



Acid lime (*Citrus aurantifolia*) production as influenced by different fertigation levels with irrigation schedules

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ABSTRACT

The sustainable production of acid lime is possible with combined use of irrigation water with fertilizer through micro-irrigation. The integrated use of drip irrigation with fertigation on yield, quality and economy of 14 year-old acid lime (*Citrus aurantifolia* Swingle) cv. Sai-Sharbati was studied during 2011–16 at Mahatma Phule Krishi Vidyapeeth, AICRP on Fruits, Rahuri (M.S.). The study was undertaken on the black soil with the base recommended dose of fertilizers (RDF) as 600:200:600 (N:P₂O₅:K₂O). The experiment was in Factorial Randomised Block Design with nine treatments, comprising three irrigation schedules, viz. 70% evaporation replenishment (ER) (I₁), 80% ER (I₂), and 90% of ER (I₃), and three fertigation levels, viz. fertigation with 60 % RDF (recommended dose of fertilizers) (F₁), 70% RDF (F₂) and 80% RDF (F₃) based NPK doses replicated six times. The highest canopy and fruit yield of acid lime was observed with the irrigation schedule at 90% ER with 80% RDF fertigation followed by 70% RDF fertigation. The highest yield efficiency (5.05 kg/m³) was also with irrigation schedule at 80% and 60% RDF fertigation. However the highest partial factor productivity of nutrients (66.12 kg fruit/kg NPK) and higher B/C ratio (1.95) was obtained with irrigation at 90% ER and with 60% RDF fertigation and by 90% ER with 80% RDF respectively. The quality production of acid lime fruits was obtained with irrigation schedule at 90% ER with 80% RDF fertigation.

Key words: Acid lime, Citrus, Fertigation, Irrigation schedule, Partial factor productivity

Acid lime (*Citrus aurantifolia* Swingle) is mainly grown in semi-arid climate of Indian states. The productivity is very low due to surface irrigation method, poor soil moisture and soil application of fertilizers with nutrient deficiencies. Irrigation scheduling and fertilizer application are the main operations affecting acid lime yield (Smajstrla 1993, Shirgure 2012). The major constraints in production are irrigation water and essential nutrients to be applied at different fruit stages to achieve the quality of citrus (Bielorai *et al.* 1984, Mageed *et al.* 1988). Acid lime being a perennial tree requires moisture and nutrients for higher orchard efficiency during all growth stages. The inadequate moisture and nutrients in critical stages hampers the fruit yield and quality drastically (Smajstrla 1993, Davies and Albrigo 1994, Shirgure *et al.* 2014). It was investigated that partial fertigation of N and K element resulted in low N content in leaves with higher TSS and acidity in juice with fruit yield in Valencia and Navel orange (Koo and Smajstrla 1984, Fouche and Bester 1987), Sunburst tangerine (Ferguson *et al.* 1990). The quality fruits were obtained with the irrigation schedule at 20% depletion of available water content (AWC) (Shirgure *et al.* 2001, Srivastava *et*

al. 2003) and 30% depletion of AWC combined with 500 N: 140 P₂O₅: 70 K₂O g/plant as fertigation in mandarin and lime respectively (Shirgure *et al.* 2004a, Shirgure 2013). The response of sweet orange to volumes of water applied under surface irrigation (V), viz. 60, 80 and 100% V along with different quantity of fertilizer, viz. 75, 100 and 125% of RFD in sandy soil and concluded that irrigation at 80% + 100% RDF produced highest yield and quality fruits (Kumar *et al.* 2013). The objective of this investigation was to study the integrated effect of different irrigation schedules and with fertigation on growth, partial factor productivity, yield, fruit quality and economics of bearing acid lime cv. Sai-Sharbati grown in central India.

MATERIALS AND METHODS

An experiment was conducted on 14 years-old bearing Sai Sarbati acid lime with plant spacing of 6 m at AICRP on Citrus, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra) during 2011–16. Different irrigation schedules based on evaporation replenishment (ER), viz. I₁, irrigation scheduling at 70% ER, I₂, irrigation scheduling at 80% ER and I₃, irrigation scheduling with 90% ER with three sub-fertigation levels, viz. F₁, fertigation with 60% RDF, F₂, fertigation with 70% RDF and F₃, fertigation with 80% RD, where RDF was applied as 600:300:600 g/plant (N:P₂O₅:K₂O) annually as per the recommendation.

