Water requirements in growth stages and effects of deficit irrigation on fruit productivity of drip irrigated Nagpur mandarin (Citrus reticulata)

Article *in* Indian Journal of Agricultural Sciences · April 2014

3 authors:

Parameshwar Shirgure
ICAR-Central Citrus Research Institute, Nagpur, India

Anoop Kumar Srivastava
National Research Centre for Citrus

Ambadas DATTATRAY Huchche
Central Citrus Research Institute (formerly National Research Centre for Citrus)

Indian Journal of Agricultural Sciences **84** (3): 317–22, March 2014/Article

Water requirements in growth stages and effects of deficit irrigation on fruit productivity of drip irrigated Nagpur mandarin (*Citrus reticulata*)

P S SHIRGURE[1], A K SRIVASTAVA[2] and A D HUCHCHE[3]

National Research Centre for Citrus, Nagpur, Maharashtra 440 010

Received: 12 November 2012; Revised accepted: 28 January 2014

ABSTRACT

The field experiment on irrigation scheduling based on pan evaporation replenishment through drip irrigation system was conducted to find out the water requirements in critical growth stages of 8-10 years old bearing Nagpur mandarin (*Citrus reticulata* Blanco) during 2009-2012 at NRC for Citrus, Nagpur. In this trial five levels of pan evaporation based irrigation schedules with respect to critical water requirement, plant growth, soil and leaf nutrient status, yield and fruit quality was investigated. The irrigations were scheduled on percent of pan evaporation replenishment (ER) in various stages of growth and fruit development. The different stages considered in this study are: Stage-I (Jan-Feb), Stage-II (Mar-Apr), Stage-III (May-Jun), Stage-IV (Jul-Aug), Stage-V (Sep-Oct) and Stage-IV (Nov-Dec).The treatments were irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (T_1), irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (T_2), irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (T_3), irrigation schedule with 80% ER in stage-I to VI (T_4) and irrigation schedule with 30% ER in stage-I to VI (T_5) with three replications in Randomized Block Design. The study indicated that the irrigation water requirement of drip irrigated Nagpur mandarin scheduled at 80% ER in stages I to VI ranged from 35.3 to 188.1 litres during 2009-2012. The growth of plant height (4.73 m) and stock girth (66.37 cm) was more in irrigation scheduled at 80% ER in stages I to VI. There is a significant in increase in canopy volume (68.97 m^3) in irrigation scheduled at 80% ER in stages I to VI. The average fruit yield recorded was 16.09 tonnes per ha. in irrigation scheduled 80% ER in stages I to VI. The average fruit weight, Total Soluble Solids, juice percentage was high in irrigation at 80% ER in stages I to VI in comparison with other irrigation schedules. The study revealed that the irrigation scheduling at critical water need affect the plant growth, yield and fruit quality of Nagpur mandarin with drip irrigation scheduling less than 80% ER in all stages.

Key words: Deficit irrigation, Fruit productivity, Fruit quality, Growth stages, Irrigation scheduling, Leaf nutrients, Nagpur mandarin, Pan evaporation, Water requirements

Nagpur mandarin (*Citrus reticulata* Blanco) is an important commercial citrus cultivar mainly grown in *Vidharbha* region of Maharashtra and adjoining states like Madhya Pradesh as well as Rajasthan. It is grown in 0.148 M ha area (fruit bearing area is 0.086 M ha). In developed countries the mandarin cultivation is practicing the evaporation based irrigation schedules and in India also mandarin orchards are also irrigated using drip irrigation systems needs to schedule based on evaporation replenishment for efficient use of water (Shirgure 2001a). Evaporation from the trees of '*Shamouti*' orange partially irrigated plots was 72% of that of the fully irrigated plot and the evaporation from the soil surface was 58%. Fruit TSS and acid contents were higher in partially irrigated plots. The water requirement of 6 year old *Kinnow* mandarin was 539 to 1276 mm depending upon the level of irrigation with average consumptive use of water. The research on influence of irrigation and nitrogen on water use and growth of *Kinnow* mandarin receiving four levels of irrigation and three levels of nitrogen (115 or 230 kg N/tree). The consumptive use varied from 667 to 1325 mm (Mageed *et al.* 1988). The critical water requirement of mandarin varies with the season, stage and age with varied climatic conditions. The water use of Nagpur mandarin under clean cultivation, the water requirement of young, middle age and mature trees was 651, 849 and 997 mm per year respectively (Ghadekar *et al.* 1989). The sap flow measurement in the grapefruit trunk and potential transpiration computed from meteorological data were used during the irrigation seasons to determine the water requirement of 17 years old trees (Cohen 1991). Seasonal water requirements of oranges ranged from 190 to 330 mm. Irrigation to replace 60% of the water consumed reduced tree growth, yield and fruit quality. Irrigating to

