DETERMINATION OF HEAT UNIT BASED CROP COEFFICIENT FOR ALFALFA IN WESTERN ARIZONA

E. C. Martin, S. W. Winans, D. Esquerra

Abstract

Alfalfa is the second largest production crop grown in Arizona with an estimated 150,000 acres of production in 1993. Water requirements for alfalfa have been estimated at 6 acre-feet per year. These two facts together make it imperative that data be gathered to help growers apply their irrigation water efficiently while maintaining their yields. In 1994, a study was initiated in the Parker Valley region of La Paz County, Arizona, to measure daily water use in alfalfa. Two sites were chosen for measurement: one site was a surface irrigated field located at the Quail Mesa Farm; the second site was a surface irrigated field located on the Colorado River Farm. The two sites were chosen to give a contrasting schedule of irrigation and allow for data collection at differing times throughout the year. Nine neutron probes were installed in each field, three 1/3 in from the head, three in the center, and three 1/3 in from the tail on one field at each location. Neutron probe readings were taken at 18", 30", 42", and 54" depths below the soil surface to measure soil moisture from 1'-2', 2'-3', 3'-4', 4'-5'. The soil moisture for the top foot was determined by gravimetric sampling. The data gathered by this study was used to compare with data used in AZSCHED, a computerized irrigation scheduling program. With this data, determination of alfalfa water used based on heat units after cutting was made to help growers better use their irrigation water.

Introduction

In an effort to better quantify water use in alfalfa, a study was begun to measure the average daily water use by alfalfa grown in La Paz County, Arizona. Over 40,000 acres of alfalfa hay were cropped in 1993 in La Paz County. Most of the alfalfa is surface irrigated using a variety of application techniques from raised beds with syphon tubes to side gates with planting on the flat. Sprinkler irrigation is also used in the valley, with several center pivot, side-roll and linear move systems in use.

Traditional irrigation scheduling used in alfalfa production is to irrigate after cutting and then irrigate again, one or two times before the next cutting, depending on the soil type, the amount of irrigation water applied and climatic conditions. Most growers follow a calendar schedule that they have developed over time through experience. Although this method has worked well for most growers, in times of non-normal weather conditions, the calendar schedule can cause problems. This is true not only when temperatures are above normal, but also when temperatures are below normal. To help avoid these pitfalls, data could be collected to develop water use based on heat units, not days after cutting. In this way, the heat unit accumulation takes care of the temperature extremes and allows the grower to irrigate in a more timely manner.

To help growers use heat-unit based water use data, the University of Arizona's Department of Agricultural and Biosystems Engineering developed a computerized irrigation scheduling program called AZSCHED. The AZSCHED (AriZona irrigation SCHEDuling) program (Fox et. al, 1992) has been used for several years with much success on cotton (Clark, et. al, 1991; Clark, et. al, 1990), wheat (Clark and Carpenter, 1990; Clark and Carpenter, 1991), and other crops (see Table 1 for a listing of available crops). Using a checkbook method of water balancing, AZSCHED utilizes real time weather data to estimate a reference crop evapotranspiration (ET_r) using the modified Penman equation (Doorenbos and Pruitt, 1977). Then, using a crop coefficient (k_c), crop evapotranspiration (ET_c) is calculated. Using soil-water data entered by the user along with irrigation and rainfall data, the program gives information on daily water use by the crop and amount of soil water available to the crop.

AZSCHED can schedule up to 60 fields per data file and the user can have an unlimited number of data files. There are 15 crops available for use with AZSCHED. The crop coefficient data were originally developed from work done by Erie et al.(1981). The Erie work produced data on water use by several crops grown in the central region of the state. The water use data were used in conjunction with historical weather data to develop crop coefficients. The crop coefficients were normalized by heat-units (Scherer et. al, 1990) to allow for use of the program over a large area.

Alfalfa was recently added to the list of crops available through AZSCHED. Like the other crop data in AZSCHED, the alfalfa data were based on work done by Erie et. al (1981). Before AZSCHED can be field tested for alfalfa, the crop water use data must first be verified. Data from this study will help to fine tune the alfalfa data in AZSCHED.

