DETERMINATION OF CONSUMPTIVE WATER USE OF CORN IN THE ARKANSAS VALLEY OF COLORADO (YEAR 2: 2014)

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Abstract. *Accurate calculations of crop consumptive water use or crop evapotranspiration (ET_c) of irrigated corn (Zea mays) are needed in the Arkansas Valley of Colorado. A locally-derived crop coefficient (K_{cr}) curve for corn is needed to convert alfalfa reference crop ET_{rs} calculated from the ASCE standardized equation to non-stressed corn ET_c at different stages of crop development. The objective of this study was to measure the seasonal ET_c of corn and develop a preliminary K_{cr} curve using data collected in 2014. A precision weighing lysimeter at Rocky Ford, Colorado was used to measure daily ET_c of furrow-irrigated corn grown under local weather and environmental conditions. The mass of an undisturbed soil monolith with an actively-growing corn crop contained in a steel tank (3 m x 3 m area; 2.4 m deep) was continuously monitored with a calibrated load cell to determine corn ET_c. Corn (Fontanelle 8V169RBC variety) was planted on the monolith and surrounding field (4 ha) on 5/6/2014. Crop height and soil water content were monitored weekly during the growing season. Hourly measurements of solar radiation, air temperature, wind speed, and humidity were used to calculate hourly and daily ASCE standardized ET_{rs} values. Daily K_{cr} values for corn were calculated as ET_c/ET_{rs}. Total season corn ET_c (5/6/2014 – 10/30/2014) was 726 mm. Average daily ET_c was 4.1 mm d^{-1}. The seasonal corn K_{cr} curve in 2014 was adequately represented ($R^2 = 0.81$) by a third order polynomial equation, with K_{cr} as a function of days after planting. The K_{cr} values were affected by delayed emergence of 30% (20 out of 66) of corn plants on the lysimeter, which may have slightly lowered the peak K_{cr} value compared to 2013 values. Corn grain water use efficiency (WUE) was 1.71 kg m^{-3}, which was comparable to published values for the High Plains.*

INTRODUCTION

Accurate estimates of crop consumptive water use are needed to effectively manage irrigation in the Arkansas River Basin of Colorado and to maintain compliance with the Arkansas River compact with Kansas. Consumptive water use is normally defined as water that is lost from the crop root zone of the soil through the processes of soil surface evaporation and transpiration from crop leaves. The two processes occur simultaneously and are difficult to separate. Therefore, the term evapotranspiration (ET) is commonly used to refer to both processes.

The American Society of Civil Engineers (ASCE) standardized reference ET equation (Allen et al., 2005) has been approved by the U.S. Supreme Court as the method of determining alfalfa reference crop ET for compliance with the Arkansas River compact (Littleworth, 2008). This equation requires accurate measurements of hourly weather data (solar radiation, air temperature, humidity, and wind speed) to calculate a reference crop ET (ET_{rs}), which is a measure of local atmospheric demand for water. Crop ET (ET_c) is then calculated by multiplying ET_{rs} by a crop coefficient (K_{cr}) that varies with crop growth and development. Simultaneous measurements of ET_c and ET_{rs} throughout the growing season are required to develop seasonal K_{cr} curves that represent local growing conditions. Daily K_{cr} values for a crop are calculated as $K_{cr} = \frac{ET_c}{ET_{rs}}$.

Corn is a dominant irrigated crop in the Arkansas River Basin and there is a need to develop a seasonal corn K_{cr} curve that represents local conditions. An accurate way to measure corn ET_c is to use a precision weighing lysimeter that measures ET_c based on changes in mass of an intact block of soil (monolith) containing an actively growing crop (Wright, 1988; ASCE, 1991, Marek, 2006). In 2006, construction of the precision weighing lysimeter for measuring crop ET was completed at the Colorado State University (CSU) – Arkansas Valley Research Center (AVRC) at Rocky Ford, Colorado. The monolith tank dimensions of the crop lysimeter are 3.0 m x 3.0 m x 2.4 m. The objectives of this study were to measure seasonal corn ET_c from the crop lysimeter operated in the Lower Arkansas Valley of Colorado during the 2014 growing season and develop a seasonal crop coefficient curve for corn that accounts for local environmental conditions in the Arkansas Basin.