[1] Senior Scientist (Soil and Water Conservation Engineering) (e mail: shirgure@gmail.com), [2] Principal Scientist (Soil Science) (e mail : srivas2007@gmail.com) and [3] Principal Scientist (Hort.) (e mail : ambadas.huchche@gmail.com)

replace 80% of the water used gave better yields and quality comparable to replacing 100% of the water consumed (Dettori and Filigheddu 1994). Washington Navel orange trees supplied with varying amount of water ranging from 68 to 126% of estimated water requirement. The results indicated that 780 mm of water was sufficient in normal year for optimum yield and tree growth. The amount corresponded to 56% of class A pan evaporation. Reducing irrigation by 37% decreased yield by 10.7%. This yield reduction was mainly due to smaller fruit size and peel thickness increased with decreasing amount of water applied (Eliadses 1998). A mature *Valencia* orange trees showed that the water use pattern over the entire season reached a maximum of 87 litres/day in January. The highest yields (190 kg/tree) and the largest average fruit size with irrigation at a crop factor of 0.9 on a 3 day cycle was obtained (Plessis 1989). Castel and Buj (1990) observed that mature *Satstuma* trees grafted on Sour orange rootstocks showed a good response on yield and quality when irrigated with 60% of the estimated ET losses from a class A pan and 80% of the control throughout the year. The irrigation scheduling based on depletion of available water content and fraction of cumulative pan evaporation in Nagpur mandarin in pre-bearing stage concluded that the evapo-transpiration varied from 213.6 mm to 875.6 mm in various schedules. The irrigation requirement of Nagpur mandarin scheduled at 0.8 of pan evaporation ranged from 15 to 73 liters during 1998-2000. The higher incremental growth of plant height, girth and canopy volume, average fruit yield (14.23 kg per tree), fruit weight (167 g) and juice percentage (43.46%) was recorded in 0.8 of pan evaporation irrigation schedules (Shirgure *et al*. 2001a). The tree growth, fruit yield as well as quality of Nagpur mandarin was greatest when irrigation was scheduled with micro-jets of 180° (2/plants) treatments (Shirgure *et al.* 2012). An attempt is made here to study the different combinations of pan evaporation based irrigation scheduling with drip irrigation system on water requirement at crucial growth stages of plant growth, fruit yield and quality of bearing Nagpur mandarin.

