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Effect of soil conditioners on soil, physiological and photosynthetic parameters of sweet orange (*Citrus sinensis* (L.) Osbeck)

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Abstract
Two types of hydrogels (Pusa hydrogel and ZEBA hydrogel) were compared with organic (ground nut husk and coconut husk) and inorganic mulches (100 µ black polythene) in Sathgudi sweet orange for soil parameters, physiological, photosynthetic and growth parameters of the leaf. Highest increase in moisture retention (68.26%), change in leaf dry weight was (0.038mg/cm/h) was recorded in plants applied with 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant). Bulk density ranged between 0.71 - 0.79 g/cm^3. Maximum (33.20 ^{0}C) soil temperature was recorded in the soil of plants mulched with 100 µ black polythene. Stomatal conductance was highest (0.019 mmol/m^2/s) in the plants that were applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant). Rate of photosynthesis was highest (35.98 µgCO_2/m^2/s) in plants mulched with 100µ black polythene. Growth parameters did not show much difference among the treatments, but comparatively the trees were larger than the control.

Keywords: Hydrogels, mulching, photosynthetic index and soil conditioners

Introduction
India, with varied agro-climatic conditions has large range of fruits in its fruit basket contributing nearly 15% of the total world fruit production. Among them, *Citrus* species, ranks forth with respect to global production having 152 million tonnes (World Data Atlas 2018) [22]. Sweet orange (*Citrus sinensis* (L.) Osbeck), is the second most important group of citrus whose 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 (3rd Advanced estimates of NHB 2018-2019). It has a productivity of 24.17 t/ha. Sathgudi, is the choicest variety of sweet orange in Andhra Pradesh due to its sweet taste, high juice content, fair flavour and pleasant aroma. The major districts growing this variety are Anantapur, Kadapa, Prakasam, Guntur, Nellore, Chittor and Kurnool in an area of 70.11 thousand hectares producing 1752.63 thousand MT. (Horticultural statistics at a glance, 2018) [9].
Citrus fruits and its products historically held a place in dietary guidance because of their impressive list of essential nutrients like vitamins, minerals (electrolytes), photochemicals (antioxidants), dietry fiber and non-starch polysaccharides that are essential for normal growth and development and overall nutritional well-being.
Flowering in *Citrus* under Andhra Pradesh conditions is induced through soil water deficit stress. Observing at patterns of precipitation, main flowering in Sathgudi is induced during January–February (*Ambe bahar*) where precipitation is normally received in June and continues up to September.
The flowering process in citrus consists of several discrete phases: flower bud induction, bud differentiation and anthesis. The induction process is associated with environmental factors and results in the commitment of meristematic cells to form reproductive structures. Ambient temperature not only has a direct effect on induction and differentiation but also affects flowering date and intensity (Cassin *et al.* 1969; Garcia-Luis *et al.* 1992) [4, 7]. Sustained periods of low temperature in winter will produce a later anthesis by delaying initiation of differentiation and reducing the subsequent growth rate of the bud (Lomas and Burd, 1983) [13]. Changing climate has changed the phenology of flowering, causing delay in flowering and subsequent development stages. This delay in flowering makes fruits to coincide with high temperature and causes a disorder called sun burn.

The affected area of sunburned fruit becomes yellow or yellow with brown centre especially on the tree facing west. The development of the fruit is also hindered leading them to drop off. This change in climate also makes the plant to coincide with the water stress or drought conditions during fruit development stage which again leads to fruit drop. All these reasons cause a serious loss to the farmer which is otherwise a very beneficial cropping season.