MATERIALS AND METHODS

THE CROP LYSIMETER

The lysimeter is located at the Arkansas Valley Research Center (38° 2´ 17.30´´ latitude and 103° 41´ 17.60´´ longitude), approximately 3.2 km east of Rocky Ford in Otero County, Colorado (NW1/4 Sec 21, T23S, R 56W). The elevation at the site is approximately 1,274 m above mean sea level. The soil type is Rocky Ford; coarse-loamy, mixed, superactive, mesic Ardic Argiustoll.

The long-term average annual precipitation at the site is 300 mm, with May through August having the highest rainfall. The total average annual snowfall is 589 mm. The annual average minimum air temperature is 2.4 °C and the annual average maximum air temperature is 21 °C. The last spring frost (0.3 °C) occurs on or before May 1 and the first fall frost on or before October 5 in 50% of the years; thus the average length of the growing season for warm-season crops like corn is 158 days.

The crop lysimeter was patterned after the lysimeters at Bushland, Texas operated by USDA-Agricultural Research Service. Marek et al. (1988) provide details of the lysimeter design. The crop lysimeter consists of an inner tank with dimensions of 3.0 m x 3.0 m surface area x 2.4 m depth and an outer containment tank. Installation and calibration of the crop lysimeter was completed in 2006. The inner tank was filled with undisturbed soil (soil monolith) from the same field where the lysimeter is located (Fig. 1). The soil tank moves freely within the outer tank and the top edges of the two are separated by a 10-mm gap. The chamber between the two tanks houses the weighing mechanism, the drainage tanks, and data loggers and has standing room for half-a-dozen people. The weighing mechanism consists of a mechanical lever scale-load cell combination (mV V^{-1} output; 0.02% CV). Based on calibration of the load cell to measure the weight of the inner tank containing the soil monolith, a unit change in load cell output (1 mV V^{-1}) is equivalent to 74.58 mm of water. Thus, changes in load cell output are simply multiplied by

74.58 to obtain the amount of water lost through ET or drainage, or amounts of water gained through precipitation or irrigation. Water that percolates through the soil monolith is collected in two drainage tanks suspended from the scale frame that supports the soil tank, so that there is no overall weight change registered by the scale as water drains into the tanks. One tank collects water from the internal portion of the monolith and the other tank collects water from the perimeter of the monolith. Sommers et al. (2009) and Berrada et al. (2008) provide details on the installation, calibration, and management of the crop lysimeter.

The lysimeter load cell output is recorded every 2 s throughout each growing season. Fifteen-minute averages of the load cell output are used in the calculation of ET_c. The difference between beginning and ending load cell outputs (mV V^{-1}) on each hour are multiplied by 74.58 mm mV^{-1} V to obtain hourly rates of ET_c (mm h^{-1}).

Figure 1. The inner tank plus soil being lowered inside the containment tank of the crop lysimeter. Photo taken by Michael Bartolo.

The dimensions of the surrounding field are 158.5 m x 256.1 m (4.06 ha). Instrumentation for measuring rainfall, wind speed and direction, air temperature and humidity, net radiation, photosynthetically active radiation, and canopy temperature were installed above the lysimeter (Fig. 2). Soil temperature sensors were installed at 0.01 m, 0.04 m, 0.5 m, 1.0 m, and 2.0 m below the soil surface of the monolith. Heat flux plates were also installed 0.1 m below the soil surface. Two 3.8-cm diameter electromechanical steel tubes (EMT) were installed in the monolith to monitor soil water content with a neutron probe (503 DR Hydroprobe, CPN International, Inc.). The neutron probe was calibrated for every 30-cm depth increment of the lysimeter soil profile (Berrada et al., 2008). Also, soil temperature sensors and neutron probe access tubes were installed adjacent to the lysimeter. Meteorological sensors are measured every 6 seconds and load cell and sensor outputs are logged by Campbell Scientific CR-7 data loggers mounted in the underground chamber. Detailed descriptions of the sensors and their placement were given by Sommers et al. (2009). The environmental instrumentation was primarily installed for calculating reference ET using the ASCE standardized reference ET equation (Allen et al., 2005).

