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Effect of different irrigation and fertigation levels on growth and yield in sweet orange (*Citrus sinensis* L. Osbeck) cv. Phule Mosambi

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Abstract

Water and nutrient use efficiency are primary requirements for optimum and sustained citrus productivity. The interactive effect of irrigation and fertigation levels on growth and yield of 10-year-old sweet orange (*Citrus sinensis* L. Osbeck) cv. Phule Mosambi was studied through a field experiment during 2017 and 2018 at research farm of AICRP on Fruits, Department of Horticulture, MPKV Rahuri. The experiment was laid out in factorial randomized block design with nine treatment combinations, comprising three irrigation levels (100%, 80% and 60% of daily crop evapo-transpiration), three fertigation levels (100%, 80% and 60% RDF based NPK doses through water soluble fertilizers) and control with surface irrigation and band placement of conventional fertilizers(SI+BPF) replicated thrice. The growth parameters such as incremental growth in plant height, E-W plant spread, N-S plant spread, canopy volume and yield parameters like fruit numbers, fruit weight and yield were observed to be significantly higher in the treatment T₁-I₁F₁ having irrigation at 100% Etc and fertigation at 100% RD through WSF however the yield was statistically at par with the treatment T₅- I₂F₂ comprising irrigation at 80% of Etc and fertigation with 80% of RD with WSF. The sustained productivity of sweet orange can be achieved with irrigation scheduled at 80% Etc along with fertigation technology at 80% RDF especially under scarcity conditions.

Keywords: Fertigation, irrigation studies, sweet orange, growth, yield

Introduction

The citrus is a leading fruit crop of World. The sweet orange (*Citrus sinensis* L. Osbeck) is one of the most important fruit crop amongst the citrus group in India and particularly in Maharashtra state. More than 78.70 per cent of world citrus production takes place in the northern hemisphere which is dominated by China, India and USA. In India, the important citrus fruits grown are mandarins, sweet oranges and acid lime sharing 40.60 per cent, 26.00 per cent and 25.10 per cent, respectively of total citrus fruit production in country. Andhra Pradesh ranks first in area (82.89 thousand ha) and production (2003.10 thousand MT) whereas, Maharashtra ranks second in area (55.20 thousand ha) and production (684.80 thousand MT) ^[1].

Sweet orange is a rich source of sugars, acids, polysaccharides and many phytochemicals such as vitamin C and carotenoids which provide health benefits against various diseases including cardiovascular and cancer diseases. *Citrus sinensis* has been shown to possess highest antiradical effect (84.80%) in comparison to *Citrus aurantifolia* and *Citrus limonum* due to presence of phenols, steroids, terpenoids and tannins ^[11]. Since sweet orange contains natural antioxidants, this citrus fruit clears the body of free radicals, thus increasing pH levels of body making them lead a healthier and energetic life and free of disease ^[12].

Sweet orange (*Citrus sinensis* L. Osbeck) is predominantly grown in sub-tropical areas of India and the growth, yield and fruit quality depends mainly on optimum soil moisture and nutrient availability. Low water use efficiency (WUE) and fertilizer use efficiency (FUE) are the two major drawbacks of surface irrigation methods ^[10]. Moreover, the substantial loss of nutrients from plant root zone through deep percolation and surface runoff under traditional methods of irrigation and fertilization causes the pollution of water in surface and ground water sources of the region, which is a threat to human life ^[5]. The use of water and nutrients through drip irrigation (DI) in concurrence with plant demand, therefore, could be one of the potential options for sustainable citrus production.

In the present investigation, different irrigation and fertigation regimes were used to provide water and fertilizers to study the influence of water and nutrients on growth and yield of sweet orange cv. Phule Mosambi.

