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RELATIONSHIP OF POTENTIAL EVAPOTRANSPIRATION AND ACTUAL EVAPOTRANSPIRATION OF *RHODODENDROM* SP. 'FORMOSA'[1]

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Abstract. **Rooted cuttings of *Rhododendron* sp. 'Formosa' were transplanted into a pine bark-based medium in 10.2-liter polyethylene containers. After 5 months, individual containers were suspended in three weighing lysimeters. All plants were irrigated when 50% of plant available water was lost from two of the three plants. Potential evapotranspiration (ET_P) was calculated using the Penman method for 4 days each week during the last 6 months of production, while actual evapotranspiration (ET_A) was measured with the lysimeters. Plant growth was assessed periodically. ET_A was weakly correlated with ET_P on a daily basis over the last 6 months of production. The correlation was not improved by including canopy characteristics into the model. However, when ET_P was summed over a 4-day period, the model (r=0.8754) may be sufficient for irrigation scheduling. On a bed area basis, the 95% confidence interval for the crop coefficient ranged from 0.50 to 0.65 for the summed Penman ET_P.**

Several studies have found excellent correlations between potential evapotranspiration (ET_P) and actual evapotranspiration (ET_A) of container-grown landscape ornamentals (Fitzpatrick, 1980, 1983b; Knox, 1989). In some cases, derived models were used with success in administering irrigation during production of several plant species (Fitzpatrick, 1983a). Previous studies used the Thornwaite method to calculate ET_P, which estimates ET_P on a monthly basis. While the Thornwaite method provides an average monthly water demand based on several years' data, it is limited in its sensitivity for scheduling daily or weekly irrigation since historical data must be used. With the erratic rainfall patterns during the rainy season in Florida, especially during the drought years of 1990 and 1993, scheduling irrigation based on historical ET_P could have resulted in insufficient irrigation at many nurseries. Inadequate irrigation would increase plant water stress and reduce plant growth (Beeson, 1992; Fitzpatrick, 1983a). Knox (1989) reported high correlations between ET_A and ET_P based on daily pan evaporation for five landscape species. Yet, there are many inherent problems associated with pan evaporation that limit its use by landscape nurseries (Jones et al., 1984). Calculation of ET_P by the Penman method is the most accurate method for daily estimation of ET_P from vegetative surfaces (Jones et al., 1984). Calculation of ET_P by the Penman method requires maximum and minimum temperature, solar radiation, and daily wind run. All may be measured electronically and input directly into a computer controlling an irrigation system. Computer control or computer-aided management would be the most efficient means of administering irrigation. However, the relationship of ET_P calculated by the Penman method to ET_A has not been established for landscape ornamentals. Thus, the objective of this study was to determine the relationship of ET_P calculated by the Penman method to ET_A for the last 6 months of production for 'Formosa' azaleas.

Materials and Methods

In early April 1992, 50 rooted cuttings of *Rhododendron* sp. 'Formosa' were singly transplanted into 10.2-liter polyethylene containers using a 3 pine bark: 1 Florida peat: 1 sand medium amended with 0.89 kgm^{-3} micronutrients (Micromax, Grace-Sierra Chemical, Milpitas, CA). Prior to installation in the lysimeters, plants were irrigated daily with *ca.* 1100 ml ($\sim$1.3 cm) of water using individual low volume spray stakes (Netafim, Israel). Plants were fertilized with 0.8 g nitrogen·$liter^{-1}$ (after dilution) derived from soluble fertilizer 20N-8.7P-16.6K (Peter's 20-20-20; Grace-Sierra Chemical) on 20 Apr. and 1 May 1992 and 17 Mar. 1993, and with 70 g of 18N-2.6P-9.9K controlled release fertilizer (Osmocote 18-6-12; Grace-Sierra Chemical) on 18 May and 3 Aug. 1992. Plants were pruned as required to promote commercially acceptable quality. The growing area was under a ca. 235 m^2 - 50% shade structure with a 1.8 m wide 30% shade cloth strip surrounding the sides beginning 30 cm above ground level.