MATERIALS AND METHODS

To identify the stages of critical water requirements and irrigation scheduling based on open pan evaporation through the drip irrigation a field experiment was conducted in the block of 0.5 ha area with 6 m spacing on 8-10 years old Nagpur mandarin at experimental farm of NRC for Citrus, Nagpur (Maharashtra) during 2009-2012. The irrigations were scheduled on percent of pan evaporation replenishment (ER) in various stages of growth and fruit development. The different stages considered in this study are: Stage-I (Jan-Feb), Stage-II (Mar-Apr), Stage-III (May-Jun), Stage-IV (Jul-Aug), Stage-V (Sep-Oct) and Stage-IV (Nov-Dec). The treatments were irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (T_1), irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (T_2), irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (T_3), irrigation schedule with 80% ER in stage-I to VI (T_4) and irrigation schedule with 30% ER in stage-I to VI (T_5) with three replications in Randomized Block Design. The irrigation was scheduled and applied to the treatments on percent pan evaporation replenishment. The texture of the soil was clay loam and depth of the soil is 41 cm. The composite soil samples were collected for determination of field capacity and permanent wilting point. Volumetric soil moisture content at field capacity (FC) and the permanent wilting point (PWP) soil moisture content was determined using pressure plate method. The FC and PWP of the field under study was 28.4% and 18.1% respectively. The available water content of the soil was 10.3%. The bulk density of the soil in field was determined using core sampler having 100 cm^3 volume and oven drying. The bulk density of the field was 1.48 g/cc. The water holding capacity of the soil was 18.54 cm/m depth of soil. Based on the average weekly open pan evaporation, the irrigation quantities were calculated taking into account of pan factor (0.7), canopy factor (0.8) and crop factor (0.6). Monthly quantity of irrigation scheduled and depth and quantity of irrigation was recorded from October-December as well as January-June months. Soil-moisture status was recorded periodically during April 2009 to March 2012 with the help of a neutron moisture probe using aluminum access tubes were installed at 70 cm depth within the tree basin and 70 cm apart from the two drippers. The fertigation was given with the fertilizer injection pump (DOSTRON, France). The quantity of fertilizers used in 100% RDF is 500:150:150 (N:P:K) applied as per the treatment schedules. The fertilizers were fertigated at fortnightly intervals from October to June. From October to January, nitrogen (N) was applied through urea (46% N) and from February to June through both urea and urea phosphate. Phosphorous (P) was applied through urea phosphate and potassium (K) through potassium chloride during February and June. The monthly precipitation, mean temperature and relative humidity for the year 1996-2008 and 2009-2012 is also presented (Table 1). The bio-metric parameters of Nagpur mandarin plants (plant height and tree spread) were recorded in October, 2009, 2010 and 2011. The plant stock girth and scion girth was taken 15 cm and 25 cm above the soil surface. The canopy volume of the mandarin tree was calculated according to formula suggested by Castle (1983). Nagpur mandarin fruit yield and quality analysis was also carried out as per procedures (Ranganna 1988). Leaf samples were collected as per procedures suggested by Srivastava *et al* (1994) and finally prepared samples were digested in di-acid mixture of H_2SO_4 : $HClO_4$ in 2.5:1 ratio. The leaf N was determined using alkaline permanganate steam distillation method, P by vanadomolybdophosphoric acid method and K flame photometrically. The data on fruit yield and quality attributing to the different irrigation schedules for 3 years were analysed by Analysis of variance method (Gomez and Gomez 1984).

Table 1 Monthly precipitation, mean temperature and relative humidity during 1996-2008 and 2009-2012

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1996-2008												
Precipitation (mm)	2	22.8	0	0	64.4	156.3	227.4	170.6	238	100.4	0	0
Mean temperature (°C)	21.2	23.9	30.4	34.2	31.9	24.8	27.8	27.9	28.2	25.7	23.5	21.6
Relative humidity (%)	68.8	66.2	47.4	37.2	50.7	64.7	91.4	93.7	91.9	90.7	83.3	67.5
2009-2012												
Precipitation (mm)	0	0	0	4.2	0	43	182.9	264.4	129	0	0	0
Mean temperature (°C)	22.4	24.3	31.7	35.5	32.6	25.9	28.8	29.1	28.3	26.4	24.3	22.6
Relative humidity (%)	67.3	65.4	45.5	36.6	30.7	62.2	89.5	91.1	90.3	88.7	82.2	58.3

