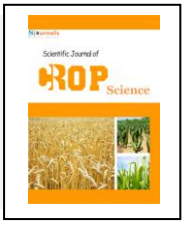
Sjournals
Scientific Journal of Crop Science (2013) 2(2) 28-35
ISSN 2322-1690

Contents lists available at Sjournals
Scientific Journal of CROP Science
Journal homepage: www.Sjournals.com



Original article

Yield and fruit quality of Nagpur mandarin *(Citrus reticulata* Blanco) as influenced by evaporation based drip irrigation schedules

P.S. Shirgure*
National Research Centre for Citrus (ICAR), Nagpur, Maharashtra-440 010.

*Corresponding author; National Research Centre for Citrus (ICAR), Nagpur, Maharashtra-440 010.

ARTICLE INFO

Article history:
Received 14 February 2013
Accepted 24 February 2013
Available online 28 February 2013

Keywords:
Critical growth stages
Water requirement
Drip irrigation scheduling
Pan evaporation replenishment
Nagpur mandarin *(Citrus reticulata* Blanco)
Yield
Fruit quality

ABSTRACT

To identify the critical stages of irrigation water requirement of bearing Nagpur mandarin through drip irrigation system a field experiment was conducted on 7-9 years old bearing Nagpur mandarin (*Citrus reticulata* Blanco) based on evaporation replenishment (ER) irrigation scheduling during 2009-12. The plant growing period was divided into 6 stages, 2 months each, starting from January to December and the effect on water use, tree growth, fruit yield and quality was studied. The irrigation water quantity given per day per plant under different treatments in various months varied from 21.3-158.5 liters per plant, 17.5-153.4 liters per plant and 20.9-164.5 liters per plant in different months during 2009-10, 2010-11 and 2011-12. The highest quantity of water was applied under the irrigation scheduled at 80 % evaporation replenishment (ER) treatment and it varied from 46.8-164.5 liters per plant in 2009-12. The average mandarin plant height was 4.57-4.83 m, stock girth was 51.5-56.3 cm and canopy volume 62.4-71.2 m^3. The only canopy volume was found significant among the various scheduling treatments. The fruit yield and quality was significantly affected under various evaporation replenishment (ER) based drip irrigation scheduling treatments. The highest fruit yield (17.25 and 21.48 tones per ha) higher TSS, juice percentage and lower acidity was observed under irrigation at 80 % ER in stages I-V and 30 % ER in stage VI during the study period. The highest TSS to acidity ratio (12.7 and 12.4) was found in the irrigation schedule with 80 % ER in stages I-V and 30 % ER in stage VI during 2010-12.

