EVAPOTRANSPIRATION OF IRRIGATED SUNFLOWER IN A SEMI-ARID ENVIRONMENT

T.A. Howell, S.R. Evett, J.A. Tolk, and K.S. Copeland

Acting Lab. Dir./Research Leader (Res. Agric. Engr.), Res. Soil Scientist, Res. Plant Physiologist, and Soil Scientist

USDA-Agricultural Research Service | Conservation & Production Research Laboratory

P.O. Drawer 10 | Bushland, TX 79012-0010 U.S.A. | http://www.cprl.ars.usda.gov

terry.howell@ars.usda.gov / steve.evett@ars.usda.gov / judy.tolk@ars.usda.gov / karen.copeland@ars.usda.gov

ABSTRACT

Sunflower (*Helianthus annuus* L.) is an alternative crop for the Southern High Plains typically produced under dryland; however irrigation offers greater potential for enhanced productivity and quality. Sunflower [cv, S 672 NuSun (Triumph Dwarf)] was grown in 2009 at Bushland, Texas on two 4.4 ha fields (designated as NE and SE) each containing a precision weighing lysimeter (3 m by 3 m by 2.3 m deep, monolith) of Pullman clay loam soil, (fine, mixed, superactive, thermic Torrertic Paleustoll). The fields, with slopes less than approximately 0.3%, were sprinkler irrigated. Evapotranspiration (ET) was determined by lysimeter water budgets. Crop coefficients (K_c) were determined from the ratio of measured crop ET to standard short-crop reference ET_o based on the ASCE-EWRI standardized equation with weather data measured nearby. The crop was planted on June 4th, emerged on June 13th, and was harvested on September 18th. Maximum crop height was 1.2 m in early August while full ground cover was achieved by mid July. Leaf area index (LAI) peaked in early August at 6.6 m^2 m^{-2} on the North field and 6.8 m^2 m^{-2} on the South field. At full-cover, LAI was 3.8-4.6 m^2 m^{-2}. Achene yields were 316 g m^{-2} and 345 g m^{-2} on the NE and SE lysimeter, respectively, with 134 and 142 g m^{-2} oil yield. The sunflower evapotranspiration was 644 mm for the NE lysimeter and 600 mm for the SE lysimeter. Water use efficiency varied from 0.49 kg m^{-3} (NE Lysimeter) to 0.58 kg m^{-3} (SE lysimeter). The maximum daily ET was 14.5 mm d^{-1}, but most days were in the 7-12 mm d^{-1} ET range at full cover. The FAO-56 four-section K_c for the initial stage (20 day post planting) was 0.15; the development stage until full cover took 17 days; the full-cover K_c averaged 1.24 for 46 days then declined to the initial K_c value 0.15 after 16 days until harvest 6 days later. The peak K_c value was larger than the mid-season K_c value (1.15) from FAO-56. The sunflower development calendar differed from the FAO-56 primarily by accelerated development.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is produced on the Texas High Plains and most Great Plains regions for both oil and non oil uses. USDA-NASS (2010) reported for the Texas High Plains that sunflower planted area increased from 13,800 ha in 2007 to 38,600 ha in 2009 with yields of 141.4 g m^{-2} in 2007 and 132.5 g m^{-2} in 2009. Previous reports for the normal range of sunflower evapotranspiration (ET) in field experiments was 300-700 mm with reported sunflower water use varying from 689 to 769 mm in well irrigated treatments (Karam et al., 2007). At Bushland, Unger (1982) reported average sunflower ET with full irrigation of 580 mm for 1978-1980. Unger (1990) reported full irrigation ET in Texas for sunflower varied from 600-950 mm, depending mainly on planting date, with early (March) plantings having greater ET than later planted sunflower (May or June).

Fully irrigated yields vary from 200-300 g m^{-2} typically up to 400 g m^{-2} (Unger, 1990). Soil water deficits should be avoided at flowering (Unger, 1990; Browne, 1977; Robinson, 1971; and Stone et al., 1996). Soil water deficits can impact sunflower quality as well (Unger, 1990). Unger (1990) summarized sunflower water use efficiency (WUE_y) for yield (achene yield per unit ET) that varied from 0.4 to 1.1 kg m^{-3}.

