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Effect of antitranspirants on growth and fruit parameters of sweet orange (*Citrus sinensis* (L.) Osbeck)

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Abstract
Climate change *i.e.* fall in temperature during flowering stage and rise during fruit development stage of Ambe bahar crop has great influence on flowering and fruiting patterns of sweet orange. As a measure to avoid fruit drop and sunburn, antitranspirants were sprayed in fortnightly intervals during the dry spell of fruit development *i.e.* from March 15th to June 30th 2019. It was recorded that, highest plant height (2.69m) was recorded in plants sprayed with liquid paraffin @ 2% whereas, highest canopy spread (3.97 m) and canopy volume (40.71 m^3) were recorded in plants sprayed with kaolin @ 1%. Fruit weight (202.83g), fruit volume (224 cm^3), fruit yield per tree (46.13 kg) fruit yield per ha (12.68 t/ha) were recorded highest with plants sprayed with liquid paraffin @ 1%. Highest juice percent (50.67%) was recorded with liquid paraffin @ 2% and lowest percent fruit drop (4.34%) in plants sprayed with cycocel @ 1000 ppm.

Keywords: Antitranspirants, citrus, climate change, fruit and growth

Introduction
Sweet orange (*Citrus sinensis* (L.) Osbeck), an important group of citrus is produced all over the world. World production was estimated to be 47.5 million tonnes. In India, it is grown over an area of 190 thousand hectares with a production of 3, 401 thousand MT constituting about 38.6% of total citrus production. Andhra Pradesh ranks first in production with 2003.11 thousand MT from an area of 82.89 thousand ha followed by Maharashtra, Punjab, Madhya Pradesh and Gujarat (3rd Advanced estimates of NHB 2018-2019). It has a productivity of 24.17 t/ha. Sathgudi is the choicest variety of sweet orange which is grown in many districts of Andhra Pradesh.

Climate change is influencing weather in many ways. In India, it is responsible for drought and temperature rise which will drastically bring down the production, if we don't initiate other possibilities to increase water use efficiency to cope up with water stress conditions.

One of the major problems due to changing climate reported by Barber and Sharpe (1971) [3] was sunburn - a physiological disorder in citrus caused by excess light and high fluctuation densities of solar radiation that affect the natural defense systems of plants, causing commercial losses of fruits. Sunburned fruit is discolored and exhibits varying degrees of cell death. It is particularly problematic in arid and semi-arid regions and has been attributed to the combination of visible light and high temperatures. It is well established that, chemical reflectants and kaolin sprays can reduce sunburn in sensitive fruits Weerakkody *et al.* (2010) [20]. Mishra *et al.* (2016) [13], reported that, in addition to those chemical reflectants, antitranspirants can be used to minimize water loss in times of drought or heat stress. However, the physiological impacts and interactions of these compounds on citrus have not been studied thoroughly.

Materials and Method
This investigations, was conducted at the experimental field of Citrus Research Station, Tirupati, Department of Fruit Science, Dr. Y.S.R. Horticultural University, in Chitoor District (Location-1) and also at farmer's field of Railway Kodur in Kadapa District, (Location-2) of Andhra Pradesh during the year 2018 to 2019. The experiment was conducted in randomized block design with nine treatments, three replications and two trees for each replication.

The experiment involved following ten treatments
A1 Cycocel 1000 ppm
A2 Cycocel 2000 ppm
A3 Salicylic Acid 500 ppm
A4 Salicylic Acid 1000 ppm
A5 Kaolin 1%
A6 Kaolin 2%
A7 Liquid Paraffin 1%
A8 Liquid Paraffin 2%
A9 Farmers Practice: Urea @ 1% spray followed by Quick lime @ 2% spray at 15 days interval

These treatments are imposed at fortnightly intervals during the dry spell of fruit development. So, the treatments were imposed from March 15th 2019 to June 30th 2019.

Fruit characters
Fruit weight (g)
The weight of five fruits per tree was recorded using digital electronic balance (Adventurer TM) and the average was presented in grams.

Fruit size at harvest
Length (mm)
The length of five fruits per tree from stalk end to blossom end was recorded using digital vernier callipers and the average was presented in mm.

Diameter (mm)
The diameter of five fruits per tree was recorded at the maximum width of the fruit at its middle point using digital vernier callipers and the average was expressed in mm.

Fruit volume (m^3)
Fruit volume is measured with water displacement method. Volume of water displaced is equal to the volume of fruit displacing it and average volume of 10 fruits was worked out.