1. Introduction

Nagpur mandarin (*Citrus reticulata Blanco*) is an important commercial citrus fruit crop grown in 0.148 M ha area with production of 8.75 M tonnes. The average productivity is 10-11 tonnes/ha, which is very low compared to other citrus cultivars grown in India. This is mainly due to basin irrigation method followed by water stress, improper and calendar method of scheduling, lack of drip irrigation scheduling systems and inadequate soil moisture availability during the critical plant growth and fruit developmental stages. Due to increasing scarcity of irrigation water, the mandarin orchards are being converted with drip irrigation systems. But the drip irrigation system is not scheduled regularly and maintaining the correct irrigation intervals as well as quantity application in critical stages of plant growth and fruit development stages. The mandarin fruit yield can be increased from 10-11 tonnes/ha and productivity potential of the Nagpur mandarin can be enhanced to 16-18 tonnes/ha with the adoption drip irrigation and frequent schedules (Shirgure *et al.,* 2001a), different degree under tree micro-jet irrigation systems (Shirgure *et al.,* 2003a) and quality fruits with micro-irrigation and fertigation technology (Shirgure *et al.,* 2001b). The irrigation water requirement of Nagpur mandarin and other citrus cultivars varies with stage, age and season under different climatic conditions. The growth of plant retards below certain critical level of available moisture depending upon soil type, climatic factor and plant genetic make up. Irrigation scheduling based on depletion of available water content as 65 % (Toledo, 1982) in Valencia orange, 40-100 % (Moreshet *et al.,* 1988) in 'Shamouti' orange and 85 % (Peres, 1987) in Valencia have been suggested. Field experiment with a mature 'Valencia' orange trees showed that the water use pattern over the entire season reached a maximum of 87 liters/day in January month. 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, 1988). In comparison of five flood irrigation treatments in Vema lemon with daily drip irrigation at 0.475 Epan, it was concluded that the drip irrigation gave higher yields as compared to flood irrigated plants (Sanehez *et al.*; 1989). The mature 'Satstuma' trees grafted on Sour orange rootstocks showed a good response in 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 (Castel and Buj, 1990). The highest increase in canopy volume (2.12 m^3) was observed with irrigation equivalent to 0.8 open pan evaporation as compared to 0.6, 0.7 and 0.9 open pan evaporation treatments in Nagpur mandarin. The highest leaf N and K was registered with irrigation equivalent to 0.8 pan evaporation (Shirgure *et al*., 2001a). In the study on irrigation scheduling based on open pan evaporation in acid lime in pre-bearing stage found that the evapo-transpiration varied from 213.6 mm to 875.6 mm in various irrigation schedules. Moreover, the change in soil-moisture distribution in the root zone of acid lime plants varied from 195.9 mm to 321.3 mm with different irrigation schedules (Shirgure *et al*., 2000). The objective of this investigation was to identify the critical growth stages of water requirement under pan evaporation based drip irrigation scheduling and effect on water use, plant growth and fruit quality of bearing Nagpur mandarin.

2. Materials and methods

A field experiment was conducted for identifying the critical stages of water requirement and irrigation scheduling based on open pan evaporation through the drip irrigation in the block of 72 x 72 m with 6 x 6 m spacing on 7-9 years old Nagpur mandarin at experimental farm of National Research Centre for Citrus, Nagpur during 2009-12. 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 viz. 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 drip irrigation schedule with 30% ER in stage-I and 80 % ER in stages II to VI (T_1), drip irrigation schedule with 30% ER in stage-II and 80 % ER in stage I and stages III to VI (T_2), drip irrigation schedule with 30% ER in stage-III and 80 % ER in stage I, stages II and stage IV to VI (T_3), drip irrigation schedule with 30% ER in stage-IV and 80 % ER in stages I-III, V and stage VI (T_4), drip irrigation schedule with 30% ER in stage-V and 80 % ER in stages I-IV and stage VI (T_5), drip irrigation schedule with 30% ER in stage-VI and 80 % ER in stages I-V(T_6), and drip irrigation schedule with 80 % ER in all stages I-VI (T_7) 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 40 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 28.3% and 18.15 % respectively. The available water content of the soil was 10.06 %. 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 1.47 g/cc. The water holding capacity of the soil was 14.78 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. Aluminum access tubes were installed to the depth of 70 cm within the tree basin and 70 cm apart from the trunk in between the two drippers. The biometric parameters of Nagpur mandarin plants (plant height and tree spread) were recorded in October, 2009, 2010 and 2011. The plant stock girth was taken 15 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 described by Ranganna (1986). Leaf samples were collected as per procedures suggested by Srivastava *et al.,* (1994) and finally prepared samples were digested in diacid mixture of H_2SO_4 : $HClO_4$ in 2.5:1 ratio. The leaf N was determined using alkaline permangate steam distillation method, P by *vanadomolybdophosphoric* acid method and K flame photo metrically (Chapman and Pratt, 1982). The data on fruit yield and quality attributing to the different irrigation schedules for 2 years were analysed by Analysis of variance method (Gomez and Gomez, 1984).

