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Effect of plant growth regulators on growth, yield and quality of sweet orange [*Citrus sinensis* (L.) Osbeck] CV. Phule Mosambi

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Abstract
An investigation on "Effect of plant growth regulators on growth, yield and quality of sweet orange [*Citrus sinensis* (L.) Osbeck] cv. Phule Mosambi" was carried out at Horticultural Research Farm, Anand Agricultural University, Anand, during March to October, 2018. The growth attributing characters like incremental plant height (8.17 cm), plant spread N-S (8.33 cm) and E-W (8.17 cm) were obtained maximum with $GA_3$100 mg/l. NAA 100 mg/l and NAA 150 mg/l significantly increased fruit retention (68.67%). The maximum number of fruits per plant (184.67) and yield per plant (42.47 kg) recorded with NAA 150 mg/l. The quality parameters like juice content (48.62%) and ascorbic acid (40. 67 mg/100 ml juice) were found maximum with GA_3 100 mg/l. The significantly higher TSS (10.00˚Brix) and lower acidity (0.47%) were recorded with 2, 4-D 30 mg/l. The maximum reducing sugar (4.48%) was obtained with GA_3 150 mg/l. Application of NAA 100 mg/l gave maximum non reducing sugar (3.11%) and total sugar (7.14%) than control.

Keywords: Sweet orange, plant growth regulators, growth, yield and quality

Introduction
Citrus fruits rank second in area and third in production in India (Anonymous, 2019). Sweet orange [*Citrus sinensis* (L.) Osbeck] is a subtropical fruit, belongs to family Rutaceae and sub family Aurantioideae. Sweet Orange is native of Southern China. It is now widely distributed and naturalized in sub tropical zone of India. In India, sweet orange occupies an area of 185 thousand hectares and production of 3266 thousand MT has been achieved with a productivity of 17.6 metric tonnes ha^{-1} (Anonymous, 2019) [1].
The citrus productivity depends on various factors, among these the plant growth regulators holds a prime position. The use of plant growth regulators has become an important component in the field of citriculture because of the wide range of potential roles they play for increasing the productivity of crop per unit area. Plant growth regulators have been used in citrus fruit production for influencing flowering, fruit set, reducing fruit drop and play a major role in fruit growth and abscission. These regulators have also been used to influence fruit quality factors like juice quality and to improve total soluble solids in different citrus species (Bons *et al*., 2015) [2]. The plant growth regulator 2, 4-D play a vital role in checking pre harvest fruit drop and ultimately increasing yield without adversely affecting the fruit quality (Kaur *et al.,* 2000) [8]. GA_3 increases the fruit length, fruit diameter, fruit weight ultimately the yield was increased (Shinde *et al*., 2008) [13]. NAA checking the fruit drop and increasing the fruit retention and increasing the fruit weight and TSS of the fruit (Ghosh *et al*., 2012) [5].

Materials and Methods
The experiment was laid out in Completely Randomized Design replicated thrice with ten treatments at Horticultural Research Farm, Anand Agricultural University, Anand, Gujarat during March to October, 2018. The treatments consisted different concentrations of plant growth regulators *viz*., T_1: NAA 100 mg/l, T_2: NAA 150 mg/l, T_3: NAA 200 mg/l, T_4: GA_3 50 mg/l, T_5: GA_3 100 mg/l, T_6: $GA_3$150 mg/l, T_7: 2, 4-D 10 mg/l, T_8: 2, 4-D 20 mg/l, T_9: 2, 4-D 30 mg/l and T_{10}: control. Plant growth regulators were applied as foliar application as per treatments on trees by foot sprayer. First spray was given on 19th March 2018 (at pea stage of the fruit) and second spray was applied one month after first spray. The data collected for different observations were subjected to statistical analysis of variance technique as described by Panse and Sukhatme (1967) [11].

Result and Discussion

Growth parameters

The data pertaining to growth parameters clearly indicated that the sweet orange trees showed different response towards the plant growth regulators treatments. The foliar application of GA_3 100 mg/l (T_5) found significantly higher in respect to incremental plant height (8.17 cm), plant spread N-S (8.33 cm) and E-W (8.17 cm).

