Effect of Leaf Removal and Tie-Up on Water Loss and Estimated Crop Coefficients for Juvenile, Trunkless, Containerized Queen Palms

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Reduction of leaf transpirational water loss is the reported benefit of leaf removal and tie-up, a commonly recommended practice when transplanting palms (Nixon & Carpenter 1978, Broschat 1991, Costonis 1995, Zaid 1999, Broschat & Meerow 2000). Such water loss is important because roots lost or damaged during transplanting are unable to take up water or do so at a much reduced level to replenish water stored in the palm, which is critical to survival when water is unavailable (Holbrook & Sinclair 1992a, 1992b). Recent work is somewhat mixed, though, on whether leaf removal and tie-up are beneficial when transplanting palms.

For example, when transplanting juvenile, trunkless specimens of Canary Island date palm (*Phoenix canariensis*) and queen palm (*Syagrus romanzoffiana*) and large, trunked specimens of Mexican fan palm (*Washingtonia robusta*), leaf removal and tie-up did not affect establishment and survival (Downer et al. 2013; Hodel et al. 2003, 2006). Broschat (1994) found a similar response for leaf tie-up when transplanting pygmy date palms (*Phoenix* *roebelinii*) if they were provided with overhead irrigation. However, Hodel et al. (2013) found that leaf removal and tie-up were beneficial when transplanting date palms (*Phoenix dactylifera*) in sustained, extremely hot and arid conditions and Broschat (1991) found that complete leaf removal was necessary when transplanting palms like the palmetto palm (*Sabal palmetto*) where all cut roots die and the palm must rely solely on stored water in the trunk for survival until a new root system can be produced. Thus, there is some doubt whether leaf removal and tie-up actually reduce water loss or, if so, how critical that loss is to survival and establishment of transplanted palms.

Also, nurseries produce ornamental palms in containers where limited soil volumes require effective water management in order for a grower to realize economical growth without wasting water. Use of evapotranspiration (ET) data can provide irrigation managers with a climate-based tool to help estimate and schedule water applications to crops effectively. This approach requires adjusting available reference ET (ET_O) values by a dimensionless crop coefficient (K_C) to account for unique physiology and water use characteristics of a given crop. A climate-based estimate of a crop's water use over a period of time, known as the crop ET (ET_C), can be derived using the equation:

$$ET_{crop} = K_C \times ET_O$$

Crop coefficients have been derived for many crops that achieve full yield while growing in large fields under excellent agronomic and soil water conditions (Allen et al. 1998), and daily, weekly, seasonal, or annual ET_{crop} (ET_C) values can be calculated for them. Plants growing in containers have limited rooting volumes and their canopies can extend beyond the container surface area, so container production systems violate some of the fundamental assumptions in the $ET_{crop} = K_C \times ET_O$ relationship. Thus, as Burger et al. (1987) and Schuch et al. (1997) pointed out, an ET_C for container-grown plants is difficult to compare with that of field-grown plants. Nevertheless, K_C values have been derived to estimate water needs of several container-grown woody nursery crops, including a few tree species (Beeson 2009; Burger et al. 1987; Schuch et al. 1997), but none has been reported for juvenile, trunkless, container-grown palm species. Holbrook and Sinclair (1992a) reported quantities of water used by container-grown palmetto palms but they did not normalize plant water use to ET_O or the plants' climate-based demand for water.

The objectives of this study were to determine the effect of leaf removal and tie-up on transpirational water loss from juvenile, trunkless queen palms, one of the most common landscape palms in subtropical regions, and to use the measured water loss to estimate K_C values for producing this palm in containers.

Materials and Methods

We conducted this study from July 27 to August 13, 2004 at the University of California South Coast Research and Extension Center (UC SCREC) in Irvine, CA, which is in the south coastal plain of California and has a maritime Mediterranean climate. Thirty juvenile, trunkless queen palms growing in 68-liter (15-gallon), standard nursery containers were used in the study. Selected for uniform height, leaf number, stem caliper, root growth, and overall quality, they were 200–300 cm tall, had five leaves 130–180 cm long and had a basal diameter of 15 cm. They were growing in Scott's Potting Medium (Scotts Miracle-Gro, Marysville, OH), a peat-vermiculite soilless potting mixture, were pest- and disease-free, and had normal green leaves and roots to the sides and bottoms of the containers.

Five leaf removal and tie-up treatments ranging from no leaf removal/no tie-up (control) to complete leaf removal were applied to the palms. Other leaf removal treatments, including the standard industry practice (SIP) (Fig. 1), consisted of removing about two-thirds of the leaf area, and were accomplished through a combination of whole and partial leaves until leaf area was reduced to the desired amount. For the leaf tie-up treatment, leaves present were tied upward using sisal twine to form a tight bunch.

We spaced the palms two meters distant in rows two meters apart in full sun (Fig. 1). The container opening, from the lip to the palm base, was covered with aluminum foil to reduce evaporative water loss from the potting medium (Fig. 1). Treatments were replicated six times and the palms were arranged in a randomized complete block design (5 treatments × 6 replications × 1 species = 30 palms total). Each row was a block in which the five treatments were completely randomized.

Containers were initially irrigated to container capacity, allowed to drain overnight, and then weighed in the morning and then again 24 hours later. The difference in weights between the two weighings would indicate the approximate amount of water lost primarily via leaf transpiration during the 24-hour period. Containers were then irrigated to container capacity again and the process repeated four times, after which we imposed a dry-down period where we weighed them on four consecutive days (three weight differences) without any irrigation until they showed obvious sign of water stress, including drooping and slight color loss of leaves and folding and drooping of pinnae.