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All the nine treatments were imposed in FRBD, with three replications and four plants/replication. The soil was clay loam (45% of clay content). The field capacity and wilting point were observed as 21.7% and 12.6% respectively and the WHC of the soil was 9.1%. The orchard was grown under uniform cultural/input management practices. The surface drip irrigation system consisting 4 drippers /plant with 8 liters/hr flow was installed along with the fertilizer dispenser. The plants were irrigated on alternate day with drip and water requirement was estimated using standard evaporation method (Lakashmi *et al.* 2019). The evaporation data was taken from agro-meteorological observatory and the water quantity was scheduled. For fertigating the required quantity of N, P and K fertilizers were used. Monthly fertigation was done using injection pump in equal splits of annually required fertilizers as estimated in the differential treatments. The plant height and scion girth was measured above the ground level. Canopy volume of the plant was calculated by using the plant spread by the Castel 1994 formula. Similarly, yield of randomly selected fruits from trees was weighed and average fruit weight was computed. The numbers of fruits were counted on each plant during harvesting and total fruit yield (kg/plant) was recorded. Fifty fruits per tree were used for fruit quality parameters (juice percent, acidity and total soluble solids). Juice percent was estimated on fruit weight basis. The total soluble solid (TSS) was determined by hand held refractometer (Erma Inc, Japan) and acidity was measured by volumetric titration with standardized sodium hydroxide, using phenolphthalein as an internal indicator (Ranganna 2001). Partial factor productivity (PFP) was estimated by dividing the fruit yield with amount of the total fertilizer nutrient (N+P+K) applied (Devasenapathy *et al.* 2008). The yield efficiency (kg/m³) was calculated as the ratio between the fruit yield harvested and the tree canopy volume in each treatment. The leaf samples collected were digested in di-acid mixture of H₂SO₄: HClO₄ in 2.5:1 ratio. The leaf N was determined using Auto Nitrogen Analyser, P by vanadomolybdophosphoric acid yellow color method and K by flame photometrically. The observational data on biometric growth, fruit yield, leaf nutrient uptake and fruit quality attributing to the different irrigation schedules and fertigation levels for 5 years were statistically analysed through Analysis of variance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Water requirement and irrigation schedules: The water requirement is a function of plant growth in terms of canopy. The effect of various irrigation schedules influenced the water use by the acid lime plant during 2011-2016. The open pan evaporation recorded during this study period varied from 4.09-10.04 mm/day in January-May months. The effective rainfall of 52.0-118.8 mm was contributed during rainy month (336.96 mm). The irrigation was not given in June-October as the effective rainfall exceeded the evaporation. The daily water requirement of acid lime varied from 21.45–53.13 liters/day/plant, 24.51–59.92 liters/day/plant and 28.69-68.71 liters/day/plant in the

irrigation schedules 70%, 80% and 90% ER respectively. The total quantity of irrigation used with 70% evaporation replenishment (ER) irrigation schedule was 11,398 liters/day/plant for 5 years from 2012–16 with mean of 950 liters/day/month. While, with 80% evaporation replenishment (ER), irrigation it was optimum as 13,049 liters/plant with mean of 1087 liters/day/month. The water use was 14,764 liters with 90% ER irrigation schedule (mean of 1,230 liters/day/month). The quantity of water use was more in summer due to lower humidity and high transpiration. Irrigation was not followed in rainy season due to lower evaporation than rainfall. Similar studies on water use in citrus crops have been reported in acid lime (Shirgure *et al.* 2000, Shirgure *et al.* 2003), Nagpur mandarin (Shirgure *et al.* 2004b), Kinnow mandarin (Mageed *et al.* 1988) and Sathgudi sweet orange (Kumar *et al.* 2013) under different climatic zones.

