effectively used to increase fruit set. Hasta-bahar (September - October) management through the use of plant growth regulators and chemicals play an important role to get maximum fruit yields during summer (Mukunda *et al.,* 2014). Hence there is a need to test the plant growth [hasta-bahar (September - October)] through the use of plant growth regulators and chemicals for their role inducing flowering for the hasta bahar crop.

Materials and Methods

The present investigation were executed at AICRP on Citrus, Citrus Research Station, Tirupati, Andhra Pradesh during the year 2015 under Dr. YSR Horticultural University with nine treatments *viz,* Spraying GA_3 @ 50 ppm during June + CCC @1000 ppm during September + KNO_3 2% during October, Spraying CCC @ 200 ppm (Chloromequat chloride) 1st in August, 2nd in September followed by light pruning in September and heavy irrigation in mid-October, Application of Paclobutrazol @ 5 ml per meter canopy 4 times at 45 days interval starting from July to December, Spraying NAA @ 200 ppm during December, Spraying 2, 4-D @ 40 ppm during November + 20 ppm during February, Imposition of 30 days of soil moisture stress during October followed by 50 ppm Ascorbic acid spray at release of stress, Spraying ethephon @ 200 ppm during the month of October, With holding irrigation (Bahar) for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November and along with control (Not spray).

The experiment was laid out in a randomized block design with three replications. The effect of different treatments was studied on yield parameters (no. of fruits per tree and fruit yield per tree) and quality parameters (Juice percentage, TSS, Acidity % and

Ascorbic acid content) on six randomly selected trees. The mean data were subjected to statistical analysis following analysis of variance technique (Panse and Sukhathme 1985).

Results and Discussion

Number of fruits per tree

Among the various treatments evaluated, number of fruits per tree was found significantly highest (234.78) with the treatment application of Paclobutrazol @ 5 ml four times starting from July to December (T_3) which was followed by spraying NAA @ 200 ppm during December (222.56) and all other treatments in the study were found on par with each other. However, lowest number of fruits (167.38) per tree was recorded with the water spray (control). The results are in conformity with findings of Tripathi and Dhakal (2005) and Devi *et al.,* (2011) in acid lime. Paclobutrazol significantly increases number of fruits per panicle and tree particularly in pruned mango trees. Maximum number of fruits could be due to increase the hormonal activity by pruning and increase number of perfect flowers, flower set, fruit set and retention by Paclobutrazol application. The increase the number of fruits per tree with the application of Paclobutrazol, NAA could be attributed to increase flower set observed with the treatments initially resulting in the more number of fruits per tree.

Fruit yield per tree

Significant differences were noticed in the yield of acid lime tree due to the sprayings of different plant growth regulators. Spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1) has recorded significantly highest fruit yield per tree (13.61 kg) compared to all other treatments fallowed by application of Paclobutrazol @ 5 ml per meter for four times starting from July to December (12.08 kg). The lowest fruit yield was recorded in control treatment (5.41 kg). Similar results were obtained by Mukunda *et al.,* (2014) in acid lime. The increased fruit yield attributed to the synthesis of chlorophyll from source to sink which leads to increase carbohydrate metabolism. This might be due to more vegetative growth attained with GA_3, which increased the vegetative shoot development at the initial sprays. Cycocel sprays during September enhancing flower bud initiation. KNO_3 sprays at later stages could have helped to set more fruits leading highest yield per tree. The results are in agreement with the findings of Thirugnanavel *et al.,* (2007) in acid lime, Jain *et al.,* (2014) high yield noticed with GA_3 100 ppm in Nagpur mandarin. Narayanlal *et al.,* (2013) who reported the highest yield per plant was found in 50 ppm GA_3 in guava. Debbarma and Hazarika (2016) also reported the GA_3 @ 100 ppm + CCC @ 1000 ppm + KNO_3 1 % increases the yield in acid lime (Table 1).

Juice percent

Highest juice percent (53.59) recorded in the treatment spraying GA_3 50 ppm during June + CCC @ 1000 ppm during September + KNO3 2% during October which was followed by spraying NAA @ 200 ppm during December (48.60) whereas, lowest juice (36.41) percentage was recorded in control treatment. The results are in conformity with the findings of Mukunda *et al.,* (2014) in acid lime variety cv. Balaji. Similar results are also recorded by Saleem *et al.,* (2008) sweet orange. Nawaz *et al.,* (2008) in Kinnow mandarin and Jagtap *et al.,* (2013) in Kagzi lime also reported increased juice percent with foliar application of GA_3 @ 50 ppm in sweet orange. Gibberellic acid might have increased the juice percentage of fruit by stimulating the functioning of enzymes

involved in physiological process. Cycocel and potassium nitrate sprays could have increased the juice content on account of their role in increasing the mobilization of carbohydrates from source to sink.

TSS

Highest TSS (8.42 ^{0}Brix) was recorded with spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1) followed by (T_8) withholding irrigation for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November (8.22 ^{0}Brix). Lowest (7.33 ^{0}Brix) TSS was recorded with control treatment (7.32 ^{0}Brix). The results are in accordance with the findings of Mukunda *et al.,* (2014) in acid lime cv. Balaji reported the highest TSS of (8.42 ^{0}Brix). Similar results are also reported by Debaje *et al.,* (2011) and Debbarma and Hazarika (2016) in acid lime. The higher TSS content, in the treatments involving plant growth regulators *viz.*, GA_3, Cycocel, Paclobutrazol, and NAA could be due to stimulation of the functioning of enzymes involved in physiological processes and due to increase in the mobilization of carbohydrates from source to sink as opined by Mukunda *et al.,* (2014).