Materials and Methods

This study was conducted at two sites in the Parker Valley region of La Paz County. One site was located at the Quail Mesa Farm. This site was irrigated using side ports with the alfalfa planted on beds. The other site, located on the Colorado River Farm, was surface irrigated with the alfalfa planted on the flat. The two sites were chosen because of their difference in irrigation techniques and soil type. The Quail Mesa site was a sandy loam soil type while the soil at the Colorado River Farm was a sandy clay loam and contained more clay.

The setup and measurements taken were the same for both sites. Initially, nine neutron probe access tubes were installed in one field at each site. The tubes were placed with three parallel tubes, approximately 50' apart, 1/3 in from the head of the field, three tubes in the center of the field, and three tubes 1/3 from the tail-end of the field. The tubes were calibrated for the probe at one foot increments down to 54". Readings were taken at 18", 30", 42", and 54", to represent soil moisture at 1'-2', 2'-3', 3'-4', and 4'-5' below the soil surface. To obtain an estimate of soil moisture in the top foot, gravimetric samples were taken in three locations in the field (head, center and tail). The gravimetric samples were weighed wet, dried in an oven, and then weighed again to determine moisture content.

Measurements were taken in accordance to irrigation and cutting schedule. The regular schedule was to measure soil moisture 1-3 days after an irrigation; then just before the next irrigation or cutting, which ever came first. When possible, measurements were taken just after a cutting and prior to the following irrigation.

In addition to the soil moisture measurements, weather data were collected at the AZMET weather station located in the Parker Valley. The daily weather data was used to calculate daily water use for grass (ET_o). The common formula used by most irrigation scheduling programs, including AZSCHED, is:

$$ET_c = ET_r * k_c \qquad [1]$$

Where:

ET_c = Evapotranspiration (water use) of crop (in this case, alfalfa)
ET_r = Evapotranspiration (water use) of reference crop (in this case, grass)
k_c = Crop coefficient

The data gathered from the soil measurements yielded water use by alfalfa (ET_c). Weather data collected at the AZMET station allowed for the calculation of water use by grass (ET_r). With these two inputs, the crop coefficient values (k_c) were calculated.

Results and Discussion

Water use data were collected throughout the summer of 1994, from April through August. Using the neutron probe data, soil moisture loss over the measurement periods were determined and an average daily water use was calculated for each site. Figures 1 and 2 show the average daily water use during the measurement period.

For the Colorado River Farm in Fig. 1, the initial measurement interval prior to late April was too long and there were not enough measurements taken prior to cutting to show peak water use. However, subsequent readings were completed in a timely manner showing peak water use to be about 0.6 inches per day in late July, early August. The Quail Mesa data (Fig. 2), was a more complete set. The daily water use peaked to 0.5 inches per day in April to a high of about 0.6 inches per day in July/August. The cutting dates, for both Figs. 1 and 2, occur when the water use curve takes a steep downward turn just after reaching the peak. Both these data sets agree with each other, although the timing of irrigation events and cuttings were different.

The data presented in Figs. 1 and 2 show the water use over 5 to 6 months. However, as previously mentioned, water use should be linked to heat units after cutting, not days after cutting, to allow for non-normal weather conditions. In Fig. 3, data from both the Colorado River Farm and the Quail Mesa Farm data are shown for the month of July. Unlike the previous two graphs, this data shows water use versus heat units after cutting. Once again, there is good correlation between the data gathered at the Colorado River Farm and the Quail Mesa Farm.

Using weather data collected at the AZMET station, grass water use data (ET_r) was calculated and then k_c values were determined. The k_c values calculated based on heat units should be the same regardless of the location or the time of year. Taking all of the daily water use data shown in Figs. 1 and 2, relating this data to heat units after cutting, and then dividing it by average water use in grass (see equation 1), k_c values can be determined. The k_c values are shown in Fig 4. For both the Colorado River and Quail Mesa sites, the k_c values are similar through the range of heat units. Additionally, the default data from the AZSCHED program is shown. The AZSCHED curve seems to fit the measured data quite well, although it does seem to be a bit high just after cutting.

