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Plant water relations, yield and nutrient content of passion fruit in relation to evaporation replenishment and fertigation

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ABSTRACT

Field experiments were carried out to study the response of passion fruit to irrigation and fertigation levels. Fruit number and yield (22.85 kg/pl) were higher with 50% evaporation replenishment rate (ER) as compared to 25% ER (18.84 kg/pl). The yield differences between 50, 75 and 100% recommended dose of fertilizer (RDF) was not significant (19.68 - 21.68 kg/pl). The response surface models fitted to the yield data indicated an optimum ER of 40 % and RDF 55%. The relative water content and leaf nutrient content was higher with 50% ER and the leaf water potentials recorded lower values with 50% ER. The total water use was 282.5 and 564 mm with 25 and 50% ER and the water use efficiency was 40 and 66 kg/ha-mm. The leaf nutrient content (N, P, K, Ca & Mg) were higher with 50% ER and 100% RDF.

Key words: Evaporation replenishment, fertigation, passion fruit, water relations.

INTRODUCTION

Passion fruit (*Passiflora edulis* Sims) is an important crop in most tropical and subtropical regions of the world and commercially grown in Australia, Hawaii, South Africa, New Zealand, the Caribbean, Columbia, Ecuador, Indonesia, Peru, Haiti, Hawaii, East Africa and Brazil. The Northeastern regions of India contributes substantially in the production of passion fruit and the crop is a novelty in southern parts of India. In recent years, there has been some interest in commercialization of passion fruit for its flavour, aroma and juice blending qualities. The plant is a vigorous perennial vine with profuse canopy and bears fruits in a span of 6-8 months after planting. The purple fruits are very attractive and bear nearly 300 to 600 fruits per plant per year.

Information on the irrigation and fertigation aspects are meagre since the crop is mainly grown as a back yard plant. Passion fruit is generally considered to need large quantities of water to fruit successfully and water deficits are reported to reduce leaf growth, flower induction and fruit size (Schaffer and Anderson, 6). They have also observed that severe moisture stress defoliate the vines and induce fruit drop. Higher yields with higher evaporation replenishment rates and fertigation has been reported in many horticultural crops like banana (Hegde and Srinivas, 2; Murali *et al.*, 5; Srinivas, 7; Kumar *et al.*, 3), and grapes (Shikhamany and Srinivas, 8). Attempts were made to standardize the drip irrigation and fertigation schedules for maximum production of passion fruit.

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MATERIALS AND METHODS

Field experiments were carried out at the IIHR, Bangalore (altitude 858 m and latitude13^0 58'N) on red sandy loam soils during 2005 to 2007. The soil of the experimental site was of low fertility (pH 7.18, organic carbon 1.36%, EC 0.56 dSm^{-1}, available N 220 ppm, available P 15.8 ppm , available K 150 ppm, Ca 70 ppm, Mg 70 ppm, S 20 ppm, Fe 4.8 ppm, Mn 2.5 ppm, Cu 1.0 ppm). The treatments consisted of two levels of drip irrigation (25 and 50% of evaporation replenishment) and four levels of fertigation (25, 50, 75 and 100% of recommended dose of fertilizer). The recommended dose of fertilizer was 500 N - 300 P_2O_5 - 500 K_20 g per plant per year, nitrogen as urea, phosphorous as single super phosphate and potash as muriate of potash were injected into the drip irrigation at weekly intervals through a fertilizer injector.

The seedlings of variety 'Kaveri' (40-day-old) were planted in the field at a spacing of 3 m × 3 m (11,111 plants/ha) in a bower system The plants were staked and later trained drawing two secondaries from the main stem. The tertiaries from the secondaries were trained on to the bower. The treatments were replicated four times in a factorial randomised block design. The soil had the capacity to hold 110 mm of available water in the top 750 mm soil profile. The ground water contribution to the root zone was considered to be negligible as the water table was below 5.0 m.

The quantity of water applied through the drip irrigation on a daily basis corresponded to replenishment of 25 and 50 per cent of USWB class 'A' pan evaporation. Rainfall, if any was deducted from the evaporation and rain in excess was disregarded. The evaporation and rainfall data during the crop growth period are presented in Fig. 1. The evaporation was higher between February and September during 2007 (5.6 - 9.9 mm) and the rainfall varied from 30 to 222.6 mm. The rainfall received during 2007 was 20 per cent higher as compared to 2006. The drip irrigation system was connected to a tube well and the outlet pressure was maintained at 1 kg/cm^2. A separate drip lateral line (16 mm) was laid for each treatment. Each treatment consisted of 2 rows of 12 plants. Two emitters were provided per plant placed at 40 cm on either side of the trunk. The discharge rate from each emitter was maintained at 4 litres per hour.

