

# Evapotranspiration-Based Irrigation for Agriculture: Crop Coefficients of Some Commercial Crops in Florida<sup>1</sup>

Isaya Kisekka, Kati W. Migliaccio, Michael D. Dukes, Jonathan H. Crane, Bruce Schaffer, Sandra M. Guzman, and Haimanote K. Bayabil<sup>2</sup>

*This article is part of a series on ET-based irrigation scheduling for agriculture. The rest of the series can be found at [https://edis.ifas.ufl.edu/topic\\_series\\_ET-based\\_irrigation\\_scheduling\\_for\\_agriculture](https://edis.ifas.ufl.edu/topic_series_ET-based_irrigation_scheduling_for_agriculture).*

## Introduction

The crop coefficient ( $K_c$ ) is one of the most important variables in the estimation of irrigation water needs for a specific crop.  $K_c$  integrates crop properties, related to the plant phenological stage, plus the effects of soil evaporation in one value. Usually,  $K_c$  values are estimated in controlled conditions related to the crop type, phenological stage, soil moisture, crop health, and crop management practices. However, these controlled estimations are not possible to reproduce in the field due to timing and management restrictions. This publication identifies typical  $K_c$  values for some of the crops commonly grown in Florida. The  $K_c$  values listed are only intended for use as guidelines in the absence of locally developed, variety-specific  $K_c$  values.

## Crop Coefficient ( $K_c$ )

The  $K_c$  integrates the characteristics of the crop that distinguish it from the reference crop (usually a short, green, well-watered crop that completely shades the ground) used to estimate reference ET ( $ET_0$ ). General guidelines on how to obtain  $ET_0$  data for most areas in Florida can be found in *Evapotranspiration-Based Irrigation for Agriculture: Sources of Evapotranspiration Data for Irrigation Scheduling in Florida* at <https://edis.ifas.ufl.edu/ae455>.

The  $K_c$  value changes over the growing period for a crop because of changes in the crop characteristics such as ground cover, crop height, and leaf area. For annual crops, the growth period is divided into four stages (i.e., initial stage, crop development, mid-season stage, and late season stage) and  $K_c$  values are calculated based on

these stages. The initial stage is the period between the planting date and 10% ground cover. The crop development stage refers to the period from 10% ground cover to the initiation of flowering or full cover. The mid-season stage refers to the period between full crop cover and the start of maturity indicated by the aging, yellowing, browning of leaves or leaf drop. The late season stage covers the period between maturity and harvest or full senescence (advanced aging of leaves). For most perennial crops in Florida, growth continues year-round, and the  $K_c$  varies by month based on the phenological stage (bloom, fruit set, fruit development, fruit maturation) of the plant and percentage of the ground shaded by the tree canopy (Allen et al. 1998).

There is minimal information about locally adapted  $K_c$  values for most crops grown in Florida. If field data exist for a crop related to local management practices, variety, and environmental conditions, it should be used to generate  $ET_c$  for estimating net irrigation water requirement. General information on estimating  $ET_c$  and net irrigation water requirements can be found in *Evapotranspiration-Based Irrigation Scheduling for Agriculture* at <https://edis.ifas.ufl.edu/ae457>. However, if locally developed  $K_c$  values do not exist, typical values listed in Table 1 and Table 2 may be used as guidelines for crops commonly grown in Florida.

## Conclusion

The  $K_c$  values listed in this publication can serve as useful guidelines for areas where locally developed  $K_c$  values are not available for specific crops or cultivars. These  $K_c$  values can be adjusted to meet local management requirements if necessary.

