Estimating Water Needs of Landscape Palms in Mediterranean Climates

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SUMMARY. The responses of five landscape palm species [king palm (*Archontophoenix cunninghamiana*), mediterranean fan palm (*Chamaerops humilis*), queen palm (*Syagrus romanzoffiana*), chinese windmill palm (*Trachycarpus fortunei*), and california fan palm (*Washingtonia filifera*)] to three levels of irrigation [50%, 25%, and 0% (no irrigation) of reference evapotranspiration] were evaluated in a coastal mediterranean climate in Irvine, CA. Cumulative leaf production varied greatly among the species, but only king and chinese windmill palms produced more leaves with additional irrigation. All species maintained at least minimally acceptable visual quality at the no-irrigation treatment. Mediterranean fan and california fan palms expressed near optimum performance with no irrigation. Many established landscape palms can maintain at least minimally acceptable appearance for an extended period with little or no supplemental water in coastal mediterranean climates. However, when rainfall plus irrigation is less than 50% of reference evapotranspiration, sensitive landscape palms could be expected to appear less attractive and grow less. Responses of palm species in this study were similar to those of many other landscape tree and shrub species, but the water needs of landscape palms are considerably less than those of commercial date palm (*Phoenix dactylifera*), oil palm (*Elaeis guineensis*), or coconut palm (*Cocos nucifera*).

Palms are important constituents of many landscapes in arid and semiarid regions where irrigation is deemed necessary for their successful establishment and maintenance. Reducing or limiting water applied to urban landscapes is a primary focus in these areas, but there is limited quantitative water needs information for palms on which to base irrigation management decisions. Growers of date palms for commercial fruit production in the desert environment of the Coachella Valley of California recount a rule of thumb that a fruit-producing tree requires 1 gal of water per day per 1 ft of trunk height in the summer. The accuracy of this assertion is suspect because there is no accounting for canopy size. A general recommendation for irrigating established landscape palms in desert landscapes is to wet the soil 2 ft deep every few weeks in the summer

and every 4 to 6 weeks in the winter (Davidson and Begman, 2000). For transplanted palms, it simply is advised to keep the root ball and backfill soil well watered (Broschat and Meerow, 2000; Pittenger et al., 2005).

Early field studies in the Coachella Valley on commercial date production employed periodic gravimetric soil moisture measurements in the root zone to assess plant water consumption. Investigators estimated mature date palms used about 64 to 83 inches of water per year (Furr and Armstrong, 1956; Pillsbury, 1938, 1941). Furr and Armstrong (1955) also observed date palms in the Coachella Valley were capable of enduring 8 weeks or more between irrigation events as long as their root zones, which were concentrated in

the top 6 ft, were re-wetted at every irrigation. Later, Robertson (1979) reported that providing 150 to 175 gal/d per palm in the summer resulted in satisfactory date fruit production. All of these reports noted that palm water use in the summer (June, July, and August) was nearly three times greater than that in the winter (December, January, and February) in the Coachella Valley area.

Evapotranspiration (ET) from a reference plant surface, known as reference evapotranspiration (ET_o), can be used to calculate climate-based estimates of plant water use or need expressed in depth of water per unit of time (Allen et al., 1998). ET_o is calculated from prevailing weather and climate data, but a crop's ET (ET_c) is influenced by its physiological regulation as well as weather conditions so that ET_c can be more or less than ET_o. The ratio of ET_c to ET_o where a given crop produces optimum growth and yield is expressed as a dimensionless crop coefficient (k_c) (Doorenbos and Pruitt, 1977). The water use or need of a given crop for a specified period of time can be estimated by applying its specific k_c to adjust ET_o data for the period.

There have been ET-based investigations on water use and irrigation management of date palm, oil palm, and coconut palm grown as commercial crops. According to Allen et al. (1998), the k_c estimates for date and other palms grown for fruit production ranges from 0.9 to 1.0 during the year. Salam and Mazrooei (2007) determined a monthly k_c for date palms in a harsh desert environment of the Middle East of 0.9 to 1.0, with an annual average k_c of 0.94. Similar values have been estimated in the field for oil palm (Nelson et al., 2006). For coconut palm, Jayakumar et al. (1988) reported the average k_c was 0.54 during the relatively dry, cooler winter months in humid

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
0.04500	kilocalorie(s)/ft ²	MJ·m ⁻²	22.2044
0.4536	lb	kg	2.2046
1.6093	mile(s)	km	0.6214
1	mmho/cm	dS·m ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

tropical climates. Using the early gravimetrically-determined water use estimates and assuming an average canopy size for commercial date palms in Coachella Valley, their approximate daily tree water use is 0.27 to 0.34 inches of water in the summer and 0.09 inches in the winter. These values are about 100% of historic ET_o for the region.