3. Results and discussion

3.1. Evaporation based irrigation scheduling and water use

The irrigation water requirement of Nagpur mandarin varied according to the different pan evaporation replenishment based drip irrigation schedules and 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 average irrigation water requirement of Nagpur mandarin per plant varied from 26.5, 52.5, 59.4 and 21.3 liters per plant with irrigation scheduling with 30 % ER in stage I, II, III and VI during 2009-10. The same was 70.8, 143, 158.5 and 56.8 liters per plant with the irrigation schedule at 80 % ER in all the stages during the year 2009-10. The average irrigation water requirement of Nagpur mandarin per plant varied from 16.5, 27.8, 57.5 and 17.5 liters per plant with irrigation scheduling with 30 % ER in stage I, II, III and VI during 2010-11. The same was 44.1, 74, 153.4 and 46.8 liters per plant with the irrigation schedule at 80 % ER in all the stages during the year 2010-11. Similarly, the average irrigation water requirement of Nagpur mandarin per plant varied from 19.4, 30.1, 61.7 and 20.9 liters per plant with irrigation scheduling with 30 % ER in stage I, II, III and VI during 2011-12. The same was 51.6, 80.2, 164.5 and 55.7 liters per plant with the irrigation schedule at 80 % ER in all the stages during the year 2011-12 (Table 1). The irrigation water requirement of Nagpur mandarin was lower in the year 2010-11 and higher in 2009-10 and 2011-12 due to the variation in evaporation rates during the various growth stages. The irrigation was not scheduled during the stages IV and V due to rains and the evapo-transpiration rate during rainy months was lower than rainfall.

3.2. Biometric growth of the Nagpur mandarin plants

The effect of different drip irrigation scheduling based on percent evaporation replenishment has influenced on the biometric growth of Nagpur mandarin. The observational data on biometric growth parameters of Nagpur mandarin revealed that out of various growth parameters, only canopy volume shown a significant response in relation to irrigation scheduling treatments (Table 2). The growth of mandarin plant (plant height, stock girth, scion girth and canopy volume) recorded during October month of the year 2009-10. Data of plant height, plant spread have been used in estimating the canopy volume (Castel, 1983).

Table 1
Weekly mean irrigation water applied (liters/day/plant) under various treatments during 2009-12.

Treatments	Stage I (Jan -Feb.)	Stage II (Mar-Apr.)	Stage III (May-June)	Stage IV (July-Aug.)	Stage V (Sept. Oct.)	Stage VI (Nov. Dec.)
			2009-10			
I_1	26.5	143.0	158.5	Rain	Rain	56.8
I_2	70.8	52.8	158.5	Rain	Rain	56.8
I_3	70.8	143.0	59.4	Rain	Rain	56.8
I_4	70.8	143.0	158.5	Rain	Rain	56.8
I_5	70.8	143.0	158.5	Rain	Rain	56.8
I_6	70.8	143.0	158.5	Rain	Rain	21.3
I_7	70.8	143.0	158.5	Rain	Rain	56.8
			2010-11			
I_1	16.5	74.0	153.4	Rain	Rain	46.8
I_2	44.1	27.8	153.4	Rain	Rain	46.8
I_3	44.1	74.0	57.5	Rain	Rain	46.8
I_4	44.1	74.0	153.4	Rain	Rain	46.8
I_5	44.1	74.0	153.4	Rain	Rain	46.8
I_6	44.1	74.0	153.4	Rain	Rain	17.5
I_7	44.1	74.0	153.4	Rain	Rain	46.8
			2011-12			
I_1	19.4	80.2	164.5	Rain	Rain	55.7
I_2	51.6	30.1	164.5	Rain	Rain	55.7
I_3	51.6	80.2	61.7	Rain	Rain	55.7
I_4	51.6	80.2	164.5	Rain	Rain	55.7
I_5	51.6	80.2	164.5	Rain	Rain	55.7
I_6	51.6	80.2	164.5	Rain	Rain	20.9
I_7	51.6	80.2	164.5	Rain	Rain	55.7

I_1 - irrigation schedule with 30% ER in stage-I and 80 % ER in stages II to VI.
I_2 - irrigation schedule with 30% ER in stage-II and 80 % ER in stage I and stages III to VI.
I_3 - irrigation schedule with 30% ER in stage-III and 80 % ER in stage I, II and stage IV to VI.
I_4 - irrigation schedule with 30% ER in stage-IV and 80 % ER in stage I-III, V and stage VI.
I_5 - irrigation schedule with 30% ER in stage-V and 80 % ER in stages I-IV and stage VI.
I_6 - irrigation schedule with 30% ER in stage-VI and 80 % ER in stages I-V.
I_7 - irrigation schedule with and 80 % ER in all stages I-VI.