Rind thickness (mm)
The rind thickness of five fruits per tree was recorded at the equatorial area using digital vernier calipers after the transverse cut and the average was expressed in mm.

Juice percent (%)
The content of juice was calculated in percentage of juice present in endocarp of five fruits per tree in relation to fruit weight and the average was expressed in percent.

Percent fruit drop before harvest (%)
For calculating fruit drop percentage, number of fruits was counted and recorded before treatment application and again the number of fruits was counted before removing the fruits for sampling which gives fruit retention percentage and this value was subtracted from 100%. Fruit drop percentage was calculated using the following formula:

$$\text{Percent fruit drop (\%)} = \frac{\text{Total fruits at final count before sampling}}{\text{Total fruit count before application}} \text{ X } 100$$

Fruit yield per tree (kg/tree): The fruits harvested from each tree and in each replication were weighed and averaged to get fruit yield. It was expressed in kilograms.

Fruit yield (t/ha)
The yield per tree is converted to yield per hectare by multiplying with plant population accommodated in one hectare and expressed in tonnes.

Number of fruits per tree
The number of fruits from three trees was counted and the average was presented.

Growth parameters
Highest tree height (2.69m) was recorded with liquid paraffin @ 2% and lowest (2.21 m) was recorded with cycocel @ 1000ppm application. Canopy spread over the two locations was found highest (3.97 m) in plants that were sprayed with kaolin @ 1% which was at par with almost all the treatments and lowest (3.46 m) was noticed in plants that were sprayed with cycocel @ 2000 pmm. Canopy volume was found highest (40.71 m^3) in plants that were sprayed with kaolin @ 1% and lowest (25.15 m^3) in plants that were sprayed with cycocel @ 1000 ppm.
These results are in agreement with Patil *et al.* (1987) [16] who worked on mosambi under severe drought conditions and observed better tree growth consequent to application of polythene mulch followed by PMA and kaolinite 6%. Abd EL Kader *et al.* (2006) [1] also recorded that spraying antitranspirants increased growth parameters. Similar results were obtained by El Abd (1996) [7] on citrus, Naiema (1989) [14] on Anna apple and Sultani fig tree, Ranney *et al.* (1989) [17] on cherry trees. Hazarika and Parthasarathy, (2002) [11] reported that antitranspirants were successful in delaying plant water stress and increasing relative growth rate.

Fruit characters
Fruit weight (g)
The maximum fruit weight at (202.83) was observed in plants that were sprayed with liquid paraffin @ 1% and minimum (161.66 g) in plants that were treated with salicylic acid @ 500 ppm.

Fruit size at harvest
Fruit length at harvest (cm)
Fruit length at harvest was maximum (6.72 cm) in plants that were applied with cycocel @ 1000 ppm and minimum (5.73 cm) in plants that were applied with salicylic acid @ 500 ppm.

Fruit diameter at harvest (cm)
The maximum fruit diameter at harvest (6.94 cm) was recorded in plants that were sprayed with liquid paraffin @ 1% while the minimum (5.84 cm) in plants that were applied with salicylic acid @ 500ppm.
According to Davenport *et al.* (1990) [4] it is not only the photosynthates and minerals but also an adequate moisture status of leaves which contribute to the growth of a shoot and fruit which is quite evident from the present investigation.

Fruit volume (cm^3)
The maximum fruit volume (224 cm^3) was recorded in plants that were sprayed with liquid paraffin @ 1% whereas the minimum (160 cm^3) was recorded in farmer's practice of spraying urea @ 1% followed by quick lime @ 2% at 15 days interval.

Rind thickness (mm)
Maximum rind thickness (5.69 mm) was recorded in fruits which were sprayed with cycocel @ 2000 ppm whereas; the

minimum value (2.80mm) was noticed in plants that were sprayed with salicylic acid @ 500 ppm.

On examination of results, it is evident that there exists a relationship between fruit growth and rind thickness. Increasing the fruit growth leads to reduction in rind thickness and *vice versa*, this shows that, increase in rind thickness during drought conditions is at the expense of pulp development. This phenomenon was found in almost all the treatments. If there was sufficient moisture present in plants then there is better growth of both pulp and rind of fruits.

Juice percent (%)

Juice percent in two locations was recorded maximum (50.67%) in plants sprayed with liquid paraffin @ 2% while minimum (40.07%) in farmers practice of spraying urea @ 1% followed by quick lime @ 2% at 15 days interval.

Fruit drop before harvest (%)

Spraying cycocel @ 1000 ppm recorded lowest percent fruit drop (4.34%) and farmer's practice of spraying urea @ 1% followed by quick lime @ 2% at 15 days interval had highest (13.29%) percent fruit drop before harvest.