The use of ET_o data to provide climate-based estimates of landscape plant water needs is a rational approach for managing and conserving water applied to landscapes (Kjelson et al., 2000; Snyder and Eching, 2006). However, a typical urban landscape violates the standard conditions upon which the relationship of k_c to ET_o is defined and estimated, which are an agricultural-type crop that achieves full yield while growing in a large field under excellent agronomic and soil water conditions (Allen et al., 1998). Water needs of nonturf landscape plants are appropriately defined as the percentage of ET_o they need to maintain appearance and intended function rather than to produce optimum growth and crop yield (Pittenger et al., 2001; Shaw and Pittenger, 2004). For landscape plants, the ET_o adjustment factor, expressed simply as a percentage of ET_o , is properly termed a "plant factor" (PF) rather than a k_c because of the emphasis on plant appearance rather than optimum growth and yield (St. Hilaire et al., 2008). Multiplying ET_o data by a PF rather than a k_c has been shown to be an effective means of estimating water needs and irrigation schedules for landscape groundcovers and shrubs (Pittenger et al., 2001; Shaw and Pittenger, 2004; Staats and Klett, 1995). This approach has also been demonstrated for estimating water needs of landscape tree plantings (Pittenger et al., 2002), but its suitability in estimating water needs of isolated landscape trees has not been well-established (Devitt et al., 1994; Montague et al., 2004). Studies on woody landscape plants' water needs show that, once established, many species maintain acceptable aesthetic and functional value when irrigated near 50% of ET_o , although they vary in response to drought and the minimum amount of water needed to remain acceptable in a landscape (Pittenger et al., 2002;

Shaw and Pittenger, 2004). However, there is virtually no research-based information on the amount of water landscape species need for optimum growth and development.

The project reported here was designed to provide some estimates of the minimum ET_o -based amount of water needed by several common landscape palms to remain aesthetically acceptable. The responses of five palm species to three levels of applied water were studied for a period of 3 years.

Materials and methods

Five palm species (king palm, mediterranean fan palm, queen palm, chinese windmill palm, and california fan palm) that had been established in the field under well-irrigated conditions for 2 years after transplanting from 1-L containers were included in the study at the University of California South Coast Research and Extension Center in Irvine. The trees were uniform in size, health, and appearance, and were planted on 15-ft centers in rows 15 ft apart. The site is in the south coastal plain of California, ≈ 10 miles inland from the Pacific Ocean, and experiences a maritime mediterranean climate. Soil at the site is a San Emigdio sandy loam [coarse-loamy, mixed (calcareous), thermic Typic Xerofluvent] with a pH of 6.9 and an electrical conductivity (EC) of $1.0 \text{ dS}\cdot\text{m}^{-1}$.

The applied water treatments were 50%, 25%, and 0% (no irrigation) of real-time ET_o . Plants in the 0% ET_o treatment received only rainfall, and no rain occurred from late spring through the early fall months when ET_o was highest, which is typical in a mediterranean climate. Water treatments were continuously scheduled from mid-Aug. 2003 through Sept. 2006 using daily ET_o estimates provided by an on-site California Irrigation Management Information System (CIMIS) automated weather station employing a modified Penman equation (California Department of Water Resources, 2009). Daily ET_o values were multiplied by the fraction assigned for each treatment (0.5, 0.25, and 0.0, respectively) and accumulated until the sum of a particular treatment reached 1.2 inches. At that time, an irrigation of 1.2 inches was applied to rows of the particular treatment. This amount of water was $\approx 50\%$ of available water-holding capacity in

the top 2 ft of soil at this site. Rainfall of 0.1 inches or more per day was subtracted from the accumulated ET_o .

