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# Effect of drip irrigation scheduling on yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco) fruits

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**ABSTRACT**

**A experiment was conducted on 7-9 year-old bearing Nagpur mandarin (*Citrus reticulata* Blanco) based on evaporation replenishment (ER) irrigation scheduling to identify the irrigation water requirement through drip irrigation system during 2009-2012 at different stages. The fruit and quality was found significantly influenced under various evaporation replenishment (ER) based drip irrigation scheduling treatments. The highest fruit yield (21.48 tonnes/ha) was observed under irrigation at 80% ER in stages I-V and 30% ER in stage VI. Among the fruit quality irrigation scheduled at 80% ER in stages I-V and 30% ER in stage VI produced higher TSS, juice content and lower acidity. The highest TSS: acid ratio (12.7) was found in the irrigation scheduled with 30% ER in stage VI and 80% ER in stages I-V followed by the drip irrigation scheduled with 80% ER in all I-VI stages (12.2).**

**Key words:** Citrus, critical growth stage**,** irrigation scheduling, Nagpur mandarin, yield.

## INTRODUCTION

Nagpur mandarin (*Citrus reticulata* Blanco) is one of the commercial citrus fruit crop grown in 1.48 lakh ha area (fruit bearing area is 86,200 ha) with production of 8.75 lakh tonnes (Shirgure, 16). The average productivity is 10-11 t/ha, which is very low as compared to other citrus cultivars grown in India. Besides other factors, it may be due to faulty irrigation. Due to increasing scarcity of water, the mandarin orchards are being covered under drip irrigation systems. Many times the drip irrigation system is not scheduled regularly and maintaining correct irrigation intervals is not taken care of properly. The fruit yield of mandarin can be increased from 10-11 t /ha and the productivity from 16-18 t/ha with proper adoption of drip irrigation (Shirgure *et al.*, 13).

The irrigation water requirement of Nagpur mandarin and other citrus cultivars vary with season and age under different climatic conditions. The growth of plant gets retarded below certain critical level of available moisture depending upon soil type, climatic factors and plant genetic make up. Irrigation scheduling based on depletion of available water content as 65 and 85% (Peres, 6) in Valencia orange, 40-100% (Moreshet *et al.*, 5) in 'Shamouti' orange, 80% (Shirgure *et al.*, 12) in Nagpur mandarin and 70% (Shirgure *et al.*, 14) in acid lime 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 l /day in January. The highest yield (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, 7). In comparison to five flood irrigation treatments in Verna lemon with daily drip irrigation at 0.475 Epan, it was concluded that the drip irrigation produced higher yield as compared to flood irrigation (Sanehez *et al.*, 9). 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, 2). With such a view the present investigation was carried out to identify the critical growth stages of water requirement under pan evaporation based drip irrigation scheduling in bearing Nagpur mandarin.

## MATERIALS AND METHODS

To identify the critical stages of water requirement based on open pan evaporation a field experiment on scheduling drip irrigation was conducted in the block of 0.5 ha m with 6 m spacing on 7-9 year-old Nagpur mandarin orchard at ICAR-National Research Centre for Citrus, Nagpur during 2009-2012. The irrigations were scheduled on percent of pan evaporation replenishment (ER) at various stages of growth and fruit development. The different stages considered for study were 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 scheduled with 30% ER in stage-I

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and 80% ER in stages II to VI ($I_1$), drip irrigation scheduled with 30% ER in stage-II and 80% ER in stage I and stages III to VI ($I_2$), drip irrigation scheduled with 30% ER in stage-III and 80% ER in stage I, stages II and IV to VI ($I_3$), drip irrigation scheduled with 30% ER in stage-IV and 80% ER in stages I-III, V and Stage VI ($I_4$), drip irrigation scheduled with 30% ER in stage-V and 80% ER in stages I-IV and stage VI ($I_5$), drip irrigation scheduled with 30% ER in stage-VI and 80% ER in stages I-V ($I_6$), and drip irrigation scheduled with 80% ER in all stages I-VI ($I_7$) with three replications in Randomized Block Design. 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 28.2 and 18.14%, 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 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 to December *vis-a-vis* January to June. 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 during October, 2009, 2010 and 2011. The plant stock girth was taken 15 cm above the ground surface. The canopy volume of the mandarin tree was calculated according to formula as suggested by Castle (1). Fruit yield and quality analyses were made as per procedures described by Ranganna (8). Leaf samples were collected and analyzed as per procedures suggested by Srivastava *et al.* (17). The leaf N was determined using alkaline permanganate steam distillation method, P by vanadomolybdophosphoric acid method and K by flame photo-metric method (Chapman and Pratt, 3). The data on fruit yield and quality attributing to the different irrigation schedules for two years were analyzed by following analysis of variance method (Gomez and Gomez, 4).

