Improving Crop Water Use Efficiency in the Edwards Region: Construction of a Weighing Lysimeters for Managing Irrigation of Row and Vegetable Crops in the Edwards Aquifer Region

December 2007 Report Submitted to:

Texas Water Development Board

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Agricultural growers are increasingly subject to tighter water restrictions. In semiarid and arid lands and areas where water usage is regulated due to ecological protection programs, limited resources, and competitive demand, agricultural water users must plan an annual water budget. In the Winter Garden region of Texas, the Edwards Aquifer is the primary source of groundwater. However, pumping from this aquifer is regulated, and growers are limited to a maximum use of 2 acre feet of water per year. A variety of crops are grown under irrigation in this region, including corn, sorghum, spinach, onion, cotton, and wheat. Determining crop water requirements specific to each crop is key in providing growers with information to a) choose whether or not to lease or sell 50% of their groundwater rights, b) select which crops(s) to grow, and c) determine the timing and quantity of irrigation events.

In 2000, growers in this region irrigated 26,000 acres (Texas Water Development Board, 2001). It is estimated that approximately 50,000 to 60,000 acre feet of groundwater could be conserved each year by implementing proper irrigation techniques, including optimizing irrigation events. To optimize irrigation events, crop water requirements throughout the growing season must first be determined.

Determining crop water use and disseminating such information to growers in a reliable, useable, and affordable format involves the use of on-site microclimatological data and crop coefficients. Crop coefficients (K_C) are the ratio of the evapotranspiration of the crop at hand (ET_C) to a reference crop (ET_O). ET_O may be measured directly from a reference crop such as a perennial grass or computed from weather data. Weighing lysimeters (Marek et al. 2006) are employed to measure ET_O and ET_C directly by detecting changes in the weight of the soil/crop unit (lysimeters' detailed information on December 2005 report). Weather data is used to compute ET_O via equations such as the FAO Penman-Monteith (Allen et al., 1998). By utilizing the following equation, all that is needed to provide growers with real time irrigation recommendations (ET_C) are local weather stations.

$ET_C = K_C \times ET_O$

This report provides information on research projects executed using the two new in-ground weighing lysimeters funded by a grant awarded to the Uvalde County Underground Water Conservation District from the Texas Water Development Board.

The aim of this project is the determination of crop coefficients (K_c) for all crops grown in the Wintergarden region and to determine exact plant water usage or crop evapotranspiration (Et_c) $ET_c = ET_o \times K_c$. Irrigation scheduling can then be improved for private consultants and growers to avoid water over use and to more precisely meet the crop water demand to produce greater yields, crop quality, and enhanced water use efficiency. Results from these experiments are in the following tables:

Corn crop coefficients:

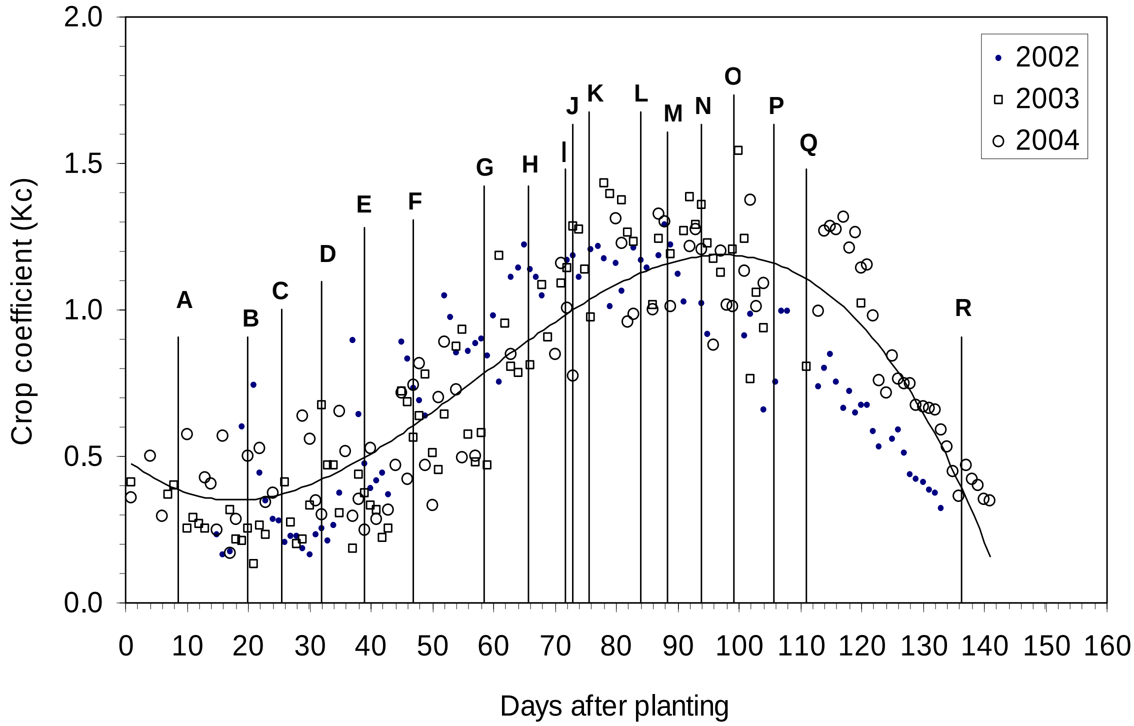

Figure 1. Corn crop coefficients as a function of days after planting in 2002, 2003 and 2004 at Uvalde, TX. Vertical lines represent 3-yr-average growth stages: A – emergence; B – 2 leaf; C – 4 leaf; D – 5 leaf; E – 6 leaf; F – 8 leaf; G – 10 leaf; H – 12 leaf; I – 14 leaf; J – tassel; K – silk; L – blister; M – milk; N – dough; O – dent; P – 1/2 mature; Q – black layer; R – harvest.

Figure 1 is a graphical representation of the crop coefficients developed for the Wintergarden region. Three years of data have been combined due to similar growing conditions. The data developed in the Wintergarden represent a great improvement from those developed by the FAO. Wintergarden data are growth stage specific and allow growers to use the proper K_c at a given growth stage of his/her crop. The implementation of FAO K_c based to an “initial, middle or end” stage of the crop is subject to interpretation that can be different from growers to growers.

Table 1. Corn crop coefficients (Kc) determined at Uvalde, Texas in comparison to those from Bushland, Texas and from FAO.

Growth stage	Uvalde	Bushland
Emergence	0.35	0.35
2-leaf	0.35	0.45
4-leaf	0.40	0.70
6-leaf	0.45	0.85
8-leaf	0.55	1.00
10-leaf	0.70	1.15
12-leaf	0.80	1.20
14-leaf	0.90	1.25
Tassel	1.00	1.25
Silk	1.00	1.30
Blister	1.05	1.30
Milk	1.15	1.30
Dough	1.20	1.20
Dent	1.20	1.00
1/2 mature	1.20	0.90
Black layer	1.15	0.70

FAO

Growth stage	Kc
Kc ini	0.30
Kc mid	1.20
Kc end	0.35

The comparison between crop coefficients developed at Bushland and those developed in the Wintergarden (Table 1), show differences during the active plant growth stages. Implementing regionalized crop coefficients can result in significant water savings.

Spinach crop coefficients:

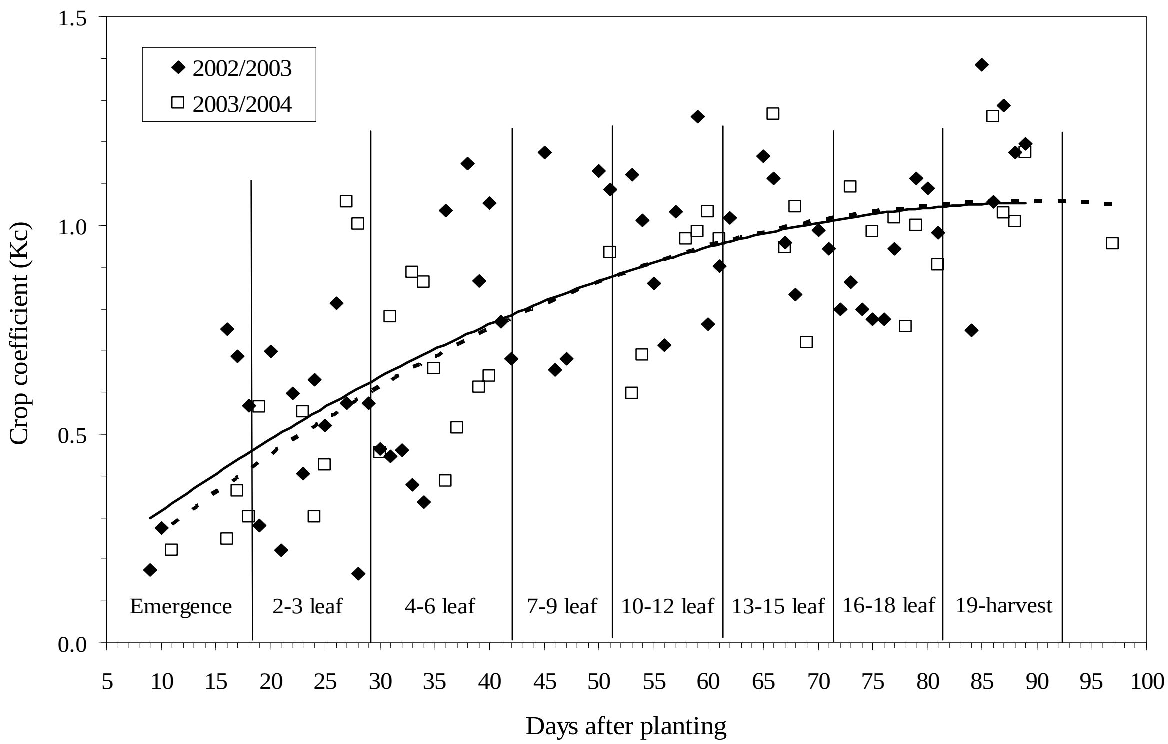

Figure 2. Spinach crop coefficients as a function of days after planting in 2002/2003 and 2003/2004 at Uvalde, TX. Vertical lines represent 2-yr-average growth stages.

Table 2. Spinach crop coefficients determined at Uvalde, Texas in comparison to those from FAO.

	Uvalde	
Growth Stage	2002	2003
Emergence	0.35	0.35
2-3 leaves	0.55	0.50
4-6 leaves	0.70	0.70
7-9 leaves	0.80	0.85
10-12 leaves	0.90	0.90
13-15 leaves	0.95	1.00
16-18 leaves	1.00	1.05
19 - harvest	1.05	1.05

FAO

Growth stage	Kc
Kc ini	0.70
Kc mid	1.00
Kc end	0.95

Availability of growth stage related crop coefficients for Spinach can improve precision application of irrigation compared to the crop coefficients developed by FAO

Onion crop coefficients:

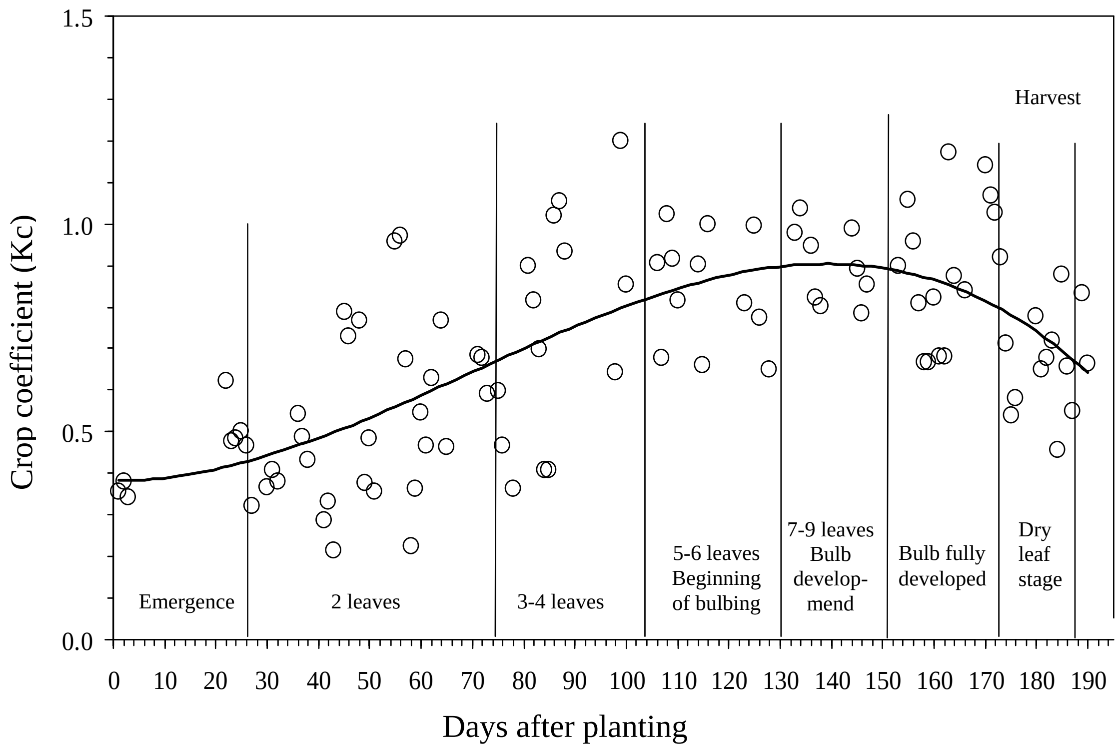

Figure 3. Onion crop coefficients of onion as a function of days after planting in 2002/2003 at Uvalde, TX.

Table 3. Onion crop coefficients determined at Uvalde, Texas in comparison with those from FAO

Growth Stage	Uvalde
Emergence	0.40
2 leaves	0.55
3-4 leaves	0.75
5-6 leaves Beginning of bulbing	0.85
7-9 leaves Bulb development	0.90
Bulb fully developed	0.85
Dry leaf stage	0.70

FAO

Growth stage	Kc
Kc ini	0.70
Kc mid	1.05
Kc end	0.75

Although we only have 1 year of data for onion crop coefficients, the difference in values and the availability of growth stage specific values, can provide significant water savings.

Cotton crop coefficients:

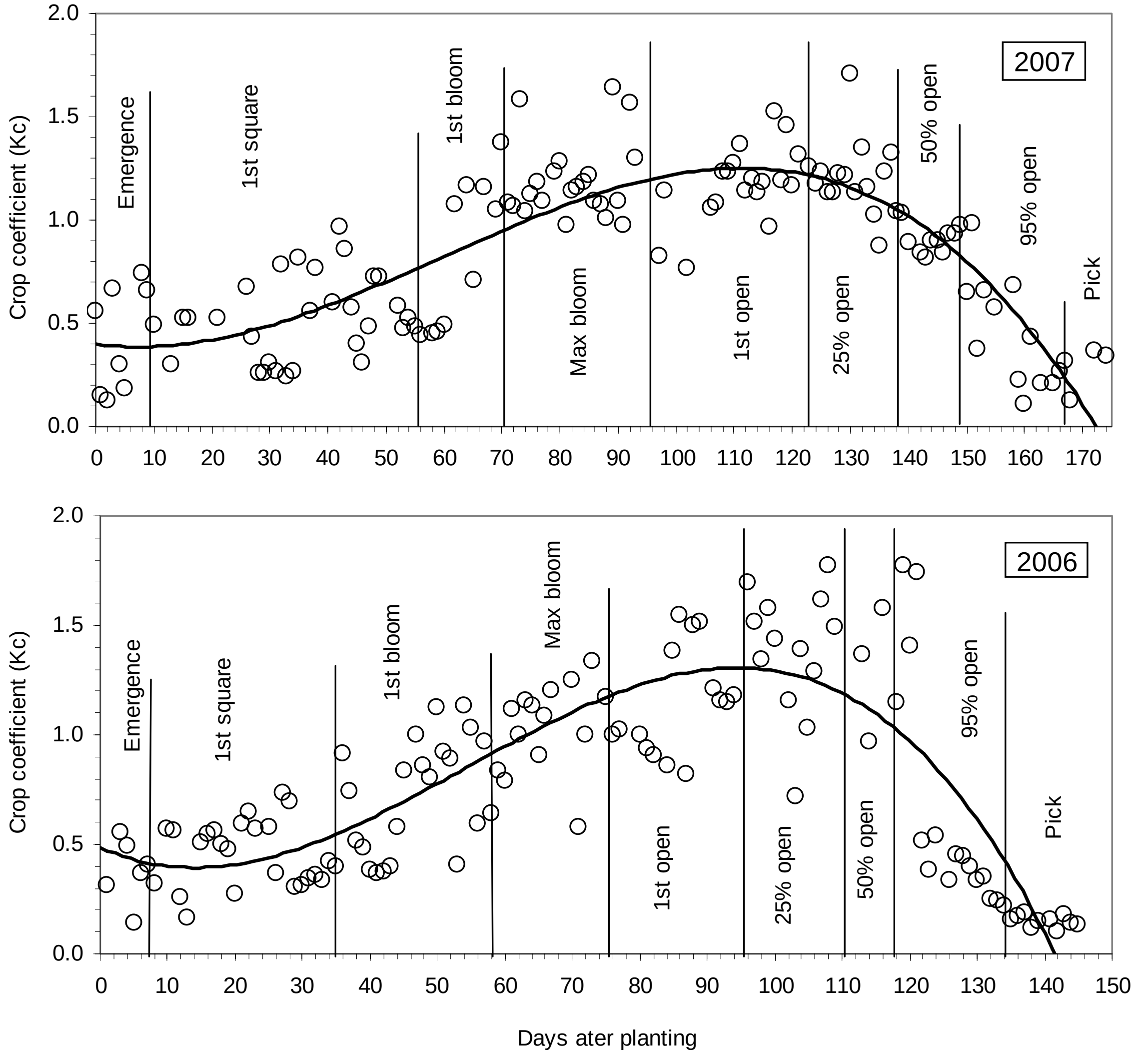

Figure 4. Crop coefficients of cotton as a function of days after planting in 2006 and 2007 at Uvalde, TX.

Table 4. Cotton crop coefficients (Kc) determined at Uvalde, Texas and comparison to those from Bushland, Texas and from FAO.

Growth Stage	Uvalde	Bushland
Seeding	0.40	0.2
1st square	0.45	0.22
1st bloom	0.80	0.44
Max bloom	1.10	1.10
1st open	1.23	1.10
25% open	1.25	0.83
50% open	1.05	0.44
95% open	0.60	0.44
Pick	0.10	0.10

FAO

Growth stage	Kc
Kc ini	0.35
Kc mid	1.15-1.20
Kc end	0.75-0.35

Cotton crop coefficients are reported in figure 4 and table 4. The graphs in figure 4 are separated by year given the extremely dry conditions of 2006 compared to the extremely wet conditions of 2007. When compared to the data reported from the high plains region we found differences during the early part of the growing season. Once again, when compared to the FAO data the availability of growth stage specific values provides better opportunities for precise water applications.