The increase in plant height by GA_3 might be due to it stimulates rapid cell elongation in part to the activation of intercalary meristematic region of the growing shoots and also increases inter nodal length of the branches. The increase in plant spread might be due to the beneficial effect of GA_3 with proper amount which increases uptake of water and nutrients and there by favour better development of plants resulting in more number of branches per plant and ultimately the greater plant spread. Similar types of observations were obtained by Dwivedi *et al.* (2018) [3] and Singh *et al.* (2018) [12] in Kinnow mandarin.

Table 1: Effect of plant growth regulators on growth of sweet orange cv. Phule Mosambi

Tr. No.	Treatments	Incremental plant height (cm)	Incremental plant spread N-S (cm)	Incremental plant spread E-W (cm)
T_1	NAA 100 mg/l	6.83	7.33	7.17
T_2	NAA 150 mg/l	7.33	7.50	7.50
T_3	NAA 200 mg/l	7.00	7.67	6.50
T_4	GA_3 50 mg/l	7.83	8.17	7.83
T_5	GA_3 100 mg/l	8.17	8.33	8.17
T_6	GA_3 150 mg/l	7.67	7.67	7.67
T_7	2, 4-D 10 mg/l	6.00	6.83	6.67
T_8	2, 4-D 20 mg/l	6.50	7.33	6.33
T_9	2, 4-D 30 mg/l	6.67	6.83	5.83
T_{10}	Control	5.67	6.00	5.17
	S.Em±	0.42	0.38	0.50
	CD (0.05)	1.24	1.13	1.47
	CV%	10.48	9.02	12.51

Yield parameters

The results of yield attributing parameters (Table 2) revealed that application of NAA 100 mg/l (T_1) and NAA 150 mg/l (T_2) significantly increased fruit retention (68.67%). Increasing fruit retention by exogenous application of auxin can be attributed making up of auxin and preventing the formation of abscission layer and thus increasing fruit retention. Similar beneficial effect of NAA on fruit retention was also recorded by Ghosh *et al.* (2012) [5] and Manju and Rawat (2015) [9] in sweet orange.

The maximum number of fruits per plant (184.67) and yield per plant (42.47 kg) recorded with treatment T_2 *i.e.* NAA 150 mg/l than control. Higher number of fruits per plant might be due to the beneficial role of plant growth regulators application in reducing fruit drop. Due to increase in number of fruits per tree and weight of individual fruit, there was significant increase in yield per tree. Similar observations were also noted by Sweety *et al.* (2018) [14] in sweet orange and Jagtap *et al.* (2013) [6] in acid lime.

While, effect of different plant growth regulators on fruit weight and volume were found non–significant because of five fruits was selected in each plant for weight and volume and may be more or less equal and hence statistical value was found non-significant.

Table 2: Effect of plant growth regulators on yield of sweet orange cv. Phule Mosambi

Tr. No.	Treatments	Fruit retention (%)	Number of fruits per plant	Fruit yield per plant (kg)	Weight of Fruit (g)	Fruit volume (cc)
T_1	NAA 100 mg/l	68.67	178.23	40.44	225.79	219.50
T_2	NAA 150 mg/l	68.67	184.67	42.47	229.30	224.50
T_3	NAA 200 mg/l	63.67	167.67	37.63	226.44	222.83
T_4	GA_3 50 mg/l	62.67	177.20	40.01	224.43	223.33
T_5	GA_3 100 mg/l	63.33	180.17	41.59	230.27	227.00
T_6	GA_3 150 mg/l	61.33	162.77	35.13	216.97	220.50
T_7	2, 4-D 10 mg/l	66.00	178.53	41.03	227.70	219.83
T_8	2, 4-D 20 mg/l	63.33	163.83	34.89	215.76	217.83
T_9	2, 4-D 30 mg/l	62.00	158.00	32.46	210.09	210.33
T_{10}	Control	48.00	137.63	29.96	211.53	210.00
	S. Em±	2.38	8.60	2.71	15.15	8.05
	CD (0.05)	7.023	25.36	8.00	NS	NS
	CV%	6.58	8.82	12.50	11.83	6.35

Quality parameters

The data (Table 3) indicated that treatment T_5 *i.e.* GA_3 100 mg/l gave maximum juice content (48.62%). It might be due to the essential role of plant growth regulators as mobilizers which preferentially direct the flow of nutrients and various organic metabolites from the other parts of the plants to the actively growing metabolic sinks. This result is in close conformity with those of Nawaz *et al.* (2008) [10] in Kinnow mandarin and Jain *et al.* (2014) [7] in Nagpur mandarin.

