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Effect of soil conditioners on growth and fruit parameters of sweet orange (*Citrus sinensis* (L.) Osbeck) in Andhra Pradesh

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Abstract
The investigation on effect of soil conditioners in sweet orange (*Citrus sinensis* (L.) Osbeck) was conducted in Rayalaseema area of Andhra Pradesh. The treatments include soil conditioners like Pusa hydrogel, Zeba hydrogel, organic and inorganic mulches. The plant growth parameters like plant height, canopy spread and canopy volume were maximum in plants that were applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant). Fruit parameters like fruit weight (220.33 g), fruit length (6.65 cm), rind thickness (4.79 mm), fruit yield per tree (66.63 kg) and number of fruits (428.66) were also maximum in fruits from the trees which were applied with 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant). Highest juice percent (61.28%) lowest fruit drop percent (1.06%) and highest fruit yield (18.31 t/ha) were recorded in 70% ER + Pusa gel @ 2 kg/acre (20 g/plant).

Keywords: Soil conditioners, orange, *Citrus sinensis* L.

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.

The three most common soil conditions that hinder plant growth and yield are low water retention capability, high evapotranspiration rate and soil moisture leaching. Apart from these, factors like unforeseen drought conditions, degradation, salination, overuse of synthetic fertilizers, pesticides and improper irrigation practices severely affect soil and plants, often rendering permanent damage to soil biota as well. Two different types of soil conditioners have been used in this research work i.e. hydrogels were compared against organic and inorganic mulches. The desirable characteristics for these hydrogels are high water absorption capacity in saline and hard water conditions, optimized absorbency under load (AUL), lowest soluble content and residual monomer, high durability and stability in the swelling environment and during storage, gradual biodegradability without formation of toxic substances, pH neutrality after swelling in water, photo stability and rewetting capability and also cost effective, whereas the main functions of the mulches are weed suppression, soil water conservation, moderation of soil temperature fluctuations (daily and seasonal), increased infiltration of water droplets from precipitation or irrigation, soil protection from traffic compaction, improved soil structure for organic mulches and the slow release of nutrients (Shirugure *et al.* 2003) and (Slathia and Paul, 2012) thereby maintaining the soil fertility. The requirement of water through mulch can further be reduced by using locally available organic materials as mulches. Continuous use of organic mulches are helpful in improving the physicochemical properties microbial flora and soil aeration (Rao and Pathak, 1998). Moreover, mulching with plastic polyethylene was found effective in conserving the soil moisture and increasing the growth, yield and quality in different citrus cultivars (Lal *et al.* 2003, Shirugure *et al.* 2005). Considering the beneficial effect of hydrogels and mulching, this investigation was undertaken to assess the effect of soil conditioners on sweet orange.

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 three replications and two trees for each replication. The experiment involved following ten treatments.

S_1 70% ER + ZEBA @ 5 kg/acre (45 g/plant)
S_2 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant)
S_3 70% ER + Pusa gel @ 2 kg/acre (20 g/plant)
S_4 70% ER + Pusa gel @ 4 kg/acre (40 g/plant)
S_5 Mulching with coconut husk (kg/plant basin)
S_6 Mulching with groundnut husk(kg/plant basin)
S_7 Mulching with 100 µ black polythene
S_8 Control

Plant height (m)
The height of a tree was measured with the help of a graduated flagstaff from the ground level to the tip of the highest shoot of the tree. The plant height was expressed as meters.

Canopy spread (m^2)
The spread of tree was measured in two directions *i.e.* North-South and East-West directions with the help of a graduated flag staff at a height where the spread was maximum. The spread in two directions was averaged to calculate the spread of the tree and was expressed in metre square.

Canopy volume (m^3)
Canopy volume was calculated according to Morse and Robertson, (1987). Canopy volume = 0.5236 × HD^2, Where H = tree height, D = tree diameter. The height of each selected tree was measured with the help of calibrated bamboo stick. For tree spread/canopy diameter (m) two observations, one each on East-West and North-South sides of selected trees were recorded.

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.

Results and Discussion
Growth parameters
Tree height (m)
Tree height was non-significant and it ranged between 2.91 m to 2.41 m. Canopy spread was also non-significant and the value ranged from 3.50 m^2 to 3.89 m^2. Canopy volume was found maximum (20.68 m^3) in plants that were applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant) while minimum (16.51m^3) in plants that were mulched with 100 µ black polythene.
Growth parameters did not show much difference among the treatments, but comparatively the trees were larger than the control. Abobatta and Khalifa (2019) [1] and Jalili *et al.* (2011) [4] reported that, application of hydrogel significantly improved the growth habit of fruit trees these results were supporting the results of the present research as the soil conditioners significantly improved the growth habit of plants. This might be due to the trees grown in soil mixed with hydrogel or soil covered with mulch under tree had more available water in soil, improving growth and producing large canopy volume. Soil conditioners also help to increase the capacity of soil cationic exchange and better absorption of water and nutrition along with lower weed intensity. The present results were in the same line with the findings of Max *et al*. (1992) [6] in Blueberry.

