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Yield of papaya irrigated with fractions of Class A pan evaporation in a semiarid environment[1,2]

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ABSTRACT

There is a scarcity of information regarding the optimum water requirement for papaya (*Carica papaya*) grown under semiarid conditions with drip irrigation in the tropics. A two-year study was conducted to determine water requirement, yield, and fruit quality traits of papaya cv Red Lady subjected to five levels of irrigation. The irrigation treatments were based on Class A pan factors that ranged from 0.25 to 1.25 in increments of 0.25. Drip irrigation was supplied three times a week on alternate days. Results showed significant effects of irrigation on number of fruits, yield and fruit length. Irrigation treatments did not have a significant effect on brix (sweetness). Highest marketable fruit weight (75,907 kg/ha) was obtained from plants irrigated according to a pan factor of 1.25. It was concluded that papaya grown under semiarid conditions should be irrigated according to a pan factor of not less than 1.25.

Key words: irrigation, papaya, yield, fruit quality

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RESUMEN

Rendimiento de papaya irrigada con cantidades de agua equivalentes a fracciones de evaporación Clase A en un ambiente semiárido

Hay muy poca información sobre los requisitos de riego para el cultivo de papaya en zonas semiáridas en los trópicos. Se realizó un estudio de dos años para determinar los efectos de riego en el rendimiento y la calidad de fruta de papaya cv Red Lady con cantidades de agua equivalentes a fracciones de la evapotranspiración (medida con un evaporímetro Clase A). Los cinco tratamientos de riego aplicados se basaron en coeficientes de evapotranspiración que fluctuaron desde 0.25 hasta 1.25, en incrementos de 0.25. El riego se aplicó tres veces por semana en días alternos. Los tratamientos de riego tuvieron un efecto significativo en el número de frutas producidas, rendimiento por hectárea y largo de fruta. Los tratamientos de riego no tuvieron efectos significativos sobre el valor de brix (dulce) en las frutas. El rendimiento comercial más alto (75,907 kg/ha) se obtuvo de plantas regadas usando un coeficiente de 1.25. Se concluyó que para la producción de papaya en zonas semiáridas las plantas deben ser irrigadas usando un coeficiente de evapotranspiración de por lo menos 1.25.

Palabras clave: riego, papaya, rendimiento, calidad de fruta

INTRODUCTION

Papaya is a tropical herbaceous dicotyledonous plant producing melon-like fruits which are rich in vitamins A and C. Total world production of papaya is estimated at 5.6×10^9 kg produced on about 338,000 hectares. The largest producers are Brazil and Mexico. Mean worldwide yield of papaya in 2002 was 16,544 kg/ha, with Mexico and Costa Rica topping all countries at 40,155 kg/ha and 38,667 kg/ha, respectively (FAO, 2003). Increased popularity of papaya during the last 10 years has resulted in a 255% increase in world exports.

Papaya can be commercially produced in a wide range of agroenvironments. The most essential requirement, particularly at early growth stages, is good soil drainage to prevent the development of root rot caused by soil-borne pathogens. Average marketable yield of five papaya hybrids and an open-pollinated cultivar was almost doubled when plants were grown on an Oxisol (123,333 kg/ha) versus a heavy-clay Ultisol (65,339 kg/ha). This yield difference was attributed in part to the effect of excess rain and less drainage at the Ultisol site (Goenaga et al., 2001).

Papaya can also be grown in a semiarid environment with irrigation. Drip irrigation technology permits the efficient use of water and can help maximize the utilization of semiarid lands for agricultural production. This technology is particularly suited to widely spaced crops such as papaya. There is very little information regarding optimum water requirements for papaya, particularly under semiarid conditions. It has been suggested that the water needs of papaya are ideally supplied by 100 mm of evenly distributed rainfall each month (Nakasone and Paull, 1998). This amount is seldom encountered in the wet-and-dry climate in which papaya is normally grown, a climate characterized by erratic rainfall patterns and prolonged dry periods, or in semiarid environments where evaporation may be three times greater than rainfall.

This study was undertaken to determine the optimum water requirement for papaya grown under semiarid conditions under drip irrigation and to examine how yield and fruit quality traits are affected by various levels of irrigation.