Allen et al. (1998) reported K_c values for sunflower as 0.15 at the initial stage after seeding and 0.90-1.15 for mid season (full cover) and declining to 0.35 at the season's end all based upon a short crop (or grass like, well watered) reference ET (ET_o). The lower mid season K_c was for rainfed crops with smaller plant densities.

The purpose was to measure ET of sprinkler irrigated sunflower in a semi-arid environment and determine crop coefficients for irrigation scheduling.

PROCEDURES

Studies were conducted at the USDA-ARS Laboratory at Bushland, TX (35º 11' N lat.; 102º 06' W long.; 1,170 m elev. above MSL). Crop ET was measured with two weighing lysimeters each located in the center of two 4.4-ha, 210 m E-W by 210 m, N-S field (two fields arranged in a rectangular pattern). The soil at this site is classified as Pullman clay loam (fine, mixed, superactive thermic Torrertic Paleustoll) which is described as slowly permeable because of a dense B22 horizon about 0.3 to 0.5 m below the surface. The plant available water holding capacity within the top 2.0 m of the profile is approximately 240 mm (~200 mm to 1.5-m depth). A calcareous layer at about the 1.4 m depth limits significant rooting and water extraction below this depth for some crops. Variations of this soil series are common to more than 1.2 million ha of land in this region and about 1/3 of the sprinkler-irrigated area in the Texas High Plains. Weighing lysimeters offer one of the most accurate means to measure ET. Predominate wind direction is SW to SSW, and the unobstructed fetch (fallow fields or dryland cropped areas) in this direction exceeds 1 km. The field slope is less than 0.3 percent. More descriptive information is provided in Howell et al. (1997).

Lysimeter mass was determined using a Campbell Scientific [1/] CR-7X data logger to measure and record the lysimeter load cell (Interface SM-50) signal at 0.5 Hz (2 s) frequency. The lysimeter mass resolution was 0.01 mm, and its accuracy exceeded 0.05 mm (Howell et al., 1995). Daily ET was determined as the difference between lysimeter mass losses (from evaporation and transpiration) and lysimeter mass gains (from irrigation, precipitation, or dew) divided by the lysimeter area (9 m^2). ET for each 24-h period was divided by 1.02 to adjust the lysimeter area to the mid point between the two walls (10 mm air gap; 9.5 mm wall thickness; 9.18-m^2 area instead of 9.00-m^2 area). Figure 1 shows the lysimeters on July 2nd and 17th, 2009.

Plant samples from 1.0-m^2 areas were obtained periodically to measure crop development. These field samples were taken at sites about 10 to 20 m away from the lysimeters in areas of the field representative of the lysimeter vegetation. Leaf area index (LAI), crop height (CH), crop width (CW), and aboveground dry matter (TDM) were measured from three samples. Final yield was measured by harvesting the aboveground plant matter from each lysimeter (9 m^2), and dry matter and yield at harvest were measured from adjacent plant samples.

Solar irradiance, wind speed, air temperature, dew point temperature, relative humidity, precipitation, and barometric pressure were measured at an adjacent weather station. Reference ET (ET_o) was computed with the ASCE/EWRI standardized equations (Allen et al., 2005) using REF-ET© v2 (Allen, 2001). Crop coefficients (K_c) were determined by dividing the crop ET by the ET_o.

[1/] The mention of trade names of commercial products in this poster is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

The sunflower hybrid was Plant Triumph S 672 Nu sun It was planted on June 4, 2009 (Day of Year, DOY, 155), and emergence was on June 13th, DOY 164). Harvest was on September 18th (DOY 261). Plant density was 11 plants m^2 (~100 plants on each weighing lysimeter).

Figure 1. Top left, NE lysimeter, top right, SE lysimeter both on July 2nd; bottom left, NE lysimeter field, bottom right, SE lysimeter field, both on July 17th for 2009 at Bushland, Texas. Photos by USDA-ARS, Bushland. All views toward the East.

RESULTS

Figure 2 shows the 2009 growing season climate, and Table 1 presents the monthly means including reference ET means (ET_o—short crop; ET_r—tall crop). The growing season rainfall was near normal at 182 mm. Most of the rain occurred in June, July, and August (Table 1).

Table 1. Monthly means of weather variables for 2009 at Bushland, Texas.