## References

- Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. "Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements." FAO Irrigation and Drainage Paper 56. Rome: Food and Agriculture Organization of the United Nations.  
<http://www.fao.org/docrep/X0490E/x0490e00.htm>
- De Azevedo, P.V., B.B. da Silva, and V.P.R. da Silva. 2003. "Water Requirements of Irrigated Mango Orchards in Northeast Brazil." *Agricultural Water Management* 58(33): 241–254.
- Dukes, M.D., L. Zotarelli, G.D. Liu, and E. H. Simonne. 2012. "Principles and Practices of Irrigation Management for Vegetables." In *The Vegetable Production Guide for Florida*. SP170. Gainesville: University of Florida Institute of Food and Agricultural Sciences.  
<https://doi.org/10.32473/edis-cv107-2006>
- Fares, A. 2008. *Water Management Software to Estimate Crop Irrigation Requirements or Consumptive Use Permitting In Hawaii*. Honolulu, HI: Department of Land and Natural Resources.  
<http://hawaii.gov/dlnr/cwrm/publishedreports/PR200808.pdf>
- Goenaga, R., and H. Irizarry. 2000. "Yield and Quality of Banana Irrigated from Fractions of Class A Pan Evaporation on an Oxisol." *Agron. J.* 92:1008–1012.
- Kisekka, I., K.W. Migliaccio, M.D. Dukes, B. Schaffer, J.H. Crane, and K. Morgan. 2009. *Evapotranspiration-Based Irrigation for Agriculture: Sources of Evapotranspiration Data for Irrigation Scheduling in Florida*. AE455. Gainesville: University of Florida Institute of Food and Agricultural Sciences.  
<https://edis.ifas.ufl.edu/ae455>
- Kisekka, I., K.W. Migliaccio, M.D. Dukes, B. Schaffer, and J.H. Crane. 2009. *Evapotranspiration-Based Irrigation Scheduling for Agriculture*. AE457. Gainesville: University of Florida Institute of Food and Agricultural Sciences.  
<https://edis.ifas.ufl.edu/ae457>
- Menzel, C.M., J.H. Oosthuizen, D.J. Roe, and V.J. Doogan. 1995. "Water Deficits at Anthesis Reduce CO<sub>2</sub> Assimilation and Yield of Lychee (*Litchi chinensis* Sonn.) Tree." *J. Tree Physiol.* 15: 611–617.
- Morgan, K.T., J.M.S. Scholberg, T.A. Obreza, and T.A. Wheaton. 2006. "Size, Biomass, and Nitrogen Relationships with Sweet Orange Tree Growth." *J. Amer. Soc. Hort. Sci.* 131(1):149–156.

## Tables

Table 1. Typical crop coefficients ( $K_c$ ) for perennial crops commonly grown in Florida.

Month	Avocado <sup>1</sup>	Banana <sup>1</sup>	Carambola <sup>2</sup>	Citrus <sup>3</sup>	Guava <sup>4</sup>	Lychee <sup>5</sup>	Mango <sup>6</sup>
January	0.70	1.00	1.00	0.79	0.80	0.40	0.60
February	0.70	1.00	1.00	0.86	0.80	0.40	0.50
March	0.86	1.10	1.15	0.93	0.80	0.90	0.45
April	0.86	1.20	1.20	0.97	0.85	1.2	0.45
May	0.98	1.20	1.20	1.03	0.90	1.2	0.50
June	0.98	1.25	1.20	1.05	1.00	0.85	0.50
July	0.98	1.25	1.15	1.05	1.00	0.85	0.60
August	0.98	1.25	1.15	1.03	1.00	0.40	0.80
September	0.86	1.10	1.20	1.00	1.00	0.40	0.80
October	0.86	1.10	1.20	0.95	0.85	0.40	0.70
November	0.70	1.00	1.10	0.87	0.80	0.40	0.70
December	0.70	1.00	1.10	0.79	0.80	0.40	0.60

**Note:** These values are only intended for use as guidelines in the absence of locally developed  $K_c$  values and may be modified to suit local growing environments and management practices.

<sup>1</sup> Time averaged  $K_c$  values for non-stressed, well-watered crops in a sub-humid climate (minimum relative humidity approximately 45% and average wind speed of 2 m/s at a height of 2 m) (Allen et al. 1998). The  $K_c$  values have been listed by month to correspond to different phenological stages of plant development. Banana values for summer months are based on Goenaga and Irizarry (2000), which was conducted under Puerto Rican conditions. Avocado values include considerations from current research at the UF/IFAS Tropical Research and Education Center (Personal communication, J. H. Crane and 2019).

<sup>2</sup> Carambola  $K_c$  is based on the phenology of plants growing in the South Florida conditions (Personal communication, J.H. Crane 2019).

<sup>3</sup> Citrus  $K_c$  values are based on recommendations by Morgan et al. (2006). More information about citrus irrigation scheduling can be obtained from Improving Citrus Nitrogen Uptake Efficiency: Effective Irrigation Scheduling (<https://doi.org/10.0.126.217/edis-ss467-2007>).

