BASAL CROP COEFFICIENTS FOR VEGETABLES IN CENTRAL ARIZONA

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Abstract

The world supply of quality water for irrigation of crops is being depleted. Growers in the arid and semi-arid regions of the world, where irrigation is a requirement for crop production, are looking for ways to conserve their water use and increase their irrigation efficiency. One tool that has been useful in helping growers reduce their irrigation water inputs is computerized irrigation scheduling programs. This study is part of a joint project between the government of Egypt (National Agricultural Research Project), USAID and The University of Arizona. Working together, researchers from Egypt and Arizona are developing water management tools that will help both countries better use their scarce water resources in arid environments. The main thrust of this segment of the project is to develop water use data on vegetables grown in both regions. These data will then be used to develop crop coefficient data to be used in AZSCHED, a computerized irrigation scheduling program developed at the University of Arizona. Using a subsurface drip irrigation (SDI) system, carrots, cauliflower, head lettuce, and tomatoes were grown to determine water use patterns and develop basal crop coefficients. Water use data were collected using a neutron moisture gauge and a time domain reflectometer (TDR). Soil water data were collected 1 day following an irrigation and just prior to the next irrigation. Additionally, three different watering regimens were employed using available water content in the rootzone as a trigger to initiate irrigation (20%, 30% and 40% depletion). The carrots, cauliflower and lettuce were planted in early October, 1993, using a randomized block design. Yield data showed no significant differences between treatments for any of the vegetables. Also, the soil moisture data did not indicate water stress in the treatments. In March of 1994, tomato transplants were planted and the irrigation treatments were altered to 30%, 40% and 50% depletion, in an attempt to get significant differences between treatments. The results for all four vegetables showed high variability in soil water data between replications, although an initial determination of basal crop coefficients was possible. Additional data will be required to better refine the crop coefficients.

Introduction

With the completion of the Central Arizona Project and the increased demand for water in the West and Southwest, Arizona food and fiber producers have encountered increases in their water costs. These increases in water costs have forced growers to become more aware of their irrigation water use. Some growers are attempting to decrease their costs by lowering their water inputs and increasing their water use efficiency. Other growers, however, are looking for alternative crops that might have a higher profit margin, helping to minimize the impact of increased water costs. One category of crop that may hold promise are vegetables.

Arizona produces over 47,370 ha of vegetable crops with an estimated value of $422.1 million. Throughout the year, somewhere in Arizona, the weather is ideal for some vegetable or melon to be grown. Arizona ranks second to California in the production of head, Romaine and leaf lettuce. Other principle vegetable crops include carrots, broccoli, potatoes, dry onions and cauliflower. These crops are grown traditionally in the West and Southwest regions of the state. However, many of the cole crops such as broccoli and cauliflower, as well as carrots, onions, and tomatoes have been grown successfully in the central region of the state.

The objective of this study was to determine water use relationships for the major vegetable crops grown in the central region of Arizona and in Egypt. Since both regions have similar climates, there were many crops which were of mutual interest to both regions. The water use data was used to develop crop coefficients that could be used in AZSCHED, a computerized irrigation scheduling program developed by the University of Arizona. This program is also being used in Egypt and will help growers in both regions more efficiently apply their irrigation water.

In response to increased public pressure for higher irrigation water use efficiency, the University of Arizona's Department of Agricultural and Biosystems Engineering developed a computerized irrigation scheduling program called AZSCHED. The AZSCHED (AriZona irrigation **SCHED**uling) 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_o) 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.

Recent work done using AZSCHED and the crop coefficients have shown some irregularities in the data. In some cases, the k_c values exceed reasonable limits, while other seem to need some fine tuning. The basis of these errors are most likely to be found in the assumptions concerning weather variables that needed to be made in order to develop the crop curves. In order to better define the crop curves, this study was begun.

Materials and Methods

The experiment was conducted at the Maricopa Agricultural Center located in Maricopa, Arizona, about 30 miles south of Phoenix. The experiment was a randomized block design with four vegetables, three water treatments and four replications. The vegetables were all planted on beds and were irrigated using buried drip tape.

The Crops

Prior to bed shaping, 500 lbs/ac of 11-52-0 dry fertilizer were broadcasted over the entire plot area. Once the beds were shaped (1 m spacing), a single line of drip tape was injected into the center of each bed. The tape was injected to a depth of approximately 7 in. The tape was a Chapin[1], turbulent twin-wall with a 15 mil thickness. The in-line emitters were

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[1]Trade names mentioned are for the benefit of the reader and no endorsement is implied by The University of Arizona over other similar products.

spaced every 9 in . and delivered water at a rate of 0.5 gpm per 100 ft. of tape. After the drip tape was injected, the beds were reshaped. Each plot consisted of four beds and was 40 ft long.