	T_{min}	T_{max}	T_{dew}	U_2	R_s	B_P	Prec.	ET_o	ET_r
Month	°C			m s^{-1}	MJ m^{-2} d^{-1}	kPa	mm	mm d^{-1}	mm d^{-1}
June	15.4	31.3	11.7	4.00	24.4	88.2	61.1	7.2	10.0
July	16.7	32.2	13.5	3.67	26.0	88.8	68.2	8.6	8.7
August	16.1	31.3	13.6	3.87	24.9	88.8	73.7	6.8	9.3
September	10.9	26.5	9.0	3.28	19.5	88.9	10.8	4.9	6.9

Sunflower CH reached 1.2 m (Fig. 3) by early August and achieved full ground cover in mid July with LAI of 3.8-4.6 m^2 m^{-2}. Maximum LAI was 6.6 m^2 m^{-2} on the North field and 6.8 m^2 m^{-2} on the South field by early August (Fig. 3). TDM maximized at 1,600 g m^{-2} by early September.

ET was 644 mm on the NE lysimeter an 600 mm on the SE lysimeter. The maximum daily ET (Fig. 4) was about 15 mm d^{-1} while mid-season ET values ranged from 7-12 mm d^{-1}.

Achene, TDM yields, and WUE are summarized in Table 2. The achene yields on the lysimeters varied from 316 g m^{-2} on the NE lysimeter to 345 g m^{-2} on the SE lysimeter with field yields varying from 296 to 315 g m^{-2}. Lysimeter TDM yield was 2,439 g m^{-2} on the NE lysimeter and 2,771 g m^{-2} on the SE lysimeter and 1,1,83 g m^{-2} in the center section of the field. Yield WUE_y was 0.49 kg m^{-3} on the NE lysimeter and 0.58 kg m^{-3} on the SE lysimeter.. The oil fractions varied from 424 g kg^{-1} on the NE lysimeter to 411 g kg^{-1} n the SE lysimeter to an average of 405 g kg^{-1}in the field. Oleic acid ranged from 732 to 657 g kg^{-1} on the NE and SE lysimeters, respectively, to 670 g kg^{-1} in the field.

Table 3 presents a summary of the crop coefficient (K_c) values for both the ASCE-EWRI (Allen et al., 2005) short reference (ET_o) and tall reference (ET_r) and the FAO-56 (ET_o; Allen et al., 1998) K_c values. The mid-season K_c values were 0.91 for the ET_r reference and 1.24 for the ET_o reference. The contrasting FAO-56 (Allen et al., 1998) mid-season K_c for sunflower was 1.15. The crop development for this dwarf sunflower hybrid was considerable shorter for this planting date than the FAO-56 data.