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Material and Methods

A two-year field trial was conducted during 2017 and 2018 at the research farm of All India Coordinated Research Project on Fruits, Department of Horticulture, MPKV, Rahuri, situated between 19°20' and 19°57' N latitude and 74°82' and 74°19' E longitude with an altitude of 531 above MSL in the scarcity zone of Ahmednagar district in Maharashtra. The pattern of rainfall is erratic and the region comes under semi-arid climate having irrigation facility. The experiment was conducted on 10 years old sweet orange (*Citrus sinensis* L. Osbeck) cv. Phule Mosambi budded on Rangpur lime rootstock (*Citrus limonia*) planted at a distance of 6 x 6 m. The soil of experimental site was medium black with pH of 8.12 and EC of 0.21 dSm⁻¹. *Ambia bahar* crop was taken in sweet orange wherein the water stress was induced in the month of November-December.

The sweet orange orchard with 60 trees was selected for ten treatments under the study. Each treatment was replicated thrice having two plants in each replication. The experiment was laid out in factorial randomized block design comprising two factors of irrigation and fertigation with each factor having three levels and a control.

In this investigation nine treatments included three irrigation levels (I) i.e., I₁-irrigation at 100% ETc, I₂- irrigation at 80% ETc and I₃- irrigation at 60% ETc. with three fertigation levels (F) i.e., F₁- 100% of RD with water soluble fertilizers (WSF), F₂- 80% of RD with WSF and F₃- 60% of RD with WSF through drip irrigation. The treatments combinations tested were T₁ -I₁F₁-Drip irrigation at 100% of ETc with 100% of RD through WSF, T₂ -I₁F₂-Drip irrigation at 100% of ETc with 80% of RD through WSF, T₃ -I₁F₃- drip irrigation at 100% of ETc with 60% of RD through WSF, T₄-I₂F₁- drip irrigation at 80% of ETc with 100% of RD through WSF, T₅- I₂F₂- drip irrigation at 80% of ETc with 80% of RD through WSF, T₆-I₂F₃- drip irrigation at 80% of ETc with 60% of RD through WSF, T₇-I₃F₁- drip irrigation at 60% of ETc with 100% of RD through WSF, T₈-I₃F₂- drip irrigation at 60% of ETc with 80% of RD through WSF, T₉-I₃F₃- drip irrigation at 60% of ETc with 60% of RD through WSF and T₁₀- Control - surface irrigation as per the farmer practice with conventional fertilizers at 100% RDF as band placement. The recommended dose of fertilizer (RDF) for sweet orange in the region is 800 g N: 300 g P₂O₅: 600 g K₂O + 20 kg FYM + 15 kg neem cake/plant/year that was used for fertigation with water soluble fertilizers (WSF) while band placement of

conventional fertilizers (BPF) were used for control. The application of fertilizers for band placement was done with urea, single super phosphate and muriate of potash while water soluble fertilizer grades like urea, urea phosphate (12:61:0), potassium phosphate (0:52:34) and sulphate of potash (0:0:50) were used for fertigation. The fertigation was done at fortnightly interval with 18 splits for each of the levels i.e. 100% (F₁), 80% (F₂) and 60% (F₃) of recommended dose through WSF in four main stages comprising 5 splits of 40% each of N, P₂O₅ and K₂O during January to March in first stage, 5 splits each of 30% N and P₂O₅ and 10% of K₂O during April and May in second stage, 4 splits each of 20% of N and P₂O₅ and K₂O during June and July in third stage and 4 splits each of 10% N and P₂O₅ and 30% K₂O during August and September in fourth stage. The band placement was done using urea, single super phosphate and muriate of potash as per recommendation in control. All standard package of practices was followed during the experiment viz., weeding, pest and disease management etc. Irrigation duration for delivery of water to different treatments was controlled with the help of control valve at the inlet of each treatment plot. Each plant in the treatment plot was irrigated with double lateral spaced at 90 cm apart each having 6 emitters of 4 L h⁻¹ discharge rate. Irrigation was given on alternate day on the basis of daily crop-evapotranspiration rate (ETc) computed from the reference evapotranspiration (ETr) with the help of Phule Jal mobile application depicting the real time ETr values of the orchard and the crop coefficient (Kc) as suggested by Allen *et al.* [2] and modified by Petillo and Castel [9] from the equation ETc= ETr x Kc. The net irrigation requirement was computed from the formula, V = [(ETr - R_e) x Kc x A x F] / Eu where, V = volume of water applied to each plant per day(mm³); ETr = Reference crop evapotranspiration at the irrigation level (mm/day); Kc = Crop coefficient (as per crop stage); A = canopy area of tree (m²) and F = wetting factor under canopy i.e., 70% of canopy area; R_e was taken as the effective rainfall(mm/day) for the day and Eu was the taken as 90% emission uniformity.