RESULTS AND DISCUSSION

Irrigation scheduling and water requirements at critical stages

The water requirement of bearing Nagpur mandarin varied according to the different pan evaporation replenishment based drip irrigation schedule combinations and various critical growth stages. The daily weather data recorded from NRCC observatory was used for irrigation scheduling based on evaporation. The daily maximum open pan evaporation ranged from minimum 3.2 mm per day in December to maximum 12.7 mm per day in May. The water requirements at different stages increased with increasing the stage I (January-February) to III (May-June) due summer months and rise in day length as well as temperature. The water quantity scheduled also varied from 30% and 40% ER to 80% ER in all the six stages of the growth. The stages III, II and I are more crucial than stages IV, V and VI in all the treatments (Table 2). Following the drip irrigation and ER based irrigation scheduling from 30 to 80% ER in stages I to VI the water requirement of bearing (8-10 years) Nagpur mandarin varied from 35.3 liters/day/plant (stage VI) to 188.1 liters/day/plant (stage III) in the irrigation schedule with 80% ER in stages I-VI. The critical water requirement of Nagpur mandarin varied from 32.3 liters/day/plant (stage VI) to 163.6 liters/day/plant (stage III) in the irrigation schedule with 60% ER in stages I, III and V and 80% ER in stages II, IV and VI. In the irrigation schedule with 40% ER in stages I, III and V and 60% ER in stages II, IV and VI the water requirement of Nagpur mandarin ranged from 26.5 liters/day/plant (stage VI) to 112.1 liters/day/plant (stage III). Similarly, the water requirement of Nagpur mandarin in the irrigation schedule with 30% ER in stages I, III and V and 40% ER in stages II, IV and VI varied from 17.7 liters/day/plant (stage VI) to 86.8 liters/day/plant (stage III). The lowest water quantity was recorded in irrigation with 30% ER in all six stages. It varied from 13.3 liters/day/plant (stage VI) to 68.8 liters/day/plant (stage III). The similar results were also observed in the earlier studies on irrigation scheduling in Nagpur mandarin (Shirgure *et al.* 2001b) and in acid lime (Shirgure *et al.* 2000).

Soil and leaf nutrient composition

The effect of differential irrigation scheduling treatments on the critical growth and water requirements was monitored with periodical analysis of soil and leaf. The soil and leaf samples were collected from different irrigation treatments were analysed for N, P and K contents as well as Fe, Mn, Zn and Cu elements in 2009-2012. Large variation in available nutrients in soil, viz. N (122.4 to 129.8 mg/kg), P (9.81 to 13.12 mg/kg), K (224.3 to 236.4 mg/kg), Fe (18.8 to 28.1 mg/kg), Mn (9.8 to 13.2 mg/kg), Cu (1.64 to 1.89) and Zn (0.72 to 0.92 mg/kg) was observed. These variations

Table 2 Average monthly water quantity applied in different irrigation schedules and various stages during the year 2009-2012

Treatment	Average monthly total irrigation quantity applied (liters/day/plant)									
	Stage-I		Stage-II		Stage-III		Stage-IV, V	Stage-VI		Total
	Jan*.	Feb.	March	April	May	June	July-Oct.	Nov.	Dec.	
T_1	19.4	29.0	40.1	82.3	63.7	86.8	R	27.8	17.7	366.8
T_2	25.8	38.7	60.1	98.4	85.0	112.1	R	41.8	26.5	488.4
T_3	38.7	58.1	80.2	151.4	127.5	163.6	R	52.7	32.3	704.5
T_4	51.6	77.5	100.2	164.4	170.0	188.1	R	55.7	35.3	842.8
T_5	17.4	27.2	30.1	61.7	63.7	68.8	R	20.9	13.3	303.1

R, Rainfall, *A 15 days stress was given for flower induction in first fortnight of January, T_1,irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI, T_2, irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI, T_3, irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI, T_4, irrigation schedule with 80% ER in stage-I to VI and T_5, irrigation schedule with 30% ER in stage-I to VI were statistically highly significant when compared with response of different irrigation scheduling treatments. The treatment irrigation schedule with 80% ER in stage-I to VI (129.8 N – 13.12 P_2O_5 – 236.4 K_2O – 28.1 Fe – 13.2 Mn – 1.72 – Cu – 0.92 Zn, mg/kg) proved to be the best treatment over rest of the other irrigation treatments (Table 3). Highly significant (P<0.05) variation in leaf nutrient status, viz. N (2.02 to 2.24%), P (0.07 to 0.11%), K (1.10 to 1.30%), Fe (17.2 to 25.8 ppm), Mn (8.8 to 13.1 ppm), Cu (7.8 to 8.4 ppm) and Zn(18.8 to 23.1 ppm) was observed in irrigation schedule with 80% ER in stage-I to VI. The treatment irrigation schedule with 80% ER in stage-I to VI recorded the highest concentration of macronutrients (N, P and K) and micronutrients (Fe, Mn, Cu, and Zn) compared to rest of the other irrigation scheduling treatments.