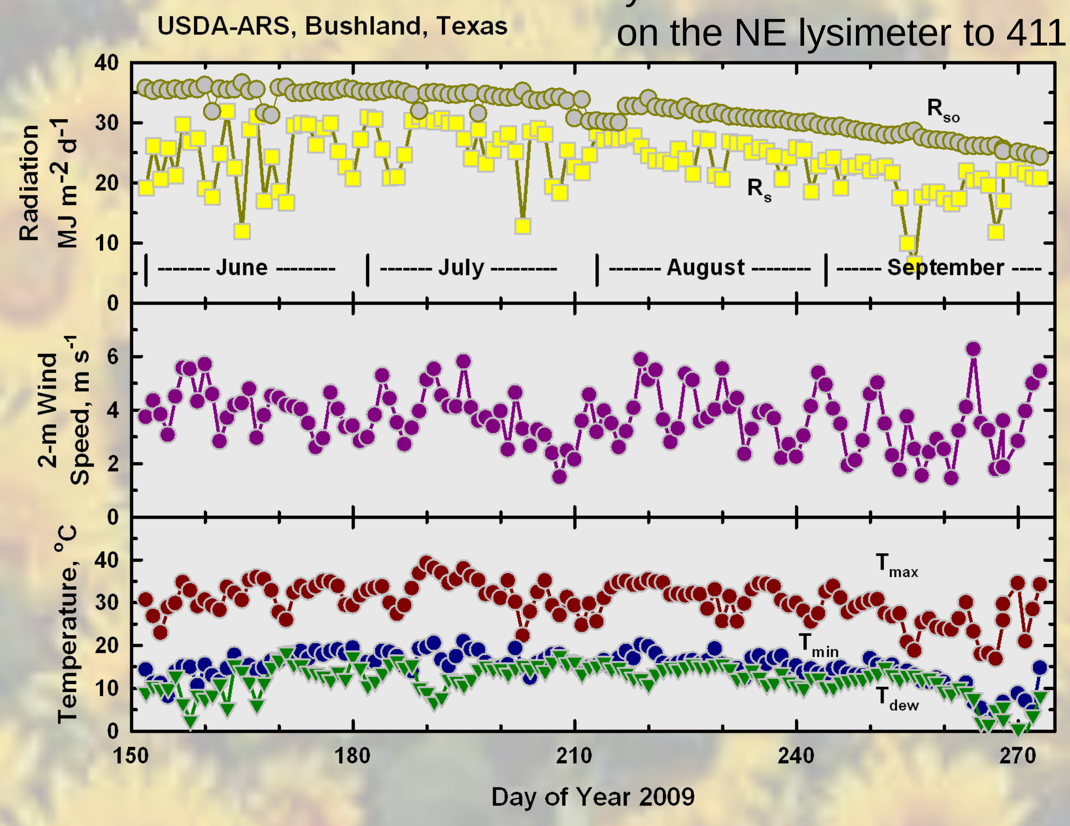

Figure 2. Weather variables during the 2009 season at Bushland, Texas

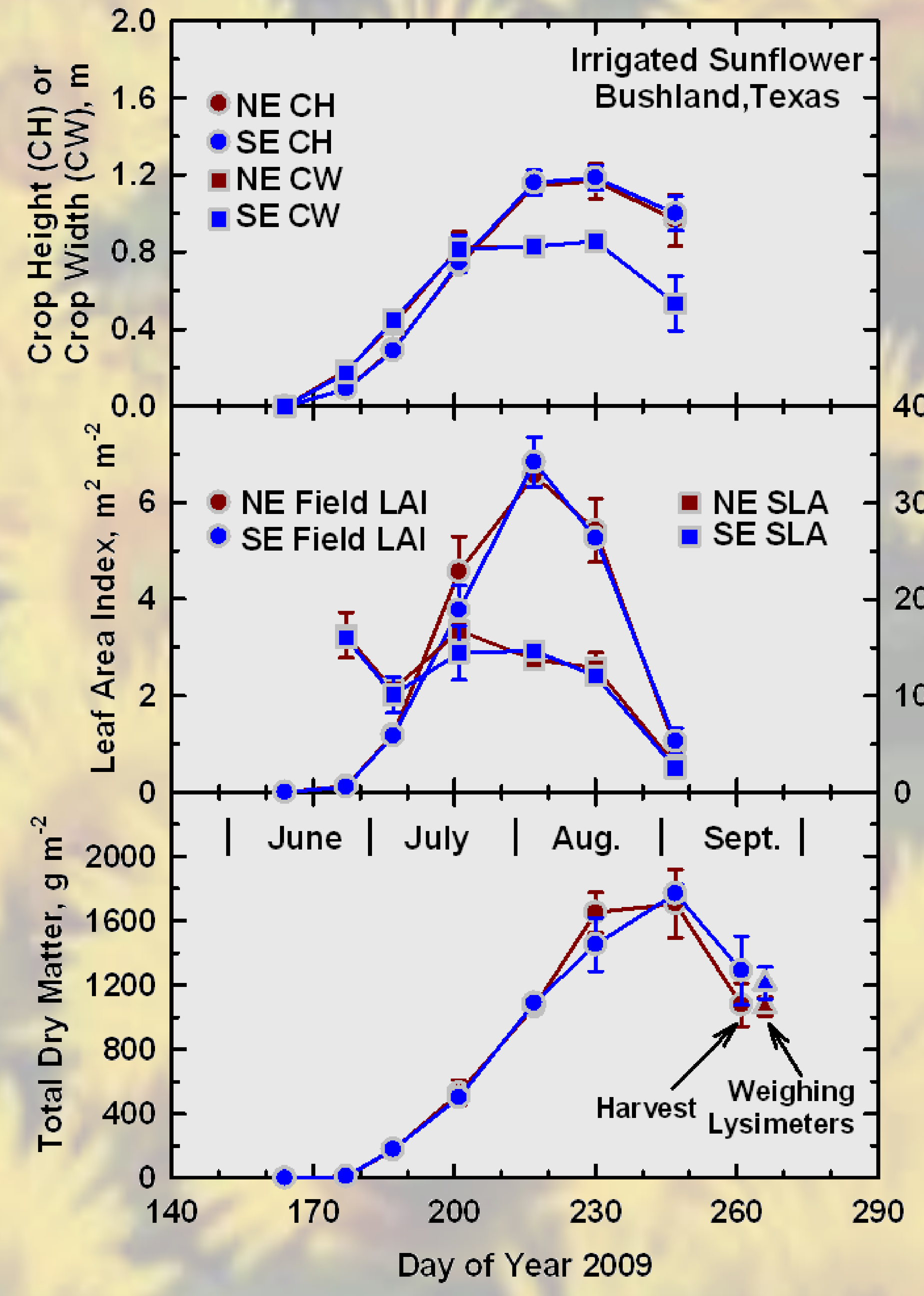

Figure 3 Sunflower development during the 2009 season at Bushland, Texas. Top is crop height (CH) and crop width (CW); middle is leaf area index (LAI) and specific leaf area (SLA); bottom is above-ground dry matter (TDM).

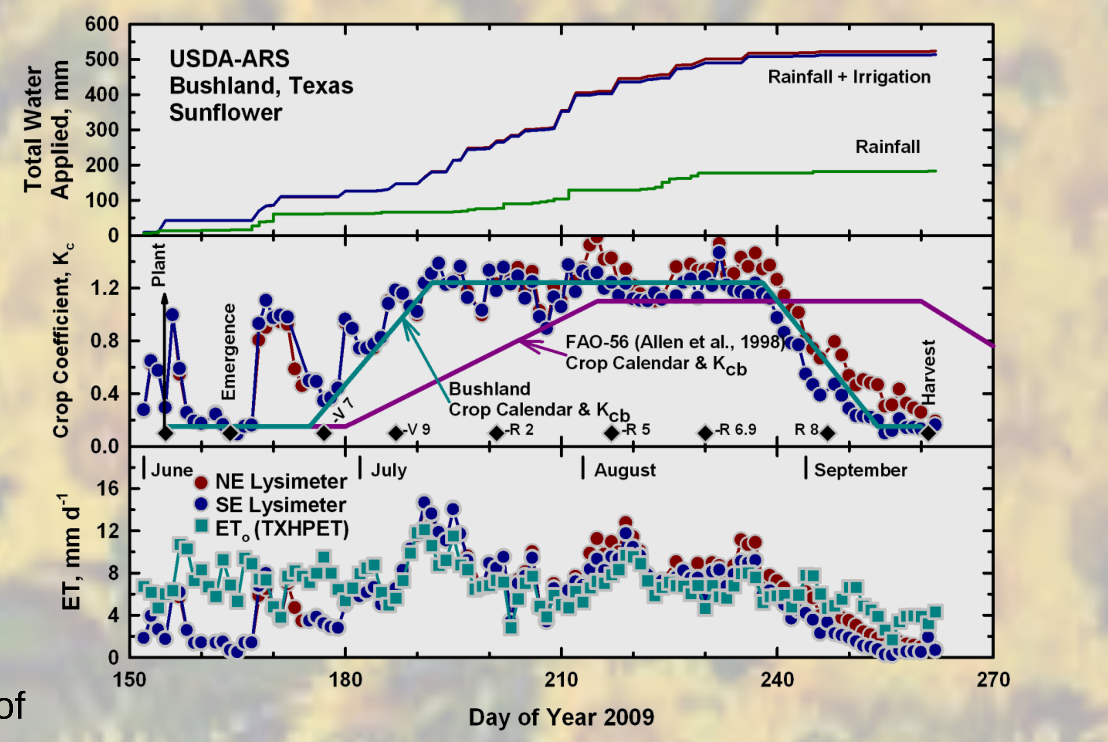

Figure 4. Sunflower ET (bottom), ET_o (bottom); crop coefficients (K_c) (middle) with crop development stage (Schneiter and Miller, 1981); rainfall and total applied water (top).