Figure 2. View of the crop lysimeter looking to the north east. The manhole for accessing the data logger, weighing mechanism, and drainage tanks is on the north side of the monolith; and micrometeorological sensors are mounted above the lysimeter.

CORN CROP MANAGEMENT

The corn crop on the lysimeter and the surrounding field were managed similarly. The corn seeds (Fontanelle 8V169RBC) were planted on 6 May 2014 at a density of 81,380 plants ha^{-1}; equivalent to 66 plants on the lysimeter. The seeds were spaced 16.2 cm in each row. Row spacing was 76 cm (30 in). Both the lysimeter and surrounding field were furrow-irrigated at approximately the same times (Table 1). Net irrigation amounts were determined from load cell readings of the monolith mass. Furrow irrigation of the lysimeter was done manually with the use of a metered hose to approximate water application rates on the surrounding field. Furrow spacing was 76 cm, with 4 furrows and 4 rows of corn on the lysimeter. Furrow irrigations on the surrounding field were done using siphon tubes conveying water from a concrete canal running along the south border of the field. The corn rows and furrows were oriented south-north, with a drainage ditch collecting tail water (surface runoff) at the north border of the field.

Table 1. Irrigation dates and amounts for corn in the crop lysimeter in 2014.

Irrigation #	Date	Net irrigation (mm)
1	9 May	83.3
2	28 May	40.0
3	2 Jun.	17.7
4	5 Jun.	11.6
5	10 Jun.	19.4
6	16 Jun.	82.4
7	7 Jul.	101.6
8	25 Jul.	59.6
9	22 Aug.	108.2
10	15 Sep.	107.2
Total		631.0

The fertilizer and chemical applications on the lysimeter and surrounding field are summarized in Table 2.

Table 2. Fertilizer and chemical applications for corn in 2014.

Date on monolith	Date on field	Chemical type	Name or grade	Application rate
14-Jan	14-Jan	Fertilizer	Cattle manure	168.5 kg ha^{-1}
30-May	30-May	Herbicide	Glyphosate (Buccaneer Plus)	2.34 L ha^{-1}
30-May	30-May	Herbicide	Status	0.22 L ha^{-1}
30-May	30-May	Surfactant	Non-ionic	0.0025 L L^{-1} water
30-May	30-May	Fertilizer (N)	Synergize	0.0125 L L^{-1} water
None	11-Jun	Fertilizer	30-0-0 liquid	112.1 kg ha^{-1}
7-Jul	None	Fertilizer	46-0-0 dry	241.9 kg ha^{-1}

WATER BALANCE AND CORN CROP MEASUREMENTS

A seasonal water balance for the crop lysimeter monolith was calculated based on load cell data (hourly changes in load cell readings, mV V^{-1}) converted to equivalent depth of water, as described in the "Crop Lysimeter" section of this report. The seasonal ET_c was calculated from water inputs [precipitation (P) and irrigation (Irr)], deep percolation (DP), and change in total soil profile water content (ΔS) from the water balance equation:

$$ET_c = P + Irr - DP + \Delta S \qquad (1)$$

No surface runoff was possible from the monolith surface because of the lysimeter tank walls that served as a barrier.

Weekly estimates of profile volumetric soil water content (SWC) from two access tubes within the monolith and four access tubes external to the monolith (9.1 m north, south, east, and west of lysimeter edges) were obtained using the calibrated neutron probe (503 DR Hydroprobe, CPN International, Inc.). As much as possible, profile SWC in the monolith was kept similar to the profile SWC of the surrounding field.

