International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 1577-1581

Received: 27-03-2020
Accepted: 29-04-2020

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

P.D Hendre, S.A Ranpise and A.G Durgude

DOI: https://doi.org/10.22271/chemi.2020.v8.i3u.9418

P.D Hendre
Subject Matter Specialist (Horticulture), Krishi Vigyan Kendra Babhaleshwar, Dist. Ahmednagar, Maharashtra, India.

S.A Ranpise
Head, Department of horticulture, MPKV, Rahuri, Maharashtra, India

A.G Durgude
Analytical Chemist, micronutrient research scheme, Department of soil science & Agril. Chemistry, MPKV, Rahuri, Maharashtra, India.

Corresponding Author:
P.D Hendre
Subject Matter Specialist (Horticulture), Krishi Vigyan Kendra Babhaleshwar, Dist. Ahmednagar, Maharashtra, India.

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 yield parameters such as no. of fruits tree^{-1}, yield in kg tree^{-1} and partial factor productivity of nutrients were observed to be significantly highest in the treatment T_1-I_1F_1 having irrigation at 100% ETc and fertigation at 100% RD through WSF than rest of the treatments however they were statistically at par with the treatment T_5- I_2F_2 comprising irrigation at 80% of ETc and fertigation with 80% of RD with WSF during 2017, 2018 and in pooled results. The nutrient use efficiency parameters like nitrogen use efficiency, phosphorus use efficiency and potassium use efficiency were observed to be significantly higher in the treatment T_3-I_1F_3 having irrigation at 100% ETc and fertigation at 60% RD through WSF which was statistically at par with the treatment T_5- I_2F_2 comprising irrigation at 80% of ETc and fertigation with 80% of RD with WSF during 2018 and in pooled results. The sustained productivity of sweet orange with highest nutrient use efficiency can be achieved with irrigation scheduled at 80% ETc along with fertigation technology at 80% RDF especially under scarcity conditions of Western Maharashtra.

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 (*Citrus sinensis* L. Osbeck) is predominantly grown in sub-tropical areas of India and the productivity 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 [12]. 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 [6]. The use of water and nutrients through drip irrigation (DI) in concurrence with plant demand, therefore, could be one of the potential options by providing maximum nutrient use efficiency for sustainable citrus production.

The drip irrigation and fertigation has better water and fertilizer use efficiency besides providing other advantages like saving in labour, water and power, greater orchard uniformity, better soil water plant relationship, rooting environment and better yield in citrus. Higher initial cost for installation of drip system could be an impediment from growers point of view but the advantages of saving in labour, water and power, maximum and uniform tree growth and imparting an immediate response to crop, better soil-water-plant relationship, rooting development, with better yield and quality makes it ideal choice (Smajstrala, 1993) [14]. Panigrahi and Srivastava (2017) [10] and Goramnagar (2017) [4] have shown promising result of nutrient use efficiency in fertigation and drip irrigation in citrus group (Shirgure *et. al.* 1999) [13]. However, such type of studies is limited in Western Maharashtra region.

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 yield and nutrient use efficiency of sweet orange cv. Phule Mosambi.