Conclusion

The data gathered in this study will be used to help better define water use patterns in alfalfa production. As shown in the data, there was very little differences in water use between the two surface systems. The data show that the initial estimates of k_c values used in AZSCHED are fairly close to the measured data. Although some slight adjustment may be required, the estimated water use values in AZSCHED do seem reasonable. The next step will be to gather more data to help refine water use patterns and k_c values even more. Information such as that gathered in this study will help growers in La Paz County as well as other areas, better use their irrigation water.

References

Clark, L.J. and E.W. Carpenter, 1990. A Comparison of Irrigation Scheduling Methods on Durum Wheat. College of Agriculture Report, Series P-84. 6pp. University of Arizona, Tucson, AZ.

Clark, L.J. and E.W. Carpenter, 1991. The Use of AZSCHED to Schedule Irrigations on Wheat. College of Agriculture Report, Series P-90. University of Arizona, Tucson, AZ.

Clark, L.J., E.W. Carpenter, T. Scherer, D. Slack, and F. Fox. 1990. Irrigation Scheduling on Long Staple Cotton. College of Agriculture Report, Series P-81. 5pp. University of Arizona, Tucson, AZ.

Clark, L.J., E.W. Carpenter, T. Scherer, D. Slack, and F. Fox. 1991. Irrigation Scheduling on Long Staple Cotton. College of Agriculture Report, Series P-87. 8pp. University of Arizona, Tucson, AZ.

Doorenbos, J. and W.O. Pruitt, 1977. Guidelines for Predicting Water Requirements. FAO Irrigation and Drainage Paper No. 24. FAO, Rome. 144p.

Erie, L.J., O.F. French, D.A. Bucks and K. Harris. 1981. Consumptive Use of Water by Major Crops in the Southwestern United States. USDA, Conservation Res. Rep. No. 29, 42pp.

Fox, F.A., Jr, T.F. Scherer, D.C. Slack and L.J. Clark. 1992. Arizona Irrigation Scheduling (AZSCHED Version 1,01): Users Manual. Cooperative Extension. University of Arizona, Tucson, AZ. Publication number: 191049.

Scherer, T.F., F. Fox, Jr., D.C. Slack and L. Clark. 1990. Near real-time irrigation scheduling using heat-unit based crop coefficients. Proceedings of the 1990 ASCE Nat. Conf. on Irr. and Drainage Egr. July 9-13, 1990. Durango, CO.

Table 1. Crops available for scheduling using the AZSCHED program.

Cotton	Grain Sorghum	Cauliflower
Sweet Corn	Safflower	Green Onions
Wheat	Late Grapes	Potatoes
Barley	Cantaloupe	Carrots
Soybeans	Broccoli	Lettuce