Weekly measurements of average corn canopy height on the lysimeter and surrounding field were taken beginning after corn emergence. Corn development stages (Iowa State University, 1993) were also observed weekly. All the biomass harvested from the lysimeter monolith was collected and air-dried to obtain corn grain, cob, and stalk dry mass. The moisture content (% by mass) of the air-dried corn grains harvested from the monolith was measured and used to convert air-dried mass to equivalent dry mass.

The water use efficiency (WUE) of the corn crop was also estimated for the season. The WUE was calculated by dividing corn grain dry mass from the monolith by total crop ET measured by the lysimeter for the season.

DEVELOPMENT OF CORN CROP COEFFICIENT CURVE

Daily crop coefficients (K_{cr}) based on the ASCE standardized alfalfa reference crop evapotranspiration (ET_{rs}) were calculated from simultaneous daily measurements of corn crop ET_c from the lysimeter and daily total alfalfa reference crop ET_{rs}. For each day, K_{cr} was calculated as:

$$K_{cr} = \frac{ET_c}{ET_{rs}} \tag{2}$$

The hourly version of the ASCE ET_{rs} equation (Allen et al., 2005) was used to calculate alfalfa reference ET_{rs} using hourly averaged micrometeorological data recorded by the CoAgMet RFD01 weather station at the CSU Arkansas Valley Research Center. Hourly ET_{rs} values were then summed for each 24-h period to obtain daily ET_{rs} values. The hourly ASCE ET_{rs} equation is given below.

$$\mathrm{ET_{rs}} = \frac{0.408\Delta(\mathrm{R_n} - \mathrm{G}) + \gamma\frac{\mathrm{C_n}}{\mathrm{T}+273}\mathrm{u_2}(\mathrm{e_s} - \mathrm{e_s})}{\Delta + \gamma(1 + \mathrm{C_d}\mathrm{u_2})} \tag{3}$$

where:
ET_{rs} = standardized alfalfa (tall) reference crop evapotranspiration (mm h^{-1}),
R_n = calculated net radiation at the crop surface (MJ m^{-2} h^{-1}),
G = soil heat flux density at the soil surface (MJ m^{-2} h^{-1}),
T = mean hourly air temperature at 1.5 to 2.5-m height (°C),
u_2 = mean hourly wind speed at 2-m height (m s^{-1}),
e_s = saturation vapor pressure at 1.5 to 2.5-m height (kPa),
e_a = mean actual vapor pressure at 1.5 to 2.5-m height (kPa),
Δ = slope of the saturation vapor pressure-temperature curve (kPa °C^{-1}),
γ = psychrometric constant (kPa °C^{-1}),
C_n = 66; numerator constant for tall reference and hourly time step (K mm s^3 Mg^{-1} h^{-1}) and
C_d = 0.25 (daytime), 1.7 (nighttime); denominator constants for tall reference and hourly time step (s m^{-1}).

Units for the 0.408 coefficient are m^2 mm MJ^{-1}.

The daily K_{cr} values were plotted against the number of days after planting through the season to develop the seasonal corn crop coefficient curve.

RESULTS AND DISCUSSION

SEASONAL WATER BALANCE AND CORN ET_C

The seasonal water balance for 2014 is shown in Table 3. The period covered 5/6/2014 to 10/30/2014 for a total of 178 days. Total corn ET_c was 726.34 mm. The maximum daily ET_c of 9.53 mm d^{-1} occurred on 7/24/2014. Precipitation in the 2014 growing season was 2.7 times the precipitation in 2013 (previous corn crop) that resulted in significant amounts of deep percolation. The profile soil water content (SWC) at the end of the growing season was 3.61 mm less than the SWC at the beginning of the season.

Table 3. Seasonal water balance of corn grown in the lysimeter in 2014 (5/6/14 - 10/30/14). All water balance components were determined from changes in the lysimeter mass.

Component	Depth of water, mm
ET_c	726.34
Irr	624.69
P	313.22
DP	218.18
ΔS	-3.61

Abbreviations: ET_c = crop evapotranspiration, Irr = irrigation, P = precipitation, DP = deep percolation, ΔS = change in soil water content.

