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Drip Fertigation–A Boon to Enhance Yield using Less Water and Fertilizers in Fruit Crop Production

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Introduction

In recent years, the share of water for agriculture has been reduced due to higher water demand for drinking, industrial and other purposes in day-to-day life. To feed the increasing population, production of more food with less water is an essential. On the other hand, sustainability of production system is another challenge. Increasing production without deteriorating the environment is the prime objective of sustainable agriculture. Use of chemical fertilizers to boost the productivity becomes a common practice in crop production. However, it has been observed that long term use of chemical fertilizers without applying organic manures or composts in appropriate quantity reduces the soil health and makes the land irresponsive to fertilizer doses. Therefore, it is a requisite to reduce the use of chemical fertilizers without affecting the productivity of crops.

Drip irrigation is one of the potential techniques to save water in different crops. Use of fertilizers through irrigation system otherwise called fertigation is an added benefit under drip irrigation. Drip fertigation not only saves water and fertilizers but may enhance yield and quality of produces in different crops.

There is a huge potential of drip-fertigation in horticultural crops especially in fruit crops. However, the information on performance of drip fertigation in different crops pertaining to water and fertilizer savings, and yield and quality improvements are required. Keeping this in mind, a study was conducted to standardise drip fertigation regime in citrus which is the third important fruit crop of India.

Materials and Methods

The study was conducted at experimental farm of National Research Centre for Citrus, Nagpur 2006-2008 with 12-year-old Nagpur mandarin (*Citrus reticulata* Blanco) plants budded on rough lemon (*Citrus Jambhiri* Lush) root stock with spacing of 6 x 6 m. The effective soil depth of experimental site is 62 cm, underlain by stony and gravel layer. The average daily Class-A pan evaporation rate varied from 2 mm in month of December to as high as 12 mm in May at the experimental site. The treatments imposed to irrigate the plants were drip irrigation at 50% of daily pan evaporation (Ep) (I_1), 75% Ep (I_2) and 100% Ep (I_3) applied through four number of 8 L h^{-1} pressure compensated on-line dripper per plant, placed at 1.0 m away from plant stem and basin (ring of 1.2 m radius) irrigation at 50% depletion of available soil water at 0-0.30 m soil profile. Irrigation quantity for different drip irrigation treatments was calculated using the formula $V= S \times Kp \times K_C \times (E - ER) / r$, where, V is the irrigation volume (l/tree/day), S the tree canopy area (m^2), Kp the pan factor (0.7), Kc the crop factor (0.6) as suggested by Allen *et al* (1998), E the daily class-A pan evaporation rate (mm), ER the effective rainfall (mm), and r the water application efficiency of irrigation system (~90%). Under basin irrigation, water was supplied through flexible hosepipe, when the soil water at 30 cm depth attains 50% of available soil water (23.9%, v/v). Water quantity applied in basin irrigation method was computed using the equation; V = (F.C – R.S.M) × d x A, where V; Volume of irrigation water (m^3), F.C; field capacity (v/v, %), R.S.M; required soil water level ≈ 23.9 (v/v, %), d; depth of effective root zone (0.30 m), A; mean canopy area of the plants. No runoff during irrigation periods was observed in the orchard, assuming effective rainfall ≈ rainfall.

The water use (WU) by the crop was estimated from water balance equation as $WU = P + I + Cp - Dp - R_f - \Delta S$; where, P is rainfall, I is depth of irrigation water, Cp is contribution through capillary rise from ground water table, Dp is deep percolation loss, R_f is surface water runoff and ΔS is change in moisture storage in the soil profile to a depth of 60 cm. All units are in millimetres. The fertilizers applied under each drip irrigation treatment were at 25% of recommended dose of fertilizer (RDF) (F_1), 50% RDF (F_2), and 75% RDF (F_3), where RDF was taken as N: P_2O_5: K_2O = 600 g: 200 g: 100 g annually for bearing Nagpur mandarin. Water soluble form of urea phosphate (N: P: K=18:44:0) and murate of potash (N: P: K= 0:0:60) were used for supplying required quantity of P and K, respectively. As a whole, ten treatments (I_1F_1, I_1F_2, I_1F_3, I_2F_1, I_2F_2, I_2F_3, I_3F_1, I_3F_2, I_3F_3 and control) were imposed in split plot design (SPD), with four replications and three adjacent plants in a row per replication.