The plant height and stock girth is not significant. But the canopy volume is significant during the 3 years of the study. The average height of the Nagpur mandarin plant ranged from 4.57-4.83 m and stock girth from 51.5-56.3 cm during the year 2010-12. The significant difference was observed in canopy volume ranging from 61.69 to 69.08 m^3 , 62.06 to 70.22 m^3 and 63.4 to 74.2 m^3 during the year 2009-10, 2010-11 and 2011-12 respectively (Table 2). The average plant height (4.71, 4.84 and 4.94 m) was higher in the irrigation schedule having 80 % ER in all six stages. The average stock girth (55.57, 56.52 and 56.81 cm) was higher in the irrigation schedule with 30% ER in stage-V and 80 % ER in stages I-IV and stage VI during the year 2009-10, 2010-11 and 2011-12 respectively. This may be mainly due to the rains and high humid conditions favoring vegetative growth and plant stock development. The various drip irrigation schedules in six stages influenced the canopy volume significantly. The

average canopy volume observed was higher 69.08 m^3 , 70.22 m^3 and 74.21 m^3 in the irrigation schedule with 30% ER in stage-VI and 80 % ER in stages I-V during the year 2009-10, 2010-11 and 2011-12 respectively. The canopy volume was moderate in the irrigation schedule 80 % ER in all the stages (68.34 m^3, 68.65 $m^3$and 71.18 m^3) during 2009-10, 2010-11 and 2011-12. The canopy volume was lowest in the irrigation schedules of 30 % ER in stages III, II and I during the years of the study. This is mainly due to availability of constant, higher and continuous soil moisture in plant active root zone. The similar 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 central Indian conditions. The highest leaf N (2.17 %), leaf P (0.083 %) and leaf K (1.12 %) was observed in the irrigation schedule with 80 % ER in stages I-V and 30 % ER in stage VI due to higher nutrient use with proper drip irrigation schedule during the study period 2009-12.

3.3. Fruit yield and quality of Nagpur mandarin

The pan evaporation based drip irrigation scheduled based on pan evaporation replenishment in six different stages had profound effect on the yield and fruit quality of the Nagpur mandarin during 2009-12. 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, acidity and TSS to acidity ratio was analysed for the study period and pooled data in presented in Table 3. The Nagpur mandarin yield and fruit quality were significantly influenced by the different ER based drip irrigation schedules during the six stages. The number of fruits per plant, fruit yield, average fruit weight, TSS and juice percentage was found significant during 2009-12. The acidity was not found significant may be due to internal maturity condition and internal fruit quality (Table 3). The average number of fruits per plant varied from 348, 332 and 311 in the drip irrigation schedule having 80 % ER in stage I and II and 30 % ER in stage III, in the drip irrigation schedule having 80 % ER in stage I and III and 30 % ER in stage II followed by the drip irrigation schedule having 30 % ER in stage I and 80 % ER II and III respectively. The number of fruits per plants was highest (628 and 631 fruits/plant) in the drip irrigation schedule with 30 % ER in stage VI and 80 % ER in stages I-V during 2010-11 and 2011-12. From this it is evident that the stages III, II and I are critical and the stages IV, VI and V are less critical from the point of irrigation water requirement of Nagpur mandarin. The various drip irrigation scheduling treatments significantly influenced the yield of the Nagpur mandarin. The highest mandarin fruit yield was recorded in the drip irrigation schedule with 30 % ER in stage VI and 80 % ER in stages I-V (17.25 and 21.48 tonnes/ha) followed by irrigation schedule with and 80 % ER in all stages (16.09 and 19.66 tones/ha) and irrigation schedule with 30% ER in stage-V and 80 % ER in stages I-IV and stage VI (16.04 and 18.94 tones/ha) in 2010-12 (Table 3). The moderately higher yield was observed in the drip irrigation schedule with 30 % ER in stage I and 80 % ER in stage II and III (8.85 and 10.7 tones/ha) followed by the irrigation schedule with 30 % ER in stage II and 80 % ER in stage I and III (8.54 and 9.84 tones/ha) and the irrigation schedule with 30 % ER in stage III and 80 % ER in stage I and II (8.15 and 8.76 tones/ha).