Drought stress can affect fruit crops in multiple ways and the three most common soil conditions that hinder plant growth and yield are low water retention capability, high evapotranspiration rate and soil moisture leaching as it alters the properties and hydrological functions of soils including soil aggregate stability and water infiltration. Water stressed plants also show decline in photosynthesis and increased photorespiration which alters the normal homeostasis of cells resulting in increased production of reactive oxygen species (Miller *et al.* 2010) [15]. Increased accumulation of ROS like superoxide radical, hydrogen peroxide, hydroxyl radicals and singlet oxygen causes oxidative damage to cell lipids, proteins, nucleic acids and chlorophyll. In response to this, plants synthesize enzymatic (superoxide dismustase, peroxidase, catalase, glutathione reductase) and nonenzymatic (ascorbate and glutathione) antioxidant molecules to minimize the levels of such harmful ROS. Producing these metabolites by plants to overcome stress conditions may reduce the yield and quality of the fruits. To ameliorate the above conditions soil conditioners like hydrogels, organic and inorganic mulches were used in the present research work.

The hydrogels used in this research are Pusa hydrogel and ZEBA hydrogel. The key characteristics of these hydrogels are high water absorption capacity in saline and hard water conditions, optimized absorbency under load, lowest soluble content and residual monomer, high durability and stability in the swelling environment and during storage. Gradual biodegradability without formation of toxic species, pH neutrality after swelling in water, photo stability and rewetting capability.

Considering the slow progress in crop improvement, there is an immediate need to develop tailor made cost effective technologies for increasing production, of citrus fruits by overcoming the maladies of fruit drop due to water stress in changing climate.

Materials and Methods

The present 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 and also at farmer's field of Railway Kodur in Kadapa District, of Andhra Pradesh during the year 2018 to 2019.

Experimental material

Three field experiments were carried out at two different locations on bearing trees (9 years old) of Sweet orange *cv* 'Sathgudi' which were budded on Rangapur lime (*Citrus limonica*) rootstock and planted at a spacing of 6 x 6 m.

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

Application of ZEBA and Pusa hydrogel

These gels are applied during March and the plants are supplied with 70% ER based irrigation. Hydrogels are placed nearly 1 metre away from the trunk by digging a shallow trench around the tree and incorporated into soil.

Mulching

Mulching was done with dry coconut husk, dry groundnut husk and 100 µ guage black polyethene on the orchard floor around the tree one foot away from trunk and spread to the end of canopy.

Soil moisture content (%)

The soil samples drawn from the area about nine inches away from the drip emitters and at a depth of 6 – 9 inches from the soil surface in the tree basins. The soil samples were weighed and dried to constant weight by maintaining temperatures between 100 – 110 ºC for 24 hours. The moisture content was derived by using the formula on fresh weight basis are given below.

$$\text{Soil moisture (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Fresh weight}} \times 100$$

Fieldscout TDR 300 Soil moisture meter was also used to measure the moisture at 30 cm depth of the soil.

Soil moisture percentage after application of soil conditioners (%)

It was calculated by using the formula

$$\text{Soil moisture percentage} = \frac{\text{Final moisture content - Initial moisture content}}{\text{Initial moisture content}} \times 100$$

Bulk density

Bulk density was calculated by using the formula

$$\text{Bulk density} = \frac{\text{Weight of dry soil}}{\text{Total soil volume}}$$

Soil volume

Measured the height of the ring which was used for collecting the soil.

Measured the diameter of the ring to record the radius (r) half the diameter.

Ring volume (cm^3) = 3.14 x r^2 x Ring height.

Soil and canopy temperature (ºC)

Mextech IR-1000 digital infrared thermometer (ºC) was used to measure temperature for soil and canopy in the hottest part of the day in peak summer. Measurements were taken on surface of the soil under the tree and on lower canopy of 30 cm away from the outer layer of the tree.

Physiological parameters

Relative water content of leaf (%)

It is defined as the percentage of water present at the time of sampling, relative to the amount of water in a saturated leaf. It was recorded during hot summer in the month of June.

Twenty, one square centimeter discs of leaves were collected from all over the canopy, were quickly weighed to record the fresh weight then they were made to float on water in the dark at room temperature (25 ˚C) for 24 hours then they are weighed to record the turgid weight. RWC was determined after drying the leaf discs at 60 ºC for 2 days for dry weight and was calculated as follows.