MATERIALS AND METHODS

An experiment was conducted from 1996 to 1998 at the Fortuna Agricultural Experiment Station of the University of Puerto Rico in the semiaraid agricultural zone of Puerto Rico. The San Antón soil is a well-drained Mollisol (fine-loamy, mixed, isohyperthermic Cumulic Haplustoll) with pH of 7.5, bulk density 1.4 g/cm^3, and 1.7% organic carbon in the first 14 cm of soil. The 28-yr mean annual rainfall is 917 mm and Class A pan evaporation is 2,149 mm. Mean monthly maximum and minimum temperatures are 31.2 and 20.8 °C. Figure 1 shows total monthly rainfall and evaporation during the experimental period, and Table 1 shows average monthly irrigation supplied to plants.

Seed of papaya cv Red Lady (Known You Seed Co., Taiwan)[6] was germinated in styrofoam seedling trays with open bottom cells containing Pro-Mix BX. Tray cells were 38 mm deep and 13 mm on each side. About 50 days after germination, seedlings with four to six leaves and a total dry weight of about 0.6 g were transplanted to the field 15 August 1996 and 16 December 1998 at a 1.8- by 1.8-m spacing. Five treatments representing different moisture regimes were arranged in a randomized complete block design with four replications. There were two rows per plot, each with 10 experimental plants and surrounded by 3.7-m alleys, with two guard plants at the end of each row to prevent overlapping of the irrigation treatments. Two days prior to transplanting, silver polyethylene mulch (1.2 m wide by 0.15 mm thick) and drip lateral lines were installed by using a mechanical mulch applicator. Drip lines were placed on the surface along the center of each row.

At transplanting, each plant received 11 g P provided as triple superphosphate. Throughout the experimental period, fertilization through the drip system was provided weekly at the rate of 10.5 kg/ha

[6]The names in this publication are used only to provide specific information. Mention of a trade name or manufacturer does not constitute a warranty of materials by the USDA-ARS or the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other materials.

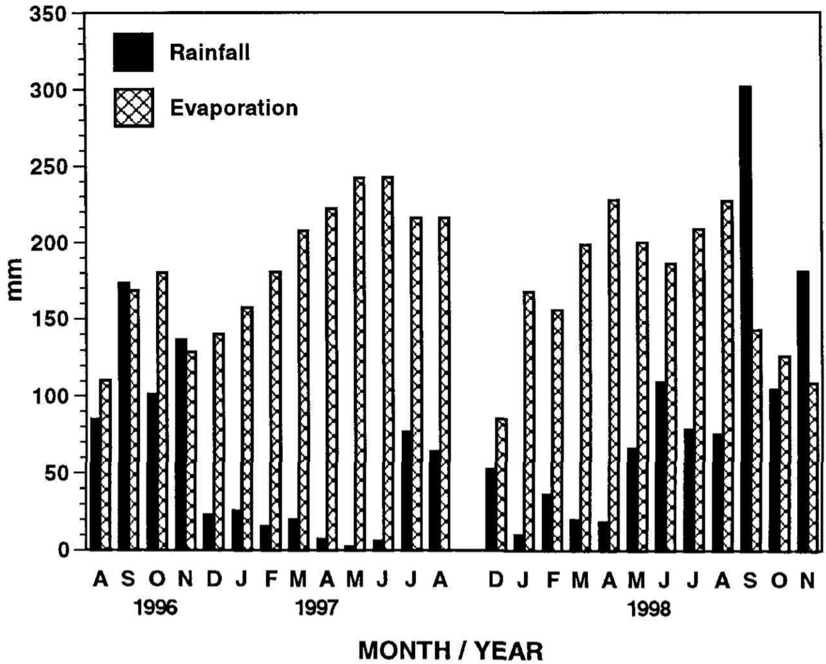

FIGURE 1. Total monthly rainfall and Class A pan evaporation during growth of papaya at the Fortuna Agricultural Experiment Station, PR.