In mid-Oct. 1992, individual plants were suspended *ca.* 5 cm above the ground in three weighting lysimeters. The remaining containers were elevated above ground using standard 20 cm bricks. A lysimeter consisted of an hemertically-sealed load cell (Model SSM-50; Interface Inc., Scottsdale, AZ) attached to a stainless steel tripod. Containers were spaced on 47-cm centers. Lysimeters weights were monitored with a data logger and multiplex board (CR10 and AM416, Campbell Scientific, Logan, UT). Load cell voltage was measured five times just prior to the beginning of each hour with the average recorded hourly. Voltages were converted to weights based on seven point calibration curves developed for each lysimeter with errors of calculated weights less than $\pm$ 7 g.

Irrigation was controlled by the data logger, a time clock, and a series of relays. When two plants weighed less than predetermined trigger weights, a relay was closed that permitted irrigation only at 0400 and 1400 hr each day. At each irrigation, *ca.* 3.0 liters per container were applied which re-saturated the medium and resulted in substantial drainage. Trigger weights were set at 50% of amount of plant available water, calculated as the difference between saturated weight and plant-wilted weight. Available water was determined in late Oct. 1992 prior to initiating the experiment and again in Feb. 1993.

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Potential evapotranspiration was calculated for Monday through Thursday each week using the Penman method supplied in the water management utility disk set (IFAS Software 009; Univ. of Fl., IFAS, Gainesville, FL). Daily temperatures were recorded with a T-type thermocouple connected to the data logger. Daily wind speed was measured with a wind odometer (Tradewinds Instruments, Enumclaw, WA). Global solar radiation was measured using a pyranometer and integrator (LI-200SB and LI-500, respectively; Li-Cor, Lincoln, NB). All meterological data were collected *ca.* 2 m above soil level in the center of the shade area. Both the wind run and solar radiation from the previous day were recorded manually at the start of each work day. Actual evapotranspiration was calculated daily for each plant by summing the hourly weight loss for each container. During rain events, weights recorded after the first weight increase until weights again began to decline were not included in the ET_A calculation.

Plant growth was determined periodically by measuring the widest canopy width and canopy width perpendicular to that and height of the tallest stem. Canopy surface areas were calculated as width 1 times width 2. Canopy volume was calculated as canopy surface area times height. During active plant growth, measurements were taken just after plants were pruned.

The relationships between ET_P and mean ET_Awere analyzed by regression. Models were developed for the complete data set and with ET_P and mean ET_A summed per 4-day period. The data were also divided into three distinct periods of quiescent and active growth with models developed for each period.

Results and Discussion

The correlation of ET_P to ET_A was significant (α= 0.01), but weak (r = 0.6472) when based on daily means collected over the 6-month period (ET_A = 116.2*ET_P + 36.8; Fig. 1). The correlation was not significantly improved using a quadratic equation nor with multi-variant analysis including canopy surface areas or canopy volumes. Correlations of ET_P to ET_A were higher when the data were separated into distinct periods (Fig. 1). These periods corresponded to quiescent (Nov.-Dec., days 0 to 59; ET_A = 158.3*ET_P - 83.9; r = 0.7790), rapid shoot growth (Jan., days 72 to 94; ET_A = 199.0*ET_P - 69.5; r = 0.4910) and canopy recovery from a hard freeze on 13 Mar. (mid-Mar.-Apr. days 140 to 172; ET_A = 123.0*ET_P -20.2; r = 0.67). Even when data were separated by period, expanding the equation to include canopy dimensions did not significantly improve the models. During the Jan. period of most rapid shoot growth, the correlation of ET_P to ET_A was especially weak. This was due to a higher ET_A per ET_P ratio during the middle of the period than at either end (Fig. 1). The Relative Water Demand (RWD) variable, as defined by Fitzpatrick (1983b) was calculated for the different periods. For the 'Formosa' azaleas, RWDs' were 15.8, 19.9, and 12.3 ml·cm^{-1} ET_P for the periods Nov.-Dec., Jan., and Mar.-Apr., respectively. The 'Formosa' values are one-tenth that of slow-growing tropical species. Reasons for this difference are not readily apparent since extrapolation of the daily ET_P to a monthly total for Nov. is similar to that calculated by Fitzpatrick.