## RESULTS AND DISCUSSION

The requirement of irrigation water varied as per pan evaporation and growth stage of fruits. The daily weather data recorded from NRCC Observatory, Nagpur was used for irrigation scheduling based on evaporation. The average irrigation requirement of Nagpur mandarin per plant varied from 26.5, 52.8, 59.4 and 21.3 l / 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 l/ plant with the irrigation scheduled at 80% ER in all the stages during 2009-10. The average irrigation water requirement of mandarin per plant varied from 16.5, 27.8, 57.5 and 17.5 l/ plant with irrigation scheduling with 30% ER in stage I, II, III and VI during 2010-2011. The same was 44.1, 74, 153.4 and 46.8 l/ plant with the irrigation scheduled at 80 % ER in all the stages during 2010-2011. Similarly, the average irrigation water requirement of mandarin per plant varied from 19.4, 30.1, 61.7 and 20.9 l/ plant with irrigation scheduling with 30% ER in stage I, II, III and VI during 2011-2012. The same was 51.6, 80.2, 164.5 and 55.7 l/ plant with the irrigation scheduled at 80% ER during all the stages during 2011-2012 (Table 1). The irrigation water requirement of mandarin was found lower during the year 2010-2011 and higher during 2009-2010 and 2011-2012. It may be due to the variation in evaporation rates during the various growth stages. The irrigation was not scheduled during the stages IV and V as these stages coincided with the rainy season.

The effect of different drip irrigation scheduling based on percent evaporation replenishment influenced the biometric growth of Nagpur mandarin. The data on biometric growth parameters revealed that out of various growth parameters, only canopy volume produced a significant response in relation to irrigation treatments (Table 2). The plant height, stock girth and scion girth is not significant. The canopy volume was found significant during the third year of the study. The average plant height ranged from 4.41-4.71 m and stock girth from 50-55.57 cm during 2009-2010. The same was 4.61-4.84 m and 52.04-56.52 cm during 2010-2011. Similarly, the average height of the mandarin plant ranged from 4.72-4.94 m and stock girth from 52.3-56.8 cm during 2011-2012. The significant difference was observed in canopy volume ranging from 61.69 to 68.34 $m^3$, 62.06 to 70.22 $m^3$ and 62.41 to 74.21 $m^3$ during the three years, respectively (Table 2). The average plant height (4.83 m) was higher in the irrigation schedule having 80% ER during all the six stages. The average stock girth (56.5 cm) was higher in the irrigation scheduled with 30% ER in stage-V and 80% ER in

**Table 1.** Weekly mean irrigation water applied (l/ plant) under various treatments.

| Treatment* | Stage I (Jan.-Feb.) | Stage II (Mar.-Apr.) | Stage III (May-June) | Stage IV (July-Aug.) | Stage V (Sept.-Oct.) | Stage VI (Nov.-Dec.) |
|---|---|---|---|---|---|---|
| | | | 2009-2010 | | | |
| $I_1$ | 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 |
| | | | 2010-2011 | | | |
| $I_1$ | 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 |
| | | | 2011-2012 | | | |
| $I_1$ | 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.

stages I-IV and stage VI during 2009-2012. This may be mainly due to the rains and high humid conditions favouring stock and scion development. Various drip irrigation schedules in six stages influenced the canopy volume significantly. Average canopy volume observed was 69.08, 70.22 and 74.21 $m^3$ and in the irrigation scheduled with 30% ER in stage-VI and 80% ER in stages I-V during 2009-2010, 2010-2011 and 2011-2012, respectively. The canopy volume was moderate in the irrigation schedule 80% ER in all the stages (68.34, 68.65 and 71.18 $m^3$) during 2009-2012. It was lowest in the irrigation schedule of 30% ER in stages III, II and I in three years of the study. This may be mainly due to availability of constant and continuous soil moisture in plant root zone. Similar observations were also recorded in the earlier studies on irrigation scheduling in Nagpur mandarin (Shirgure *et al.*, 11) and in acid lime (Shirgure *et al.*, 10) under central Indian citrus growing conditions.

Drip irrigation scheduled based on pan evaporation replenishment in six different stages had profound effect on the yield and quality of fruits during 2009-2012. The yield and fruit quality were significantly influenced by the different drip irrigation schedules during the six stages. The number of fruits per plant, fruit yield, average fruit weight, TSS and juice content was found significant during 2010-2012. The fruit acidity was not found significant. It may be due to internal maturity condition and internal fruit quality (Table 3).

**Table 2.** Growth in biometric parameters and leaf nutrient content of Nagpur mandarin as affected by drip irrigation schedule.

| Treatment* | 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) | | | |
| $I_1$ | 50.0 | 52.0 | 52.3 | 51.5 |
| $I_2$ | 53.7 | 54.7 | 55.0 | 54.5 |
| $I_3$ | 55.4 | 56.4 | 56.7 | 56.2 |
| $I_4$ | 54.0 | 55.0 | 55.4 | 54.9 |
| $I_5$ | 55.5 | 56.5 | 56.8 | 56.3 |
| $I_6$ | 53.4 | 54.4 | 55.1 | 54.3 |
| $I_7$ | 53.4 | 54.4 | 54.6 | 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 highlighted in context to Table 1.