Fruit parameters
Fruit weight (g)
Fruit weight was recorded maximum (220.33 g) in plants that were applied with coconut husk as mulch which were at par (199.83 g) with those plants that were applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant) while minimum fruit weight (161.16 g) was recorded in fruits from the plants with no soil conditioners.

Size of fruit at harvest

Fruit length at harvest (cm)

Maximum and minimum fruit length were recorded as 6.65 cm in plants applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant) and 5.83 cm in soils of plants with no conditioners respectively.

Fruit diameter at harvest (cm)

Fruit diameter was highest 7.07 cm in plants mulched with coconut husk and lowest 5.92 cm in soils of plants with no conditioners.

Fruit volume (cm^3)

Fruit volume was highest (229.50 cm^3) in plants mulched with coconut husk and lowest (174.50 cm^3) in fruits from the plants with no soil conditioners.

These results are in accordance with the results of Abobatta and Khalifa (2019) [1] who reported that there was an increase in fruit volume significantly with increase in hydrogel concentration.

Rind thickness (mm)

Rind thickness was recorded highest (4.79 mm) in fruits from the trees which were applied with 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) whereas; the minimum value (2.76 mm) was noticed in fruits from the plants with no soil conditioners. These results were in agreement with Pattanaaik *et al*. (2015) [7, 8].

Juice percent (%)

Juice percent was highest 61.28% in plants applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) whereas, 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) had reported lowest juice percentage of 28.65%.

Water availability and high relative water content were responsible for high juice percent in fruits. As these same treatments were having high relative water content so that might be the reason to have high juice percent. These results are in accordance with the results given by Pattanaaik *et al*. (2015) [7, 8] in *Citrus limon*.

Fruit drop before harvest (%)

Fruit drop percent was lowest (1.06%) in plants applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) and mulching with coconut husk has highest (5.47%).

Fruit yield per tree (kg)

Fruit yield per tree was highest (66.63 kg) in plants treated with 70% ER + ZEBA @ 5 kg/acre (45 g/plant) and lowest 31.71 kg was in fruits from the plants with no soil conditioners.

Number of fruits per tree

Highest number of fruits (428.66) was recorded in plants that were applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant) and the lowest 177.66 were recorded in fruits from the plants with no soil conditioners.

Fruit yield (t/ha)

Highest Fruit yield (t/ha) 18.31 t/ha was recorded in plants that were applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) and the lowest yield 8.72 t/ha was recorded in plants with no soil conditioners.

These results showed that highest yield was recorded in trees that were treated with hydrogels followed by mulching.

Hydrogel increases yield due to increasing water availability as the soil was wet for a longer time, this increases the availability of nutrients, and also helps in reducing the fruit drop due to water stress, this agrees with the study of Pattanaaik *et al.* (2015) [7, 8] for the increased yield of *Citrus reticulata* and *Citrus limon* by the application of hydrogel and Barakat *et al.* (2015) [2] on Grand nain banana plants, who found that, increasing the amount of hydrogel increased flower number per shoot, fruit setting and yield (Kg/tree). These results are in conformation with Abobatta and Khalifa (2019) [1] in 'Washington Naval' orange and Costa *et al.* (2015) [3] in strawberry.

Mulching also have given good yields when compared to control this was due to mulch which helps root growth by maintaining relatively lower rhizosphere temperature, enhancing growth of beneficial macro and micro fauna, besides conserving moisture for a longer period. The results obtained here are in conformity with the results showed by Zaman *et al.* (1999) [11], Tu *et al*. (2003) [9] and Wang *et al*. (2014) [10]. They showed that high microbial biomass and activity often lead to high nutrient availability to crops, through enhancing both the microbial biomass turnover and the degradation of non-microbial organic materials.

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

Treatments	Tree height (m)			Canopy spread (m)			Canopy volume (m^3)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	2.41	2.74	2.57	4.25	3.55	3.84	20.58	17.72	20.68
S2	2.41	2.62	2.51	3.33	3.40	3.50	13.42	21.66	17.55
S3	2.62	2.79	2.71	4.13	3.45	3.89	19.05	18.18	18.40
S4	2.45	2.74	2.60	3.37	3.49	3.59	16.34	21.01	17.73
S5	2.45	2.72	2.59	3.65	3.41	3.78	15.23	19.22	17.47
S6	2.54	2.79	2.66	3.83	3.46	3.65	17.94	19.48	18.50
S7	2.21	2.78	2.49	3.33	3.39	3.53	14.56	18.61	16.51
S8	3.00	2.82	2.91	3.54	3.31	3.64	16.61	19.29	17.53
SE(m) +	-	0.03	-	-	-	-	0.42	0.68	0.33
CD	NS	0.11	NS	NS	NS	NS	1.28	2.09	1.03
Min	2.21	2.62	2.49	3.33	3.31	3.50	13.42	17.72	16.51
Max	3.00	2.82	2.91	4.25	3.55	3.89	20.58	21.66	20.68