This is clearly indicates that the stage III (May-June), stage II (March-April) and stage I (January-February) are critical for water need and in order of III, II and I due to increase in summer months and rise in temperature as well as evapo-transpiration demand of the mandarin plants. This clearly indicates that 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 (121.1 and 122.4 g) and lowest acidity (0.81-0.82) is observed in the drip irrigation schedule with 80 % ER in stages I-V and 30 % ER in stage VI. The TSS (10.2-10.3 ^{o}Brix) and juice percent (39.1-39.3 %) was more in irrigation schedule with 80 % ER in stages I-V and 30 % ER in stage VI. The TSS to acidity ratio is 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 are more sweet with less acidity. This ratio was analysed for all the treatments. The highest TSS/acidity (12.7) was found in the irrigation schedule with 80 % ER in stages I-V and 30 % ER in stage VI, followed by the drip irrigation schedule with 80 % ER in all I-VI stages (12.12). The lowest ratio (10.7) was observed the drip irrigation schedule with 30 % ER in stage III and 80 % ER in stages I-II and stages IV-VI. This clearly indicates that water requirement in the stage III (May-Jun.) very essential to get good quality fruits. The similar fruit yield and quality results are observed in mandarin (Shirgure *et al.,* 2001b) and acid lime (Shirgure *et al.,* 2004b).

Table 2
Plant height, stock girth and canopy volume of Nagpur mandarin as affected by drip irrigation schedules during 2009-12.

Treatments*	Year			
	2009-2010	2010-2011	2011-2012	Mean
		Plant height (m)		
I_1	4.41	4.61	4.72	4.58
I_2	4.52	4.72	4.81	4.68
I_3	4.48	4.68	4.78	4.65
I_4	4.33	4.63	4.74	4.57
I_5	4.66	4.79	4.80	4.75
I_6	4.57	4.82	4.93	4.77
I_7	4.71	4.84	4.94	4.83
CD *(P= 0.05)*	NS	NS	NS	NS
		Stock girth (cm)		
I_1	50.00	52.04	52.35	51.5
I_2	53.76	54.70	55.02	54.5
I_3	55.43	56.43	56.72	56.2
I_4	54.09	55.09	55.40	54.9
I_5	55.57	56.52	56.81	56.3
I_6	53.45	54.44	55.12	54.3
I_7	53.43	54.47	54.61	54.2
CD *(P= 0.05)*	NS	NS	NS	NS
		Canopy volume (m^3)		
I_1	61.69	62.06	63.41	62.4
I_2	64.02	67.28	67.14	66.1
I_3	64.08	68.01	64.05	65.4
I_4	65.27	70.05	69.93	68.4
I_5	66.05	69.86	71.32	69.1
I_6	69.08	70.22	74.21	71.2
I_7	68.34	68.65	71.18	69.4
CD *(P= 0.05)*	1.04	2.4	2.2	2.27

* The treatments are as per the details given below the Table 1.

The critical stages of irrigation water requirement of bearing Nagpur mandarin through drip irrigation system based on evaporation replenishment (ER) was investigated during 2009-12.The effect on water requirement, growth, fruit yield and quality has been studied. The highest quantity of water was applied under the irrigation scheduled at 80 % evaporation replenishment (ER) treatment and it varied from 56.8 to 158.5 liters/day/plant in 2009-10, 46.8-153.4 liter/day/plant in 2010-11 and 56.8 to 158.5 liters/day/plant in 2011-12. The only canopy volume was found significant among the various irrigation scheduling treatments. The fruit yield and quality parameters (TSS, juice percentage and acidity) recorded were significantly affected under various evaporation

replenishment based drip irrigation scheduling treatments. The highest fruit yield and higher quality fruits can be obtained with drip irrigation schedule with at 80 % ER during January to October month and 30 % ER in November-December. The highest TSS to acidity ratio could be obtained if the irrigation schedule with 30 % ER in November-December and 80 % ER in November-December is employed to the bearing Nagpur mandarin.