RWC (%) = Fresh weight - Dry weight/Turgid weight - Dry weight x 100

Stomatal density (No./mm^2)

The leaves were collected from the treated shoots which had grown during the previous season on the South side of the tree in full sunlight. Small pieces were cut from the median portion of the lamina of each leaf and put into acetic-formalin-alcohol, where they remained until utilized for the study of the stomata. Tangential sections of the leaf blades were easily cut with a razor and were studied under DMi8 Leica inverted microscope from Wetzlar, Germany Leica Microsystems. The young orange leaves generally contain high hesperidin which makes it opaque, so it was necessary to treat all sections with a dilute solution of potassium hydroxide, until the hesperidin is removed. The sections from fresh material were put into 90 percent alcohol to remove the chlorophyll, then stained with alcoholic safronin and finally cleared in dilute potassium hydroxide. The number of stomata in area of 1 mm^2 was counted and the average of ten or more areas was recorded. Areas in the vicinity of oil glands, epidermal hairs and large veins were avoided (Reed and Hirano, 1931) [20].

Rate of transpiration (mol of $H_2O/cm^2/s$), stomatal conductance (mmol/m^2/s) and rate of photosynthesis (µg CO_2 /m^2)

All these three parameters were measured for three newly formed mature leaves which are fully exposed to Sun from all the four sides of the tree branches. This was done in the morning from 8:00 AM to 10:00 AM using artificial sunlight (1000 µEim m^{-2} sec^{-1}) with portable photosynthetic meter with light control (Licor, Model-LI 6400).

Water use efficiency (µmole CO_2/m mole H_2O)

The ratio of photosynthesis and rate of transpiration gives the water use efficiency.

Photosynthetic index

Change in leaf dry weight (mg/cm^2/h^2)

To determine the change in leaf dry weight, ten leaves at random on each experimental tree were tagged and 20 leaf discs of 1 cm^2 diameter with a cork borer from one side of these leaves in the morning were taken and dried in an oven for 24 hours at 70 ˚C. Discs from other side of the midrib of the same leaves were removed in the evening 10 hours after first removal and were dried as those of morning discs. After ensuring complete drying of both sets of leaf discs, their dry weight was recorded. Any increase in weight was recorded. Any increase in weight in evening discs over morning discs was attributed to accumulation of photosythates synthesized during 10 hours and expressed as mg cm^{-2} h^{-2}.

SPAD chlorophyll meter reading (µmol of chlorophyll per m^2)

The SPAD meter (Soil Plant Analytical Development) is a simple hand held and portable instrument which provides information on the relative amount of leaf chlorophyll. The SCMR was measured on mature active leaves. SPAD meter of Minolta, NJ, USA (SPAD 502).

Growth parameters

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) [16]. Canopy volume = $0.5236 \times HD^2$, 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.

Soil physical parameters

Soil moisture content (%)

The soil moisture content of the areas of experiment before application of soil conditioners ranged from 32.83% to 35%.

After application of soil conditioners

There was a significant difference among the treatments in both the locations. The mean values in two locations was recorded maximum (55.65%) in soils treated with 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) and minimum (38.56%) in soils with no soil conditioners.

Percent increase in soil moisture content

This data was recorded after fruiting and before harvest in the month of June. There was significant difference among the treatments at both the locations. It was noticed that there was an increase in soil moisture retention after application of soil conditioners. Highest increase in moisture retention (68.26%) was recorded after application of 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) which was at par (58.92%) with soils applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) (48.60%) while lowest soil moisture retention (17.56%) was recorded in soils of plants with no soil conditioner.

Effectiveness of hydrogels in improving water availability can vary with soil type, dosage and the method of application. This improvement of water availability is due to, hydrogel granules which slowly release the absorbed water through diffusion in response to soil drying; it also checks the deep percolation and evaporative losses so that applied water remains available for plant use for an extended period of time. These results were also supported by Cannazza *et al*. 2014 [3], Pattanaaik *et al.* (2015a) [18, 19], Liao *et al.* (2016), Pattanaaik *et al*. (2015b) [18, 19] and Farzi *et al.* (2017) in Olive cultivars.