To estimate K_c, the container weight differences from the control treatments only were converted to volumes [1 gram of water = 1 cubic centimeter of water (cm^3)]. Then ET_c was determined using the equation:

ET_c (cm) = volume of water used (cm^3) / container surface area (cm^2), where the container surface area was 1105 cm^2.

Finally, the K_c was derived by the equation:

$$K_c = ET_c / ET_o.$$

A California Irrigation Management and Information System (CIMIS) weather station at UC SCREC (CIMIS Station 75) collected climate data and recorded real-time daily evapotranspiration during the study (CDWR 2010). Mean weights of water lost per weighing interval were calculated, analysis of variance tests (ANOVA) conducted, and means compared using Fischer's Protected Least Significant Difference Test.

Results and Discussion

Daily ET_o during the experiment was about five mm, typical for a midsummer day at UC SCREC (Table 1) (CDWR 2010). All leaf removal and tie-up treatments significantly reduced plant transpirational water loss until the four-day dry down period, which began August 11 (Table 1). After that, among all leaf removal and tie-up treatments, only complete leaf removal reduced water loss, but then only for one day and only compared to the control, after which there were no differences among any treatments. As expected, complete leaf removal resulted in the greatest reduction of water loss.

The dry-down period simulates water deficits that transplanted palms would likely experience because of extensive root loss. Water loss tended to decrease through out the dry-down period, suggesting that the water-stressed palms responded by reducing water loss through some physiological mechanism, such as stomatal closure. Dufrene and Saugier (1993) found that African oil palm (*Elaeis guineensis*) underwent stomatal regulation during periods of moderate water deficit and experienced decreased transpiration with no change in net assimilation, thus producing an increased water-use efficiency. Our findings tend to support the possibility of a similar response in queen palms.

Extrapolating our findings from containerized palms with intact root systems to field- or landscape-grown transplanted palms where most of the root system was removed is difficult. In transplanted palms with much reduced root systems water uptake is typically severely impaired and water stress much greater than with containerized palms with intact root systems that can readily rehydrate following irrigation. Nonetheless, we can conclude that leaf removal and tie-up, which reduced water loss only temporarily, are probably of limited benefit in most situations. However, they are likely beneficial in other instances, for example when transplanting some species in extremely hot, arid conditions where water demands would be exceedingly high or where all a palm's roots die when cut during transplanting. Indeed, as noted earlier, the benefits of leaf removal and tie-up when transplanting palms are somewhat mixed and depend to a great extent on the species and location (local climate factors like temperature and humidity).

The daily calculated K_c values of the control plants ranged from 2.1 to 4.0 (mean 3.1) (Table 1). If considering only the non-dry-down period when the palms were not water stressed, then the values ranged from 3.2 to 4 (mean 3.6). These values primarily reflect only transpirational water loss and, therefore, slightly under represent actual water demand of these palms. However, the values are likely to be mostly accurate relative to container-grown plants because the evaporation component is low due to the reduced surface area of exposed media for plants growing in containers. The average K_c values are comparable in magnitude to those that Burger et al. (1987) and Schuch et al. (1997) developed for several woody shrubs, which generally ranged from about 1.0 to 5.0.

1. Queen palms, showing various leaf removal and tie-up treatments and study lay out. The aluminum foil covering the surface of the containers reduces evaporative water loss (D.R. Hodel).

Although K_c values for container-grown plants do not reflect the true water use characteristics of plant species when grown in the field, and vary considerably due to specific growth stages of the crop, time of year, and location (Burger et al. 1987, Schuch et al. 1997), they can be useful and easy to apply for estimating irrigation needs of plants being produced or maintained in a container system and are another tool to help nursery and irrigation managers schedule irrigations more accurately.

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Table 1. Mean water loss, reference evapotranspiration (ET_o), crop evapotranspiration (ET_c), and crop coefficient (K_c) for each one-day period during the leaf removal/tie-up, water-loss study of juvenile, trunkless queen palms (*Syagrus romanzoffiana*) growing in 68-liter (15-gallon) containers, July to August, 2004, UC SCREC, Irvine, California.

Treatments: Leaf Removal[z]	Leaf Tie-up[z]	7/28	7/30	8/4	8/6	8/11	8/12	8/13	
		Mean Plant Water Loss per Day (kg)							
No[y]	No	2.0a[x]	2.1a	1.8a	2.1A	1.9a	1.4	0.9	
Yes[w]	Yes	0.9b	1.0b	1.1b	1.2B	1.5ab	1.2	0.9	
Yes	No	1.0b	1.2b	1.3b	1.4B	1.5ab	1.3	0.9	
No	Yes	1.1b	1.4b	1.4b	1.5B	1.5ab	1.3	0.8	
Complete	—-	0.3c	0.4c	0.5c	0.5c	0.9bc	0.9	0.8	
Significance[x]		***	***	***	***	*	NS	NS	
		ET_o[v], ET_c and K_c per Day							Daily Mean
ET_o (mm)		5.66	5.21	4.88	4.83	5.63	5.27	3.81	5.04
ET_c (mm)		18.1	19.00	16.29	19.00	17.20	12.67	8.14	15.77
K_c		3.2	3.7	3.3	4.0	3.0	2.5	2.1	3.1

[z] Leaf removal and tie-up were performed according to standard industry practices.

[y] Control.

[x] Mean water losses within a column for the same date followed by different letter are significantly different according to Fisher's Protected Least Significant Difference Test. NS, *, **, *** = not significant and significant at $P \leq 0.05, 0.01, 0.001$ respectively.

[w] Standard industry practice.

[v] Data recorded at California Irrigation Management System Station 75, Irvine, California.

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