Water was applied by fixed-spray center-strip spray nozzles (Toro 570 CST; Toro, Riverside, CA) placed within rows and spaced between trees to provide head-to-head coverage. The wetting pattern of each nozzle measured $\approx 4.5 \times 15$ ft so that the entire length of each tree row plus 7.5 ft beyond the end was uniformly wetted about 4.5 ft wide. Thus, the soil under the crown projection of each tree was wetted according to the assigned water treatment. The total irrigation runtime needed for the irrigation system to apply 1.2 inches of water was divided into multiple 6-min cycles to prevent runoff into adjacent rows, and a water flow meter was installed in each irrigation replicate to monitor actual water applied. Irrigation water was nonpotable agriculture water with a pH of 7.0 and an EC 1.0 of $\text{dS}\cdot\text{m}^{-1}$ provided by the Irvine Ranch Water District.

Weeds were managed by a combination of hand weeding and spot sprays of glyphosate. Trees were fertilized annually with a palm special fertilizer at a rate that delivered 0.2 lb actual nitrogen per palm.

The experiment was designed as a randomized split-plot with nine rows where each row was randomly assigned as an applied water treatment block in which the five palm species were randomly replicated three times as single trees. There were three rows (blocks) of each applied water treatment.

Tree responses to water treatments were evaluated by recording the number of new leaves produced, measuring the total increase in tree height, and rating the visual quality of tree aesthetic appearance twice per year. Visual quality was rated each time by the same three-member panel on a 1 to 5 scale where 1 = dead, 3 = minimally acceptable appearance in a landscape, and 5 = excellent color and optimum aesthetic appearance. Data were analyzed as a two-factor factorial experiment. Analysis of variance was conducted for the total number of new leaves, total height increase, and average quality rating using the Mixed Procedure of SAS (version 9; SAS Institute, Cary, NC). The overall error rate for multiple comparisons was controlled by Tukey-Kramer adjustment.

Assumptions of normality, equal variance, and independence were validated for all tests using the GLM Procedure.

Results and discussion

Annual ET_o averaged 49 inches during the study and was normal for this location. However, annual precipitation, which averages about 14 inches per year, varied from well below normal to more than twice normal during the study. Precipitation recorded in year 1 (Aug. 2003–July 2004) and year 3 (Aug. 2004–July 2005) was 7.0 inches and 8.7 inches, respectively, while in year 2 (Aug. 2004–July 2005) it was 29.3 inches. The summers were warm and dry with high solar radiation (Table 1). Nearly all of the irrigations each year were scheduled from April through November, with average irrigation intervals of 10 to 14 d for the 50% ET_o treatment, and 24 to 28 d for the 25% ET_o treatment. The sum of irrigation plus effective rainfall accurately met the applied water targets in the 50% and 25% ET_o treatments.

Cumulative leaf production differed greatly among species (Fig. 1). In general, king and queen palms produced relatively few leaves during the study (9 or less), whereas mediterranean and california fan palms produced about 90 leaves. However, only king and chinese windmill palms produced more leaves with more applied water. King palms produced about 20% more leaves at the 50% ET_o treatment and chinese windmill palms produced nearly 10% more leaves at the 50% treatment. The data also suggest mediterranean fan and queen palms might produce more leaves with more water. Only king palm showed a cumulative height increase with more water (data not shown).

Most importantly from a landscape management perspective, all species maintained at least minimally acceptable visual quality with no supplemental irrigation during the study (Fig. 2). Queen and chinese windmill palms were the only species that had improved appearance with more water. The visual quality of these two species was $\approx 25\%$ greater when they were irrigated at 25% or 50% ET_o . Chinese windmill was the only species to express noticeable drought symptoms. When receiving less than 50% ET_o , mature leaves on the south and

Table 1. Monthly reference evapotranspiration (ET_o) and precipitation, average daily solar radiation, average maximum and minimum air temperatures, and average dew point temperatures for the warmer months from Aug. 2003 through Sept. 2006 at Irvine, CA.^z

Year/ month	ET_o (inches) ^y	Precipitation (inches)	Avg daily solar radiation (MJ·m ⁻²) ^y	Avg maximum air temp (°F) ^y	Avg minimum air temp (°F)	Avg dew point temp (°F)
2003						
August	6.54	0.0	25.44	85.3	61.2	61.9
September	4.67	0.0	20.59	80.2	59.9	61.4
2004						
April	4.72	0.6	22.00	71.5	50.7	51.3
May	5.78	0.0	24.18	77.0	55.1	53.5
June	4.94	0.0	22.30	74.1	59.1	59.0
July	6.44	0.0	26.40	81.2	60.7	60.8
August	5.66	0.0	23.47	79.8	59.9	61.7
September	5.24	0.5	20.17	83.0	60.9	59.9
2005						
April	4.99	1.2	22.64	70.4	47.8	47.1
May	5.71	0.5	24.31	74.2	54.8	55.5
June	4.98	0.1	22.80	73.7	56.5	57.1
July	6.56	0.0	25.90	81.8	61.8	62.3
August	5.68	0.0	22.34	81.5	60.9	61.9
September	4.51	0.0	18.91	79.1	56.0	56.5
2006						
April	3.68	2.2	17.99	66.5	48.2	49.8
May	4.56	0.5	20.25	72.0	55.7	56.5
June	5.44	0.0	22.51	80.8	60.0	60.9
July	6.40	0.0	23.51	87.7	65.6	63.5
August	5.81	0.0	22.47	81.9	60.2	61.4
September	4.89	0.0	19.71	81.6	57.2	58.6