The first harvest was done after 185 days after planting and the harvests continued up to 360 days at an interval of 8 - 10 days. The number of fruits harvested and their weights were recorded and summed up after 20 pickings (1st crop) and 15 pickings (2nd crop). The total soluble solids were recorded using a hand refractometer (ERMA). The leaf samples were collected during the peak fruiting period (10 months after planting) and the nutrient content were determined for N, P, K, S, Ca and Mg following the standard procedures. The water potentials were determined using HR33T-Dew point micro-voltmeter (Wescor, USA) and the average of three readings taken at monthly intervals are presented. Response surface models were fitted to the yield data for determining the optimum values for irrigation and fertigation. The response surface methodology (1) is a sequential form of experimentation used to optimize response variable (dependent variable) made of a statistical model of different explanatory variables. This method is a collection of techniques that were developed as a means to find optimum settings of input factors or design variables that optimize or maximize, minimize or target measured response or outcome variables. The mathematical representations of this model are detailed below:

Linear model of first degree with out cross product terms;

$$Y = a + \sum bi\, Xi + e \quad (1)$$

Linear model of first degree with cross product (interaction) terms:

$$Y = a + \sum b_i X_i + \sum\sum b_{ij} X_i X_j + e \quad (2)$$

The quadratic response surface model (also called as Second Order Response Design (SORD) is expressed as: $Y = a + \sum b_i X_i + \sum\sum b_{ij} X_i X_j + \sum b_{ii} X^2 + e$ (3)

Where, Y is the response variable (yield, kg); X is are explanatory variables (levels of fertilizer dose and fertigation schedules) and a, b is are unknown constants to be estimated. The error term 'e' is distributed as identically independently distributed . normal with constant variance. The details regarding the methodology for developing response surface models are elucidated by Montgomery (4).

RESULTS AND DISCUSSION

The fruit number and yield were higher with 50% ER in both the crops as compared to 25% ER (Table 1). The yield increase was 17 and 12% respectively for the 1st and 2nd crops. The yield increase was largely due to higher fruit number with 50% ER (15%). Irrigations scheduled at 50% ER was able to meet the evaporative demands of the large canopy which resulted in higher vine growth and leaf area. As the fruits are borne at each leaf axil, the increased

Table 1. Fruit yield, TSS and leaf nutrient content in relation to evaporation replenishment and fertigation passion fruit.

Evaporation replenishment (ER)	1st crop		2nd crop fruit yield (kg/plant)	TSS (°Brix)	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)
	Fruit No./ plant	Yield (kg/ plant)								
25% ER	305	18.84	9.65	15.4	1.32	0.22	1.47	0.22	1.00	0.252
50% ER	361	22.85	11.86	15.0	1.46	0.29	1.69	0.24	1.20	0.297
CD at 5%	22.3	1.43	1.62	NS	0.10	NS	NS	0.01	0.11	0.03
Fertigation levels										
25% RDF*	304	18.65	8.52	15.0	1.30	0.17	1.45	0.21	0.92	0.255
50% RDF	313	19.68	10.65	15.3	1.41	0.20	1.50	0.22	0.95	0.261
75% RDF	352	21.48	11.53	15.5	1.43	0.26	1.53	0.23	1.23	0.275
100% RDF	365	21.68	12.10	15.1	1.43	0.28	1.85	0.24	1.29	0.305
CD at 5%	31.5	2.02	1.70	NS	NS	NS	0.21	0.01	0.16	0.052

*Recommended dose of fertilizers

vine vigour and growth ultimately contributed for more number of fruits and higher fruit yield. The relative water content was higher with 50% ER (84.5%) as compared to 25% ER (78%).an indication of higher turgidity that might have resulted in better uptake of nutrients as reflected in higher nutrient contents which ultimately contributed for higher vine growth and yield. The leaf water potential was less negative at 50% ER as compared to 25% ER. Leaf growth was suppressed in passion fruit when the pre-dawn leaf water potential was - 2.48 Mpa (Schaffer and Anderson, 6). Higher yields with increase in evaporation replenishments have been reported in banana (Srinivas, 7). The total soluble solids did not show any marked difference with evaporation replenishment rates. The response surface model indicated an optimum ER of 40.6%.

Increase in fertigation levels also increased the fruit number and yield up to 75% RDF only. The yield increase was 14% with 100% RDF and 13% with 75% RDF as compared to 25% RDF. This yield increase was largely due to increase in fruit number per plant. which was a consequence of higher vine vigour, increase in the relative water content as well as higher nutrient content. Optimum yields in banana with 75% RDF has been reported by Srinivas (7) and similar reports in acid lime by Shirgure *et al.* (8). The total soluble solids marginally increased at 50 and 75% RDF, although the differences were not significant. The optimum RDF was 54.5% as indicated by the response curve fitted to the yield data.

In general, the NO_3-N content and EC values of the soil increased with depth irrespective of the irrigation and fertigation levels (Table 2). On the contrary, the pH values decreased with depth. The NO_3-N content was higher with 50% ER and 50% RDF, the pH was higher with 25% ER and 25% RDF and the EC values was higher with 25% ER and 50% RDF. Passion fruit yields were higher with irrigations scheduled at 50% ER and the yield differences between 50, 75 and 100% RDF was not significant. However, the response surface models indicated an optimum ER of 40% and RDF of 55%.