Four vegetables were studied in this experiment; carrots (Apache), head lettuce (Winterhaven), cauliflower (Snow-Pack) and tomatoes (Early Girl). The carrots, cauliflower and lettuce were planted on October 12, 1993. The carrots were planted in a herringbone configuration with 3 rows on each side of the bed, for a total of six rows per bed. Plant spacing was approximately 1.5 in. The lettuce was planted in two rows per bed, one on each side of the drip tape. The lettuce was planted with a spacing of 4 in. and then thinned to 12 in. The cauliflower was also planted with two rows per bed like the lettuce. However, the cauliflower was thinned to 18 in. spacing. Nitrogen applications were made throughout the season to assure adequate growth. The nitrogen used was UAN 32 and was injected through the drip system. A total of 67 lbs../ac of additional nitrogen was added to the plots throughout the season. The lettuce was harvested on February 28, 1994; the carrots were harvested on March 3, 1994; and the cauliflower was harvested on March 23, 1994. All crops were harvested when they reached marketable size and/or quality.

To conserve space and utilize the existing irrigation system, the tomatoes were planted on the same beds that the lettuce occupied previously. After harvest, the lettuce was machine cut and plowed into the soil. The tillage was very light and shallow, so as not to disturb the existing drip tape. Prior to bed shaping, 300 lbs./ac dry fertilizer were broadcasted over the tomato plot area. The beds were then reshaped, over the existing tape, and tomato transplants were planted on March 15, 1994. The tomatoes were spaced at 18 in. In addition to the preplant fertilizer application, an additional 40 lbs./ac was applied throughout the season. Harvesting of the tomatoes began on May 13, 1994 and continued bi-weekly, until June 16, 1994. The experiment was terminated on June 16 because there were no new flowers appearing (due to high temperatures) and the fruit was beginning to rot and show signs of sun-burn.

The Irrigation

Irrigation treatments were used to help determine an optimum soil moisture depletion level for each crop. The treatments were 20%, 30% and 40% depletion of potential available water in the soil profile of the plant's rootzone. Therefore, as the plants grew and their roots expanded downward into the soil profile, the potential available water also increased. Readings were taken with a neutron moisture gauge at 6, 12, 18, and 24 in. depths. One set of readings were taken in each plot. Half-way into the season, a time domain reflectometer (TDR) was acquired and wave guides for the reflectometer were installed at 6, 12, 18, and 24 in., again in all plots. Using the data gathered by the neutron probe and the TDR, determinations of soil moisture content were made. Readings were taken prior to an irrigation and one day after an irrigation. Irrigation applications were made so as to refill the soil profile to 100 % available water content in the rootzone of the crop. Rainfall and other weather parameters were collected by a Campbell Scientific CR-10 weather station located at the Center.

Results and Discussion

Yield Data

The crops were harvested when they reached "market quality and/or size". A six meter length of bed was harvested from each rep. Data were collected on total biomass, fruit biomass and individual fruit size and quality. The yield data for this study are shown in Table 2.

For the cauliflower and carrots, there were no significant differences in yield between treatments. Further analysis of the carrots, comparing parameters such as cull weight, carrot diameter, or total biomass also showed no significant differences. The cauliflower also showed no significant differences when comparing total biomass or average head weight. The lettuce, however, did show a yield difference between the 30% depletion level and the 20% and 40% depletion level. Further analyses of other parameters such as number of marketable heads, average head weight, and head size did not show any differences between treatments. The tomatoes, like the other crops, did not show any significant difference in yield. The 40% depletion treatment did produce less tomatoes than the 20% and 30% treatments, but they had a higher average weight.

Development of Crop Coefficients

The crop coefficient data are shown in figures 1 through 4. The carrot data, Figure 1, shows the comparison between the original k_c data derived from the Erie data and the new k_c data measured. The old AZSCHED data shows that the k_c value went as high as 1.4 at the peak of the season. However, the new measured data shows a peak of approximately 1.0, which is similar to other findings.

The cauliflower data, shown in Figure 2, shows a similar trend in that the measured values are lower than the values originally derived for the Erie data. However, the cauliflower crop was damaged by an infestation of flea beetles, which caused much damage to plant leaves, and may have effected growth and yield.

The lettuce data shown in Figure 3, again shows a shift downward by the measured data. Also, there is a slight shifting of the peak to the left, indicating that peak k_c may occur earlier in the plant's growth cycle.

The final set of data are for tomatoes, Figure 4. In this figure, the only the measured values and the predicted k_c curve are shown because there were no data on tomatoes from the Erie study. The data shows much scatter, although a predicted crop curve was determined.