The incremental plant height, E-W plant spread, N-S plant spread and canopy volume were recorded as the difference in the values at the start of bahar and at the end of harvest while the canopy volume was calculated from the formula as suggested by Castle [3]. The number of fruits, weight of fruit and yield kg/tree and t/ha were recorded by following standard procedure.

Table 1: Water requirement of sweet orange at different irrigation level (ha-mmmmonth⁻¹)

Year	2017					2018				
	Effective Rainfall	100% ETc	80% ETc	60% ETc	Control	Effective Rainfall	100% ETc	80% ETc	60% ETc	Control
January	0	17.50	14.00	10.50	22.98	0	16.11	12.89	9.66	22.92
February	0	47.68	38.14	28.61	62.59	0	39.98	31.99	23.99	55.09
March	0	69.35	55.48	41.61	94.62	0	66.53	53.22	39.92	87.13
April	0	100.86	80.69	60.51	133.44	1	98.02	78.41	58.81	132.01
May	10.2	126.65	101.32	75.99	161.64	0	120.27	96.21	72.16	166.16
June	141.6	99.44	79.55	59.66	130.54	91	101.01	80.81	60.61	137.19
July	29	90.29	72.23	54.17	122.90	105.8	83.50	66.80	50.10	107.12
August	223	81.47	65.18	48.88	102.59	89	68.42	54.73	41.05	96.08
September	186.6	69.91	55.93	41.95	91.78	3.8	79.67	63.74	47.80	107.13
October	49.4	58.57	46.86	35.14	79.56	0	72.92	58.34	43.75	94.44
Total	639.8	761.72	609.38	457.02	1002.64	290.6	746.43	597.14	447.85	1005.27

Results and Discussion

The data presented in Table 2 revealed that, the interaction effect of irrigation and fertigation and individual effect of

irrigation and fertigation on growth of sweet orange was found significant during 2017, 2018 and in pooled result. The irrigation level I₁, drip irrigation at 100% of ETc recorded

significantly maximum incremental plant height (11.76 cm, 11.78 cm and 11.77 cm), incremental E-W plant spread (11.24 cm, 11.11 cm and 11.18cm), incremental N-S plant spread (11.76 cm, 11.37 cm and 11.57 cm) and incremental canopy volume (3.67 m³, 4.05 m³ and 3.86 m³) during 2017, 2018 and in pooled result. The growth is due to the expansion and multiplication of cell where the optimum levels of water

play vital role. A maximum growth was observed in I₁ with 100% of ETc, which might be due to the optimum availability of water for vegetative growth, these results are in accordance with Shirgure *et al.*, 2004 in acid lime ^[13], Kumar *et al.* 2013 ^[7] in sweet orange and Vijaya *et al.*, 2017 ^[14] in Kinnow mandarin.

Table 2: Effect of irrigation and fertigation levels on incremental growth parameters in sweet orange

