Adjustment of Closed Canopy Crop Coefficients of Pecans for Open Canopy Orchards

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Introduction

Pecan production is an essential component of irrigated agriculture in southern New Mexico. Seasonally, pecan consumptive water use is high compared to most crops, and was estimated to be 131 cm for mature trees (Miyamoto, 1983). In the arid southwest water is a limiting resource. Thus, farmers need to maximize irrigation water use efficiency (IWUE), defined as the ratio of crop yield to seasonal irrigation water applied, including rain (Howell, 1994).

The consumptive water use of pecans is a combination of evaporation from the soil and transpiration through the leaves. The two processes occur simultaneously and are usually measured together as evapotranspiration (ET). Estimation of crop ET under local weather conditions is based on potential ET of a reference crop (well-watered grass or alfalfa), ETr. The ETr is then multiplied by a crop coefficient (K) to obtain crop ET (ETc) under standard conditions. Standard conditions are defined as large fields under optimum soil water, excellent management and environmental conditions that allow the crop to achieve full production under the given climatic conditions (Allen et al., 1998). The K of pecans, the ratio of ETc and ETr, varies according to tree age, tree spacing, growth stage within a season, and local weather conditions. The effect of tree age and spacing is manifested in the amount of canopy cover (influences solar energy partitioning between soil evaporation and tree transpiration) and the rooting extent. Thus, there is a need for a method to adjust K values according to tree age and spacing.

When pecan trees are young the water use is proportional to the amount of solar radiation intercepted by the canopy. Miyamoto (1983) developed K values for orchards based on the size of the trunk and the tree spacing. Allen et al. (1998) suggested adjusting K by effective canopy cover (ECC) where ECC is defined as the proportion of the soil surface shaded by a crop at solar noon. Johnson et al. (2000, 2002) found a linear relationship between the K for peach trees and ECC for closed canopy trees where K = 1.5 ECC. In another study, Goodwin et al. (2003) determined that K = 1.4 ECC for peach trees. Consequently, the daily water use of a tree (ETc), where shading from adjacent trees does not affect the calculation, is proportional to the light interception and reference evapotranspiration (ETr) where:

$$ETc = 1.5\ ECC\ ETr \qquad [1]$$

Another method to determine K for young orchards throughout the growing season is by adjusting the closed canopy crop coefficient (Kmax) by the ECC where:

$$K / Kmax = a\ ECC^{b} \qquad [2]$$

Evapotranspiration is then equal to:

$$ETc = K\ ETr \qquad [3]$$

The objective of this study was to derive a relationship described by equation [2] that is applicable to pecan orchards of varying ECC.

Materials and Methods

Measurements of trunk diameter, crown diameter, and crown height were taken from pecan orchards of varying age and tree spacing. Measurements were taken from ten trees in each orchard. The ECC for each orchard was calculated based on average crown projected area (i.e. crown area projected to the ground calculated from the measurement of the drip line of the crown in a north-south and east-west direction) at solar noon and the tree spacing. The K/Kmax values were determined from Miyamoto’s functions (Table 4 in Miyamoto, 1983) for pecan trees based on tree spacing and trunk diameter at breast height. The K/Kmax values for different orchards were plotted against corresponding ECC values. The resulting function for pecans was compared with similar functions found in the literature for almond and peach trees.

Results

Data from the literature that relate K/Kmax to ECC for almonds and peaches were found to be comparable with data from pecan orchards. Fereres (1980) obtained a non linear function relating K/Kmax with ECC for immature deciduous almond trees. A graph of this data was also published by Aljibury et al. (1992) and is included in Figure 1. A single power function does not fit the data well over the whole range and the data must be represented by two functions – one to describe the relationship for small orchards (lower range) and another to describe the relationship for midsize orchards (upper range). Synder (personal communication, 2003) found that Fereres’ (1980) data fit a sine curve of the form K/Kmax versus sine (ECC/70*PI/2) over the full range of the data (Fig. 1). Synder selected values of predicted K/Kmax from the plotted curve of Fereres (1980) for 10%, 20%, ..., 70% ground cover and then calculated the sine (ECC/70 * PI/2) for each ground cover condition (Fig. 1).