The higher TSS (10.00^0 Brix) was recorded in the treatment T_9 (2, 4-D 30 mg/l). Auxins have been known to be involved in synthesis of α-amylase which converts starch in sugars and consequently, increases osmotic pressure of the cell which results in accumulation of water and other solutes and increases TSS. The similar result was observed by Sweety *et al.* (2018) [14] in sweet orange, Kaur *et al.* (2000) [8] and Nawaz *et al.* (2008) [10] in Kinnow mandarin.

The minimum acidity (0.47%) was recorded in the treatment T_9 *i. e.* 2, 4-D 30 mg/l. Whereas, maximum acidity (0.70%)

was observed in control (T_1). The reduction in acidity directly related to metabolic changes with fast conversion of starch into sugars and their derivatives by Nawaz *et al.* (2008) [10] and Jain *et al.* (2014) [7].

The significantly higher reducing sugar (4.48%) was recorded with T_6 (GA_3 150 mg/l). The beneficial effect of GA_3 in increasing reducing sugar might be due to hydrolysis of complex polysaccharides into simple sugars and mobilization of carbohydrates from source to sink and ultimately results in increased reducing sugar. Similar results were reported by Jain *et al.* (2014) [7] in Nagpur mandarin.

The maximum non reducing sugar (3.11%) and total sugar (7.14%) were recorded in the treatment T_1 *i. e.* NAA 100 mg/l. The spraying of NAA might have influenced the physiological processes particularly increased accumulation of carbohydrates and breakdown of complex polymer into simple substance, which ultimately leads to accumulation of more dry matter and minerals due to more total sugars in fruits and increased in sugar conversion of reserved starch and other polysaccharides into soluble form of sugar. These findings are supported by the results obtained by Garasiya *et al.* (2013) [4] in guava.

A preview of the data indicated that sweet orange plants treated by $GA_3$100 mg/l (T_5) registered higher ascorbic acid (40. 67 mg/100 ml juice). The increase in ascorbic acid with gibberellic acid may be due to catalytic influence of gibberellic acid on its biosynthesis from its precursor glucose-6-phosphate or the inhibition of its conversion to dehydro-ascorbic acid by ascorbic acid or both. These observations are in close agreement with the reports of Jain *et al.* (2014) [7] in Nagpur mandarin, Shinde *et al.* (2008) [13] and Jagtap *et al.* (2013) [6] in acid lime.

Table 3: Effect of plant growth regulators on quality of sweet orange cv. Phule Mosambi

Sr. No.	Treatments	Juice (%)	TSS (°Brix)	Acidity (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	Ascorbic acid (mg/100 ml juice)
T_1	NAA 100 mg/l	47.11	8.67	0.59	4.03	3.11	7.14	32.20
T_2	NAA 150 mg/l	47.50	8.50	0.53	3.83	2.97	6.80	36.15
T_3	NAA 200 mg/l	44.22	9.83	0.57	3.63	3.10	6.73	38.98
T_4	GA_3 50 mg/l	47.17	9.50	0.55	4.25	2.47	6.72	38.41
T_5	GA_3 100 mg/l	48.62	9.17	0.51	4.37	1.98	6.35	40.67
T_6	GA_3 150 mg/l	46.26	9.67	0.53	4.48	2.34	6.82	33.33
T_7	2, 4-D 10 mg/l	43.22	9.50	0.55	4.39	2.45	6.84	34.46
T_8	2, 4-D 20 mg/l	44.09	9.67	0.61	4.04	2.26	6.30	34.46
T_9	2, 4-D 30 mg/l	42.91	10.00	0.47	4.17	2.39	6.56	38.98
T_{10}	Control	41.50	8.33	0.70	3.92	2.11	6.03	37.85
	S.Em±	1.13	0.34	0.04	0.13	0.12	0.13	0.93
	CD (0.05)	3.32	1.01	0.11	0.38	0.34	0.38	2.74
	CV%	4.31	6.37	11.92	5.41	7.97	3.37	4.40

Conclusion

From the results it can be concluded that application of plant growth regulators exhibited beneficial effect on growth, yield and quality of sweet orange. The application of NAA 150 mg/l was found better in improving fruit retention, number of fruits per plant and fruit yield per plant. Whereas, $GA_3$100 mg/l was found superior for growth parameters as well as juice, ascorbic acid content of fruits. While, 2, 4-D 30 mg/l gave higher TSS and lower acidity.

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