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EFFECT OF PLANT GROWTH REGULATORS AND ZINC ON FRUITING AND YIELD PARAMETERS OF ACID LIME (*CITRUS AURANTIFOLIA* SWINGLE) UNDER MALWA PLATEAU CONDITIONS

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ABSTRACT
An experiment was conducted to study the effect of plant growth regulators and zinc on fruiting and yield parameters of Acid Lime (*Citrus aurantifolia* Swingle). The treatments comprised combinations of foliar spray of NAA, GA_3, Zinc and control. Altogether, 15 treatments were applied in a randomized block design with three replications. Among all the treatments, the foliar spray of NAA 200 ppm + GA_3 100 ppm + Zinc 1.0 % was found to be the best for maximum increase in fruit set (49.67 %), fruit retention (65.70 %), fruit volume (36.83 ml), fruit length (4.22 cm), fruit diameter (4.11 cm), rind thickness (1.69 mm), juice percentage (49.00 %), number of fruit per plant (976.33), fruit weight (39.07 g) and reduced the number of days from initiation of flower to fruit set (25.00 Days), fruit drop (34.29 %) and number of days from fruit set to fruit maturity (145.00 days), fruit yield per plant (38.10Kg). Quality parameters like ascorbic acid (32.00 mg), total sugars and TSS (8.33 ^{0}B) were also improved and acidity (6.42 %) were reduced with the foliar application of NAA 200 ppm + GA_3 100 ppm + Zinc 1.0 %.

INTRODUCTION

Citrus are the most important fruits of the world. Citrus are cultivated widely in the tropical and sub-tropical regions. It ranks third among the sub-tropical fruits of the world with different varieties. Madhya Pradesh is the fourth largest citrus producing state in the country and accounts for 10.7% of the total production in the country (NHB, 2013). Acid lime (*Citrus aurantifolia* Swingle) is the member of family Rutaceae. It is a rich source of vitamin "C" and has good antioxidant properties. Fruits being acidic in nature, they are largely used for garnishing and flavouring several vegetarian and non- vegetarian dishes. Besides its value-added products like pickle, juice, squash etc., lime peel oil, peel powder are also in great demand in soap and cosmetic industry (Debaje *et al.,* 2011). In india, Acid lime is grown on a large scale in Madhya Pradesh where its fruits yielded 113.34 (000 MT) and covers 9.24 (000 Ha) (NHB, 2013). The average yield of citrus in India is far below than other citrus producing countries like Brazil where it is 40 to 60 tons ha-^{1} (Ibrahim *et al*., 2011). Citrus orchards in india are facing problem of fruit size, color, quality and excessive premature fruit drop which is due to the incomplete pollination (Jagtap *et al*., 2013) and deficiencies of essential nutrients (Ibrahim *et al*., 2007). Nutrient deficiency disturbs the production of plant growth regulators controlling size, color and premature fruit dropping. The above mentioned factors cause fruit drop and application of nutrients or plant growth regulators is recommended to reduce premature fruit drop (Nawaz *et al.,* 2008, Shinde *et al.,* 2008 and Iqbal *et al.,* 2009). Flower/fruit dropping was recorded at anthesis which continued up to the time of harvest (Modise *et al.,* 2009). The initial dropping is due to abscission of weak fruit lets, which appear after anthesis. Abscission layer at the stem resulting in fruit drop is formed due to imbalance of auxins, cytokinins, and gibberellins (Balal *et al*., 2011). As the fruit size at an early stage is very small, the dropping is minimal. However, it is very severe when fruits are of medium size and whole area under citrus trees is covered with dropped fruits (Saleem *et al*., 2005). Plant growth regulators applied near the terminal buds of trees may increase the rate of growth by stimulating more or less constant growth during the season. Plant growth regulators are used mainly to delay and reduce unwanted fruit abscission (fruit drop), to delay the senescence and to promote abscission of excess fruit (thinning to increase the size of the remaining fruit) and to inhibit the growth of suckers on the trunk. The plant growth regulator, Auxin play a vital role in checking pre harvest fruit drop and ultimately increasing yield without adversely affecting the fruit quality. NAA checking the fruit drop and increasing the fruit retention and also increasing the fruit weight and TSS of the fruits GA_3 increase the fruit height, fruit diameter, fruit weight ultimately the yield was increased (Shinde *et al.,* 2008). Severe deficiency of Zn was noted long ago in the citrus orchards of Madhya Pradesh (Agrawal, 2003). Zinc is an important element for flowering, fruiting, growth and quality of fruits. Zinc also increase the chlorophyll content of leaves and play an important role in enzymatic activities and is necessary for growth and development of fruits. It is also involved in

regulating the protein and carbohydrate metabolism. It is also promotes synthesis of IAA through tryptophan's which serves as a precursor for auxin synthesis and directly affects the growth parameters (Sharma *et al.,* 2008). Keeping the above fact the paper deals with the effect of plant growth regulators and zinc on fruiting and yield parameters of *Citrus aurantifolia* cv Kagzi Lime.

