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Development of a Simple Reference Evapotranspiration Model for Irrigation of Woody Ornamentals

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***Abstract*. Rooted cuttings of *Rhaphiolepis indica*, a low slow-growing evergreen shrub, were grown outdoors in weighing lysimeters to market size in 11.4-L containers. Actual evapotranspiration (ET_A) and evaporation from containers shaded with plastic foliage was determined daily. The first 60 days after transplanting, substrate evaporation accounted for most of ET_A and was the major component through the first 127 days. ET_A generally followed variations in reference evapotranspiration (ETo). Mean cumulative ET_A to produce 90% of measured plants to market size was 101 L or 1.99-m depth per plant based on container surface area. Water need indices, similar to crop coefficients, were highly correlated with percent canopy closure using an exponential decay equation (r^2 = 0.898), but a more precise estimate at higher canopy closures was achieved using a third-order inverse polynomial equation (r^2 = 0.907). When combined with similar previous data from *Viburnum odoratissimum* and *Ligustrum japonicum*, the inverse polynomial equation correlation was 0.802 for all three shrubs. This implies the %Closure model provides a good general base for ETo-based irrigation of woody evergreen shrub species based on canopy size and spacing with improved precision when individual equations are derived by species.**

Interest in reducing irrigation volumes during production of landscape ornamental plants has increased worldwide as population pressures on freshwater supplies have increased (Bacci et al., 2008; Caceres et al., 2008; Jury and Vaux, 2005). Early work by Burger et al. (1987) and Regan (1997) calculated crop coefficients (Kc) to relate woody plant actual ET_A to Penman-Montieth-based reference evapotranspiration. However, these Kcs were based on a fixed value of container surface area; thus, they are accurate only for plants of the same canopy and container size. Regan (1997) attempted to remedy this by periodically calculating Kcs per species and cultivar as they grew from liners to market size plants in 3.8-L containers. Later, Schuch and Burger (1997) used Fourier curve transformations to calculate Kc, again based on upper container diameters for several species of woody ornamental plants to adjust for the quiescent period during the winter for plants that required two growing seasons to reach marketable size. Each species required a unique equation.

In 2004, a new model to calculate a crop coefficient, termed water needs index (WNI), was proposed (Beeson, 2004). The term was invented because nursery production and landscapes violate the conditions of a large uniform fetch required for calculating crop coefficients as defined previously (Doorenbos and Pruitt, 1977). WNI is calculated as a function of canopy closure of groups of plants, relating individual plant ET_A to plant size and canopy ventilation and radiation (Beeson, 2005; Eq. 1):

$$WNI = \frac{(ET_A \div PCA)}{ETo} \qquad [1]$$

where PCA is the horizontal planar projected canopy area and ETo is reference evapotranspiration. Under well-watered conditions, transpiration increases with canopy growth and is proportional to ETo. Concurrently, evaporation from the substrate surface remains constant or declines as canopies begin shading the substrate surface (Beeson, 2004, 2010b). As canopies expand to fill in the space between them, canopy closure approaches 100% and then increases greater than 100% as a result of branch overlap. As canopy closure increases beyond 67% to 100% closure, canopy ventilation is minimized with most ET_A occurring in the upper 40% of the canopy at 100% closure (Beeson, 2010a), yet the reduced canopy transpiration is still strongly linked to ETo and horizontal planar-projected canopy size. Although the model was developed using *Ligustrum japonicum* Thunb. (ligustrum; Beeson, 2004), it was later shown to also be applicable to *Viburnum odoratissimum* Ker Gawl (viburnum; Beeson, 2010b). When data from the two species were combined, the correlation was 0.843. Both species are considered upright spreading shrubs (DACS, 1994) and require the same production time of ≈12 months to grow from rooted cuttings to market size (minimum 0.6 m tall by 0.45 m average width; DACS, 1994) in central Florida. Mean cumulative ET_A was 8% greater for viburnum (155 L) than the ligustrum shrubs (143 L).

Rhaphiolepis indica (L.) Lindl. Ex Ker Gawl (Indian hawthorn) is a low-growing, mounding shrub (Halfacre and Shawcroft, 1989) and considered drought-tolerant. Growth is episodic with up to three flushes a year in central Florida. At marketable size in 11.4-L containers, canopies are 0.3 m tall and 0.45 m in average width, generally less than half (0.061 m^3) the canopy volume of ligustrum or viburnum (0.136 m^3). Objectives of this research were to quantify daily ET_A of Indian hawthorn from transplanted rooted cutting to market size in 11.4-L containers. This along with environmental and growth data were used to evaluate applicability of the canopy closure model for plants with a low broad canopy architecture. The data here were also combined with previous data from ligustrum and viburnum to investigate the versatility of this model for contrasting species.

Materials and Methods

On 25 Apr. 2006, rooted cuttings of *Rhaphiolepis indica* (L.) Lindl (Indian hawthorn) produced in 5.7-cm peat pots (70000041; Jiffy Products of America, Lorain, OH) were transplanted into 11.4-L black polyethylene containers (C1200; Nursery Supply, Chambersburg, PA) at the Mid-Florida Research and Education Center in Apopka, FL. Commercially prepared substrate (Florida Potting Soil, Inc., Apopka, FL) consisted of 55% pine bark fines:36% Nupeat:9% sand by volume and was amended with 2.9 $kg \cdot m^{-3}$ dolomite limestone and 0.86 $kg \cdot m^{-3}$ micronutrients (Micro-Max; Scotts Company Inc., Marysville, OH). NuPeat is a mixture of equal parts of composted hardwood bark, composted yard waste, and Florida sedge peat that passes through a 12.5-mm screen.

Containers were placed on black polyethylene ground cloth on 0.444-m centers in a square arrangement within a production area measuring 9.2 m × 9.8 m. Containers were not respaced. The experimental area was irrigated at midnight as needed with overhead impact sprinklers situated at each corner. Before container placement, sprinkler heads were adjusted to achieve a Christiansen uniformity coefficient of 0.88 (Haman et al., 1977). Application rate for the irrigated area calculated after the final adjustment was 2.56 $cm \cdot h^{-1}$.

Fertilization. Each container was top-dressed with 55 g of controlled-release fertilizer (18N–2.6P–9.9K; 18-6-12 Nutricote, 8 to 9 months; Florikan E.S.A, Sarasota, FL) on 25 Apr. 2006 and treated with pre-emergence herbicide (Ornamental Herbicide II; Scotts Co., Marysville, OH). On 28 Apr. 2006, and again 2 weeks later, each container was given ≈150 mL of a 300 $mg \cdot L^{-1}$ nitrogen liquid fertilizer (Peter's 20-20-20; Scotts Co.) solution by hand. On 23 Feb. 2007, each container

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