Treatments	Incremental plant height (cm)			Incremental E-W plant spread (cm)			Incremental N-S plant spread (cm)			Incremental canopy volume (m ³)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
Irrigation Levels (I)												
I ₁	11.76	11.78	11.77	11.24	11.11	11.18	11.76	11.37	11.57	3.67	4.05	3.86
I ₂	11.51	11.60	11.56	10.77	10.84	10.80	11.63	10.91	11.27	3.49	3.91	3.70
I ₃	9.95	10.06	10.01	9.81	9.90	9.85	10.45	10.03	10.24	2.72	3.00	2.86
SE (m) ±	0.09	0.10	0.09	0.11	0.08	0.09	0.04	0.07	0.05	0.04	0.04	0.03
CD at 5%	0.26	0.30	0.28	0.33	0.23	0.28	0.12	0.21	0.15	0.11	0.12	0.10
Fertigation Levels (F)												
F ₁	11.69	11.70	11.69	11.01	11.02	11.02	11.62	11.13	11.37	3.54	3.95	3.74
F ₂	11.15	11.35	11.25	10.71	10.71	10.71	11.53	10.76	11.14	3.38	3.74	3.56
F ₃	10.39	10.38	10.39	10.09	10.12	10.11	10.70	10.42	10.56	2.97	3.26	3.12
SE (m) ±	0.09	0.10	0.09	0.11	0.08	0.09	0.04	0.07	0.05	0.04	0.04	0.03
CD at 5%	0.26	0.30	0.28	0.33	0.23	0.28	0.12	0.21	0.15	0.11	0.12	0.10
Interaction (I X F)												
T ₁ -I ₁ F ₁	12.21	12.27	12.24	11.87	11.64	11.76	12.14	11.86	12.00	3.93	4.35	4.14
T ₂ -I ₁ F ₂	12.00	12.00	12.00	11.38	11.31	11.35	12.06	11.38	11.72	3.80	4.19	4.00
T ₃ -I ₁ F ₃	11.09	11.03	11.06	10.47	10.39	10.43	11.09	10.87	10.98	3.28	3.61	3.44
T ₄ -I ₂ F ₁	11.89	11.96	11.92	11.21	11.24	11.23	12.00	11.00	11.50	3.74	4.22	3.98
T ₅ -I ₂ F ₂	11.78	12.22	12.00	11.00	11.00	11.00	12.00	11.00	11.50	3.63	4.10	3.87
T ₆ -I ₂ F ₃	10.87	10.62	10.75	10.09	10.28	10.19	10.89	10.72	10.81	3.09	3.42	3.25
T ₇ -I ₃ F ₁	10.96	10.87	10.92	9.96	10.19	10.08	10.71	10.53	10.62	2.94	3.27	3.11
T ₈ -I ₃ F ₂	9.67	9.83	9.75	9.75	9.81	9.78	10.53	9.89	10.21	2.69	2.94	2.82
T ₉ -I ₃ F ₃	9.22	9.49	9.36	9.71	9.70	9.70	10.12	9.68	9.90	2.52	2.77	2.65
SE (m) ±	0.15	0.18	0.16	0.19	0.14	0.16	0.07	0.13	0.09	0.06	0.07	0.06
CD at 5%	0.44	0.53	0.48	0.57	0.41	0.48	0.21	0.37	0.26	0.18	0.21	0.17
T ₁₀ -Control	10.48	10.21	9.83	9.84	9.89	9.86	10.62	10.14	10.38	2.79	3.07	2.93

Similarly, within fertigation level F₁, fertigation with 100% RDF recorded significantly maximum incremental plant height (11.69 cm, 11.70 cm and 11.69 cm), incremental E-W plant spread (11.01 cm, 11.02 cm and 11.02 cm), incremental N-S plant spread (11.62 cm, 11.13 cm and 11.37 cm) and incremental canopy volume (3.54 m³, 3.95 m³ and 3.74 m³) during 2017, 2018 and in pooled result followed by F₂ i. e. fertigation with 80% RDF. The interaction effect of irrigation and fertigation on growth parameters was also significant wherein the maximum incremental plant height (12.21 cm, 12.27 cm and 12.24 cm), incremental E-W plant spread (11.87 cm, 11.64 cm and 11.76 cm), incremental N-S plant

spread (12.14 cm, 11.86 cm and 12.00 cm) and incremental canopy volume (3.93 m³, 4.35 m³ and 4.14 m³) during 2017, 2018 and in pooled result were recorded in T₁ i.e. I₁F₁ having drip irrigation at 100% ETc and fertigation with 100% of RD with WSF followed by T₂ i.e. I₁F₂ with drip irrigation at 100% ETc and fertigation with 80% of RD with WSF. This might be because of increased nutritional flow of nutrients in the presence of optimum moisture which is utilized in maximizing growth characteristics. The results are in conformity with Panigrahi *et al.* (2012) ^[8] in Nagpur mandarin.