Bio-metrics, partial factor productivity and yield efficiency: The results showed that, the interaction of irrigation schedule and fertigation on biometric parameters and yield efficiency of acid lime was found significant. Except irrigation schedule at 90% ER, the plant height increased from 3.02–3.35 m and from 3.16–3.38 m by increasing levels of fertigation from 60–80% RDF, with irrigation schedule at 70% ER and 80% ER, respectively. Similarly the canopy increased from 13.75–18.35 m³ and from 15.19–22.72 m³ by increasing levels of fertigation from 60–80% RDF, with irrigation schedule at 70% ER and 80% ER, respectively. Interestingly, the treatment effect on plant height and canopy was significantly higher with irrigation at 90% ER than at 70% ER with 80% RDF fertigation. The mean plant height and canopy volume was recorded maximum with irrigation at 90% ER followed by irrigation at 80% ER with fertigation level of 60–80% RDF. While the lowest mean plant height and canopy was observed with irrigation scheduled at 70% ER + fertigation level of 60–80% RDF. The citrus fruit production was significantly improved by micro-irrigation system and fertigation technique (Srivastava *et al.* 2003, Shirgure *et al.* 2014). The yield data showed that, the interaction effect of irrigation and fertigation on fruit yield were also significant and higher fruit yield/tree (100.77 kg/tree) was recorded in irrigation scheduled at 90% ER + 80% of RDF fertigation, it was at par with irrigation scheduled at 80% ER + 80% of RDF fertigation. The lower yield was observed in irrigation scheduled at 70% ER irrigation schedule + 80% of RDF fertigation (Table 1). The number of the fruits per tree depends upon the adequacy of soil moisture and nutrients. The number of fruits per plant ranged from 1561–1621, 1607–1715 and 1690–1842 in irrigation schedule at 70% ER, 80% ER and 90% ER, respectively during 2012–16. The highest number of acid lime fruits (1842) was observed in irrigation schedule at 90% ER + 80% fertigation level. However, the effect of the integrated effect on fruit production was maximum with irrigation at 90% ER + 80% RDF fertigation (27.91 t/ha) followed by irrigation at 90% ER + 70% of RDF fertigation (26.82 t/ha). The lowest yield was recorded with irrigation scheduling at

Table 1 Effect of irrigation schedule and fertigation on biometrics, fruit yield, partial factor productivity and yield efficiency in acid lime (Mean: 2011–12 to 2015–16)

Treatment	Plant height (m)	Canopy volume (m ³)	Fruit yield (kg/tree)	PFP* (kg fruit/kg NPK)	Yield efficiency (kg/m ³)
I ₁ F ₁	3.02	13.75	65.95	48.86	4.80
I ₁ F ₂	3.12	15.19	74.43	47.10	4.90
I ₁ F ₃	3.35	18.35	81.47	45.26	4.44
I ₂ F ₁	3.16	15.19	76.67	56.79	5.05
I ₂ F ₂	3.35	18.02	83.91	53.10	4.66
I ₂ F ₃	3.68	22.72	91.34	53.40	4.02
I ₃ F ₁	3.28	17.86	84.81	66.12	4.75
I ₃ F ₂	3.71	23.91	96.85	60.83	4.05
I ₃ F ₃	3.79	25.08	100.77	53.95	4.02
SE(m) ±	0.14	2.45	1.47	--	--
CD (P=0.05)	0.42	6.88	4.23	--	--

I₁, Irrigation at 70% ER; I₂, Irrigation at 80% ER; I₃, Irrigation at 90% ER; F₁, Fertigation with 60% RDF; F₂, Fertigation with 70% RDF and F₃, Fertigation with 80% RDF.

*PFP-Partial Factor productivity (kg fruit /kg of NPK use).

70% ER along with 60% RDF fertigation (18.27 t/ha). The research on irrigation schedules at critical stages of water requirements showed higher growth and yield with irrigation scheduled at 80% ER in Nagpur mandarin (Shirgure *et al.* 2001, Shirgure *et al.* 2014) and acid lime (Shirgure *et al.* 2004a) with reduced fertilizer doses over conventional method in black soils.

The integrated use of inputs increased not only the yield efficiency and partial factor productivity but also the water-fertilizer use efficiency. The partial factor productivity of macro-nutrients (NPK) for *ambia bahar* was calculated for the fruit yield from the individual tree (Table 1). The maximum partial factor productivity (PFP) 66.12 and 60.83 kg fruit/kg NPK use were noticed in the irrigation schedule at 90% ER + 60% RDF fertigation and 70% RDF fertigation respectively, which were significantly superior over the other treatments. The partial factor productivity 56.79 and 47.10 kg fruit/kg NPK use were observed in the irrigation schedule at 80% ER along + 60% RDF fertigation and irrigation schedule at 70% ER + 70% RDF fertigation respectively. The highest yield efficiency was recorded as 5.05 and 4.75 kg fruit/m³ of canopy in the irrigation scheduled at 80% ER + 60% RDF fertigation and irrigation scheduled at 90% ER + 60% RDF fertigation respectively. Lower yield efficiency of 4.90 kg fruit/m³ of canopy was observed in the irrigation schedule at 70% ER + 70% RDF fertigation. Similar studies were reported in *Sathgudi* sweet orange (Lakashmi *et al.* 2019).