N and 13.0 kg/ha K; urea and potassium nitrate were the nutrient sources. Weekly fertilization also included 0.26 and 0.08 kg/ha of Zn and Fe, respectively, supplied in their EDTA chelate forms, and 0.29 kg/ha Mn supplied as DTPA chelate. Insects and weeds were controlled by following the recommended cultural practices (Toro, 1993). The equation of Young and Wu (1981) was used to calculate the amount of irrigation applied to plants. The equation assumes that the evapotranspiration (ET) of a papaya plant is equal to the evaporation from a body of water with a free surface equal to the plant area as determined by a Class A pan evaporimeter. In this study, the equation was modified to include a pan coefficient (K_p) value of 0.70 and a modified average crop coefficient (K_c) of 0.42 (Doorenbos and Pruitt, 1977) to obtain a theoretical value of potential evapotranspiration (ETc).

Class A pan factors (proportion of pan evaporation), ranging from 0.25 for Treatment 1 to 1.25 for Treatment 5 in increments of 0.25, were used to obtain fractions of ETc. A pan factor of 1.0 means that the water

TABLE 1. *Average monthly irrigation applied to papaya plants subjected to five levels of irrigation as determined by pan factor (proportional to Class A pan evaporation) during a 2-yr period, 1996-1998.*

	Proportion of Pan Evaporation				
Month	0.25	0.50	0.75	1.0	1.25
	L/plant				
January	79	155	234	318	392
February	68	134	200	268	336
March	88	173	261	347	436
April	101	202	277	369	509
May	85	164	247	339	426
June	96	194	288	388	484
July	76	151	226	304	381
August	79	169	252	338	424
September	16	29	45	60	76
October	18	26	31	39	45
November	31	42	53	63	74
December	66	129	192	255	313
Total	803	1,568	2,306	3,088	3,896
Average	66.9	130.7	192.1	257.3	324.7

applied to the plants of that treatment replaced that lost through calculated evapotranspiration; this amount was hence considered the theoretical optimum.

The plants were subjected to the five moisture treatments starting about two months after transplanting. The amount of water applied varied weekly, depending on Class A pan evaporation and rainfall. The previous week's evaporation and rainfall data were used to determine the irrigation needs for the following week. Irrigation was supplied three times during the following week on alternate days. No irrigation was provided when the total rainfall exceeded 19 mm per week as this amount was sufficient to wet the soil area that was exposed as a result of breaking small sections of the mulch to make the planting hole at transplanting time.

Water for irrigation was obtained from a supply well which draws water from the unconfined alluvial aquifer underlying the study area. Submain lines equipped with volumetric metering valves to monitor the water from the main line were provided for each treatment. Lateral lines equipped with built-in 4 L/h-emitters spaced 61 cm apart branched out from the submains along the inner side of each plant row and about 21 cm from the plant stem.

The first harvest of fruits was at about six months after transplanting. Fruits were harvested at color break when they started to show a tinge of yellow at the apical end of the fruit. At each harvest, number and weight of marketable and non-marketable (deformed) fruits were determined. Representative fruits totaling about 25% of those harvested were used to determine fruit length. Brix readings were also taken with a sugar refractometer when the fruits ripened, about five days after harvest. Analysis of variance and best-fit curves were determined by using the ANOVA and GLM procedures, respectively, of the SAS program package (SAS Institute, 1987). Only coefficients with $P \leq 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Differences among irrigation treatments and years were highly significant ($P \leq 0.01$) for most of the response variables that were studied (analysis of variance not shown). An exception was the brix value, which was not affected by irrigation treatments. The treatment × year interaction was not significant; therefore, data were averaged over years.

Total Class A pan evaporation was 2.5 times greater than the amount of total rainfall recorded during the 25-month experimental period. In 16 of the 25 months, evaporation was twice the amount of rainfall (Figure 1). This finding indicates that large soil-water deficits would have occurred without irrigation. Overall, less irrigation was required during September through November; more, from January through June (Table 1).

Total number of fruits produced was linearly related to the amount of water applied (i.e., pan factor). This response was mainly the result of a significant increase in the number of marketable fruits with increments in pan factor treatment (Figure 2). The total number of fruits increased from 53,731 to 74,891 kg/ha for pan factor treatments 0.25 and 1.25, respectively. In both treatment extremes, marketable fruits represented 78% of the total fruits produced.