<sup>4</sup> Guava  $K_c$  values are taken from a report by Fares (2008) for Hawaiian conditions latitude of about 21° N and longitude 157° W.  $K_c$  values in the table have been listed by month to reflect the guava season in South Florida (May to October). More information can be obtained at <http://treephys.oxfordjournals.org/cgi/reprint/15/9/611>.

<sup>5</sup> Lychee  $K_c$  values are based on work by Menzel et al. (1995) and were determined in a lychee orchard in subtropical South Africa using an evaporation pan. More information on the study can be obtained at <http://treephys.oxfordjournals.org/cgi/reprint/15/9/611>.

<sup>6</sup> Mango  $K_c$  values were obtained from De Azevedo et al. (2003) in a study at Petrolina in northeastern Brazil. Mango orchard  $ET_c$  was measured using Bowen ratio and soil water balance methods.  $K_c$  values in the table have been listed by month to reflect the mango season in South Florida (May to October).

Table 2. Typical crop coefficients ( $K_c$ ) at various growth stages for annual crops commonly grown in Florida.

Crop	Initial Stage	Mid-stage	Late-stage
Tomatoes <sup>7</sup>	0.4	0.9	0.75
Squash <sup>1</sup>		0.95	0.75
Green pepper <sup>1</sup>		1.05	0.9
Green beans <sup>1</sup>	0.5	1.05	0.9
Cucumber <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	0.95	0.9
Cabbage <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	1.05	0.95
Potatoes <sup>1</sup>		1.15	0.75
Sweet potatoes <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	1.1	0.7
Carrots <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	1.05	0.75
Okra <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	1.0	0.9

Crop	Initial Stage	Mid-stage	Late-stage
Strawberries <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	0.5	0.6
Sweet corn <sup>7</sup>	0.2 <sup>7a</sup> –0.4 <sup>7b</sup>	1.1	1.0

**Note:** These values are only intended for use as guidelines in the absence of locally developed K<sub>c</sub> values and may be modified to suit local growing environments and management practices.

<sup>1</sup> Time averaged K<sub>c</sub> values for non-stressed, well-watered crops in a sub-humid climate (minimum relative humidity approximately 45% and average wind speed of 2 m/s at a height of 2 m) (Allen et al. 1998).

<sup>7</sup> K<sub>c</sub> values are from *Vegetable Production Guide for Florida* (SP170), "Principles and Practices of Irrigation Management for Vegetables." More information about this publication can be found at <https://edis.ifas.ufl.edu/collections/vph>.

<sup>7a</sup> represents small row spacing (high population densities).

<sup>7b</sup> represents wide row spacing (low population densities).

<sup>1</sup>This document is AE456, one of a series of the Department of Agricultural and Biological Engineering, UF/IFAS Extension. Original publication date January 2010. Revised February 2013 and June 2019. Visit the EDIS website at <https://edis.ifas.ufl.edu> for the currently supported version of this publication.

<sup>2</sup>Kati W. Migliaccio, dean of the UF/IFAS College of Agriculture and Life Sciences and professor of water conservation, UF/IFAS Agricultural and Biological Engineering Department, Gainesville, FL; Michael D. Dukes, director, UF/IFAS Nutrient Management Program, associate dean for special initiatives, UF/IFAS Extension, professor, Department of Agricultural and Biological Engineering, and director, Center for Land Use Efficiency; Jonathan H. Crane, professor, tropical fruit crop specialist, and associate center director, Department of Horticultural Sciences, UF/IFAS Tropical Research and Education Center, Homestead, FL; Bruce Schaffer, professor, ecophysiology of subtropical and tropical horticultural crops, Department of Horticultural Sciences, UF/IFAS Tropical Research and Education Center, Homestead, FL; Sandra M. Guzmán, assistant professor, water resources, Department of Agricultural and Biological Engineering, UF/IFAS Indian River Research and Education Center; Haimanote Bayabil, associate professor, water resources, Department of Agricultural and Biological Engineering, UF/IFAS Tropical Research and Education Center, Homestead, FL; UF/IFAS Extension, Gainesville, FL 32611.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. For more information on obtaining other UF/IFAS Extension publications, contact your county's UF/IFAS Extension office. U.S. Department of Agriculture, UF/IFAS Extension Service, University of Florida, IFAS, Florida A & M University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Andra Johnson, dean for UF/IFAS Extension.