Wheat crop coefficients:

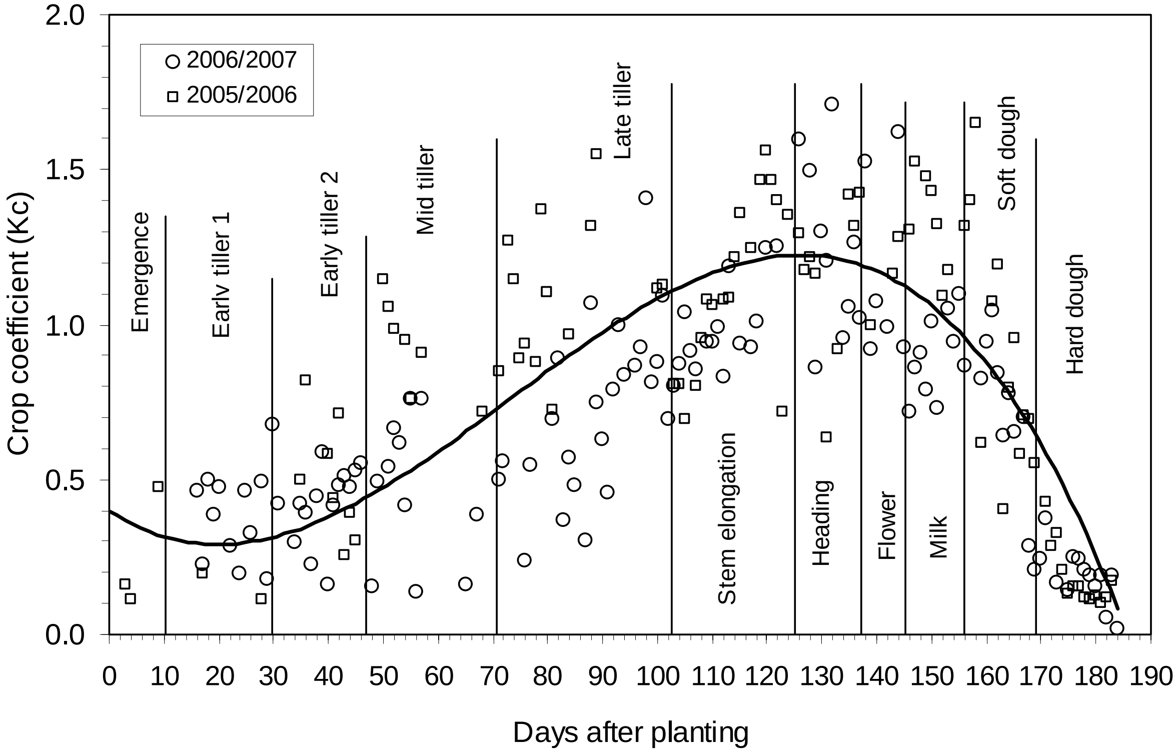

Figure 5. Crop coefficients of wheat as a function of days after planting in 2005/2006 and 2006/2007 at Uvalde, TX. Vertical lines represent a yr-average growth stages.

Table 5. Wheat crop coefficients determined at Uvalde, Texas in comparison to those from Bushland, Texas and from FAO.

Growth Stage	Uvalde	Bushland
Emergence	0.53	0.50
Early tiller 1	0.40	0.50
Early tiller 2	0.43	0.45
Mid tiller	0.63	0.90
Late tiller	0.93	1.00
Stem elongation	1.18	1.25
Heading	1.23	1.35
Flower	1.18	1.30
Milk	1.08	1.10
Soft dough	0.85	0.90
Hard dough	0.35	0.70

FAO

Growth stage	Kc
Kc ini	0.70
Kc mid	1.15
Kc end	0.25

No significant differences were found between the crop coefficients developed in the High Plains region and those developed for the Edwards region. FAO crop coefficient for the initial growth stage is significantly higher then the value recommended for the Edwards region and the High Plains.

