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Role of plant growth regulators on vegetative growth, yield and quality of sweet orange (*Citrus sinensis* L.) cv. Sathgudi

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Abstract
A field experiment was carried out to study the "Role of plant growth regulators on vegetative growth, yield and quality of sweet orange cv. Sathgudi at Horticulture Research Station, Konda Mallepally, Nalgonda Dist. during 2017 to 2019. Experimental findings revealed that, among the growth regulators, NAA 100 ppm recorded maximum plant height (303.33 cm), girth (47.0 cm), canopy spread North-South (362.67 cm), number of fruits/tree (324.67), average fruit weight (177.33 g), yield (57.00 kg/tree) and TSS (8.57 ºBrix) compared to control and other treatments. From the results, it can be concluded that of exogenous application of plant growth regulators like NAA and 2,4-D showed influence on sweet orange in growth, yield and quality.

Keywords: Growth regulators, NAA, GA_3, yield, sweet orange, Sathgudi

Introduction
Sweet orange is an important citrus crop grown in India. It is mainly cultivated in Maharashtra, Andhra Pradesh, Telangana, Karnataka, Punjab, Haryana and Rajasthan. In India citrus is grown in an area of 1.26 lakh ha with a production of 21.1 lakh tonnes and productivity of 16.7 t/ha. Sweet orange flowers throughout the year in three distinct seasons *viz.*, Ambe bahar, Mrig bahar and Hasta bahar. Due to continuous flowering and heavy crop load coupled with dry and arid conditions during post bloom stages in Telangana State, there is a problem of flower and fruit drop at various stages of fruit development leading to reduction in total yield. In Telangana, it is estimated that, the fruit drop in sweet orange commences from January to May during hot summers. The plant growth regulators actively regulate the vegetative growth and development by increasing the metabolism of cells thus improving the flowering and yield. There is great influence of exogenous application of plant growth regulators like GA_3 and 2,4-D in sweet orange plants by improving juice quantity, TSS, total sugars (Saleem *et al*., 2007) [9]. Application of plant growth regulators like NAA and GA_3 significantly improved fruit weight in sweet orange (Ghosh *et al*., 2012) [3]. Taking into consideration of above facts present experiment was designed to study the role of plant growth regulators on vegetative growth, yield and quality of sweet orange.

Materials and Methods
The present investigation was conducted from 2017-19 at the experimental orchard of Horticulture Research Station, Konda Mallepally, Nalgonda on fifteen years old trees of Sathgudi sweet orange budded on Rangpur lime rootstock. The experiment was laid out in randomized block design (RBD) in three replications and ten treatments. The treatments consisted of T_1 - Control (Without growth regulators), T_2 - 2,4-D 20 ppm, T_3 - 2,4 - D 30 ppm, T_4 - 2,4 - D 40 ppm, T_5 - NAA 50 ppm, T_6 - NAA 100 ppm, T_7 - NAA 150 ppm, T_8 - GA_3 50 ppm, T_9 - GA_3 100 ppm, T_{10} - GA_3 150 ppm. Spraying of plant growth regulators was done during the first and last week of October every year. Fruit samples were collected in the last week of August. The observation on plant height, girth, canopy spread, number of fruits per tree, average fruit weight and yield (kg/tree) were recorded. The total soluble solids of the pulp for each treatment were recorded with the help of had refractometer of 0-30 (^{0}Brix) range and expressed as per cent total soluble solids of the fruit (A.O.A.C. 1960) [1]. The acidity was determined by diluting the known volume of clear juice, filtered through a muslin cloth, with distilled water and titrating the same against standard sodium hydroxide solution, using phenolphthalein indicator.

The result was expressed in terms of citric acid as per cent total titratable acidity of the fruit juice according to the method given in (A.O.A.C. 1960) [1]. Ascorbic acid was estimated by 2, 6 dichlorophenol dye method (Ranganna. 1977) [8].