El-Antably (1976) [8] reported that, lower concentration of CCC resulted in increasing auxin contents which reduced the abscission. These results are in conformation with the experiments done by Gonzales and Borroto (1987) [9] in Valencia orange, Lakshmi *et al.* (2014) [12], Deshmukh *et al.* (2015) [6] and Debbarma and Hazarika (2016) [5] in Acid lime.

Fruit yield per tree (kg)

Fruit yield per tree was highest (46.13 kg) in plants that were sprayed with liquid paraffin @ 1% and lowest (18.46 kg) in plants that were treated with urea @ 1% followed by quick lime @ 2% at 15 days interval.

Saleh *et al.* (2006) [1] reported that, antitranspirants improved yield (kg/tree) and recorded the maximum number of fruits and yield per tree for 'Washington navel orange' and 'Succary orange' tree.

Number of fruits per tree

Highest number of fruits (370.16) was recorded in plants that were sprayed with liquid paraffin @ 2% and the lowest number of fruits (144.66) was recorded in plants sprayed with salicylic acid @ 1000 ppm.

Selah *et al*. 2006 reported that kaolin spray @ 4% once at early March has improved yield as the maximum number of fruits and yield per tree by about 35.4% and 27.5% for Washington navel orange and by 25.9% and 36.9% for 'Succary orange' tree in the first and second seasons, respectively. Gullo *et al.* (2020) [10] reported that, total average yield per tree over two years was 25% higher in kaolin treated plants.

Fruit yield (t/ha)

Highest fruit yield (12.68 t/ha) was recorded in plants that were sprayed with liquid paraffin @ 1% and the lowest (5.49 t/ha) fruit yield was recorded in plants sprayed with salicylic acid 1000 ppm. These results are in line with Saleh *et al.* (2006) [1] on Washington navel Succary orange tree, Abd El-Nasser (1993) and Shabaan *et al.* (1989) [19] in Jaffa and Balady orange.

Table 1: Effect of antitranspirants on growth parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Tree height (m)			Canopy spread (m^2)			Canopy volume (m^3)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled
A1	2.30	2.12	2.21	3.71	3.49	3.60	27.13	15.71	21.74
A2	2.70	2.17	2.43	3.37	3.55	3.46	35.65	15.59	23.93
A3	3.12	2.16	2.64	4.06	3.28	3.67	57.58	15.07	32.25
A4	2.71	2.18	2.44	3.91	3.67	3.79	45.70	14.38	28.22
A5	2.58	2.18	2.38	4.42	3.52	3.97	51.58	15.94	32.33
A6	3.00	2.18	2.59	4.58	3.31	3.94	68.93	15.31	37.72
A7	3.04	2.21	2.63	3.94	3.34	3.64	53.85	15.38	32.35
A8	3.17	2.21	2.69	4.29	3.35	3.82	65.58	14.24	34.98
A9	3.04	2.21	2.63	4.29	3.30	3.80	67.96	13.88	36.85
SE(m)+	-	-	0.089	0.18	0.06	0.10	0.47	-	0.59
CD	NS	NS	0.26	0.54	0.18	0.31	1.43	NS	1.78
Min	2.30	2.12	2.21	3.37	3.28	3.46	27.13	13.88	21.47
Max	3.17	2.21	2.69	4.58	3.67	3.97	68.93	15.59	37.72

Table 2a: Effect of antitranspirants on fruit parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Fruit weight (g)			Fruit length at harvest (cm)			Fruit diameter at harvest (cm)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled
A1	173.00	175.33	174.16	5.67	5.78	5.73	6.23	6.31	6.27
A2	170.33	179.33	174.83	6.01	6.13	6.07	6.16	6.21	6.19
A3	154.66	168.66	161.66	5.65	5.80	5.73	5.83	5.85	5.84
A4	161.66	177.66	169.66	5.81	5.86	5.84	6.16	6.21	6.19
A5	194.00	181.33	187.66	5.85	5.95	5.90	5.90	5.87	5.89
A6	165.66	185.00	175.33	5.74	5.78	5.76	6.23	6.26	6.25
A7	200.00	205.66	202.83	6.68	6.76	6.72	6.93	6.95	6.94
A8	160.33	182.33	171.33	6.21	6.48	6.35	6.26	6.33	6.30
A9	164.00	168.66	166.33	5.86	5.96	5.91	6.20	6.07	6.14
SE(m)+	5.41	5.40	4.73	0.14	0.17	0.13	0.13	0.08	0.08
CD	16.36	16.34	14.32	0.44	0.51	0.40	0.40	0.25	0.26