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 $19^0$20' and $19^0$57' N latitude and $74^0$82' and $74^0$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.*, I_1-irrigation at 100% ETc., I_2- irrigation at 80% ETc. and I_3- irrigation at 60% ETc. with three fertigation levels (F) *i.e.*, F_1- 100% of RD with water soluble fertilizers (WSF), F_2- 80 % of RD with WSF and F_3- 60% of RD with WSF through drip irrigation. The treatments combinations tested were T_1 -I_1F_1-Drip irrigation at 100% of ETc with 100% of RD through WSF, T_2 -I_1F_2-Drip irrigation at 100% of ETc with 80% of RD through WSF, T_3 -I_1F_3- drip irrigation at 100% of ETc with 60% of RD through WSF, T_4-I_2F_1- drip irrigation at 80% of ETc with 100% of RD through WSF, T_5-I_2F_2- drip irrigation at 80% of ETc with 80% of RD through WSF, T_6-I_2F_3- drip irrigation at 80% of ETc with 60% of RD through WSF, T_7-I_3F_1- drip irrigation at 60% of ETc with 100% of RD through WSF, T_8-I_3F_2- drip irrigation at 60% of ETc with 80% of RD through WSF, T_9-I_3F_3- drip irrigation at 60% of ETc with 60% of RD through WSF and T_{10}- 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 P_2O_5: 600 g K_2O + 20 kg FYM + 15 kg neem cake/plant/year which was used for fertigation with water soluble fertilizers (WSF) while band placement of conventional fertilizers (BPF) method was 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% (F_1), 80% (F_2) and 60% (F_3) of recommended dose through WSF in four main stages comprising 5 splits of 40% each of N, P_2O_5 and K_2O during January to March in first stage, 5 splits each of 30% N and P_2O5 and 10% of K_2O during April and May in second stage, 4 splits each of 20% of N and P_2O5 and K_2O during June and July in third stage and 4 splits each of 10% N and P_2O_5 and 30% K_2O 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 [11] from the equation ETc= ETr x Kc. The net irrigation requirement was computed from the formula, $V = [(ETr - R_e) \times Kc \times A \times F] / Eu$ where, V = volume of water applied to each plant per day(mm^3); ETr = Reference crop evapotranspiration at the irrigation level (mm/day); Kc = Crop coefficient (as per crop stage); A = canopy area of tree (m^2) 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 fruits harvested from the observational plants during each harvest were counted and weighed for each treatment plot and total fruit yield in number of fruits and kg per tree was calculated and recorded accordingly. Fertilizer use efficiency (FUE) was obtained from the ratio of quantity of each nutrient fertilizer used to produce per unit fruit production. Whereas, Partial factor productivity was estimated by dividing the fruit yield (kg $tree^{-1}$) with amount of the total fertilizer nutrient (N + P + K) applied (kg $tree^{-1}$) (Devasenpathy *et al.* 2008) [3].

1. Nitrogen UE = Fruit yield (kg $tree^{-1}$) / fertilizer (N) applied (kg $tree^{-1}$)
2. Phosphorus UE = Fruit yield (kg $tree^{-1}$) / fertilizer (P) applied (kg $tree^{-1}$)
3. Potassium UE = Fruit yield (kg $tree^{-1}$) / fertilizer (K) applied (kg $tree^{-1}$)
4. PFP = Fruit yield (kg $tree^{-1}$) / total nutrient (N+P+K) applied (kg $tree^{-1}$)

Results and discussion

Yield

The data presented in table 1 revealed that, the individual effect of irrigation and fertigation and the interaction effect of irrigation and fertigation on yield in number of fruits and in kg per tree of sweet orange was found significant during 2017, 2018 and in pooled result. The irrigation level I_1, drip irrigation at 100% of ETc recorded significantly maximum number of fruits (311.1, 320.0 and 315.5) and maximum yield in kg tree^{-1} (62.64, 66.58 and 64.61) during 2017, 2018 and in pooled result, respectively, which was followed I_2. The highest number of fruits and fruit yield in I_1 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) [9] in Nagpur mandarin and Kumar *et al.* (2013) [8] in sweet orange.

Table 1: Effect of irrigation and fertigation levels on yield in no. of fruits and kg per tree in sweet Orange during *Ambia bahar*

Treatments	Yield in number of fruits tree^{-1}			Yield (kg tree^{-1})		
	2017	2018	Pooled	2017	2018	Pooled
Irrigation Levels (I)						
I_1 : 100% ETc	311.1	320.0	315.5	62.64	66.58	64.61
I_2 : 80% ETc	296.0	305.7	300.8	58.46	62.40	60.43
I_3 : 60% ETc	225.9	237.0	231.5	40.15	44.09	42.12
SE (m) ±	5.3	5.7	5.3	1.27	1.50	1.23
CD at 5 %	15.8	16.9	15.9	3.76	4.46	3.66
Fertigation Levels (F)						
F_1: 100% RD	294.7	304.3	299.5	58.98	62.92	60.95
F_2 : 80% RD	292.8	300.7	296.7	57.73	61.67	59.70
F_3 : 60% RD	245.5	257.7	251.6	44.54	48.48	46.51
SE (m) ±	5.3	5.7	5.3	1.27	1.50	1.23
CD at 5 %	15.8	16.9	15.9	3.76	4.46	3.66
Interaction (I X F)						
T_1 -I_1F_1	332.1	340.0	336.1	69.31	73.25	71.28
T_2 -I_1F_2	327.9	336.0	332.0	67.87	71.81	69.84
T_3 -I_1F_3	273.1	284.0	278.6	50.75	54.69	52.72
T_4 -I_2F_1	322.6	331.0	326.8	65.58	69.52	67.55
T_5 -I_2F_2	319.5	328.0	323.8	64.85	68.79	66.82
T_6 -I_2F_3	246.0	258.0	252.0	44.95	48.88	46.91
T_7 -I_3F_1	229.4	242.0	235.7	42.05	45.99	44.02
T_8 -I_3F_2	231.0	238.0	234.5	40.47	44.41	42.44
T_9 -I_3F_3	217.4	231.0	224.2	37.94	41.87	39.91
SE (m) ±	9.2	9.8	9.2	2.19	2.60	2.13
CD at 5 %	27.3	29.2	27.5	6.51	7.72	6.34
T_{10} -Control	239.6	252.0	245.8	43.14	47.08	45.11