Table 2a: Effect of soil conditioners 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	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	198.66	201.00	199.83	6.53	6.76	6.65	6.76	7.09	6.93
S2	178.00	197.00	187.50	6.46	6.61	6.54	6.53	7.02	6.78
S3	161.33	162.33	161.83	6.00	6.30	6.15	6.43	6.58	6.51
S4	162.00	168.33	165.16	6.33	6.25	6.29	6.50	6.87	6.69
S5	211.00	220.33	215.66	6.40	6.44	6.42	6.96	7.16	7.07
S6	182.33	184.33	183.33	6.00	6.31	6.15	6.46	6.61	6.54
S7	186.66	190.00	188.33	6.30	6.11	6.20	6.73	7.00	6.86
S8	158.33	164.00	161.16	5.66	5.83	5.75	6.00	5.83	5.92
SE(m) +	8.72	6.52	6.65	-	0.07	0.11	-	0.12	0.11
CD	26.71	19.98	20.37	NS	0.22	0.35	NS	0.37	0.36
Min	158.33	162.33	161.16	5.66	5.83	5.75	6.00	5.83	5.92
Max	211.00	220.33	215.66	6.53	6.76	6.65	6.96	7.16	7.07

Table 2b: Effect of soil conditioners 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	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	210.00	217.00	213.50	4.22	4.29	4.25	39.50	39.90	39.70	3.99 (2.21)	3.91 (2.18)	3.94 (2.20)
S2	226.66	208.66	217.66	4.80	4.76	4.79	28.03	29.28	28.65	2.03 (1.73)	2.09 (1.75)	2.06 (1.74)
S3	189.33	193.00	191.16	3.52	3.57	3.55	60.89	61.66	61.28	0.78 (1.33)	1.34 (1.53)	1.06 (1.43)
S4	192.66	214.66	203.66	3.78	3.73	3.76	32.97	31.74	32.35	1.95 (1.71)	2.20 (1.78)	2.07 (1.75)
S5	226.66	232.33	229.50	4.43	4.34	4.39	53.25	55.40	54.32	5.40 (2.52)	5.55 (2.56)	5.47 (2.54)
S6	183.33	187.33	185.33	3.37	3.54	3.45	42.06	45.51	43.78	3.61 (2.14)	3.98 (2.23)	3.79 (2.18)
S7	193.33	207.33	200.33	3.57	3.71	3.64	41.53	44.19	42.86	2.49 (1.85)	3.35 (2.08)	2.92 (1.97)
S8	166.66	182.33	174.50	2.80	2.72	2.76	57.00	52.08	54.54	6.40 (2.64)	4.93 (2.36)	5.67 (2.51)
SE(m) +	12.19	8.422	9.286	0.13	0.08	0.09	2.64	2.49	2.29	0.19	0.19	0.18
CD	37.33	25.79	28.43	0.42	0.26	0.28	8.10	7.64	7.02	0.59	0.58	0.55
Min	166.66	182.33	174.50	2.80	2.72	2.76	28.03	29.28	28.65	0.78 (1.33)	1.34 (1.53)	1.06 (1.43)
Max	226.66	232.33	229.50	4.80	4.76	4.79	60.89	61.66	61.28	5.40 (2.52)	5.55 (2.56)	5.47 (2.54)

Table 2c: Effect of soil conditioners 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	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	66.60	66.66	66.63	455.66	401.66	428.66	18.31	17.30	17.80
S2	65.12	66.29	65.71	354.00	367.66	360.83	17.91	17.44	17.67
S3	65.99	62.94	64.46	425.00	388.00	406.50	19.32	17.31	18.31
S4	53.52	61.11	57.31	336.00	363.00	349.50	14.72	16.80	15.76
S5	43.73	44.82	44.27	198.66	203.33	201.00	12.02	12.32	12.17
S6	40.69	42.20	41.44	205.33	229.33	217.33	11.19	11.60	11.39
S7	49.86	52.61	51.24	252.66	277.00	264.83	13.71	14.47	14.09
S8	33.37	30.04	31.71	172.00	183.33	177.66	9.18	8.26	8.72
SE(m) +	1.27	1.51	0.72	7.33	6.74	4.39	0.34	0.48	0.32
CD	3.91	4.64	2.23	22.47	20.64	13.47	1.06	1.49	0.99
Min	33.37	30.04	31.71	172.00	183.33	177.66	9.18	8.26	8.72
Max	66.60	66.66	66.63	455.66	401.66	428.66	19.32	17.44	18.31

Conclusion

70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) followed by 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) over mulching had practically high-water absorption capacity, that was reserved in subsequent wetting and drying cycles. The favourable influence of hydrogel application was due to increasing water availability, as the soil was wet for a longer time and increases the availability of nutrient supply, improving the efficiency of macro elements which in turn increased the production. The use of hydrogel amendments as cultural practice will be useful for increased plant survival under drought conditions.

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