Min	154.66	168.66	161.66	5.65	5.78	5.73	5.83	5.85	5.84
Max	200.00	205.66	202.83	6.68	6.76	6.72	6.93	6.95	6.94

Table 2b: Effect of antitranspirants on fruit parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Fruit volume (cm^3)			Rind thickness (mm)			Juice percent (%)			Fruit drop percent (%)		
	Experimental locations			Experimental locations			Experimental locations			Experimental locations		
	Location-1	Location-2	Pooled	Location-1	Location-2	Pooled	Location-1	Location - 2	Pooled	Location - 1	Location - 2	Pooled
A1	173.33	169.33	171.33	4.42	4.40	4.41	41.08	44.22	42.65	4.52 (2.33)	4.15 (2.66)	4.34 (2.30)
A2	160.00	191.66	175.83	5.67	5.71	5.69	40.97	45.28	43.13	10.06 (3.31)	11.92 (3.59)	10.99 (3.46)
A3	158.66	166.33	162.50	2.70	2.89	2.80	41.48	44.84	43.16	9.25 (3.18)	5.67 (2.47)	7.46 (2.86)
A4	170.00	192.33	181.16	4.18	4.39	4.28	44.29	45.58	44.94	6.40 (2.71)	6.02 (2.64)	6.22 (2.67)
A5	189.33	176.00	182.66	4.43	4.54	4.48	44.89	49.86	47.38	8.37 (3.04)	8.53 (3.07)	8.45 (3.06)
A6	160.00	206.66	183.33	4.63	4.69	4.66	39.30	43.29	41.30	12.69 (3.68)	11.39 (3.51)	12.04 (3.60)
A7	210.00	238.66	224.33	3.23	3.51	3.37	41.85	44.89	43.37	6.47 (2.72)	5.66 (2.57)	6.06 (2.65)
A8	157.33	189.66	173.50	5.63	5.60	5.62	50.07	51.27	50.67	5.09 (2.46)	4.91 (2.42)	5.00 (2.44)
A9	157.00	163.00	160.00	3.16	3.37	3.27	39.65	40.49	40.07	13.71 (3.76)	12.87 (3.66)	13.29 (3.71)
SE(m)+	7.83	7.19	4.46	0.11	0.13	0.10	1.81	1.87	1.43	0.26	0.25	0.24
CD	11.08	21.74	13.50	0.35	0.39	0.30	5.48	5.65	4.34	0.79	0.77	0.73
Min	157.00	163.00	160.83	2.70	2.89	2.80	39.30	40.49	40.07	4.52 (2.33)	4.15 (2.66)	4.34 2.30
Max	210.00	238.66	224.33	5.67	5.71	5.69	50.07	51.27	50.67	13.71 (3.76)	12.87 (3.66)	13.29 (3.71)

Table 2c: Effect of antitranspirants on fruit parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Fruit yield per tree (kg)			Number of fruits per tree			Fruit yield (t/ha)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled	Location - 1	Location - 2	Pooled
A1	25.18	34.58	29.88	180.66	187.66	184.16	6.92	9.51	8.21
A2	33.60	31.61	32.61	136.66	166.33	151.50	9.24	8.69	8.96
A3	33.77	32.47	33.13	265.33	298.00	281.66	9.29	8.93	9.47
A4	19.01	23.02	21.01	136.00	153.33	144.66	5.23	5.75	5.49
A5	27.26	30.24	28.75	169.33	175.33	172.33	7.50	8.31	7.90
A6	23.73	25.28	24.51	156.00	163.66	159.83	6.52	6.95	6.74
A7	46.86	45.40	46.13	418.66	309.33	281.33	12.89	12.48	12.68
A8	38.10	39.58	38.84	253.33	321.66	370.16	10.47	10.88	10.68
A9	16.02	20.91	18.46	146.66	152.66	149.66	5.40	7.25	6.33
SE(m)+	2.47	1.62	1.44	27.81	6.29	11.86	0.63	0.51	0.38
CD	7.46	5.11	4.35	84.12	19.02	35.88	1.92	1.56	1.17
Min	16.02	20.91	18.46	136.00	152.66	144.66	5.23	5.75	5.49
Max	46.86	45.40	46.13	418.66	309.33	370.16	12.89	12.48	12.68

Conclusion

It can be concluded from the experiment that spraying liquid paraffin @ 1% every fortnightly interval has given good results for growth and fruit parameters.

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