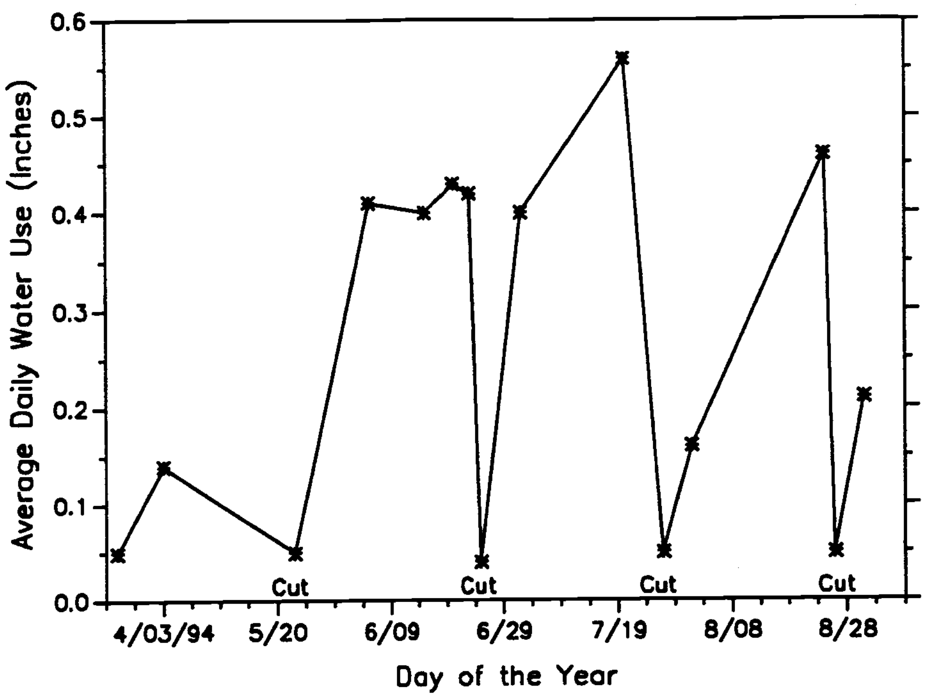

Figure 1. Average daily water use for alfalfa at the Colorado River Farm. Parker, Arizona, 1994.

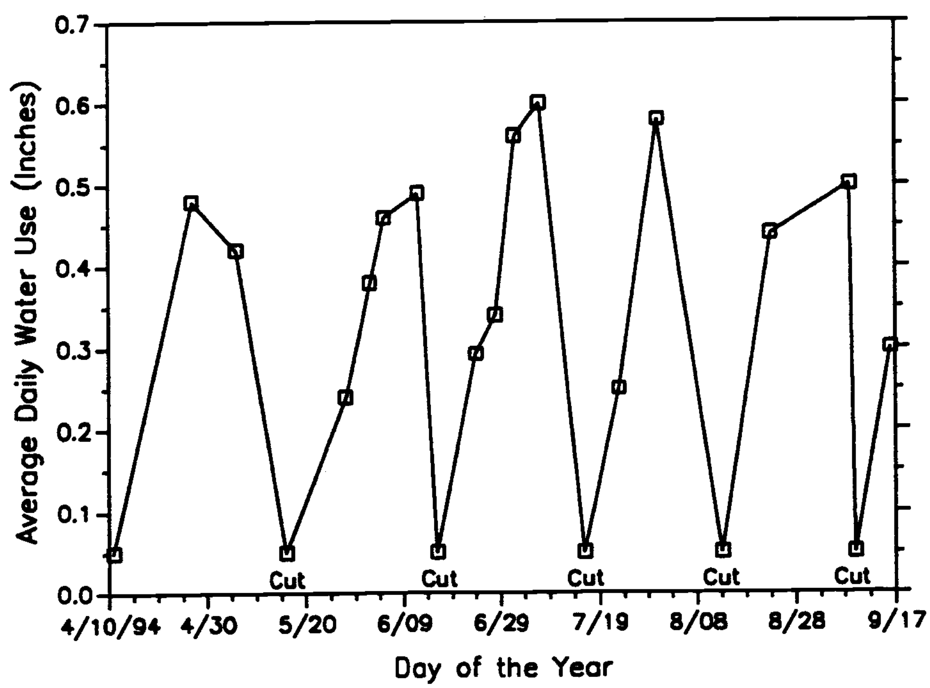

Figure 2. Average daily water use for alfalfa at Quail Mesa Farm. Parker, Arizona, 1994.