Increments in pan factor treatment significantly increased fruit yield. The highest marketable fruit weight of 75,907 kg/ha was obtained with the application of irrigation according to a pan factor of 1.25 (Figure 3). This weight was 33, 27, 17, and 8% higher than that obtained in plants irrigated with a pan factor of 0.25, 0.50, 0.75, and 1.0, respectively. The increase in marketable fruit weight with increments in pan factor treatment was the result of significant increases in fruit number and fruit length (Figures 2 and 4). Similar responses have been obtained with other fruit crops (Goenaga and Irizarry, 1995; Goenaga et al., 1993). Fruits from plants irrigated with a pan factor treatment of 1.25 were almost 13% longer than those irrigated with a pan factor

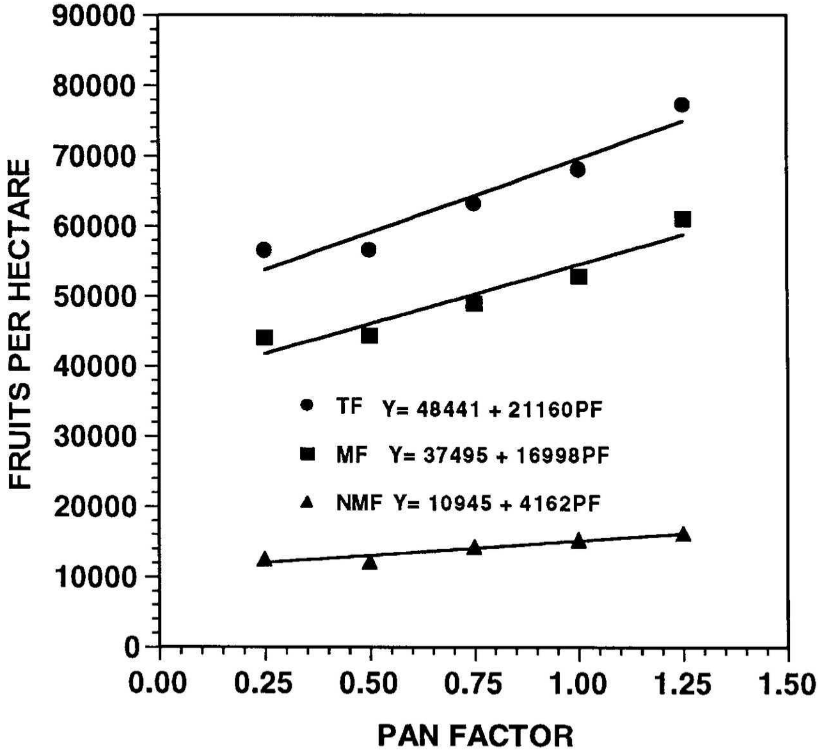

FIGURE 2. Number of total (TF), marketable (MF) and non-marketable (NMF) papaya fruits as influenced by irrigation based on proportion of pan evaporation (pan factor).

of 0.25. Water deficits occurring during reproductive stages are known to cause yield loss. In this study, the significantly lower number of marketable fruits and yield in plants irrigated with low pan factor treatments may have been the result of inhibition of flower development, failure of fertilization or reduction of both vegetative source and reproductive sink activity (Westgate, 1994; Pugnaire et al., 1999).

Brix (sweetness) values were not significantly different among irrigation treatments and averaged 11.7. This value is higher than that obtained by Goenaga et al. (2001) when the same variety was grown in different agroenvironments.

From this investigation we conclude that papaya should be irrigated by using a pan factor of at least 1.25. The use of a lower pan factor results in significant reduction in yield. The results reported in this