Among fertigation treatments, significantly highest number of fruits (294.7, 304.3 and 299.5 fruits tree^{-1}) and highest fruit yield (58.98, 62.92 and 60.95 kg tree^{-1}) were recorded during 2017, 2018 and in pooled result, respectively, in F_1 which was followed by F_2.The highest number of fruits and fruit yield in F_1 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) [8] in sweet orange.

The interaction effect of irrigation and fertigation on yield parameters was found to be significant. The treatment T_1 i.e. I_1F_1, 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}) and fruit yield (69.31, 73.25 and 71.28 kg tree^{-1}) during 2017, 2018 and in pooled result, respectively, which was observed to be at par with the treatment T_5 i.e. I_2F_2 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 whereas 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 also recorded by Goud *et al.* (2017) [5] in Nagpur mandarin, Vijaya *et al.* 2017) [15] and Jogdand and Jagtap (2018) [7] in sweet orange.

Nutrient use efficiency

The data in the table 2 revealed that the effect of various irrigation and fertigation levels and its interaction effect on nutrient use efficiency in terms of nitrogen, phosphorus and potassium were found to be significant during 2018 and in pooled result but the interaction effect of irrigation and fertigation on nitrogen use efficiency (NUE), phosphorus use efficiency (PUE) and potassium use efficiency (KUE) was observed to be non-significant during 2017. The effect of various irrigation and fertigation levels and its interaction effect on partial factor productivity was observed to significant during 2017, 2018 and in pooled result.

Table 2: Effect of irrigation and fertigation levels on fertilizer use efficiency in sweet orange

	Nitrogen use efficiency (kg fruits kg^{-1} N)			Phosphorus use efficiency (kg fruits kg^{-1} P)			Potassium use efficiency (kg fruits kg^{-1} K)			Partial factor productivity (kg fruits kg^{-1} NPK)		
Treatments	**2017**	**2018**	**Pooled**	**2017**	**2018**	**Pooled**	**2017**	**2018**	**Pooled**	**2017**	**2018**	**Pooled**
Irrigation Levels (I)												
I_1: 100% ETc	99.47	105.90	102.69	265.26	282.40	273.83	132.63	141.20	136.91	36.85	39.17	38.01
I_2 : 80% ETc	92.31	98.74	95.53	246.17	263.31	254.74	123.08	131.65	127.37	34.39	36.70	35.55
I_3 : 60% ETc	64.95	71.37	68.16	173.19	190.33	181.76	86.59	95.16	90.88	23.62	25.94	24.78
SE (m) ±	2.21	2.06	1.91	5.88	5.48	5.10	2.94	2.74	2.55	0.74	0.88	0.73
CD at 5 %	6.56	6.11	5.69	17.48	16.28	15.17	8.74	8.14	7.58	2.21	2.62	2.15
Fertigation Levels (F)												
F_1: 100% RD	73.73	78.65	76.19	196.60	209.73	203.17	98.30	104.87	101.58	34.69	37.01	35.85
F_2 : 80% RD	90.20	96.36	93.28	240.55	256.96	248.75	120.27	128.48	124.38	33.96	36.28	35.12
F_3 : 60% RD	92.80	101.00	96.90	247.46	269.35	258.41	123.73	134.67	129.20	26.20	28.52	27.36
SE (m) ±	2.21	2.06	1.91	5.88	5.48	5.10	2.94	2.74	2.55	0.74	0.88	0.73
CD at 5 %	6.56	6.11	5.69	17.48	16.28	15.17	8.74	8.14	7.58	2.21	2.62	2.15
Interaction (I X F)												
T_1 -I_1F_1	86.64	91.57	89.10	231.05	244.18	237.61	115.52	122.09	118.81	40.77	43.09	41.93
T_2 -I_1F_2	106.04	112.20	109.12	282.79	299.20	290.99	141.39	149.60	145.50	39.92	42.24	41.08
T_3 -I_1F_3	105.73	113.93	109.83	281.94	303.82	292.88	140.97	151.91	146.44	29.85	32.17	31.01
T_4 -I_2F_1	81.97	86.90	84.44	218.60	231.73	225.16	109.30	115.86	112.58	38.58	40.89	39.73
T_5 -I_2F_2	101.33	107.48	104.41	270.21	286.62	278.42	135.11	143.31	139.21	38.15	40.46	39.31