Profile SWC was monitored to aid in irrigation scheduling and to assess root water extraction patterns throughout the growing season. Neutron probe readings of volumetric SWC at selected depths are shown in Figure 3. Readings from the 70 cm depth indicated that this layer had the least water-holding capacity. Irrigations or rainfall penetrated down to 190 cm below the monolith surface. SWC readings at the 190 cm depth exceeded field capacity (0.30 $cm^3\ cm^{-3}$) at least twice during the growing season. This was consistent with the observed deep percolation that occurred during the season. In general, the SWC readings indicated that the soil profile had adequate moisture to maintain the corn crop without water stress. The greatest variability in SWC was seen at the 30 cm and 70 cm depths, indicating that root water uptake was most active in these soil layers.

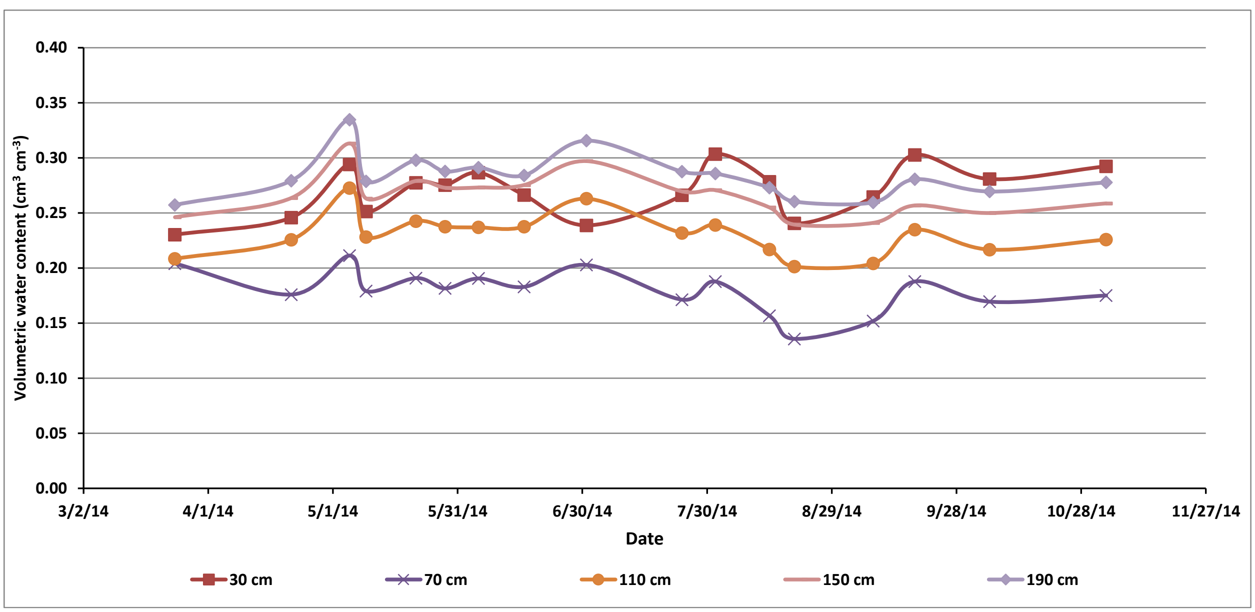

Figure 3. Volumetric soil water content ($cm^3\ cm^{-3}$) throughout the 2014 growing season as measured by neutron moisture meter at 30 cm, 70 cm, 110 cm, 150 cm, and 190 cm.

SEASONAL CORN CROP COEFFICIENT CURVE

Equation 2 was used to calculate daily values of corn K_{cr} for the entire growing season. Days when irrigation or precipitation occurred were excluded from the K_{cr} calculations to remove spikes in K_{cr} caused by evaporation of water from wet canopies or from the wetted soil surface. Figure 4 shows the scatter plot of daily K_{cr} values. The solid black line is a fitted K_{cr} curve using a third order polynomial, which explains 81% of the variability in K_{cr} with days after planting.