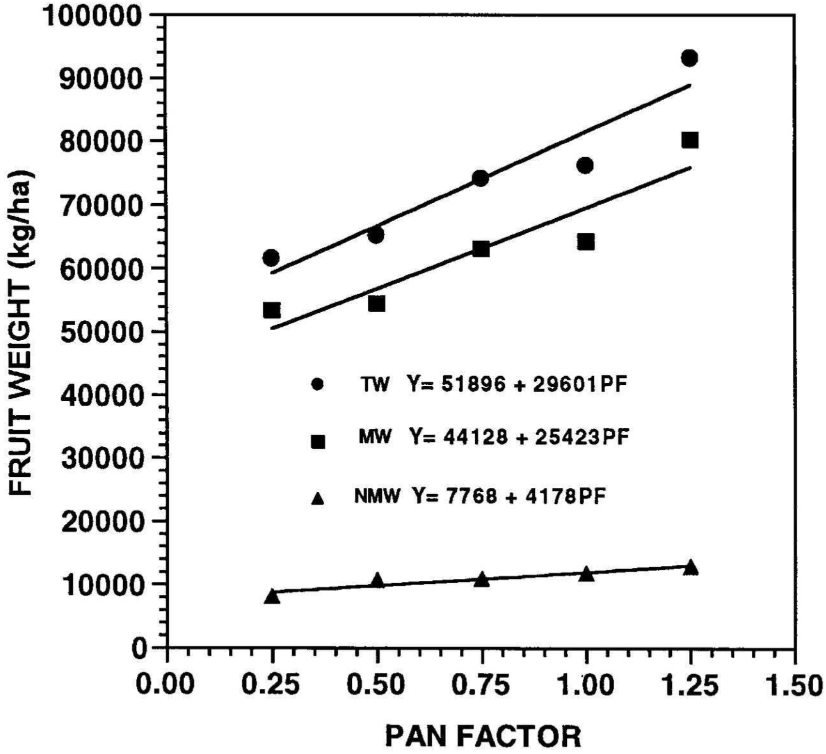

FIGURE 3. Relationship between irrigation based on proportion of pan evaporation (pan factor) and total (TW), marketable (MW), and non-marketable (NMW) fruit weight of papaya.

study demonstrate that profitable papaya yields can be attained in the semiarid agricultural zone of Puerto Rico if proper irrigation practices are followed. Assuming that a grower can achieve the highest marketable fruit yield in this study and that farm gate prices are $9.00 per box of 18.14 kg, then a gross income of $37,660 per hectare can be attained.

Updated procedures recommending the use of the Penman-Monteith method for calculating crop evapotranspiration were published by FAO after this study was completed (Allen et al., 1998). Therefore, it is recommended that this method be used in future studies on irrigation requirements of papaya and that, if necessary, refinements be made to our recommendation.

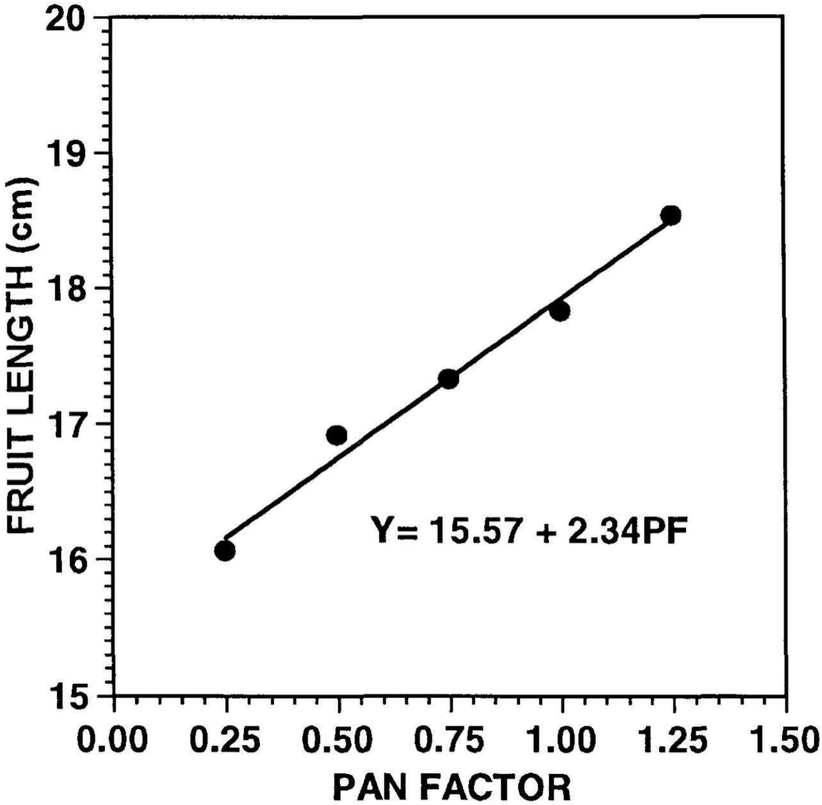

FIGURE 4. Relationship between irrigation based on proportion of pan evaporation (pan factor) and length of papaya fruits.

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