Bulk density (g/cm^3)

Bulk density is an important soil property, depending on factors like soil texture and soil organic matter, influences a range of soil properties including rooting depth, infiltration, porosity and water and nutrient availability which in turn influence soil productivity. It ranged between 0.71 - 0.79 g/cm^3.

Soil temperature (ºC)

The maximum (33.20 ºC) soil temperature was recorded in the soil of plants mulched with 100 µ black polythene and minimum (30.55 ºC) was recorded in the soils of plants mulched with ground nut husk. The results from the present study were in accordance with the Hitoshi *et al.* (2007) [8] in 'Satsuma' mandarin orchards.

Physiological parameters

Relative water content of leaf (%)

Relative water content of leaf among the treatments over the locations revealed that plants mulched with coconut husk has recorded significantly maximum (57.16%) RWC while minimum (25.33%) in plants applied with 70% ER + ZEBA @ 7.5 kg/acre.

Leaf relative water content (RWC) is an important indicator of water status in plants (Lugojan and Ciulca, 2011) [14] decrease in RWC of leaf under moisture stressed condition was due to reduced absorption of water from the soil and inability to control water loss through the stomata. Application of soil conditioners to the soil improved the availability of water in the soil which in-turn increased the leaf water content. This was also observed by Wang *et al.* (2014) [14] and Ananthi *et al.* (2013) [2] under arid region conditions. Ferreira *et al.* (2014) [6] observed that hydrogel minimized the adverse effects of water deficit in tangerine and orange cultivars by improving gas exchange and plant water status.

Stomatal density (stomata per mm^2)

Stomatal density among the treatments in two locations ranged from 306.13 to 506.54 stomata per mm^2 and all the treatments were on par with each other.

Rate of transpiration (mol of $H_2O/cm^2/s$)

Rate of transpiration among the treatments in two locations was observed to be lowest (1.62 mol of $H_2O/cm^2/s$) in plants with no soil conditioners which was on par (1.77 mol of $H_2O/cm^2/s$) with the plants that were applied with 70% ER + Pusa gel @ 4 kg/acre (40 g/plant) and highest (6.23 mol of $H_2O/cm^2/s$) in plants that were applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant).

Stomatal conductance (mmol/m^2/s)

Stomatal conductance was highest (0.019 mmol/m^2/s) in the plants that were applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) and lowest (0.001 mmol/m^2/s) in plants with no soil conditioners. Chehab *et al.* (2017) [5] reported that hydrogel injection in the soil improved midday stomatal conductance in Olive grove.

Water use efficiency (kg/ha/cm)

Water use efficiency at two locations was recorded to be highest (21.52 kg/ha/cm) in plants with no soil conditioners while lowest (4.97 kg/ha/cm) in plants that were sprayed with 70% ER + ZEBA @ 5 kg/acre (45 g/plant).

Generally two mechanisms may improve water use efficiency of the leaf (i) decreasing transpiration by reducing stomatal openings while maintaining higher photosynthesis and (ii) enhancing photosynthetic enzyme activities to improve the photosynthetic rate by maintaining higher stomatal transpiration. In the present study, hydrogel application induced a larger increase in the photosynthetic enzyme activity and improved the leaf instantaneous water use efficiency. The present results were in line with the studies of Kassim *et al.* (2017) [11] in 'Grand Nain' banana, Chehab *et al*. (2017) [5] in an olive and Li *et al.* (2009) [12] in apricot.

Leaf temperature (ºC)

Maximum and minimum leaf temperatures were recorded (33.20 ºC) in plants that were applied with 70% ER + Pusa gel @ 2 kg/acre (20 g/plant) and (31.26 ºC) in plants mulched with 100 µ black polythene respectively.

Photosynthetic index parameters

Change in leaf dry weight (mg/cm/h)

Change in leaf dry weight was observed highest (0.038mg/cm/h) in plants applied with 70% ER + ZEBA @ 7.5 kg/acre (70 g/plant) and lowest (0.017 mg/cm/h) was recorded in plants that were mulched with coconut husk.