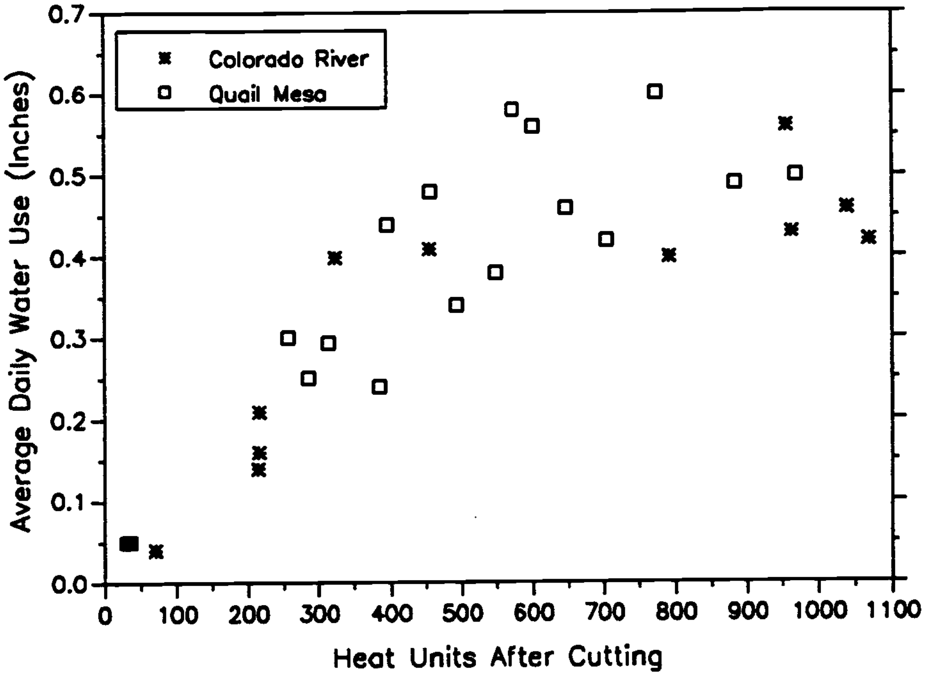

Figure 3. Average daily water use for all readings, all sites based on heat units after cutting. Parker, Arizona, 1994.

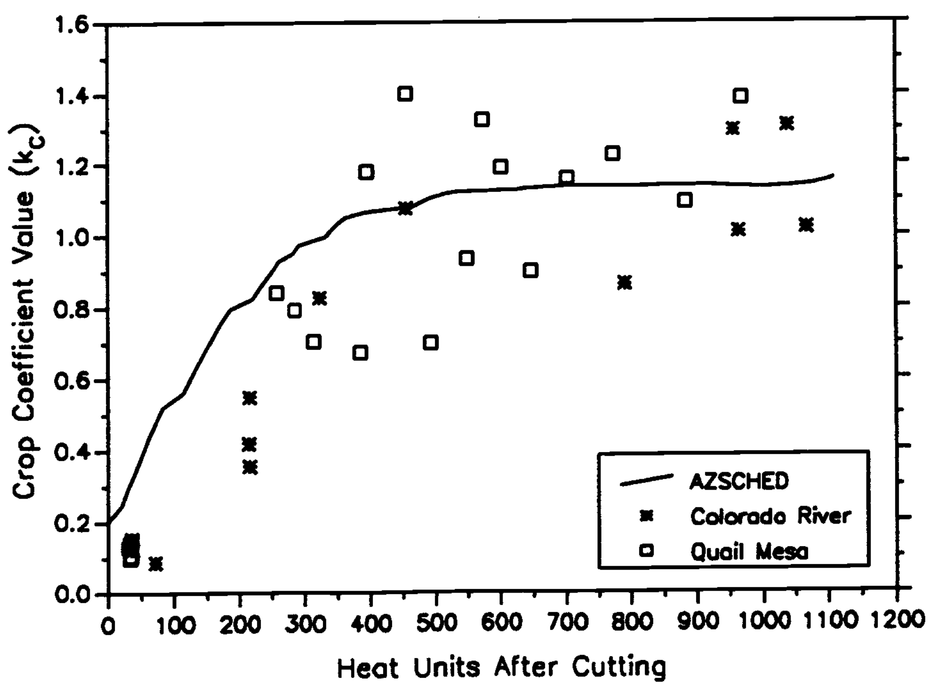

Figure 4. Crop coefficient (k_c) values for measured values and AZSCHED calculated values. Parker, Arizona, 1994.