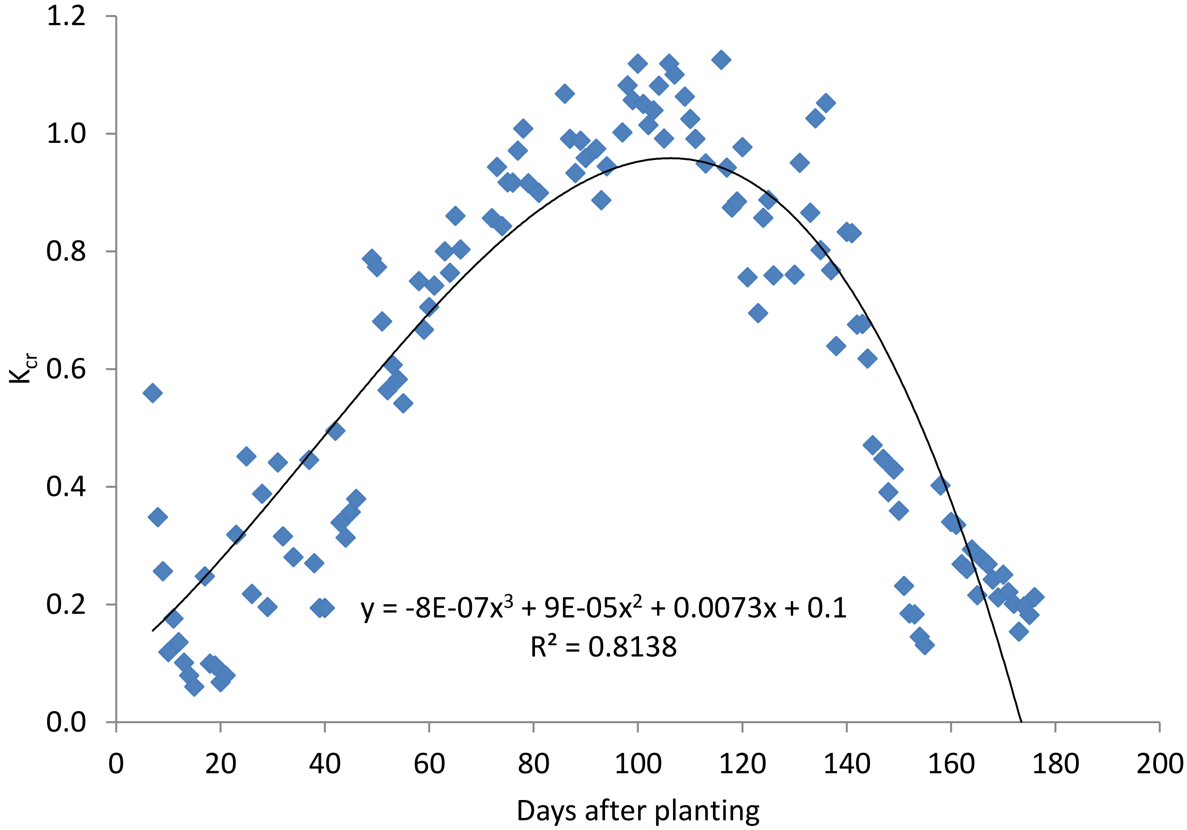

Figure 4. Seasonal corn crop coefficient (K_{cr}) curve for 2014 at Rocky Ford, CO. The equation shown can be used to estimate K_{cr} (shown as y) using days after planting (shown as x).

CORN GROWTH AND YIELD

Corn canopy height increased exponentially in early June, 2014 (Fig. 5). Afterwards, the increase in canopy height was approximately linear until mid-July. The rate of increase slowed down at the end of July, reaching a peak height of around 260 cm. Twenty seeds failed to germinate and emerge by 2 June 2014 and were replanted. This resulted in 30% (20 out of 66) of the corn plants on the monolith being delayed in growth relative to the other 70% of the plants. The height of delayed plants are shown in Fig. 5 as “shortest”. The tallest plants (70%) on the monolith were very similar in height to the corn plants outside (Exterior) of the lysimeter.