T_6-I_2F_3	93.64	101.84	97.74	249.70	271.58	260.64	124.85	135.79	130.32	26.44	28.76	27.60
T_7-I_3F_1	52.56	57.49	55.02	140.17	153.30	146.73	70.08	76.65	73.37	24.74	27.05	25.89
T_8-I_3F_2	63.24	69.39	66.32	168.64	185.05	176.84	84.32	92.52	88.42	23.81	26.12	24.97
T_9-I_3F_3	79.03	87.24	83.14	210.76	232.64	221.70	105.38	116.32	110.85	22.32	24.63	23.47
SE (m) ±	3.82	3.56	3.32	10.19	9.49	8.84	5.10	4.75	4.42	1.29	1.53	1.26
CD at 5 %	NS	10.58	9.85	NS	28.20	26.27	NS	14.10	13.13	3.83	4.54	3.73
T_{10}-Control	53.93	58.85	56.39	143.81	156.94	150.37	71.90	78.47	75.19	25.38	27.69	26.54

The NUE, PUE, KUE and partial factor productivity (PFP) were significantly influenced by the irrigation levels during 2017, 2018 and in pooled results. The irrigation level I_1 recorded significantly higher NUE (99.47, 105.9 and 102.69 kg fruit kg^{-1} N), PUE (265.26, 282.4 and 273.83 kg fruit kg^{-1} P), KUE (132.63, 141.2 and 136.91 kg fruit kg^{-1} K) and PFP (36.85, 39.17 and 38.01 kg fruit kg^{-1} NPK) during 2017, 2018 and in pooled result however the PFP under I_1 during 2018 was observed to be at par with the irrigation level I_2. Among the fertigation levels, the fertigation level F_3 showed significantly higher NUE (92.8, 101 and 96.9 kg fruit kg^{-1} N), PUE (247.46, 269.35 and 258.41 kg fruit kg^{-1} P), KUE (123.73, 134.67 and 129.2 kg fruit kg^{-1} K) respectively during 2017, 2018 and in pooled result which was observed to be at par with F_2. However the PFP under the fertigation level F_1 was found to be significantly higher but was statistically at par with F_2 during 2017, 2018 and in pooled result.

The interaction effect of irrigation and fertigation levels on NUE, PUE and KUE was observed to be significant during 2018 and in pooled mean but was observed to be non-significant during 2017. The treatment T_3 i.e. I_1F_3 comprising irrigation at 100% ETc and fertigation at 60% RD through WSF showed significantly highest NUE (113.93 and 109.83 kg fruit kg^{-1} N), PUE (303.82 and 292.88 kg fruit kg^{-1} P), KUE (151.91 and 146.44 kg fruit kg^{-1} K) during 2018 and in pooled mean. However, the T_3 was observed to be at par with T_2 which is irrigation at 100% ETc and fertigation at 80% RD through WSF and treatment T_5 comprising irrigation at 80% ETc and fertigation at 80% RD through WSF during 2018 and in pooled result.

Significantly highest PFP (40.77, 43.09 and 41.93 kg fruit kg^{-1} NPK) was recorded in the treatment T_1 i.e. I_1F_1 comprising irrigation at 100% ETc and fertigation at 100% RD through WSF during 2017, 2018 and in pooled result which was observed to be at par with the treatments T_2 i.e. I_1F_2 comprising irrigation at 100% ETc and fertigation at 80% RD through WSF, treatment T_4 i.e. I_2F_1 comprising irrigation at 80% ETc and fertigation at 100% RD through WSF and treatment T_5 i.e. I_2F_2 comprising irrigation at 80% ETc and fertigation at 80% RD through WSF during both the years and in pooled result. The above results might be due to the fact that the fertigation for supply of nutrients exactly and uniformly only in the wetted active root zone leads to optimum supply of nutrients and reduces the nutrient leaching losses below the root zone which ultimately increases the efficiency of overall fertilizers.