Discussion

The yield data did not produce any significant differences and therefore the depletion levels could not be determined. Assumptions of available water may have been in error and future experiments will require more precise measurements of field capacity and wilting point.

The results of the development of the crop coefficients is encouraging but will require further testing. The variability of the soil and the associated measurements have produced much scatter in the data. The study was continued this season, with the addition of dry onions.

The water use data gave some insight into possible alterations of the k_c values presently used by AZSCHED for vegetable crops. All of the data indicates the peak k_c values may need to be reduced. Also, since most of the crops are harvested at peak crop quality, and not necessarily at the end of the growth cycle, it is difficult to determine k_c values toward the end of the growing season.

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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

Table 2. Yield data for the vegetable water use study. Maricopa Agricultural Center, Maricopa, AZ, 1994.

Percent Depletion	Crop Yield (cwtacre)*			
	Lettuce	Cauliflower	Carrots	Tomatoes**
20	235a	93a	196a	303a
30	212b	86a	190a	278a
40	250a	93a	174a	295a

* Values followed by the same letter are not significantly different (P=0.05; SKN Test)

** Tomato depletion levels were changed from 20%, 30%, 40% to 30%, 40% and 50%.

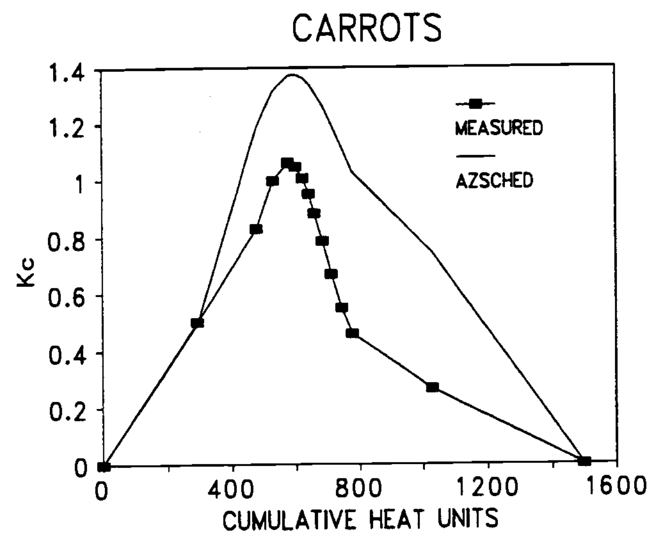

Figure 1. Crop coefficient data for carrots. Maricopa Agricultural center, Maricopa, AZ. 1994

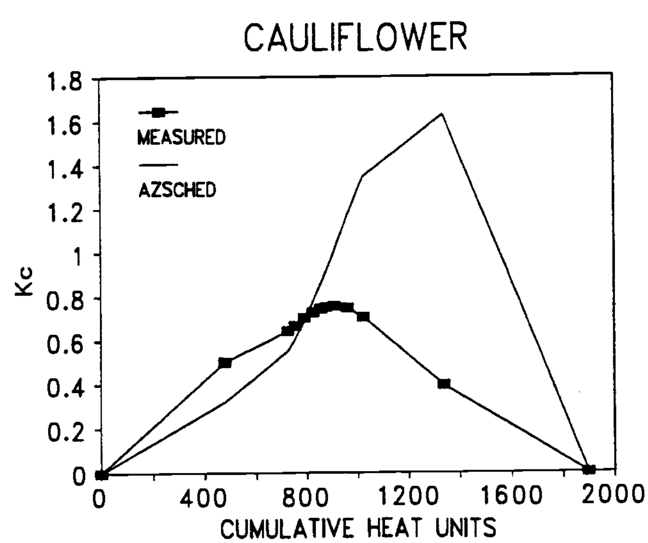

Figure 2. Crop coefficient data for cauliflower. Maricopa Agricultural Center, Maricopa, AZ. 1994