MATERIALS AND METHODS

The present experiments were conducted with the aim to improve the control of excessive premature fruit drop and enhance the fruit yield and quality by exogenous application of NAA, GA_3 and Zn on Acid lime (*Citrus aurantifolia* Swingle) cv Kagzi Lime. The experiment was conducted at the *Instructional Cum Research Fruit orchard*, K.N.K. College of Horticulture, Mandsaur (M.P.), Department of Fruit Science, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.). Mandsaur is situated at 23.45º to 24.13º N latitude and 74.44ºto 75.18º E longitudes at an altitude of 435 m MSL. It has a subtropical climate with hot summer and cool winter. The temperature rises up to 46ºC during summer and falls to 3.6ºC during winter with an occasional occurrence of frost. The average rainfall is 579.2 mm, most of which occurs during July to September, winter and summer rain are uncommon. The meteorological data such as maximum and minimum temperature (34.6ºC/week to 8ºC/week), maximum relative humidity (87.4%/week) and maximum rainfall (112.9 mm/week) were recorded during the experimental period. The experiment was laid out in randomized block design with three replications. An experiment comprised of 15 treatments consisting of foliar spray of NAA (100 and 200 ppm), GA_3 (50 and 100 ppm), Zinc (0.5 % and 1.0 %) including control alone and in combinations. The control plants were sprayed with distilled water. Spray was done at initiation of flowering and same spray is repeated at pea stage. At this time, maximum fruit drops as well as maximum growth occurs due to high competition (Awasthi *et al.,* 1975). Observations on various characters of plants *i.e.* reproductive, physical, bio-chemical and yield parameters of Acid lime fruits with different treatments application were recorded and their average were calculated. The data collected were subjected to statistical analysis of variance. The significance of the treatments was tested through 'F' test at 5 per cent level of significance.

RESULTS AND DISCUSSION

Reproductive parameters

Results of present study indicated that, application of various plant growth regulators at different concentrations significantly improved by reducing the number of days taken from initiation of flower to fruit set, fruit drop, fruit retention and number of days taken from fruit set to fruit maturity. The result revealed that the minimum number of days (25.00) taken from initiation of flower to fruit set, least fruit drop (34.29 %) and reduced number of days (145.00) taken from fruit set to fruit maturity were recorded with foliar spray of T_{14} (NAA 200 ppm + GA_3 100 ppm + Zinc 1.0%). Whereas, maximum number of days (33.33) taken from initiation of flower to fruit set, fruit drop per cent (45.80) and number of days (159.33) taken from fruit set to fruit maturity were observed in control, respectively. Fruit set and fruit retention per cent were also significantly affected by application of plant growth regulators and zinc. Maximum per cent fruit set (49.67 %) and fruit retention (65.70 %) were recorded with foliar spray of T_{14} (NAA 200 ppm + GA_3 100 ppm + Zinc 1.0%), whereas, minimum (37.07 %) and (54.19 %) in control respectively. This may be due to that GA_3 believed to serve as a mediating process for faster translocation and mobilization of stored metabolites or phothosynthates from source to sink and also play significant role in increasing auxin synthesis in ovaries (Jagtap *et al.,* 2013). The role of GA_3 was to multiply and to lengthen the meristematic cell, which results in earlier fruit set (Wahdan *et al.,* 2011). The zinc might had produced pronounced effect on hastening growth by way of production of more auxins. Zinc also plays a specific role in fertilization as pollen grains contain a very high

Table 1 : Effect of plant growth regulators and zinc on reproductive and fruiting parameters of acid lime