Delayed germination and growth of 30% of the plants on the lysimeter may explain why the average peak K_{cr} values in 2014 (Fig. 4) were slightly lower than peak values in 2013.

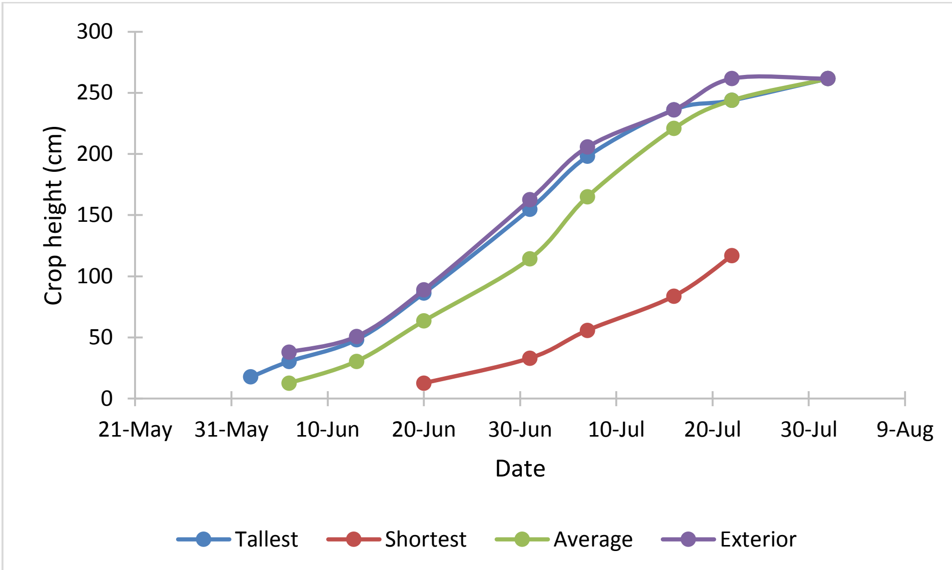

Figure 5. Corn canopy height (cm) during the 2014 growing season.

The observed average corn developmental stages in 2014 are summarized in Table 5. The corn growth stages defined by Iowa State University (1993) were used in documenting crop development. The dates of vegetative (V) and reproductive (R) stages were noted when at least 50% of the plants on the lysimeter were at the specified stage of development. The plants emerged from the ground on 5/23/2014, started their reproductive phase at the end of July, and were physiologically mature by 9/22/2014. Natural drying of the corn grains occurred until the 10/30/2014 harvest.

Table 5. Observed corn crop developmental stages on the lysimeter in 2014.

Date	Stage[a]	Description[a]
6 May	Planting	
23 May	VE	Emergence from the ground
6 June	V4	4^{th} leaf
13 June	V5	5^{th} leaf
1 July	V8	8^{th} leaf
7 July	V9	9^{th} leaf
16 July	V13	13^{th} leaf
22 July	VT	tasseling
9 August	R3	milk
22 August	R5	dent
22 September	R6	physiological maturity
30 October	Harvest	

[a]Based on vegetative (V) and reproductive (R) stages defined by Iowa State University (1993).

The total dry matter grain yield from the monolith was 11.43 kg. This was equivalent to a corn grain yield (dry matter) of 12,704 kg ha^{-1}. The seasonal corn ET_c in equivalent volume of water from the effective monolith surface area of 9.181 m^2 was 6.67 m^3 of water. The effective monolith surface area extends to the mid-point of the gap between the monolith and outer tank, and more accurately represents the ground area covered by the corn canopy on the monolith. The ratio of dry grain yield and total season ET_c, which is a measure of grain water use efficiency (WUE), was 1.71 kg m^{-3}. This grain WUE was close to the upper range of values reported by Tolk et al. (1998) for the high plains (1.05 – 1.63 kg m^{-3}).