The treatment irrigation schedule with 80% ER in stage-I to VI recorded the highest concentration of macronutrients (2.24% N – 0.11% P – 1.14% K) and micronutrients (25.8 ppm Fe – 13.1 ppm Mn – 8.0 ppm Cu – 23.1 ppm Zn, mg/kg) compared to rest of the other treatments. Leaf N (2.14%), P (0.08%) and K (1.29%) contents were observed significantly higher with irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI than N (2.10%), P (0.08%) and K (1.2%) content with irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI. The lowest leaf nutrient composition N (2.02%), P (0.07%) and K (1.10%) was observed in the irrigation schedule irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI during 2009-2012 (Table 4).

Biometric growth of Nagpur mandarin plants

The effect of different drip irrigation scheduling combinations based on percent evaporation replenishment has influenced on the biometric growth of 7-9 years Nagpur mandarin during 2009-2012. The observational data on biometric growth parameters of Nagpur mandarin revealed that out of various growth parameters, only canopy volume produced a significant response in relation to irrigation treatments. The growth of mandarin plant (plant height, stock girth, and canopy volume) recorded during October month of the year 2009-10, 2010-11 and 2011-12. The data of plant height and plant spread have been used in estimating the canopy volume of the tree (Castel 1983). The plant height and stock girth is not significant. But the canopy volume is significant during the three years of the study (Table 4).

The highest average plant height (4.73 m) and stock girth (66.37 cm) of the Nagpur mandarin plant was recorded in irrigation schedule with 80% ER during the stage I-VI. The plant height (4.71 m) and stock girth (66.35 cm) was medium in irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI , followed by irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (plant height, 4.50 m; and stock girth 65.60 cm) and irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (plant height (4.53 m; and stock girth 66.14 cm). The lowest plant height (4.46 m) and stock girth (63.61 cm) was observed in irrigation schedule with 30% ER in stage-I to VI during 2009 to 2012. The significant growth was observed in

Table 3 Available soil and leaf nutrient status under different irrigation treatments during 2009-2012

Treatments	Available soil nutrients						
	Macronutrients (mg/kg)			Micronutrients (mg/kg)			
	N	P	K	Fe	Mn	Cu	Zn
T_1	122.4	9.81	224.3	18.8	9.8	1.64	0.72
T_2	124.8	10.86	228.4	21.2	10.1	1.82	0.82
T_3	126.9	11.11	231.6	24.6	11.6	1.80	0.80
T_4	129.8	13.12	236.4	28.1	13.2	1.72	0.92
T_5	126.4	12.10	232.8	27.6	12.1	1.89	0.90
CD (*P=0.05*)	1.7	1.04	1.81	1.90	0.70	NS	0.01
	Leaf nutrient composition						
T_1	2.02	0.07	1.10	17.2	8.8	7.8	18.8
T_2	2.10	0.08	1.20	19.2	9.2	8.2	19.2
T_3	2.14	0.08	1.29	21.4	11.2	8.1	20.2
T_4	2.24	0.11	1.14	25.8	13.1	8.0	23.1
T_5	2.20	0.10	1.30	24.0	12.2	8.4	21.8
CD (*P=0.05*)	0.08	0.006	0.10	1.8	1.1	NS	0.40

* The treatments are as per the details given below the Table 2.

Table 4 Nagpur mandarin growth under different pan evaporation based irrigation scheduling treatments