TreatmentsDetails	Number of days taken from initiation of flower to fruit set	Number of days taken from fruit set to fruit maturity	FruitSet (%)	Fruit Drop (%)	Fruit Reten -tion (%)	Fruit volume (ml)	Specific Gravity	Fruit length (cm)	Fruit Dia- meter (cm)
Control	33.33	159.33	37.07	45.80	54.19	27.00	1.03	3.41	3.40
NAA 100 ppm	29.00	156.00	41.97	39.12	60.88	29.92	1.06	3.79	3.76
NAA 200 ppm	28.67	153.67	44.60	37.49	62.50	31.75	1.06	3.84	3.80
GA_3 50 ppm	28.33	153.33	43.30	43.88	56.12	32.42	1.03	3.94	3.85
GA_3 100 ppm	27.67	148.33	45.60	40.84	59.16	34.58	1.08	4.03	3.96
Zn 0.5 %	31.00	152.00	44.77	42.82	57.17	28.33	1.10	3.76	3.73
Zn 1.0 %	29.00	147.00	46.13	40.21	59.79	29.87	1.11	3.80	3.78
NAA 100 ppm + GA_3 50 ppm	27.67	153.00	44.57	38.81	61.18	33.52	1.05	4.03	3.90
GA_3 50 ppm + Zn 0.5 %	28.00	149.67	46.50	41.41	58.59	32.02	1.07	3.96	3.86
NAA 100 ppm + Zn 0.5 %	28.67	150.67	45.80	38.09	61.91	30.50	1.04	3.81	3.78
NAA 200 ppm + GA_3 100 ppm	26.67	147.33	46.20	37.35	62.64	36.22	1.06	4.12	4.05
GA3 100 ppm + Zn 1.0 %	27.67	146.00	48.87	39.76	60.24	35.75	1.06	4.08	4.00
NAA 200 ppm + Zn 1.0 %	28.33	146.33	47.90	36.76	63.24	32.47	1.07	3.86	3.85
NAA 100 ppm + GA_3 50 ppm + Zn 0.5 %	27.33	148.00	47.67	37.47	62.52	34.17	1.03	3.98	3.91
NAA 200 ppm + GA_3 100 ppm + Zn 1.0 %	25.00	145.00	49.67	34.29	65.70	36.83	1.07	4.22	4.11
S. Em ±	1.06	1.83	1.13	1.56	1.19	0.98	0.05	0.12	0.08
C.D. at 5%	3.08	5.32	3.28	4.52	3.47	2.85	NS	0.34	0.23

Table 2 : Effect of plant growth regulators and zinc on fruiting, biochemical and yield parameters of acid lime

TreatmentsDetails	Number of sacs per fruit	Number of seeds per fruit	Juice (%)	Aci-dity (%)	Ascorbic acid (mg/100g)	TSS (°Brix)	TSS/ acid Ratio	Number of fruits per plant	Fruit Weight (g)	Fruit Yield per plant (kg)
Control	8.33	11.33	36.50	7.14	25.89	6.47	0.91	743.00	27.67	20.56
NAA 100 ppm	9.67	9.67	40.33	6.82	28.74	7.27	1.07	898.00	31.75	28.48
NAA 200 ppm	9.33	9.33	42.15	6.78	29.57	7.47	1.10	922.00	33.50	30.86
GA_3 50 ppm	10.00	8.67	44.73	6.75	28.90	7.53	1.12	839.00	33.53	28.12
GA_3 100 ppm	10.67	8.33	46.63	6.69	29.92	7.80	1.16	841.67	37.58	31.56
Zn 0.5 %	11.00	10.67	38.90	6.65	29.59	7.47	1.12	867.33	31.03	26.86
Zn 1.0 %	11.67	10.33	41.96	6.62	30.95	7.73	1.17	876.67	33.07	29.02
NAA 100 ppm + GA_3 50 ppm	10.00	7.33	46.19	6.72	28.97	7.60	1.13	901.67	35.12	31.65
GA_3 50 ppm + Zn 0.5 %	12.00	8.33	44.88	6.60	30.18	7.67	1.16	870.67	34.27	29.85
NAA 100 ppm + Zn 0.5 %	11.33	9.33	41.18	6.63	29.60	7.53	1.14	923.00	31.92	29.44
NAA 200 ppm + GA_3 100 ppm	10.67	7.00	47.93	6.68	30.26	7.87	1.18	935.33	38.51	36.02
GA3 100 ppm + Zn 1.0 %	12.33	8.00	46.90	6.55	31.62	8.00	1.22	880.33	38.09	33.54
NAA 200 ppm + Zn 1.0 %	11.67	8.33	44.10	6.62	31.27	7.80	1.18	954.00	34.83	33.23
NAA 100 ppm + GA_3 50 ppm + Zn 0.5 %	11.33	8.00	46.85	6.61	30.93	7.60	1.15	921.00	35.46	32.69
NAA 200 ppm + GA_3 100 ppm + Zn 1.0 %	12.67	7.67	49.00	6.42	32.00	8.33	1.30	976.33	39.07	38.10
S. Em ±	0.56	0.32	1.06	0.08	0.67	0.24	0.03	24.05	1.64	1.64
C.D. at 5%	1.64	0.93	3.09	0.24	1.96	0.71	0.11	69.69	4.75	4.75