CONCLUSION

Total season ET_c of corn for 2014 in the lysimeter in the Lower Arkansas Valley of Colorado was 726 mm (5/6/2014 – 10/30/2014). Average daily ET_c was 4.1 mm d^{-1} for the 178-day period, with a peak ET_c of 9.5 mm d^{-1} occurring on 7/24/2014. A total of 625 mm of irrigation water was applied on the lysimeter, in addition to 313 mm of precipitation. This resulted in 218 mm of deep percolation from the monolith. The soil water content of the soil profile decreased by 3.6 mm, from 5/6/2014 to 10/30/2014.

The seasonal corn K_{cr} curve in 2014 was adequately represented ($R^2 = 0.81$) by a third order polynomial equation.

After the 5/6/2014 planting date, the corn plants emerged on 5/23/2014 and were physiologically mature by 9/22/2014. However, 30% of the plants on the lysimeter were delayed in emergence and plant development; and this may have caused slightly lower K_{cr} values compared to the 2013 corn growing season. The corn canopy reached a peak height of 260 cm. Total dry matter grain yield from the lysimeter was 11.43 kg, or an equivalent of 12,704 kg ha^{-1}. Corn grain WUE was 1.71 kg m^{-3}, which was comparable to published values for the High Plains.

This study provided a second growing season of actual corn ET_c in the Lower Arkansas Valley of Colorado that can help guide irrigation water management for corn in the Valley and eventually provide better corn ET_c estimates for Arkansas River compact compliance.

ACKNOWLEDGEMENTS

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REFERENCES

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. Food and Agriculture Organization of the United Nations, Rome, Italy: FAO.

Allen, R.G., Walter, I.A., Elliott, R., Howell, T., Itenfisu, D., and Jensen, M. (Eds.). 2005. The ASCE standardized reference evapotranspiration equation. Environmental and Water Resources Institute of the American Society of Civil Engineers, Reston, Virginia.

ASCE. 1991. Lysimeters for evapotranspiration and environmental measurements: proceedings of the International Symposium on Lysimetry. Allen, R.G. (ed.), Honolulu, Hawaii, July 23-25, 1991. 444 p.

Berrada, A., Simmons, L., Straw, D., Bartolo, M., and Ley, T. 2008. “The large lysimeter at the Arkansas Valley Research Center: Ojectives and accomplishments” Technical Bulletin TB08-02, http://www.colostate.edu/Depts/AES/Pubs/pdf/tb08-2.pdf, Agricultural Experiment Station, Colorado State University, Fort Collins, Colorado.

Iowa State University. 1993. How a corn plant develops, Spec. Rept. No. 48. Ames, Iowa: Cooperative Extension Service. http://www.soilcropandmore.info/crops/Corn/How-Corn-Grows/ (Accessed 28 April 2014).

Littleworth, A.L. 2008. Kansas v. Colorado. Fifth and Final Report (vol. I). Supreme Court of the United States.

Marek, T.H., Schneider, A.D., Howell, T.A., and Ebeling, L.L. 1988. Design and construction of large weighing monolithic lysimeters. Trans. ASAE 31(2), 477-484.

Marek, T., Piccinni, G., Schneider, A., Howell, T., Jett, M., Dusek, D. 2006. Weighing lysimeters for the determination of crop water requirements and crop coefficients. App. Eng. Ag. 22(6):851-856.

Sommers, L.E., Andales, A.A., Bartolo, M.E., Berrada, A., Johnson, F.P., Ley, T.W., Schafer, B., Simmons, L.H., Straw, D., and Waskom, R.M. 2009. Project 5-30205 - Final Report: Direct Determination of Crop Evapotranspiration in the Arkansas Valley with a Weighing Lysimeter. Colorado Water Institute, Fort Collins, Colorado.

Tolk, J.A., Howell, T.A., Evett, S.R. 1998. Evapotranspiration and yield of corn grown on three high plains soils. Agronomy Journal 90(4):447-454.

Wright, J. L. 1988. Daily and seasonal evapotranspiration and yield of irrigated alfalfa in southern Idaho. Agronomy Journal 80 (4):662-669.