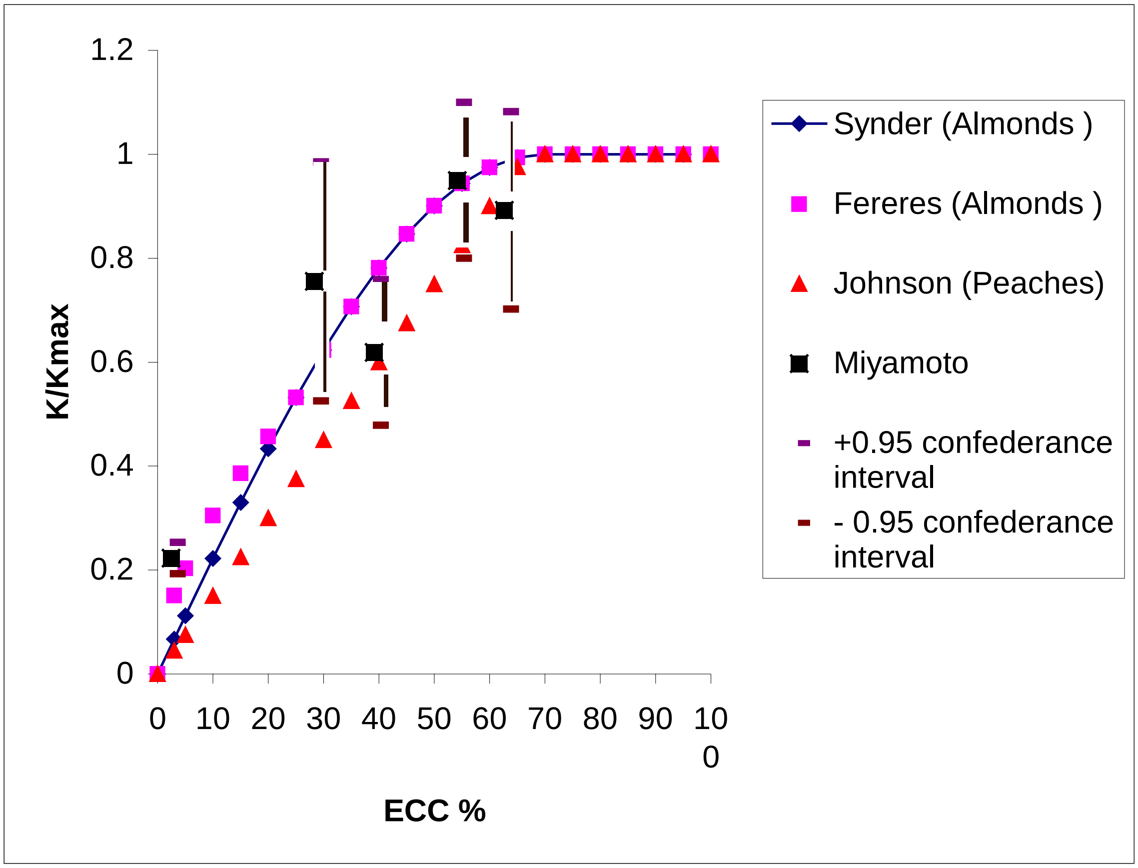

Figure 1. Crop coefficient (K)/ Crop coefficient (Kmax) mature canopy vs ECC

The original figure by Fereres (1980) had a slope of 2.25 in the 0 to 20% ECC range compared to a lower slope of 2.1 in the function developed by Snyder. Consequently, a separate function must be used to describe the relationship in the 0 to 20% ECC range that corresponds to young trees. If the cover is evaluated over the 20 to 65% ECC range then the slope by Fereres is 1.3, which is close to the 1.5 value determined by Johnson et al. (2002) for peach trees (Fig. 1). The higher slope in the 0 to 20% ECC range may be evidence that additional ET accrues due to local advection from the exposed soil surrounding the young trees (e.g. Young trees planted in 10 m by 10 m spacing have wide spaces between them that are subject to advection.). Thus the adjustment factor K/Kmax in the 0 to 20% ECC range may adjust for local advection in addition to the adjustment for less light interception by the small canopies. After the ECC reaches 20 percent, a slope of 1.3 to 1.5 can be used to calculate the scaling factor. If a slope of 1.3 is used for ECC > 20%, then K/Kmax reaches a value of 1 at an ECC of 65%. This is the same value determined by Johnson et al. (2002) at which peach trees achieve Kmax (i.e. ETc is at the same magnitude as mature orchards).

When Miyamoto's (1983) data were converted to the format of equation [2] and plotted (Fig. 1), the function derived for almond orchards was within the +/- 0.95

confidence interval of the plotted data. Because of the closer spacing for peach trees, the peach tree function is linear and does not show the curvature of the function at small tree size that is characteristic of almonds and pecan orchards.

Conclusion

A continuous function described by Snynder (personal communication, 2003) that relates K/Kmax and ECC can be used to adjust the K of pecan orchards of varying age and tree spacing (i.e. varying ECC). For better accuracy in the 0 to 20% ECC range that is common in young pecan orchards, two functions (either power or linear) can be used to describe the reduction of K relative to a mature pecan orchard (Kmax) – one function for the 0 to 20% ECC range and another function for ECC > 20%. The data from Miyamoto (1983) for young pecan orchards deviate slightly from the functions based on data from Fereres (1980) and Johnson (2002) and additional research is needed to reconcile the differences.

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