Table 3
Effect of various irrigation schedules on the Nagpur mandarin yield and fruit quality parameters during 2010-2012.

Treatment	Yield parameters			Quality parameters		
	No. of fruits/plant	Average Fruit weight (g)	Total yield (tones/ha)	Juice (%)	Acidity (%)	T.S.S (^{0}Brix)
			2010-2011			
I_1	348	110.2	8.85	37.4	0.84	9.11
I_2	332	103.4	8.54	37.2	0.85	9.13
I_3	311	102.8	8.15	37.3	0.85	9.09
I_4	571	105.2	15.28	38.4	0.83	9.69
I_5	576	116.3	16.04	38.7	0.83	10.02
I_6	628	121.1	17.25	39.3	0.81	10.3
I_7	581	119.3	16.09	38.9	0.82	10.0
CD(*P=0.05*)	102	8.1	0.71	0.54	NS	0.32
			2011-2012			
I_1	354	109.3	10.71	37.2	0.85	9.10
I_2	340	104.5	9.84	37.1	0.85	9.11
I_3	314	103.1	8.76	37.3	0.84	9.07
I_4	582	105.8	17.05	38.1	0.84	9.63
I_5	591	115.7	18.94	38.3	0.85	10
I_6	631	122.9	21.48	39.1	0.82	10.2
I_7	597	118.9	19.66	38.7	0.83	9.9
CD(*P=0.05*)	92	7.9	0.81	0.45	NS	0.18

* The treatments are as per the details given below the Table 1.

References

Castle, W., 1983. Growth, yield and cold hardiness of seven year old “Bearss” lemon on twenty seven rootstocks, *Proc. Florida State Hort. Soc.* 96, 23–25.

Castel, J.R., Buj, A., 1990. Response of Satsuma oranges to high frequency deficit irrigation. *Irrig. sci.;* 11 (20), 121-127.

Chapman, H.D., Pratt, P.F., ed. 1982. Methods of analysis for soils, plants and waters. Division of Agricultural Science, Univ. of California, USA pp. 61

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

Moreshet, S., Cohen, Y., Fuchs, M., 1988. Water use and yield of a mature *Shamouti* orange orchard submitted to root volume restriction and intensive canopy pruning. *Proceedings of Sixth International Citrus Cong. Tel Aviv, Israel,* 2, 739-746.

Peres, E.M.T., 1987. Effect of irrigation on the yield and quality of orange fruits. *Rosteniev dni Nauki,* 24 (2), 71-76.

Plessis, S.F., Du., 1988. Irrigation scheduling. *Proceedings of the Sixth International Citrus Congress,* Tel Aviv, Isreal, 988, P-731.

Ranganna, S., 1986. Handbook of analysis and quality control for fruit and vegetable products. *Tata Mc. Grow Hil Pub. Comp. Ltd., New Delhi,* pp 881-2.

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

Shirgure, P.S., Marathe, R.A., Ram, L., 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., 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., 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., Singh, S., 2003a. Evaluating micro-irrigation systems in Nagpur mandarin under sub-humid tropical climate. *Tropical Agriculture* 80 (2), 91-96.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2003b. 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., 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., 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.

Srviastava, A.K., Ram, L., Huchche, A.D., Kohli, R.R., Dass, H.C., 1994. Standardisation of leaf sampling technique in Nagpur mandarin under sub-humid tropical climate. *Indian J. Hort. Sci.* 51(1), 32-6.

Toledo, P., 1982. Soil moisture level studies for up to 5 year old 'Olinda Valencia' oranges. *Ciencia y Tecniica enla Agricultura Riego y Drenaje*, 5 (1), 17 - 30.