Treatment*	Year			
	2009-2010	2010-2011	2011-2012	Mean
	Plant height (m)			
T_1	4.47	4.51	4.63	4.53
T_2	4.36	4.43	4.71	4.50
T_3	4.64	4.65	4.85	4.71
T_4	4.55	4.68	4.98	4.73
T_5	4.42	4.45	4.51	4.46
CD (*P= 0.05*)	NS	NS	NS	NS
	Stock girth (cm)			
T_1	65.41	66.21	66.81	66.14
T_2	64.05	65.82	66.93	65.60
T_3	65.52	66.67	66.86	66.35
T_4	63.47	67.70	67.94	66.37
T_5	62.83	63.93	64.08	63.61
CD (*P= 0.05*)	NS	NS	NS	NS
	Canopy volume (m^3)			
T_1	64.18	66.12	68.42	66.24
T_2	65.26	67.42	69.13	67.27
T_3	67.19	68.55	70.45	68.73
T_4	64.23	69.43	73.25	68.97
T_5	62.55	63.41	65.72	63.89
CD (*P= 0.05*)	1.5	1.41	1.35	1.39

* The treatments are as per the details given below the Table 2.

canopy volume ranging from 62.55 to 67.19 m^3, 63.41 to 69.49 m^3 and 65.72 to 73.25 m^3 during the year 2009-10, 2010-11 and 2011-12 respectively. The highest average canopy volume of the Nagpur mandarin plant (68.97 m^3) was recorded in irrigation schedule with 80% ER during the stage I-VI. The average canopy volume of the mandarin plant was medium (68.73 m^3) in irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI, followed by irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (67.27 m^3) and irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (plant height (66.24 m^3). The lowest plant canopy (68.97 m^3) was observed in irrigation schedule with 30% ER in stage-I to VI during 2009 to 2012 (Table 4). This may be mainly due to the higher and frequent irrigation scheduled favoring plant growth development. The similar type of observations were also recorded in the earlier studies on irrigation scheduling in Nagpur mandarin (Shirgure *et al.* 2001a) and in acid lime (Shirgure *et al.* 2004a) under the central Indian conditions.

Nagpur mandarin fruit yield and quality

The pan evaporation based drip irrigation scheduled based on pan evaporation replenishment in six different stages had a profound effect on the yield and fruit quality of the Nagpur mandarin during 2009-2012. The Nagpur mandarin fruits were harvested during first fortnight of November month in the year 2009, 2010 and 2011. The average number of fruits per plant, yield, TSS, Juice content, and acidity was analysed for the study period and pooled data and mean values were presented. The Nagpur mandarin yield and fruit quality were significantly influenced by the different combinations of irrigation schedules during the six stages of drip irrigated Nagpur mandarin. The number of fruits per plant, fruit yield, average fruit weight, total soluble solids (TSS) juice percentage and acidity was found significant during 2010-11 and 2011-12 (Table 5). The average number of fruits per plant was 312 to 527 in all the drip irrigation scheduling treatments. The highest number of fruits per plant (527 fruits/plant) was in the drip irrigation schedule with irrigation schedule with 80% ER in stage-I to VI followed by irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (494 fruits/plant), irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (444 fruits/plant) and irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (361fruits/plant). The lowest number of fruits per plant was with irrigation schedule with 30% ER in stage-I to VI (312 fruits/plant) may be due to lower soil moisture content with 30% ER drip irrigation schedule during the critical growth and fruit development stages.

The various drip irrigation scheduling treatments significantly influenced the yield of the Nagpur mandarin. The average Nagpur mandarin fruit yield was 7.83 to 16.09 tonnes/ha in all the combinations of pan evaporation replenishment drip irrigation schedules. The highest fruit yield per hectare was in the drip irrigation schedule with irrigation schedule with 80% ER in stage-I to VI (16.09 tonnes/ha) followed by irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI (14.56 tonnes/ha), irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI (11.92 tonnes/ha) and

Table 5 Effect of various irrigation schedules on the Nagpur mandarin yield and fruit quality parameters during 2009-2012