Results and Discussion

Vegetative parameters

The data depicted in table 1. revealing that there is significant difference among growth regulators with respect to vegetative growth parameters. Among plant growth regulators maximum plant height (303.33 cm), girth (47.00 cm) and canopy spread (NS) (362.67 cm) were recorded with application of NAA 100 ppm which was at with application of NAA 50 ppm. Whereas, minimum plant height (213.33 cm) and plant girth (28.00 cm) was registered in untreated control. This might be due to the cell enlargement and stem elongation in plants sprayed with NAA. However, plant growth regulators were not significantly differed with respect to canopy spread in East-west direction.

Table 1: Effect of growth regulators on vegetative growth parameters in sweet orang cv. Sathgudi.

Treatments	Plant height (cm)	Plant girth (cm)	Canopy spread	
			North – South (cm)	East -West (cm)
T_1: Control	213.33^c	28.00^c	229.33^c	303.00
T_2: 2,4-D 20 ppm	238.00^b	34.00^b	256.00^c	250.00
T_3: 2,4 – D 30 ppm	227.00^b	33.67^b	320.67^a	308.33
T_4: 2,4 – D 40 ppm	232.67^b	36.67^b	255.00^c	264.33
T_5: NAA 50 ppm	256.67^b	42.33^a	330.67^a	348.33
T_6: NAA 100 ppm	303.33^a	47.00^a	362.67^a	355.00
T_7: NAA 150 ppm	234.67^b	36.00^b	304.67^b	311.00
T_8: $GA_3$50 ppm	207.67^c	35.00^b	291.33^b	249.33
T_9: $GA_3$100 ppm	231.00^b	34.00^b	256.33^c	253.33
T_{10}: $GA_3$150 ppm	239.33^b	35.67^b	308.67^b	281.00
SE (m)	13.99	1.80	15.58	25.42
CD (0.05)	41.90	5.41	46.66	N.S

The similar increase in vegetative growth was earlier reported by Ghosh *et al*., (2012) [3] in sweet orange trees applied with NAA. Davies (1987) [2] stated that, NAA belongs to artificial forms of Auxins. Auxins show main role in cell elongation, cell division, vascular tissue, differentiation, apical dominance, leaf senescence and fruit abscission. The increase in plant height, stem girth and canopy of Sathgudi sweet orange might be due to that elongation that happened in cell which leads to shoot elongation ultimately resulted in increase of vegetative growth with NAA foliar application.

Yield parameters

The data presented in Table 2 show that the number of fruits per tree, average fruit weight (g) and yield (kg/tree) was significantly influenced by different concentrations of NAA, 2,4-D and GA_3. The maximum number of fruits was observed in T_6- NAA 100 ppm (324.67 fruit/tree) followed by T_{10}-GA_3 150 ppm (252.00 fruit/tree). While the maximum average fruit weight (g) was founding T_6-NAA 100 ppm (177.33g) and minimum was recorded T_1 (150.33g) similarly yield was recorded T_6-NAA 150 ppm (57.00 kg/tree) and minimum yield was recorded T_1 (28.67 kg/tree) in control respectively. The maximum number of fruits per tree and yield per plant was obtained with spray of NAA 100 ppm might be attributed to external application of growth regulators which prevented the formation of abscission layer. The results of present investigation are in conformation with the findings of (Ingle *et al*., 2001) [4] in Nagpur Mandarin and (Ghosh *et al*., 2012) [3] in Sweet orange. The higher level of auxins in plant and fruit found helpful in mobilization of food material and nutrients, thus increasing the fruit yield in sweet orange.