concentration of zinc and help to ease perfect pollination plays pollen germination and pollen tube growth which result in early fruit (Marschner, 1995; Outten *et al*., 2001; Pandey *et al*., 2006). When the all three components used in combinations their synergistic effect significantly effect to improve the reproductive parameters. These results are similar to the findings of Kachave and Bhosale (2007) in Kagzi Lime, Haribabu (1980) in Kagzi lime and Choudhary *et al*. (2013) in Nagpur mandarin.

Fruiting parameters

It is clearly evident from the data (Table 1and 2) that fruiting parameters of fruit were significantly affected by application of plant growth regulators and zinc except specific gravity. Foliar spray of T_{14} (NAA 200 ppm + GA_3 100 ppm + Zinc 1.0%) recorded significantly maximum fruit volume (36.83 ml), fruit length (4.22 cm), fruit diameter (4.11 cm), juice percentage (49 ml) and number of sacs per fruit (12.67). While, minimum number of seeds per fruit (7.00) was recorded with foliar spray of T_{10} (NAA 200 ppm + GA_3 100 ppm). Although,Specific gravity was non-significant. The increase in physical parameters by the application of plant growth regulators and Zinc might be due to optimum supply of plant nutrients and growth hormones in right amount during the entire crop growth period causing vigorous vegetative development of the plants and ultimately production of more photosynthates (Sachs and Hackett, 1972). The other possible reason for enhancement of fruit size with NAA, GA_3 and zinc might be due to their involvement in hormonal metabolism, increased cell division, elongation and expansion of cells. The results are in accordance with the findings reported Jagtap *et al*. (2013), Shinde *et al*. (2008), Kachave and Bhosale (2007) in Acid Lime, Yadav and Chaturvedi (2004) in ber, Dixit *et al*. (2013) in Litchi and Gaur *et al*. (2014) in guava.

Bio-Chemical and yield parameters of fruits

The perusal of data (Table 3) indicated that, application of plant growth regulators and Zinc were significantly affected the bio-chemical parameters of fruit. The maximum ascorbic acid (32.00 mg/100 g), TSS (8.33°Brix), TSS:acid ratio (1.30) and minimum acidity (6. 42 %) were recorded with foliar spray of T_{14} (NAA 200 ppm + GA_3 100 ppm + Zinc 1.0%). This might be due the facts that Zinc and NAA helpful in process of photosynthesis which leads to the accumulations of oligosaccharides and polysaccharides in higher amount besides this also regulators the enzymatic activity and the enzymes that metabolize the carbohydrates into simple sugars, thereby increase in sugars and TSS and reduced acidity of fruit (Ilyas *et al*., 2015). These results are also agreement with the findings of Debaje *et al*. (2011) and Jain *et al*. (2014) in Nagpur Mandarin and Kumar *et al*. (2015) in guava. Various yield parameters of fruit were also significantly affected by application of plant growth regulators and zinc. Maximum number of fruits per plant (976.33), fruit weight (39.07 g) and yield per plant (38.10 kg) were observed with foliar spray of T_{14} (NAA 200 ppm + GA_3 100 ppm + Zinc 1.0%) while, minimum number of fruits per plant (743.00), average fruit weight (27.67 g) and yield per plant (20.56 kg) were recorded in control (Table 2). An increase in fruit yield/tree might be due to more availability of gibberellic acid. Gibberellic acid promotes cell elongation, cell enlargement, increase in number of cells and also helps in increasing fruit volume, diameter and weight ultimately the fruit yield per tree was obtain maximum. The other possible reason might be combination effect of NAA and zinc increased vegetative growth as well as increasing chlorophyll content of leaves which might have resulted in the synthesis of more photosynthates and their translocation to the fruit which may have increased the yield attributes to the fruits (Razzaq *et al*., 2013). These results are more or less in conformity with the findings reported by Kachave and Bhosale (2007), Thirugnanavel *et al*. (2007), Shinde *et al*. (2008), Devi *et al*. (2011), Debaje *et al*. (2011), Singh *et al*. (2011) and Jagtap *et al*. (2013).

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