Chlorophyll content (µmol of chlorophyll per m^2)

Chlorophyll content was non-significant and it was in the range of 64.23 µmol of chlorophyll per m^2 to 73.83 µmol of chlorophyll per m^2. Soil conditioners like hydrogels and mulches improved the chlorophyll content in the present experiment and these results were in harmony with Wang *et al*. (2014) [14] and Zamanipour *et al*. (2014).

Rate of photosynthesis (µg $CO_2/m^2/s$)

Rate of photosynthesis was highest (35.98 µg$CO_2/m^2/s$) in plants mulched with 100µ black polythene and lowest (31.00 µg $CO_2/m^2/s$) in plants applied with 70% ER + ZEBA @ 5 kg/acre (45 g/plant).

Growth parameters

Tree height was non-significant and it ranged between 2.91 m to 2.41 m. Canopy spread of the trees was from 3.50 m^2 to 3.89 m^2. Canopy volume was 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) was recorded 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) [10] reported that, application of hydrogel significantly improved the growth habit of fruit trees. 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.

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

Treatments	Soil moisture content (%) (Before)			Soil moisture content (%) (After)			(%) Increase in soil moisture content			Bulk density (g/cm^3)			Soil temperature (^{o}C)		
	Experimental locations			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	Location - 1	Location - 2	Mean
S1	36.66	32.33	34.50	41.40	40.26	40.83	19.97	24.66	18.36	0.79	0.78	0.79	34.50	30.03	32.26
S2	33.33	33.00	33.16	55.60	55.70	55.65	67.87	68.85	68.26	0.80	0.75	0.78	33.16	30.23	31.70
S3	33.33	33.00	33.16	55.70	49.60	52.65	68.05	51.08	58.92	0.79	0.76	0.78	35.70	30.20	32.95
S4	33.66	32.33	33.00	53.90	46.33	50.11	63.55	43.36	51.96	0.76	0.73	0.75	32.43	31.46	31.95
S5	34.66	35.00	34.83	51.83	50.43	51.13	48.74	43.89	46.73	0.74	0.74	0.74	30.53	30.66	30.60
S6	35.33	34.66	35.00	56.73	52.63	54.68	62.40	51.87	56.52	0.70	0.72	0.71	32.03	29.06	30.55
S7	32.66	33.66	33.16	44.10	42.50	43.30	33.03	26.48	30.65	0.73	0.76	0.74	37.43	28.96	33.20
S8	32.66	33.00	32.83	39.60	37.53	38.56	20.76	13.79	17.56	0.69	0.73	0.71	30.73	30.76	30.75
SE(m)+	-	-	-	1.98	1.93	1.71	6.15	5.60	5.82	0.02	-	-	1.43	0.40	-
CD	NS	NS	NS	6.06	5.91	5.24	18.84	17.17	17.83	0.06	NS	NS	4.39	1.23	NS
Min	32.66	32.33	32.83	39.60	37.53	38.56	19.97	13.79	17.56	0.69	0.72	0.71	30.53	28.96	30.55
Max	36.66	35.00	35.00	56.73	55.70	55.56	68.05	68.85	68.26	0.80	0.78	0.79	37.43	31.46	33.20

Table 2: Effect of soil conditioners on physiological parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Relative water content of leaf (%)			Stomatal density (per mm^2)			Rate of transpiration (mol of $H_2O/cm^2/s$)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Mean	Location - 1	Location – 2	Mean	Location - 1	Location - 2	Mean
S1	26.66	28.66	27.66	481.26	484.46	482.87	6.25	6.21	6.23
S2	25.66	25.00	25.33	482.16	492.76	487.47	3.87	3.72	3.80
S3	31.00	31.66	31.33	449.53	444.46	447.02	4.21	4.12	4.17
S4	40.33	38.00	39.16	482.63	455.06	468.85	1.47	2.06	1.77
S5	59.00	55.33	57.16	511.13	501.93	506.54	4.22	4.25	4.24
S6	47.66	46.33	47.00	500.56	491.40	495.97	3.28	3.15	3.22
S7	52.66	50.33	51.50	299.23	313.03	306.13	4.50	4.46	4.48
S8	37.33	33.33	35.33	298.33	314.90	306.59	1.41	1.81	1.62
SE(m) +	6.89	3.90	5.06	14.12	19.64	14.83	0.06	0.23	0.10
CD	21.10	11.95	15.50	43.24	60.16	45.43	0.19	0.71	0.32
Min	25.66	25.00	25.33	298.33	313.03	306.13	1.41	1.81	1.62
Max	59.00	55.33	57.16	511.13	501.93	506.54	6.25	6.21	6.23