Treatment*	Year			
	2009-2010	2010-2011	2011-2012	Mean
Number of fruits per plant				
T_1	328	415	342	361
T_2	340	510	483	444
T_3	353	572	558	494
T_4	357	615	610	527
T_5	315	302	321	312
CD *(P= 0.05)*	NS	8.4	6.4	
Fruit yield (tonnes/ha)				
T_1	9.19	6.91	9.59	8.56
T_2	10.38	10.12	15.26	11.92
T_3	11.05	14.50	18.13	14.56
T_4	11.52	16.22	20.53	16.09
T_5	8.88	5.34	9.27	7.83
CD *(P= 0.05)*	NS	1.05	1.94	
Average fruit weight (g)				
T_1	101.2	108.2	101.3	103.5
T_2	110.3	112.5	114.1	112.3
T_3	113.1	118.7	117.3	116.3
T_4	116.5	120.3	121.5	119.4
T_5	101.8	103.7	104.3	103.2
CD *(P= 0.05)*	NS	2.5	1.34	
Total soluble solids (^{o} Brix)				
T_1	9.56	9.51	9.47	9.51
T_2	9.58	9.62	9.59	9.59
T_3	9.73	10.11	10.08	9.97
T_4	9.81	10.05	10.07	9.97
T_5	9.63	9.23	9.19	9.35
CD *(P= 0.05)*	NS	0.7	0.6	
Juice percent (%)				
T_1	36.1	36.4	36.3	36.2
T_2	36.2	37.5	37.1	36.9
T_3	36.5	38.1	37.8	37.4
T_4	37.1	39.2	39.1	38.4
T_5	36.2	35.0	35.2	35.4
CD *(P= 0.05)*	NS	1.2	1.1	
Acidity (%)				
T_1	0.84	0.83	0.82	0.83
T_2	0.83	0.82	0.81	0.82
T_3	0.81	0.79	0.78	0.79
T_4	0.82	0.80	0.79	0.80
T_5	0.86	0.84	0.83	0.84
CD *(P= 0.05)*	NS	0.01	0.01	

* The treatments are as per the details given below the Table 2.

irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI (8.56 tonnes/ha). The lowest fruit yield was with irrigation schedule with 30% ER in stage-I to VI (7.83 tonnes/ha) may be due to lower soil moisture available with 30% irrigation schedule during the critical fruit growth development periods during 2009-2012 (Table 5). This is clearly indicated that the stage III (May-June), stage II (March-April) and stage I (January-February) most need irrigation. The drip irrigation schedules based on ER maintained higher as well as continuous soil moisture influenced by the water and nutrient uptake resulting into good quality fruits besides enhancing the yield. The highest average fruit weight (119.4 g), TSS (9.97 °Brix), juice percent (38.4%) and lowest acidity (0.80) is observed in the drip irrigation schedule with 80% ER in stage-I to VI followed by irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI. The average fruit weight (116.3 g), TSS (9.97 °Brix), juice percent (37.4%) and acidity (0.79) is observed in this drip irrigation schedule with 60% ER in stage-I, III, V and 80% ER in stages II, IV and VI. The moderate fruit quality was observed with irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI, followed by irrigation schedule with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI. The lower average fruit weight (112.3 g), TSS (9.59 °Brix), juice percent (36.9%) and acidity (0.82) was observed in this drip irrigation schedule with 40% ER in stage-I, III, V and 60% ER in stages II, IV and VI. In the treatment of irrigation with 30% ER in stage-I, III, V and 40% ER in stages II, IV and VI the average fruit weight (103.5 g), TSS (9.51 °Brix), juice percent (36.2%) and acidity (0.83) was observed to be lower. The lowest average fruit weight (103.2 g), TSS (9.35 °Brix), juice percent (35.4%) and highest acidity (0.84) is observed in the drip irrigation schedule with 30% ER in stage-I to VI. The higher TSS to acidity ratio is the indicator of sweetness of the fruit of *Ambia* flush during October-November month. If the TSS to acidity ratio is high means that the fruits have more TSS (total soluble solids) and less acidity. This ratio was analysed and the highest TSS to acidity ratio (12.62) was found in the irrigation schedule with 60% in combination to 80% ER in stage I-VI followed by the drip irrigation schedule with 80% ER in all I-VI stages (12.46). The lowest TSS to acidity (11.13) was observed the drip irrigation schedule with 30% ER in stage I-VI. The similar fruit yield and quality experimental results are observed in *verna* lemon (Sanehez *et al.* 1989), Nagpur mandarin (Shirgure *et al.* 2001b, 2003b) and acid lime (Shirgure *et al.* 2004b).