Table.1 Effect of plant growth regulators on yield parameters of summer crop in acid lime cv. Balaji

Treatments	**No: of fruits per tree**	**Fruit yield per tree**
T_1 - Spray GA_3 @ 50 ppm during June + CCC @1000 ppm during September + KNO_3 2 % during October	214.83	13.61
T_2 - Sprayings 200 ppm CCC (Chloromequat chloride) 1st in august, 2nd in September followed by light pruning in September and heavy irrigation in mid-October	211.16	10.28
T_3 -Drenching Paclobutrazol @ 5 ml per meter canopy 4 times starting from July to December	234.78	12.08
T_4 . Spraying NAA @ 200 ppm during December	222.55	10.11
T_5 - Spraying 2, 4-D @ 40 ppm during November +20 ppm during February	220.91	9.61
T_6 - 30 days of soil moisture stress during October with 50 ppm Ascorbic acid Spray at release of stress	208.91	9.45
T_7 - Spraying ethephon @ 200 ppm during October	212.54	9.30
T_8 – Withholding irrigation (Bahar) for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November	218.82	9.43
T_9 - Control	167.38	5.41
SE(m) ±	2.165	0.067
CD (5%)	6.547	0.202

Table.2 Effect of plant growth regulators on quality parameters of summer crop in acid lime cv. Balaji

Treatments	Juice percentage	TSS	Acidity %	Ascorbic acid content
T_1 - Spray GA_3 @ 50 ppm during June + CCC @1000 ppm during September + KNO_3 2 % during October	53.59 (47.04)	8.42	6.79 (15.10)	61.09
T_2 - Sprayings 200 ppm CCC (Chloromequat chloride) 1st in august, 2nd in September followed by light pruning in September and heavy irrigation in mid-October	45.47 (42.38)	8.15	6.69 (14.98)	45.18
T_3 -Drenching Paclobutrazol @ 5 ml per meter canopy 4 times starting from July to December	47.86 (43.75)	8.09	6.56 (14.83)	48.83
T_4 - Spraying NAA @ 200 ppm during December	48.59 (44.17)	8.16	6.40 (14.65)	38.41
T_5 - Spraying 2, 4-D @ 40 ppm during November +20 ppm during February	45.19 (42.22)	7.66	6.50 (14.76)	54.92
T_6 - 30 days of soil moisture stress during October with 50 ppm Ascorbic acid Spray at release of stress	46.73 (43.11)	7.93	6.52 (14.79)	44.10
T_7 - Spraying ethephon @ 200 ppm during October	46.03 (42.70)	7.59	6.95 (15.28)	45.08
T_8 – Withholding irrigation (Bahar) for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November	44.90 (42.05)	8.22	7.29 (15.66)	45.21
T_9 - Control	36.41 (37.10)	7.32	5.99 (14.16)	37.52
SE(m) ±	0.338	0.024	0.032	0.699
CD (5%)	1.022	0.074	0.097	2.115

Acidity %

From the results it is observed that the differences for acidity among the treatments were non-significant. The lowest (5.99) percent of acidity was observed with the control treatment. However, the treatment *i.e.* (T_8) withholding irrigation for 30 days in September followed by application of recommended dose of fertilizers and irrigation in the month of November gave significantly highest (7.29) acidity percentage.

Ascorbic acid content

The ascorbic acid content was significantly varied among the treatments. significantly highest ascorbic acid content (61.09) was noticed in spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 2 % during October (T_1) followed by spraying of 2, 4-D @ 40 ppm during November + 20 ppm during February (54.92) whereas, lowest ascorbic acid content was recorded in control treatment (37.52). Similar

findings were also observed by Debbarma and Hazarika (2015) in acid lime, Azher Nawaz *et al.,* (2011) with Kinnow mandarin, Debaje *et al.,* (2011) in acid lime and Jagtap *et al.,* (2013) in Kagzi lime. The increase in the ascorbic acid content could be attributed to the role of plant growth regulators in breaking down organic acids in to sugars at the time of fruit ripening, further plant growth regulators viz., GA_3, 2, 4-D, Paclobutrazol and Cycocel might have assisted the translocation of sugars from vegetative parts to developing fruits. It is also known that gibberellins are known to play crucial role in the sugar metabolism of plants (Table 2).

From the investigations it can be concluded that maximum number of fruits per tree was (234.78) with the treatment application of Paclobutrazol @ 5 ml four times starting from July to December (T_3), maximum fruit yield per tree was recorded with Spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1), Highest juice percent (53.59) recorded in the treatment spraying GA_3 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 2% during October, Highest TSS (8.42 ^{0}Brix) was recorded with spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 @ 2 % during October (T_1), highest ascorbic acid content (61.09) was noticed in spraying GA_3 @ 50 ppm during June + CCC @ 1000 ppm during September + KNO_3 2 % during October (T_1) and the differences for acidity among the treatments was non-significant.

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