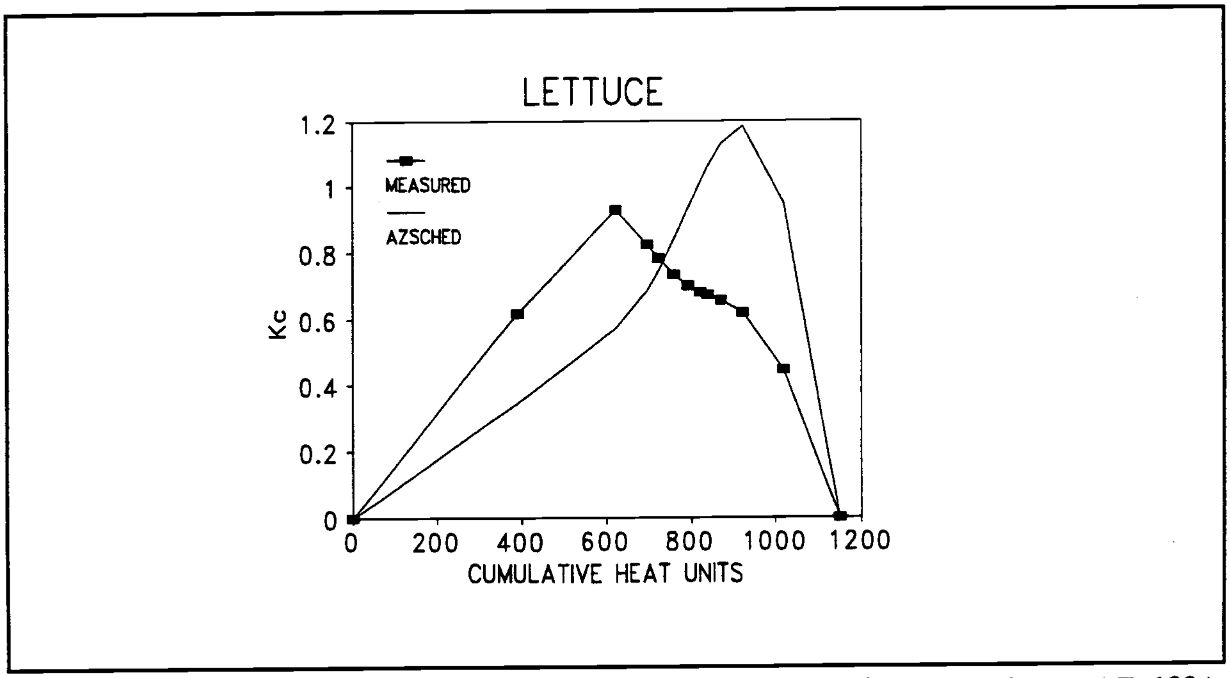

Figure 3. Crop coefficient data for lettuce. Maricopa Agricultural Center, Maricopa, AZ. 1994.

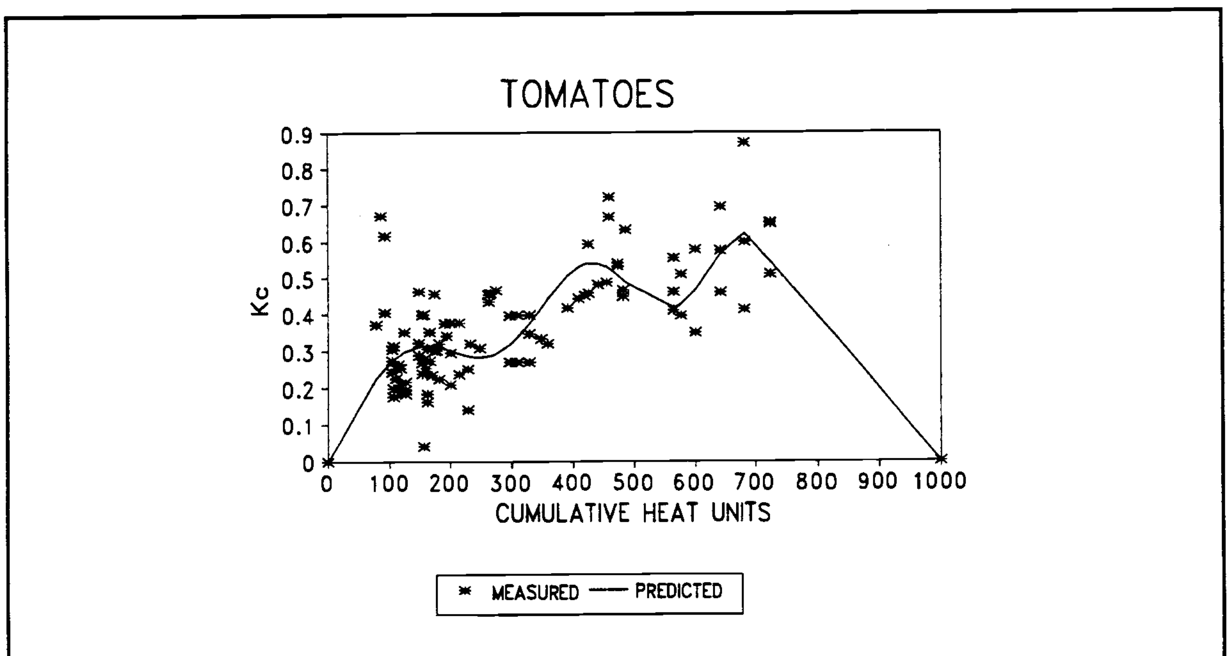

Figure 4. Crop coefficient data for tomatoes. Maricopa Agricultural Center, Maricopa, AZ. 1994.