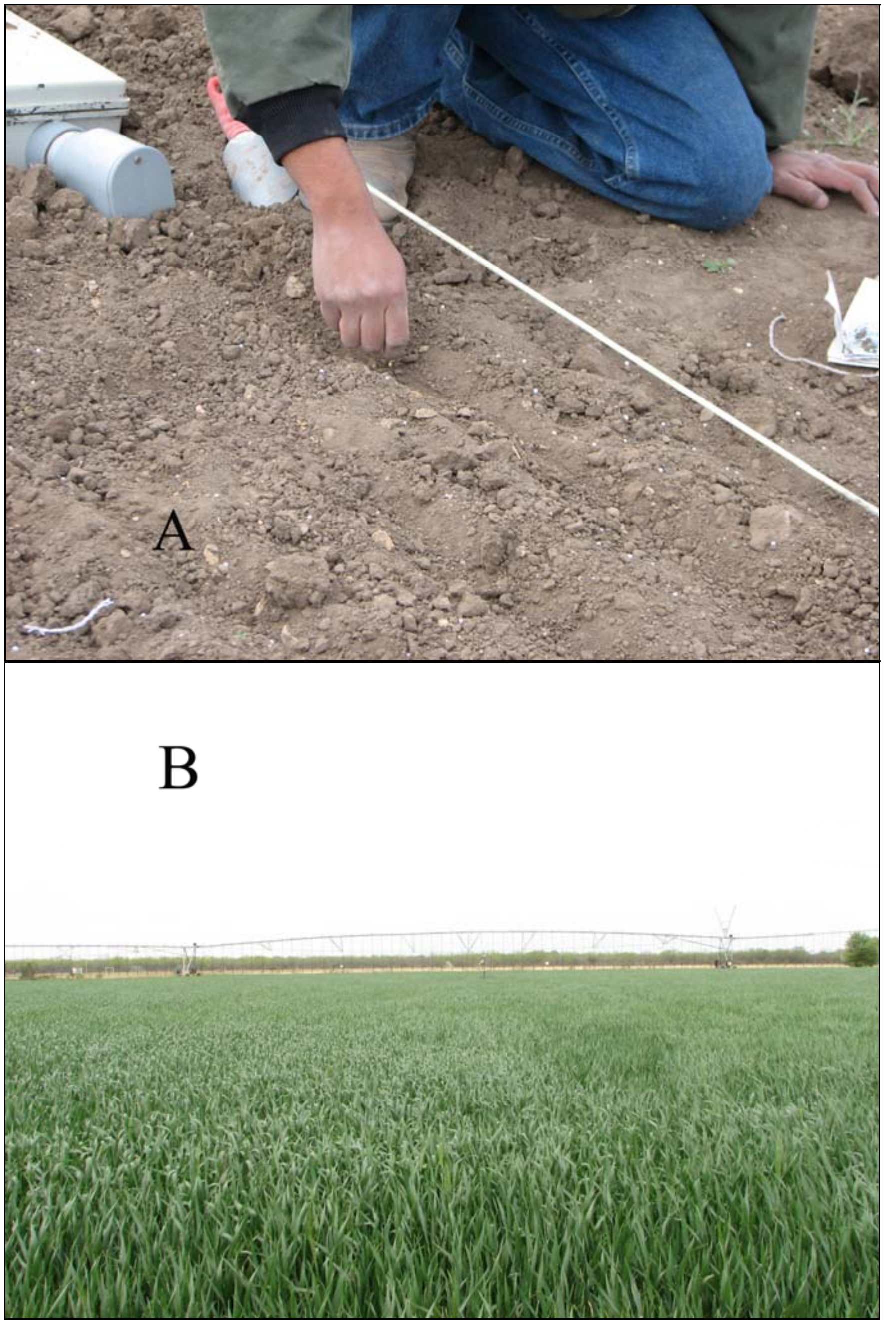

Figure 6. A. Picture showing hand-seeding in the lysimeter plot and (B) wheat during the growing season in the same area at the Texas A&M Agricultural Research and Extension Center - Uvalde.