Table 3: Effect of irrigation and fertigation levels on yield parameters in sweet orange

Treatments	No. of fruits tree ⁻¹			Weight of fruits (g)			Yield in kg tree ⁻¹			Yield in t ha ⁻¹		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
Irrigation Levels (I)												
I ₁	311.1	320.0	315.5	200.49	207.24	203.87	62.64	66.58	64.61	17.35	18.44	17.90
I ₂	296.0	305.7	300.8	196.32	203.07	199.70	58.46	62.40	60.43	16.19	17.28	16.74
I ₃	225.9	237.0	231.5	179.22	185.97	182.60	40.15	44.09	42.12	11.12	12.21	11.67
SE (m) ±	5.3	5.7	5.3	1.12	1.16	0.93	1.27	1.50	1.23	0.41	0.42	0.37
CD at 5%	15.8	16.9	15.9	3.32	3.45	2.77	3.76	4.46	3.66	1.22	1.23	1.10
Fertigation Levels (F)												
F ₁	294.7	304.3	299.5	198.42	205.17	201.80	58.98	62.92	60.95	16.34	17.43	16.88
F ₂	292.8	300.7	296.7	196.60	203.35	199.97	57.73	61.67	59.70	15.99	17.08	16.54
F ₃	245.5	257.7	251.6	181.02	187.77	184.40	44.54	48.48	46.51	12.34	13.43	12.88
SE (m) ±	5.3	5.7	5.3	1.12	1.16	0.93	1.27	1.50	1.23	0.41	0.42	0.37
CD at 5%	15.8	16.9	15.9	3.32	3.45	2.77	3.76	4.46	3.66	1.22	1.23	1.10

Interaction (I X F)												
T ₁ -I ₁ F ₁	332.1	340.0	336.1	208.70	215.45	212.07	69.31	73.25	71.28	19.20	20.29	19.75
T ₂ -I ₁ F ₂	327.9	336.0	332.0	206.96	213.71	210.34	67.87	71.81	69.84	18.80	19.89	19.35
T ₃ -I ₁ F ₃	273.1	284.0	278.6	185.81	192.56	189.19	50.75	54.69	52.72	14.06	15.15	14.60
T ₄ -I ₂ F ₁	322.6	331.0	326.8	203.27	210.02	206.65	65.58	69.52	67.55	18.17	19.26	18.71
T ₅ -I ₂ F ₂	319.5	328.0	323.8	202.97	209.72	206.35	64.85	68.79	66.82	17.96	19.05	18.51
T ₆ -I ₂ F ₃	246.0	258.0	252.0	182.72	189.47	186.10	44.95	48.88	46.91	12.45	13.54	13.00
T ₇ -I ₃ F ₁	229.4	242.0	235.7	183.29	190.04	186.66	42.05	45.99	44.02	11.65	12.74	12.19
T ₈ -I ₃ F ₂	231.0	238.0	234.5	179.85	186.60	183.23	40.47	44.41	42.44	11.21	12.30	11.76
T ₉ -I ₃ F ₃	217.4	231.0	224.2	174.53	181.28	177.90	37.94	41.87	39.91	10.51	11.60	11.05
SE (m) ±	9.2	9.8	9.2	1.93	2.01	1.62	2.19	2.60	2.13	0.71	0.72	0.64
CD at 5%	27.3	29.2	27.5	5.74	5.97	4.80	6.51	7.72	6.34	2.11	2.14	1.90
T ₁₀ -Control	239.6	252.0	245.8	180.08	186.83	183.45	43.14	47.08	45.11	11.95	13.04	12.50