Fruit quality parameters: The acid lime quality parameters (the juice content, TSS, acidity, ascorbic acid and rind thickness) were significantly influenced by the

integrative effect of irrigation schedules with fertigation. The better quality parameters were recorded with irrigation at 90% ER (juice content 52.87%, TSS 8.42°Brix, acidity 6.35%, ascorbic acid 32.30 mg/100 ml and rind thickness 1.67 mm) + 80% RDF fertigation and significantly better than either irrigation at 70% ER along + 80% RDF fertigation or a irrigation at 80% ER + 80% RDF fertigation. However, the irrigation schedule with 70% ER + 60% RDF fertigation gave the poor quality fruits. The highest TSS to acidity ratio (1.33) was found in the irrigation schedule with 90% ER with 80% RDF fertigation followed by the irrigation schedule with 80% ER with 80% RDF fertigation (1.21). The lowest TSS to acidity (1.18) was observed the irrigation schedule with 70% ER with 60% RDF fertigation. The similar studies showed the improvement in quality of citrus fruits in response to irrigation schedule and fertigation in Nagpur mandarin (Shirgure *et al.* 2014; Shirgure *et al.* 2016) and acid lime (Shirgure *et al.* 2004a).

Leaf nutrient status and economics: The fertigation improves nutrient use efficiency and minimizes fixation and leaching of nutrients, soil fertility improvement coupled with water use efficiency (Alva *et al.* 2008, Shirgure and Srivastava 2013). The integrated effects of irrigation schedules with fertigation have shown a significant response on leaf macro-nutrients (leaf N, P and K) and micro-nutrients (Fe, Mn, Cu and Zn) uptake in acid lime. The highest leaf N, P and K was observed in irrigation scheduling at 90% ER + 80% RDF fertigation (2.48% N, 0.14% P and 2.63% K). The same was observed to be 2.38%, 2.30% and 2.17% with irrigation schedule at 70%, 80% and 90% ER with 80% RDF fertigation, respectively. The lower leaf N uptake (2.01%) was observed in irrigation schedule of 70% + 60% RDF fertigation due to lower moisture and poor availability of nutrients. The effect of treatments on leaf P concentration was also significant in relation to levels. Leaf phosphorus (P) concentration showed maximum value of 0.14% with irrigation at 90% ER, which was significantly higher than either irrigation at 70% ER (0.11%) or at 80% ER (0.13%). The P content was observed to be 0.11%, 0.13% and 0.14% with irrigation schedule at 70% ER, 80% ER and 90% ER at 80% RDF fertigation treatment, respectively. The lower leaf P uptake (0.08%) was observed in irrigation schedule of 70% ER with 60% RDF fertigation due to low mobility and fixing of the P with soil in inadequate moisture regime. Maximum leaf K (2.63%) was observed with irrigation at 90% ER followed by irrigation at 80% ER (2.34%) and 70% ER (2.04%) with 80% RDF fertigation. These observations indicated that the optimum leaf K can be achieved with irrigation schedule at 80–90% ER. The increase in leaf K was maximum with increasing fertigation levels from 60–80% RDF, proportionately higher with irrigation at 90% ER than at either 70% ER or 80% ER. Increasing fertigation levels, from 60–80% RDF with irrigation at 80% ER and 90% ER showed more distinctive changes in concentration of N, P and K in index leaves, compared to different fertigation levels with irrigation at 90% ER. The interactive effect of treatments has shown a positive response on leaf micro-

nutrients uptake in acid lime. The effect was significant on zinc and non-significant in case of manganese, copper and iron elements. The highest leaf Fe and Cu was observed in irrigation scheduling at 90% ER + 60% RDF fertigation. The highest leaf Mn and Zn was observed in irrigation scheduling at 90% ER along + 80% RDF fertigation. The lowest micronutrient status was recorded in irrigation schedule with 70% ER + 60% RDF fertigation. Similar results of nutrient uptake with fertigation were also reported in Nagpur mandarin (Shirgure *et al.* 2016), Sathgudi sweet orange (Lakashmi *et al.* 2019) and acid lime (Shirgure 1999, Shirgure *et al.* 2001b). The quality acid lime fruits fetches high market price with enhancing the net profit of cultivation (Shirgure *et al.* 2002). The highest net profit of acid lime production was varied from ₹ 113726–164111 ₹/ha, ₹ 158078–205199 ₹/ha and ₹ 191956–244309 ₹/ha with irrigation schedule at 70%, 80% and 90% ER along with 60–80% RDF fertigation treatments respectively. It was also revealed that the maximum cost benefit ratio (B:C) 1.95 was observed in irrigation schedule at 90% ER combined + 70% and 80% RDF followed by irrigation at 80% ER + 80% of RDF fertigation (1.82), which is considered to be optimum as far as the inputs cost is concerned in acid lime cultivation. The higher yield efficiency, fruit quality and partial factor productivity of inputs is possible with irrigation scheduling at 90% ER with 80% of RDF fertigation with saving of inputs.

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