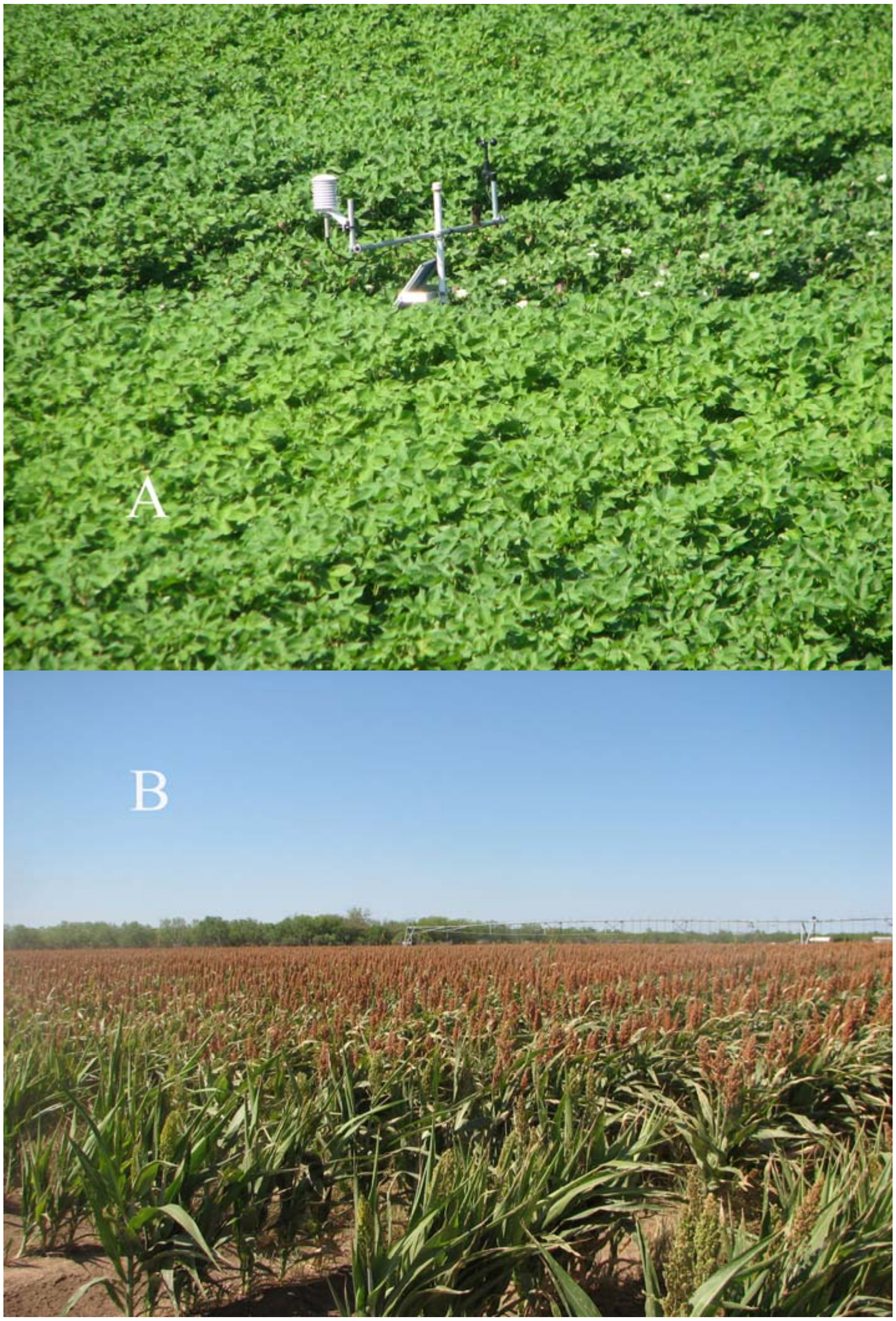

Figure 7. A: Picture showing cotton during the growing season in the lysimeter plot and (B) sorghum late in the growing season in the lysimeter field at the Texas A&M Agricultural Research and Extension Center - Uvalde.

References

Allen et al., Crop Evapotranspiration, 1998. FAO Irrigation and Drainage paper 56.

Marek et al. Weighing lysimeters for the determination of Kc, 2006. Applied Eng. Agri. 22: 851-856