Table 3: Effect of soil conditioners on physiological parameters of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Stomatal conductance (mmol/m^2/s)			Water use efficiency (µmole CO_2/m mole H2O)			Leaf temperature (^{o}C)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	0.006	0.005	0.005	4.97	4.97	4.97	34.33	31.96	33.15
S2	0.017	0.012	0.015	8.49	8.92	8.71	34.70	30.50	32.60
S3	0.018	0.021	0.019	8.19	8.53	8.35	35.16	31.23	33.20
S4	0.001	0.002	0.002	22.84	16.76	19.80	33.93	30.76	32.35
S5	0.004	0.004	0.004	8.41	8.08	8.24	33.46	29.26	31.36
S6	0.003	0.003	0.003	10.47	10.32	10.40	34.43	29.30	31.86
S7	0.018	0.018	0.018	7.87	8.22	8.05	33.90	28.73	31.31
S8	0.001	0.002	0.001	24.56	18.48	21.52	33.33	29.20	31.26
SE(m) +	0.001	0.000	0.000	0.80	1.12	0.53	-	0.43	0.33
CD	0.002	0.001	0.001	2.47	3.43	1.64	NS	1.31	1.02
Min	0.001	0.002	0.001	4.97	4.97	4.97	33.33	29.20	31.26
Max	0.018	0.021	0.019	24.56	18.48	21.52	35.16	31.96	33.20

Table 4: Effect of soil conditioners on photosynthetic index of sweet orange (*Citrus sinensis* L. Osbeck)

Treatments	Change in leaf dry weight (mg/cm^2/h^2)			Chlorophyll content (µmol of chlorophyll per m^2)			Rate of photosynthesis (µg $CO_2/m^2/s$)		
	Experimental locations			Experimental locations			Experimental locations		
	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean	Location - 1	Location - 2	Mean
S1	0.032	0.035	0.034	71.80	70.76	71.28	31.10	30.90	31.00
S2	0.037	0.039	0.038	69.50	70.43	69.96	32.90	33.13	33.01
S3	0.023	0.026	0.025	67.70	68.73	68.21	34.50	35.13	34.81
S4	0.034	0.035	0.035	72.30	75.36	73.83	33.40	34.03	33.71
S5	0.018	0.017	0.018	71.20	71.36	71.28	35.50	34.40	34.95
S6	0.023	0.033	0.028	66.46	66.83	66.65	34.30	32.20	33.25
S7	0.027	0.023	0.025	67.00	64.23	65.61	35.40	36.56	35.98
S8	0.038	0.034	0.036	73.93	71.76	72.85	34.40	32.00	33.20

SE(m) +	-	0.002	-	-	-	-	0.68	-	0.88
CD	NS	0.005	NS	NS	NS	NS	2.10	NS	2.70
Min	0.018	0.017	0.018	66.46	64.23	65.61	31.10	30.90	31.00
Max	0.038	0.039	0.038	73.93	75.36	73.83	35.40	36.56	35.98

Table 5: 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

Conclusion

This study clearly indicated that, 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, improved 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.