The yield parameters in relation to different drip irrigation and fertigation treatments are presented in Table 3. Among irrigation treatments, significantly highest number of fruits (311.1, 320 and 315.5 fruits tree⁻¹), highest weight of fruit (200.49 g, 207.24 g and 203.87 g), fruit yield (62.64, 66.58, 64.61 kg tree⁻¹) and (17.35, 18.44 and 17.90 tha⁻¹) were recorded during 2017, 2018 and in pooled result in I₁ which was followed by I₂. The highest number of fruits, weight of fruits and fruit yield in I₁ i. e. 100% irrigation might be due to constant and adequate availability of moisture in plant rhizosphere during fruit developmental stages that eventually enhanced the fruit retention capacity of plant. The results are in conformity with those of Panigrahi *et al.* (2012) [8] in Nagpur mandarin and Kumar *et al.* (2013) [7] in sweet orange. Among fertigation treatments, significantly highest number of fruits (294.7, 304.3 and 299.5 fruits tree⁻¹), highest weight of fruit (198.42 g, 205.17 g and 201.80 g), fruit yield (58.98, 62.92 and 60.95 kg tree⁻¹) and (16.34, 17.43 and 16.88 tha⁻¹) were recorded during 2017, 2018 and in pooled result in F₁ which was followed by F₂. The highest number of fruits, weight of fruits and fruit yield in F₁ i. e. fertigation with 100% RD through WSF might be due to optimum level of nutrient absorption because of maintenance of field capacity conditions in the root zone with fertigation which led to maximum fruit number, weight and fruit yield. The results are in conformity with those of Kumar *et al.* (2013) [7] in sweet orange.

The interaction effect of irrigation and fertigation on yield parameters was found to be significant. The treatment T₁ i.e. I₁F₁, irrigation at 100% ETc and fertigation with 100% RD with WSF recorded highest number of fruits (332.1, 340 and 336.1 fruits tree⁻¹), weight of fruit (208.70 g, 215.45 g and 212.07 g), fruit yield (69.31, 73.25 and 71.28 kg tree⁻¹) and (19.20, 20.29 and 19.75 t ha⁻¹) during 2017, 2018 and in pooled result. The yield parameters like number of fruits tree⁻¹, fruit yield in kg tree⁻¹ and ton ha⁻¹ under the treatment T₁ i.e. I₁F₁ were observed to be at par with the treatment T₅ i.e. I₂F₂ having drip irrigation at 80% ETc and fertigation with 80% of RD with WSF corroborating the fact that optimum moisture and nutrients through drip irrigation causes higher fruit yield where as the application of nutrients through broadcasting and flow irrigation leads to more losses of applied fertilizers by leaching or soil fixation. Greater improvement in vegetative growth and yield parameters at higher irrigation and fertigation level was possible due to sufficient and continuous availability of moisture along with major nutrients (NPK) contributing towards vegetative development of plants as a result of higher partitioning of photosynthates, better photosynthetic area and cell turgidity. Similar results were recorded by Goud *et al.* (2017) [4] in Nagpur mandarin and Jogdand and Jagtap (2018) [6] in sweet orange.

Conclusion

Considering two-year study of irrigation and fertigation level, it was concluded that the treatment T₁, i.e. I₁F₁ having irrigation level 100% of ETc and fertigation with 100% of RDF with WSF followed by the treatment T₂ i.e. I₁F₂ having irrigation at 100% of ETc and fertigation at 80% of RDF through water soluble fertilizer and the treatment T₅ i.e. I₂F₂ having irrigation at 80% of ETc and fertigation at 80% of RDF through water soluble fertilizer were found to be superior and statistically at par, therefore, the farmers need to be advised to adopt the treatment T₅ i.e. I₂F₂ having irrigation at 80% of ETc and fertigation at 80% of RDF through water soluble fertilizer which is a better option for maximizing the yield in sweet orange cv. Phule Mosambi through optimization of water and fertilizer use.

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