The soil water content was monitored twice in a week at 0.30 m, and 0.60 m depths by neutron moisture meter (Troxler model-4300, USA). The indexed leaf samples (2^{nd} – 4^{th} leaf from tip of branches) surrounding the trees at a height of 1.5 m to 1.8 m from the ground were collected at the end of irrigation seasons and nutrient (N, P, K, Fe, Mn, Cu, and Zn) analysis was done as per the standard procedures. The canopy volume was calculated based on the formulae $0.5233\ H\ W^2$, where H = (tree height – stem height) and W the canopy width. The weight of total fruits from each tree under various treatments was recorded and 5 fruits per tree were taken randomly for determination of fruit quality parameters (juice percent, acidity and total soluble solids). All the data generated were subjected to analysis of variance (ANOVA) and the critical difference (CD) at 5% probability was obtained according to the standard methods.

Results and Discussion

Irrigation Water Quantity

Irrigation was applied during flowering (November) to fruit enlargement stages (June). The water applied under various irrigation treatments (Table 1) was lowest in December (12.5 – 41 L day^{-1} $plant^{-1}$) and highest in May (75.6 – 165.5 L day^{-1} $plant^{-1}$). It was due to increased atmospheric evaporative demand from December to

May, which was evident from pan evaporation data. The basin irrigation consumed higher quantity of water (41 – 165.5 L day^{-1} $plant^{-1}$) over drip irrigation (12.5 – 151.2 L day^{-1} $plant^{-1}$) during both the years of experiment. Irrigation was withheld during rainy season (July-October) due to lower cumulative evaporation than rainfall. Overall, the quantities of water applied through drip irrigation were 2798, 4196 and 5595 m^3 ha^{-1} yr^{-1} under 50%, 75% and 100% Ep irrigation regimes, respectively, over 6340 $m^3ha^{-1}yr^{-1}$ in basin irrigation.

Table 1. Mean daily irrigation water applied (L day^{-1} $plant^{-1}$) under different irrigation treatments in various months

Treatment	Months								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	TWA* (m^3 ha^{-1} yr^{-1})
I_1	21.8	12.5	19.6	31.7	47.6	61.8	75.6	59.3	2798
I_2	32.8	19.0	29.4	47.6	71.4	92.6	113.4	88.9	4196
I_3	43.7	25.0	39.2	63.4	95.2	123.5	151.2	118.6	5595
$^+$BI+BPF (Control)	50.5	41.0	45.2	82.3	107.8	134.6	165.5	132.4	6340

*TWA: Total water applied; I_1: Drip irrigation (DI) at 50% Class-A pan evaporation (Ep), I_2: DI at 75% Ep, I_3: DI at 100% Ep; $^+$BI: Basin irrigation and BPF: Band placement of fertilizers

Soil Water Variation

The mean monthly soil water variation observed at 0.30 and 0.60 m depths during irrigation periods indicated that all the drip irrigation regimes (except 50% Ep) with fertigation showed a significantly higher soil water content (25.8–28.0%, v/v) compared to basin irrigation with band placement of fertilizer (24.2–26.7%, v/v) at 0.30 m depth. The fluctuation of soil water content between two measurements in a week under basin irrigation was observed to be wider than that under any of the drip irrigation treatment. It was due to higher rate of evaporation from larger wetted surface area under basin irrigation. The higher soil water content at 0.60 m depth under basin irrigation indicated the percolation of irrigation water from 0–0.30 m soil profile under basin irrigation. The higher soil water depletion was observed in higher levels of fertilizer with any irrigation regime.

Leaf Nutrients Composition

The various irrigation and fertigation treatments were observed to produce a significant response on leaf nutrient composition. Increase in irrigation regime from 50% Ep (I_1) to 75% Ep (I_2) under drip irrigation enhanced the leaf N content in corresponding fertilizers levels. The further increase in irrigation to 100% Ep (I_3) reduced leaf N content. The highest leaf N (2.15%) was registered under I_2F_3 and lowest under I_1F_1 (1.65% N) versus 1.98% leaf-N in BI with BPF. Leaf K content followed the similar pattern of response as leaf N. Leaf-P content increased with increasing both irrigation and fertilizer levels applied through drip-irrigation, with highest magnitude under I_3F_3.