References

1. Abobatta WF, Khalifa SM. Influence of hydrogel composites soil conditioner on navel orange growth and productivity. Journal of Agriculture and Horticulture Research 2019;2(2):1-6.
2. Ananthi K, Vijayaraghavan H, Karuppaiya M, Anand T. Drought-induced changes in chlorophyll stability index, relative water content and yield of cotton genotypes. Insight Botany 2013;3(1):1-5.
3. Cannazza G, Andrea C, Benedetto ED, Demitri C, Madaghiele M, Sannino A. Experimental assessment of the use of a novel superabsorbent polymer (SAP) for the optimization of water consumption in agricultural irrigation process. Water 2014;6:2056-69.
4. Cassin JJ, Bourdeaut A, Fougue V, Furon JP, Gaillard J, Le Bourdelles, Montagut G, Moreuil C. The influence of climate upon blooming of citrus in tropical areas. Proceeding 1st International Citrus Symposium 1969;1:315–23.
5. Chehab H, Tekaya M, Mechri B, Jemai A, Guiaa M, Mahjoub. Effect of the super absorbent polymer stocksorb on leaf turgor pressure, tree performance and oil quality of olive trees *cv*. Chemlali grown under field conditions in an arid region of Tunisia. Agricultural Water Management 2017;192:221-31.
6. Ferreira EA, Silva VA, Silva EA, Silveira. Hydrogel efficiency and physiological responses of seedless citrus cultivar seedlings under water deficit. Pesquisa Agropecuaria Tropical 2014;44(2):158-65.
7. Garcia Luis A, Kanduser M, Santamarina P, Guardiola JL. Low temperature influence on flowering in Citrus. The separation of inductive and bud dormancy releasing effects. Physiologia plantarum 1992;86:648-52.
8. Hitoshi O, Katsuji N, Takuji Sawamoto, Haruo T, Toshio H, John YY, Kazuyuki Y. Emission of N_2O and CO_2 and uptake of CH_4 in Soil from a Satsuma mandarin orchard under mulching cultivation in central Japan. Journal of Japanese Society for Horticultural Sciences 2007;76(4):279–87.
9. Horticultural Statistics at a Glance. Ministry of Agriculture and farmer's welfare Government of India 2018.
10. Jalili K, Jalili J, Sohrabi H. Effect of super absorbent polymer (Tarawat A 200) and irrigation interval on growth of almond sapling. Water and Soil Science 2011;21(2):121-34.
11. Kassim FS, El-Koly MF, Hosny SS. Evaluation of super absorbent polymer application on yield and water use efficiency of Grand Naine banana plant. Middle East Journal of Agriculture Research 2017;6(1):188-98.
12. Li YK, Xu TW, Ouyang ZY. Micromorphology of macromolecular superabsorbent polymer and its fractal characteristics. Journal of Applied Polymer Science 2009;113(6):3510–19.
13. Lomas J, Burd P. Prediction of the commencement and duration of the flowering period of citrus. Journal of Agrometeorology 1983;28:387-96.
14. Lugojan C, Ciulca S. Evaluation of relative water content in winter wheat. Journal of Horticulture, Forestery and Biotechnology 2011;15:173–7.
15. Miller G, Suzuki N, Ciftci YS, Mittler R. Reactive oxygen species homeostasis and signaling during drought and salinity stresses. Plant Cell & Environment 2010;33(4):453-67.
16. Morse JG, Robertson CA. Calculating canopy area of citrus trees and surface area of fruits. Florida Entomol. 70-168. Journal of American Society for Horticultural Sciences 1987;115(1):6-8.
17. National Horticultural Board. Area and Production Statastics. 3rd advanced estimates of 2018-2019 2019.
18. Pattanaaik SK, Barun SL, Wangchu P, Debnath BN, Hazarika S, Pandey AK. Effect of hydrogel on water and nutrient management of *Citrus limon*. International

Journal of Agriculture Innovations and Research 2015;3(5):1555-8.
19. Pattanaaik SK, Wangchu L, Baruns BN, Hazarika S, Singh M, Pandey AK. Effect of hydrogel on water and nutrient management of *Citrus reticulate*. Research on Crops 2015;16(1):98-103.
20. Reed HS, Hirano E. The density of stomata in citrus leaves. Journal of Agricultural Research 1931;43(3):209-2.
21. Wang X, Lu S, Gao C. Biomass based multifunctional fertilizer system featuring controlled release nutrient, water retention and amelioration of soil. RSC advances 2014;4(35):18382-90.
22. World Data Atlas Knoema. Citrus fruit production quantity 2018.