The average number of fruits per plant varied from 348, 332 and 311 in the irrigation schedule having 80% ER in stage I and II and 30% ER in stage III, in the irrigation schedule having 80% ER in stage I and III and 30% ER in stage II followed by the irrigation schedule having 30% ER in stage I and 80% ER II and III; respectively. The number of fruits per plant was highest (628 and 631) in the irrigation schedule with 30% ER in stage VI and 80% ER in stages I-V during 2010-2011 and 2011-2012. 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. Various drip irrigation scheduling treatments significantly influenced the yield of the mandarin. The highest 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 t/ ha) followed by irrigation schedule with and 80% ER in all stages (16.09 and 19.66 t/ 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 t/ ha) in 2010-2012 (Table 3). 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 tonnes/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 t/ ha) and the irrigation schedule with 30% ER in stage III and 80% ER in stage I and II (8.15 and 8.76 t/ ha). This clearly indicates that the stage-III (May-June), stage-II (March-April) and stage-I (January-February) are critical for water requirement in the order of III, II and I due to increase in summer months and rise in evapo-transpiration demand of the plants. It may be due to the fact that drip irrigation schedules based on ER maintained higher as well as continuous soil moisture *vis-a-vis* nutrient uptake resulting in enhanced yield. The highest average fruit weight (121.1 and 122.4 g) and lowest acidity (0.81 and 0.82%) was observed in the drip irrigation scheduled with 30% ER in stage VI and 80% ER in stages I-V. The TSS (10.2 to 10.3°Brix) and juice percent (39.1 to 39.3%) was more in irrigation scheduled with 30% ER in stage VI and 80% ER in stages I-V. The high TSS: acid ratio is indicator of sweetness of the fruit of *Ambia* flush during October-November. If the TSS to acid ratio is high, it means that the fruits have more total soluble solids and less acidity (Table 3). The highest TSS: acid ratio (12.7) was found in the irrigation scheduled with 30% ER in stage VI and 80% ER in stages I-V followed by the drip irrigation schedule with 80% ER in all I-VI stages (12.2). The lowest TSS; acid ratio (10.7) was observed the drip irrigation scheduled with 30% ER in stage III and 80% ER in stages I-II and stages IV-VI. This clearly indicates that water supply in stage III (May-June) is very essential to get good quality fruits. The similar fruit yield and quality results were observed in mandarin (Shirgure *et al.*, 12) and acid lime (Shirgure *et al.*, 15).

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**Table 3.** Effect of irrigation schedules on the Nagpur mandarin yield and fruit quality parameters during 2010-2011 and 2011-2012.

| Treatment* | Yield parameter | | | Quality parameter | | | TSS: acid ratio |
|---|---|---|---|---|---|---|---|
| | No. of fruits/ plant | Fruit wt. (g) | Yield (t/ ha) | Juice (%) | Acidity (%) | TSS (°Brix) | |
| | | | 2010-2011 | | | | |
| $I_1$ | 348 | 110.2 | 8.85 | 37.4 | 0.84 | 9.11 | 10.8 |
| $I_2$ | 332 | 103.4 | 8.54 | 37.2 | 0.85 | 9.13 | 10.7 |
| $I_3$ | 311 | 102.8 | 8.15 | 37.3 | 0.85 | 9.09 | 10.7 |
| $I_4$ | 571 | 105.2 | 15.28 | 38.4 | 0.83 | 9.69 | 11.6 |
| $I_5$ | 576 | 116.3 | 16.04 | 38.7 | 0.83 | 10.02 | 12.0 |
| $I_6$ | 628 | 121.1 | 17.25 | 39.3 | 0.81 | 10.3 | 12.7 |
| $I_7$ | 581 | 119.3 | 16.09 | 38.9 | 0.82 | 10.0 | 12.2 |
| 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 | 10.7 |
| $I_2$ | 340 | 104.5 | 9.84 | 37.1 | 0.85 | 9.11 | 10.7 |
| $I_3$ | 314 | 103.1 | 8.96 | 37.3 | 0.84 | 9.07 | 10.8 |
| $I_4$ | 582 | 105.8 | 17.05 | 38.1 | 0.84 | 9.63 | 11.4 |
| $I_5$ | 591 | 115.7 | 18.94 | 38.3 | 0.85 | 10.0 | 11.7 |
| $I_6$ | 631 | 122.9 | 21.48 | 39.1 | 0.82 | 10.2 | 12.4 |
| $I_7$ | 597 | 118.9 | 19.66 | 38.7 | 0.83 | 9.9 | 11.9 |
| CD($P$ = $0.05$) | 92 | 7.9 | 0.81 | 0.45 | NS | 0.18 | -- |

*The treatments as shown in Table 1.

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