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Table 2. Plant water relations, soil NO_3-N, pH and EC variations in relation to evaporation replenishment and fertigation in passion fruit.

Evaporation replenishment (ER)	NO_3-N content (mg/kg)			pH			EC (dSm^{-1})			Relative water content (%)	Leaf water potential (M/pa)
	Soil depth (cm)										
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45		
25% ER + 25% RDF*	20	23	26	7.6	7.5	7.3	0.16	0.21	0.23	77	-2.20
25% ER + 50% RDF	22	24	25	6.9	6.1	6.3	0.20	0.28	0.34	79	-2.21
25% ER + 75% RDF	16	18	20	6.8	6.1	6.1	0.15	0.16	0.17	78	-2.22
25% ER + 100% RDF	14	15	17	6.3	6.2	6.0	0.12	0.13	0.17	79	-2.28
50% ER + 25% RDF	18	20	23	6.8	6.5	6.1	0.13	0.15	0.18	82	-1.85
50% ER + 50% RDF	28	32	36	5.9	6.1	6.3	0.18	0.23	0.28	84	-1.94
50% ER + 75% RDF	15	17	20	7.0	7.1	7.2	0.28	0.32	0.33	86	-2.01
50% ER + 100% RDF	13	15	18	5.9	6.1	6.3	0.26	0.28	0.31	86	-2.07

*Recommended dose of fertilizer

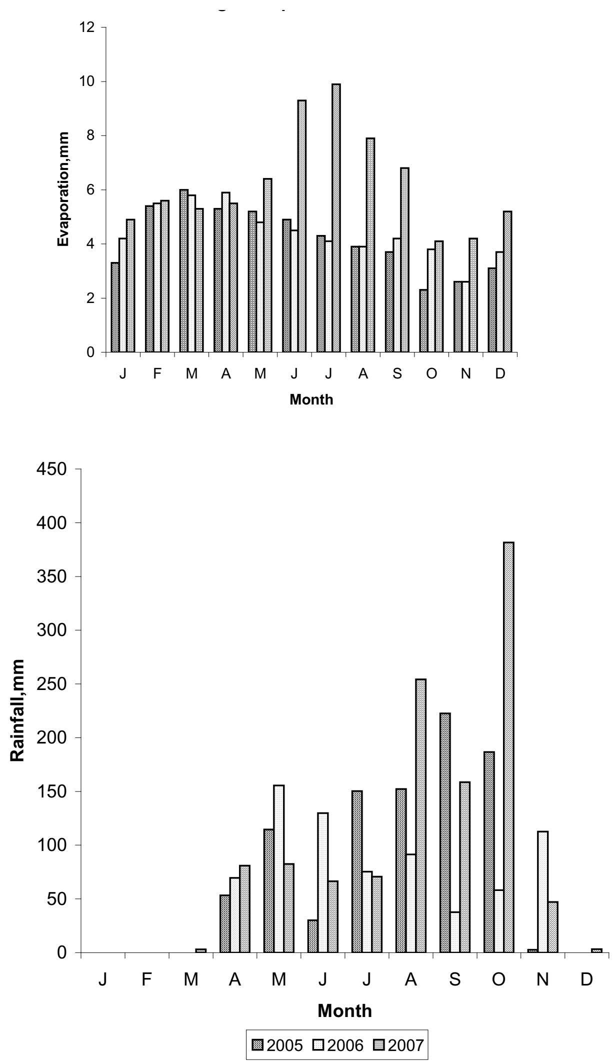
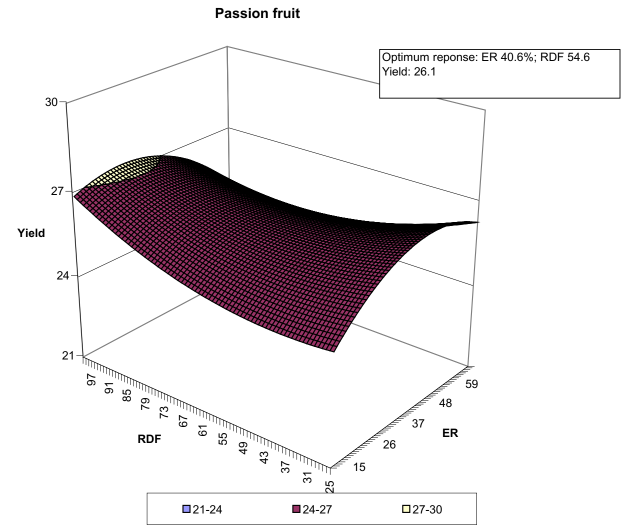


Fig. 1. Evaporation and Rainfall during the crop growth period.



$$Y = 23.2 + 0.18\ ER - 0.03\ RDF - 0.0008\ ER*RDF - 0.0016\ ER^2 + 0.00055\ RDF^2$$

Fig. 2. Response surface models for passion fruit.

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