When daily ET_P and ET_A were summed over the 4-day week, the predictive power of the model was greatly enhanced (r = 0.8754), though the coefficient for ET_P changed little (ET_A = 119.7*ET_P +58; Fig. 2). Inclusion of either canopy surface area or canopy volume did not significantly (α=0.05) improve the model (data not shown). The lack of a canopy effect is in contrast to the results of Knox (1989) with azaleas grown in 3.8-liter containers. This difference may be due to the erratic nature of the canopy dimensions measured in this study (Fig. 3) and limited replication. The erratic nature was due to the effects of pruning and the mid-Mar. 1993 freeze.

The low correlations of daily ET_P to ET_A during periods of active shoot growth suggest calculation of daily ET_P with the Penman equation cannot be used to adequately estimate the daily ET_A of 'Formosa' azaleas during shoot expansion. However, the better agreement of cumulative ET_P to cumulative ET_A over a 4-day period may be sufficient for irrigation scheduling. Yet during periods of explosive shoot growth, such as those that normally occur after winter quiescent (Jan. here), excessive ET_A may induce significant water stress and limit growth if irrigation is strictly based on the semi-weekly ET_P calcu-

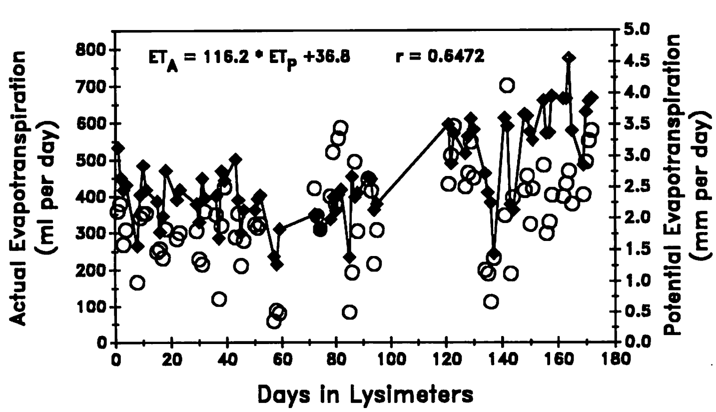

Fig. 1. Measured mean actual evapotranspiration (open circles) and potential evapotranspiration (solid diamonds) calculated by the Penman equation during the last six months of production for 'Formosa' azaleas grown in 10.3-liter containers. Day 0 corresponds to 1 Nov. 1992 with day 172 corresponding to 22 Apr. 1993.

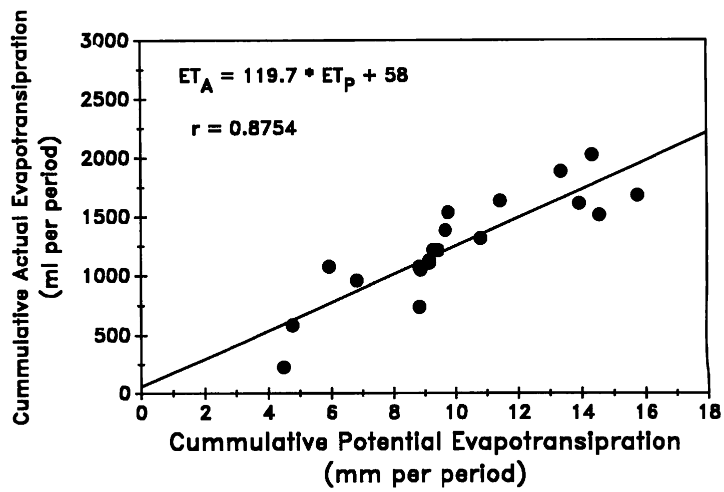

Fig. 2. Relationship of cumulative actual evapotranspiration and cumulative potential evapotranspiration estimated by the Penman equation. Each point is the mean of the 4-day sum for each lysimeter based on three replications.