Plant Growth

The annual incremental vegetative growth parameters (plant height, stock girth, scion girth, canopy volume) of the plants under different treatments were recorded for two years and the mean values are presented. The mean annual increase in plant height, stock girth, scion girth, and canopy volume varied in the range 0.25 – 0.55 m, 3.1 – 5.6 cm, 2.9 – 5.4 cm and 6.23 – 9.98 m^3, respectively, under drip-fertigation treatments (except I_1F_1) over 0.22 m (plant height), 3.0 m (stock girth), 2.8 cm (scion girth), and 5.96 m^3 (canopy volume) under BI with BPF. The highest magnitude of all incremental growth parameters was recorded under drip irrigation at 75% Ep with 75% RDF.

Fruit yield and quality

Fruit yield changed significantly in response to irrigation and fertigation levels individually and in combination (Table 2). The highest fruit number (523) and fruit weight (110.3 g) was recorded in I_2F_3 followed by I_3F_3. The average annual fruit yield increased with increase in fertilizer level under each drip-irrigation regime. However, the annual fruit yield was observed to increase from 8.5 t/ha in I_1F_1 to as high as 16.03 t/ha in I_2F_3 against 10.0 t/ha in BI with BPF. The higher fruit yield under optimal drip-fertigation over surface irrigation with conventional fertilization was also observed earlier in various citrus cultivars (Morgan *et al*, 2009).

All the fruit quality parameters (juice content, TSS and acidity) varied significantly with irrigation and fertigation levels. The fruits having highest juice content (41.8%) and TSS (10.2 ^{0}Brix) and lowest acidity (0.82%) were harvested in I_2F_3. The BI with BPF produced the fruits with 38.4% juice content, 0.84% acidity and 9.4 ^{0}Brix TSS. The higher TSS and lower acidity in fruits under optimal water supply and fertilization through drip system over surface irrigation with broadcasting method of fertilization was also observed earlier in 'Valencia' orange (Koo and Smajstrla, 1984).

Table 2. Yield and fruit quality as affected by irrigation and fertigation in Nagpur mandarin

Treatment		Yield parameters			Quality parameters		
		No. of fruits/plant	Average Fruit weight (g)	Total yield (t/ha)	Juice (%)	Acidity (%)	T.S.S (^{0}Brix)
I_1	F_1	364	84.0	8.50	37.4	0.85	9.4
	F_2	384	87.2	9.30	38.6	0.83	9.5
	F_3	421	89.6	10.48	38.7	0.83	9.5
I_2	F_1	409	89.8	10.21	38.4	0.81	9.6
	F_2	447	98.5	12.24	39.3	0.82	9.6
	F_3	523	110.3	16.03	41.8	0.82	10.2
I_3	F_1	411	96.2	11.00	39.9	0.84	10.1
	F_2	468	102.6	13.35	40.2	0.85	10.0
	F_3	518	109.5	15.77	40.4	0.86	9.7
$^+$BI+BPF		380	94.6	10.00	38.4	0.84	9.4
	I	5.6	9.8	0.82	1.08	0.006	0.62
$CD_{0.05}$	F	4.2	5.6	0.67	0.87	0.008	0.44
	IxF	6.8	10.2	0.97	1.12	0.01	0.87

Conclusions

The application of irrigation and fertilizers through drip system is found to be a potential water and fertilizer saving technique in Nagpur mandarin. The optimal drip irrigation regime (75% of class-A pan evaporation) in combination with 75% of recommended dose of fertilizers (RDF) saved around 50% water and 25% fertilizers over basin irrigation with band placement of fertilization. Drip-fertigation also enhanced the fruit yield to the tune of 60% and improved the fruit qualities (Juice percent, TSS, acidity) over basin irrigation with band fertilization method in Nagpur mandarin. The higher productivity with superior quality fruits using less water and fertilizers under drip-fertigation warrants its adoption in Nagpur mandarin orchards of central India. This could help in bringing more area under irrigation, resulting in large increase in production of citrus with prolonged orchard longevity.

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