Table 2: Effect of growth regulators on yield parameters in sweet orange cv. Sathgudi

Treatments	No. of fruits / tree	Avg. fruit weight (g)	Yield (kg / tree)
T_1: Control	198.00^d	150.33^c	28.67^d
T_2: 2,4-D 20 ppm	208.00^c	162.67^b	41.67^b
T_3: 2,4 – D 30 ppm	198.33^d	154.00^b	31.33^d
T_4: 2,4 – D 40 ppm	242.00^b	160.00^b	37.00^c
T_5: NAA 50 ppm	251.33^b	159.67^b	43.33^b
T_6: NAA 100 ppm	324.67^a	177.33^a	57.00^a
T_7: NAA 150 ppm	215.67^c	164.33^b	54.33^a
T_8: $GA_3$50 ppm	200.67^c	173.67^a	54.67^a
T_9: $GA_3$100 ppm	203.33^c	173.33^a	53.00^a
T_{10}: $GA_3$150 ppm	252.00^b	161.00^b	41.67^b
SE (m)	8.10	3.85	1.52
CD (0.05)	24.27	11.54	4.57

Increase in yield may also be attributed to the elevated concentrations of NAA mediated synthesis of polygalacturonase enzymes, which result in the drop of fruits, as the number of fruit decreases, the individual weight and size of the fruit increases due to normal load sharing and that happened exactly for plants kept under control as there was less number of fruits so the weight of individual fruits increased. This may be due to the immediate absorption of auxins, which might have increased the endogenous auxin level that resulted in cell elongation which accelerated the development of fruits. Increase in fruit weight might be attributed to the exogenous supply of NAA which might have helped in strengthening of the middle lamella and consequently cell wall and might have increased the mobilization of food materials and minerals from another part of the plant towards developing fruits that are extremely active metabolic sink which, in turn, could have increased the fruit weight. These results conformed with the findings of (Kaur *et al*., 2005) [6] in Kinnow mandarin and (Katiyar *et al*., 2008) [5] in guava.

Quality parameters

The data in respect of quality parameters was presented Table 3 which revealed that the application of different treatments significantly increased the percent juice content and TSS of the fruit. The treatment T_6-NAA 100 ppm recorded the maximum juice percent (45.67%) and TSS content of fruit (8.57 ^{0}Brix). In respect to acidity, different treatments significantly affected the acidity percent in juice. The treatment T_1 – control and T_4-2,4-D 30 ppm recorded the lowest acidity (0.67%).

Table 3: Effect of growth regulators on quality parameters in sweet orange cv. Sathgudi

Treatments	Juice (%)	TSS (^{0}Brix)	Acidity (%)	Ascorbic acid (mg /100 ml)
T_1: Control	40.50^b	7.97^b	0.67^b	70.50
T_2: 2,4-D 20 ppm	44.17^a	7.87^b	0.72^b	73.00
T_3: 2,4 – D 30 ppm	42.17^b	8.15^a	0.81^a	72.67
T_4: 2,4 – D 40 ppm	41.33^b	8.47^a	0.67^b	72.00
T_5: NAA 50 ppm	44.00^a	8.44^a	0.69^b	72.33
T_6: NAA 100 ppm	45.67^a	8.57^a	0.72^b	72.17
T_7: NAA 150 ppm	39.00^c	8.43^a	0.76^a	72.33
T_8: $GA_3$50 ppm	39.67^b	8.45^a	0.70^b	71.00
T_9: $GA_3$100 ppm	43.67^a	8.17^a	0.69^b	71.67
T_{10}: $GA_3$150 ppm	41.33^b	8.16^a	0.78^a	73.33
SE (m)	1.05	0.14	0.02	1.07
CD (0.05)	3.15	0.44	0.07	N.S

Ascorbic acid content was found to be non-significant among all the treatments. The increase in TSS might be due to its action on converting the complex substance into simple ones, which enhances the metabolic activity of fruits. The increase in TSS and sugars due to the application of NAA in the present investigation might be due to its action on converting complex substances (starch) into simpler ones (sugar) through higher respiration and carbon assimilation activity. The quick metabolic transformation of starch into soluble sugars and early ripening in response to growth substance lead to an increase in TSS. Similar findings were observed in guava by Yaday *et al*., (2001) [11]. The above results of the present investigations are in close agreement with the reports of Manish *et al*., (2018) [7] in guava and Sweety *et al*., (2018) [10] in sweet orange.

Conclusion

Based on the above results, it can be concluded that, to increase vegetative growth, yield and quality of sweet orange cv. Sathgudi NAA 100 ppm sprayed twice, first and last week of October was found promising.

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