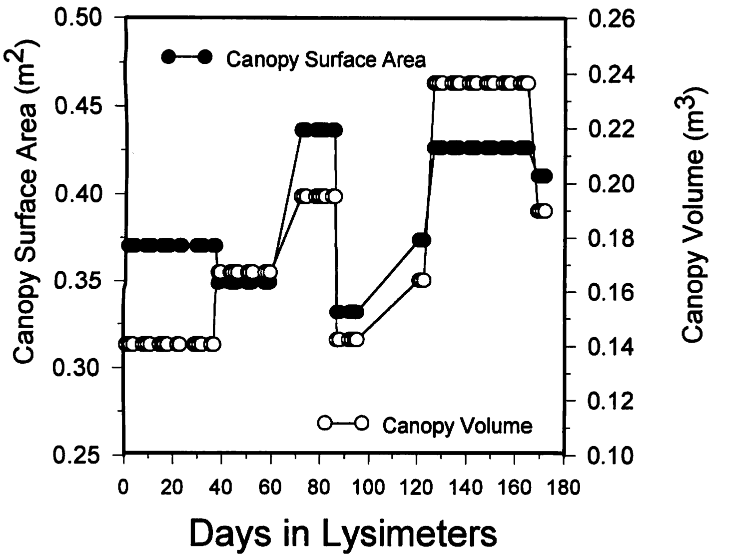

Fig. 3. Mean canopy surface areas and mean canopy volumes (width1 x width2 x height) of 'Formosa' azaleas during the period plants were within the lysimeters. Day 0 corresponds to 1 Nov. 1992 with day 172 corresponding to 22 Apr. 1993. Means are based on three replications.

lations. Higher correlations of ET_P to ET_A may have been obtained if canopy dimensions had been measured more frequently or measurements had occurred during a longer period of active growth.

Based on the bed surface area (0.209 m^2) allocated to each container, a crop coefficient with a mean of 0.59 can be calculated for 'Formosa' azaleas over the 6-month period. The 95% confidence interval for this coefficient ranges from 0.50 to 0.69. Based on mean canopy surface area during the same period, the crop coefficient was 0.31 with a 95% confidence interval of 0.27 to 0.35. The canopy area basis is comparable to the 25% replacement of ET_P shown to produce acceptable growth of field-grown gardenia (Ponder, et al., 1984), while the 59% replacement is similar to the minimum requirements of field-grown Japanese holly and dogwood (Eakes et al., 1985).

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ENERGY REQUIREMENTS FOR FLORIDA ORNAMENTALS PRODUCTION[1]

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Abstract. **A spreadsheet-based microcomputer energy consumption model of Florida agricultural production has been developed. The Florida Agricultural Energy Consumption Model (FAECM) quantifies as many as 21 categories of direct and indirect energy inputs required for producing each of approximately 60 major and another 30 minor crop and livestock commodities. Eight different budgets are used to cover all Florida ornamentals production. The model is based on production budgets converted to energy budgets, and production levels.**

The model will be described. Results will be presented for Florida ornamentals production and for specific commodities. Florida ornamentals production required 7.50 trillion Btu of direct energy and 25.0 trillion Btu of total primary energy in 1990. Foliage crops are first among ornamentals and second among all agricultural commodities in both direct and total primary energy consumption. Comparisons will be drawn with other Florida agricultural commodities, with all of Florida agriculture, and with total Florida energy consumption.

Previous estimates of the energy required in the production of Florida ornamental horticultural products are almost non-existent. Smerdon et al. (1974) provided per acre and statewide estimates for diesel, gasoline and LP gas consumption for chrysanthemums and gladioli. However, no other energy consumption estimates for ornamentals production, in Florida or elsewhere, were found in the literature. Comprehensive and complete assessments are needed that include all energy-requiring inputs to enable focusing of research efforts to achieve better energy pro-

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