REFERENCES

Castle W. 1983. Growth, yield and cold hardiness of seven year old "Bearss" lemon on twenty seven rootstocks. *Proceedings of Florida State Horticultural Society* **96:** 23–5.

Castel J R and Buj A. 1990. Response of Satsuma oranges to high frequency deficit irrigation. *Irrigation Science* **11** (2): 121–7.

Cohen Y. 1991. Determination of orchard water requirement by a combined trunk sap flow and meteorological approach. *Irrigation Science* **12**(2): 93–8.

Dettori S and Filigheddu M R. 1994. Lysimetric estimation of water consumption by orange cv. Washington Navel. *Rinsta di Prutticoltura e di ortofloncoltura* **56**(7-8): 55–7.

Eliadses A. 1998. Effect of the amount of water and the extent of wetted area on tree growth, yield and fruit quality of Washington Navel orange. *Technical Bulletin-Cyprus. Agricultural Research Institute.* No. 193, p 8.

Ghadekar S R, Dixit S V and Patil V P. 1989. Climatological water requirement of the citrus under Nagpur agroclimatic conditions. *PKV Research Journal* **13**(2): 143–8.

Gomez K A and Gomez A A. 1984. *Statistical Procedures fior Agriculture Research,* pp 664–5. John Wiley and Sons.

Mageed K J A, Sharma B B and Sinha A K. 1988. Influence of irrigation and nitrogen on water use and growth of Kinnow mandarin. *Indian Journal of Agricultural Science* **58**(6): 284–6.

Plessis S F Du. 1989. Irrigation scheduling of citrus, Research results. *Water and Irrigation Review* **9** (4): 4–6.

Ranganna S. 1986. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, pp 881–2. Tata McGraw Hill Pub. Comp. Ltd, New Delhi.

Sanehez Blenco M J, Torrecillas A, Leon A and Del Amor F. 1989. The effect of different irrigation treatments on yield and quality of verna lemon. *Plant and Soil* **120** (2): 299–302.

Shirgure P S, Marathe R A, Lallan Ram and Singh S. 2000. Irrigation scheduling in acid lime as affected by different soil moisture regimes. *Indian Journal of Agricultural Sciences* **70** (3): 173–6.

Shirgure P S, Srivastava A K and Singh S. 2001a. Effect of pan evaporation based irrigation scheduling on yield and quality of drip irrigated Nagpur mandarin. *Indian Journal of Agricultural Sciences* **71** (4): 264–6.

Shirgure P S, Srivastava A K and Singh S. 2001b. Growth, yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco) in relation to irrigation and fertigation. *Indian Journal of Agricultural Sciences* **71** (8): 547–50.

Shirgure P S, Srivastava A K and Singh S. 2003. Irrigation scheduling and fertigation in acid lime (*Citrus aurantifolia* Swingle). *Indian Journal of Agricultural Sciences* **73** (7): 363–7.

Shirgure P S, Srivastava A K, Singh S and Pimpale A R. 2004a. Drip irrigation scheduling growth, yield and quality of acid lime (*Citrus aurantifolia* Swingle). *Indian Journal of Agricultural Sciences* **74** (2): 92–4.

Shirgure P S, Srivastava A K and Singh S. 2004b. Growth, yield and quality of acid lime under pan evaporation based drip irrigation scheduling. *Indian Journal of Soil Conservation* **32** (1): 32–5.

Shirgure P S and Srivastava A K. 2012. The effect of four under tree micro-jet irrigation (180-300^0) systems on fruit yield and quality of Nagpur mandarin in Central India. *Scientific Journal of Agricultural Review* **1** (7): 177–86.

Shirgure P S. 2012. Micro-irrigation systems, automation and fertigation in citrus. *Scientific Journal of Review* **1**(5): 156–69.

Smajstrla A G. 1993. Micro-irrigation for Citrus production in Florida. *Hortculture Science* **28**(4): 295–8

Srviastava A K, Ram Lallan, Huchche A D, Kohli R R and H C Dass. 1994. Standardisation of leaf sampling technique in Nagpur mandarin under sub-humid tropical climate. *Indian Journal of Horticultural Science* **51**(1) : 32–6.