Similar results were shown by Goramnagar *et al.* (2017) [4] in acid lime and by Kumar *et al.* (2013) [8] in sweet orange.

Conclusion

Considering two-year study of irrigation and fertigation level, it was concluded that the treatment treatment T_5 i.e. I_2F_2 having irrigation at 80% of ETc and fertigation at 80% of RDF through water soluble fertilizer was found to be superior in providing a better nutrient use efficiency in terms of nitrogen, phosphorus and potassium use and a better partial factor productivity and therefore is a judicious option for maximizing the yield in sweet orange cv. Phule Mosambi with optimization of water and fertilizer use through fertigation.

References

1. Anonymous. Horticulture statistics at a glance 2018, National Horticulture Database, 2018, 175-177.
2. Allen R.G, Pariera L.S, Raes Smith M. Crop evapotranspiration: Guidelines for computing crop requirement, Irrigation and Drainage, FAO, Rome, Italy, 1998, 56.
3. Devasenapathy P, Ramesh T, Gangawar B. Efficiency indices for agriculture management research, New India publishing agency, New Delhi, 2008.
4. Goramnagar H.B, Nagare P.K, Bharad S.G, Sonune B.A, Raut R.F. Effect of chemical fertilizer through fertigation and micro-irrigation on fruit yield and nutrient use efficiency in acid lime of semi-arid climatic conditions of Maharashtra, *Int. J of Chem Studies.* 2017; 5(6):31-35.
5. Goud Sudharshan, Pimpale Anil, Kharche Vilas. Effect of fertigation on growth, yield and quality of Nagpur mandarin, *Agril Bull Env Pharmacol Life Sci.* 2017; 6(1):172-176.
6. Hanson Blaine, Simunek R, Jiri Jirka, Hopmans Jan W. Evaluation of urea–ammonium–nitrate fertigation with drip irrigation using numerical modelling *Agric Water Manage.* 2006; 86(1-2):102-113.
7. Jogdand S.M, Jagtap D.D. Studies on irrigation and nutrient interactions in sweet orange (*Citrus sinensis* (L.) Osbeck), *Chem Sci Rev Let.* 2018; 7(27):819823.
8. Kumar H, Yadav P.K, Singh A.K, Sharma S.K. Evaluation of water regime and fertigation on growth, yield and economics of sweet orange (*Citrus sinensis* L. Osbeck) cv. Mosambi, *Asian J of Hort*. 2013; 8:709-713.
9. Panigrahi P, Srivastava A.K, Huchche A.D, Singh Shyam. Plant nutrition in response to drip versus basin irrigation in young Nagpur mandarin on Inceptisol, *J Plant Nutri.* 2012; 35:215–224.
10. Panigrahi P, Srivastava A.K. Water and nutrient management effects on water use and yield of drip irrigated citrus in Vertisol under a sub-humid region, *J Integ Agric.* 2017; 16:1184–1194.
11. Petillo M.G, Castel J.R. Water balance and crop coefficient estimation of a citrus orchard in Uruguay, *Spanish J Agric Res.* 2007; 5(2):1-12.
12. Phene C.J, Ruskin R. Potential of subsurface drip irrigation for management of nitrate in wastewater. *Proceedings, Fifth International Micro irrigation Congress, Orlando, FL.* 1995; 2-6:155-167.
13. Shirgure P.S, Lallan Ram S, Singh, Marathe R.A, Yadav R.P. Effect of nitrogen fertigation on vegetative growth and leaf nutrient content of acid lime (*Citrus aurantifolia* Swingle) in central India, Indian J soil cons. 1999; 27(1):45-49.
14. Smajstrla AG. Micro-irrigation for citrus production in Florida *Hort Sci.* 1993; 28(4):295-298.

15. Vijaya H.M, Godara R.K, Shashank Singh, Nidhi Sharma. Influence of different level of water and fertilizer application through drip system on growth and yield of kinnow mandarin (*Citrus reticulata* Blanco) *J of Exp Bio Agril Sci.* 2017; 5(6):840-845.