^zData from California Irrigation Management Information System (CIMIS) Station No. 75.

^y1 inch = 2.54 cm, 1 MJ·m⁻² = 22.2044 kilocalories/ft², (°F – 32) ÷ 1.8 = °C.

Fig. 1. Cumulative leaf production by five palm species grown at three levels of irrigation based on percentages of reference evapotranspiration (ET_o) from Aug. 2003 to Sept. 2006 in Irvine, CA. The overall error rate of multiple comparisons was controlled by Tukey-Kramer adjustment. Values followed by the same letter within a species are not significantly different at $P < 0.05$.

west aspects of this species became seriously sun burned, which was reflected in lower visual quality ratings at the 25% and 0% ET_o treatments.

It is important to note that the visual quality of king palms was minimally acceptable at all treatments and was at this level when the study

Fig. 2. Visual quality ratings of five palm species grown at three levels of irrigation based on percentages of reference evapotranspiration (ET_0) from Aug. 2003 to Sept. 2006 in Irvine, CA (1 = dead, 3 = minimum acceptable appearance, 5 = optimum appearance). The overall error rate of multiple comparisons was controlled by Tukey-Kramer adjustment. Values followed by the same letter within a species are not significantly different at $P < 0.05$.

began. This suggests that their performance was affected by one or more factors other than the amount of water received (e.g., climate or soil conditions). Conversely, mediterranean fan and california fan palms maintained growth and nearly optimum visual quality with no irrigation, which demonstrates these species are very well adapted to this climate and require little supplemental water after establishment.

The responses of the palm species in this study are similar to those of other landscape tree and shrub species. A 5-year study with landscape trees in inland southern California found 14 of 28 species evaluated were capable of maintaining at least acceptable aesthetic appearance, though often reduced growth, when irrigated at 35% of ET_0 versus 80% of ET_0 following establishment (Pittenger et al., 2002). Compared with the coastal area where our study was conducted, inland southern California experiences average maximum summer air temperatures that are 10 °F higher and average summer ET_0 values 15% to 20% higher. A 4-year study in the southern end of the San Francisco Bay area with young transplanted oaks (*Quercus* spp.) found that irrigation at 0%, 25%, or 50% of ET_0 had no effect on their growth after they were provided a well-irrigated 1-year establishment period (Costello et al., 2005). The area in which the study was conducted experiences

summer maximum temperatures and ET_0 values similar to those in our study. A 3-year investigation with 30 shrub species receiving irrigation of 0%, 18%, and 36% of ET_0 at the immediate coast of southern California, which experiences fog during portions of many summer days, found the aesthetic appearance as well as growth of several species were reduced with less water (Shaw and Pittenger, 2004). However, 11 species maintained acceptable appearance with no irrigation and another 14 species were aesthetically acceptable at 18% of ET_0 .

Palms grown for their landscape aesthetics and functional value need considerably less water than date, oil, or coconut palms grown for their commercial crops. Many established landscape palms can maintain at least minimally acceptable appearance for an extended period with little or no supplemental water in coastal mediterranean climates, but it is reasonable they might need more summer irrigation when grown several miles inland from the seacoast or other areas with higher ET_0 rates than were experienced in this study. Established landscape palms that are well adapted to a mediterranean climate can maintain nearly optimum visual quality and growth with little if any supplemental irrigation. Sensitive landscape palms, such as queen and chinese windmill palms, can be expected to maintain minimally acceptable visual quality but appear less attractive or

grow less when total water provided (rainfall plus irrigation) is less than 50% ET_0 . It is not possible from this study to discern if providing total water in excess of 50% ET_0 would result in better growth or visual quality of landscape palms.

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