Table 2. Sunflower ET, achene yields, TDM yields, WUE, and oil fractions in 2009 at Bushland, Texas.

		ET mm	Yield g m^{-2}	TDM g m^{-2}	WUE_y kg m^{-3}	WUE_{dm} kg m^{-3}	Oil g kg^{-1}	Oleic Acid g kg^{-1}	Linoleic Acid g kg^{-1}
Lys	NE	644	316.3	2,439.1	0.49	3.79	424	732	172
Lys	SE	600	345.2	2,770.5	0.58	4.62	411	657	245
Field	W		315.2				409	681	225
Field	C		295.8	1,182.9			406	668	234
Field	E		299.8				401	659	243

Table 3. Crop coefficient summary for sunflower at Bushland, Texas in 2009.

	Init.	Dev.	Mid	Late	
	L_{int}	L_{dev}	L_{mid}	L_{late}	Total
	days				
Bushland	20	17	46	16	99
FAO-56	25	35	45	25	130
	K_{cini}	K_{cmid}	K_{cend}		
Bushland (ET_r)	0.10	0.91	0.10		
Bushland (ET_o)	0.15	1.24	0.15		
FAO-56 (ET_o)	0.15	1.15	0.35		

REFERENCES

Allen, R.G. 2001. REF-ET: Reference evapotranspiration calculation software for FAO and ASCE standardized equations, Version 2.0 for Windows. University of Idaho, Kimberly Research and Extension Center. 76 p.

Allen, R.G., l.S. Periera, D. Raes, and M. Smith. 1998. Cop evapotranspiration: Guidelines for computing crop water requirements. Irrig. and Drain. Paper No. 56. Rome, Italy: United Nations, Food and Agric. Org.

Allen, R.G., I.A. Walter, R.L. Elliott, T.A. Howell, D. Itenfisu, M.E. Jensen, and R.L. Snyder, R.L. (eds.). 2005. The ASCE standardized reference evapotranspiration equation. Am. Soc. Civil Engr., Water Resources Institute, Reston, VA. 59 p. with supplemental appendices.

Browne, C.L. 1977. Effect of date of final irrigation on yield and yield components of sunflowers in a semiarid environment. Aust. J. Exp. Agric. Anim. Husb. 17:482-488.

Gajri, P.R., K.S. Gill, M.R. Chaudhary, and R. Singh. 1997. Irrigation of sunflower (*Helianthus annuus* L.) in relation to tillage and mulching. Agric. Water Manage. 34:149-160.

Howell, T. A., A. D. Schneider, D.A. Dusek, T.H. Marek, and J.L. Steiner 1995. Calibration and scale performance of Bushland weighing lysimeters. Trans. ASAE 38:1019-1024.

Karam, F., R. Lahoud, R. Masaad, R. Kabalan, J. Breidi, C. Chalita, and Y. Rouphael. 2007. Evapotranspiration, seed yield and water use efficieny of drip irrigated sunflower under full and deficit irrigation conditions. Agric. Water Manage. 90(3):213-223.

Robinson, R.G. 1971. New crops for irrigated sandy soils in Minnesota. Sci. 27:10–11.

Schneiter, A.A., and J.F. Miller. 1981. Description of sunflower growth stages. Crop Sci. 21:901-903.

Soriano, M.A., F. Orgaz, F.J. Villalobos, and E. Fereres. 2004. Efficiency of water use of early planting of sunflower. Euro. J. Agron. 21:465-476.

Stone, L.R., A.J. Schlegel, R.E. Gwin, and A.H. Khan, A.H. 1996. Response of corn, grain sorghum, and sunflower to irrigation in the High Plains of Kansas. Agric. Water Manage. 30:251-259.

Unger, P.W. 1990. Sunflower. Chapter 25 in Irrigation of Agricultural Crops (eds. B.A. Stewart and D.R. Nielsen). Agron. Nomo. 30. ASA, CSSA, SSSA., Madison, Wis.

Unger, P.W., 1982. Time and frequency of irrigation effects on sunflower production and water use. Soil Sci. Soc. Am. J. 46:1072-1076.

USDA-NASS. 2010. 2008 Texas annual statistics bulletin and NASS web site at http://www.nass.usda.gov. Viewed on October 25, 2010.