PROJECT NO. RM-7 .

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2000 – December 31, 2000

PROJECT TITLE: Measuring Crop Water Use (ET_c) in California Rice

PROJECT LEADER: Richard L. Snyder, Biometeorologist
University of California
One Shields Avenue
LAWR
Davis, CA 95616-8627

PRINCIPAL UC INVERSTIGATORS:

John F. Williams, Farm Advisor
University of California Cooperative Extension
Sutter-Yuba Counties
Yuba City, CA

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OBJECTIVES AND EXPERIMETNS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

The objective of this project was to develop accurate rice crop water use information for use by industry, water purveyors and policy makers. Previous estimates of rice crop evapotranspiration (ET_c) were based on studies done in 1968 and 1969 and published by Lourence and Pruitt (1971), using full season cultivars. Because of changes in varieties and in the method to estimate reference evapotranspiration (ET_o) the old figures are unlikely to accurately portray how much water a modern rice crop uses. This is the first known attempt to measure full season rice ET_c and to determine K_c values for rice grown in California since 1969. At that time, the California Irrigation Management Information System (CIMIS) did not exist and there was no good local estimate of reference evapotranspiration (ET_o) where the rice ET_c was measured. In this study, crop coefficients were determined using the recently developed surface renewal method and crop coefficients were calculated using ET_o estimates from a nearby CIMIS station. The research was conducted in a rice crop located in the Y where northbound California 99 and California 70 highways split in Sutter County. The location is within a few miles of the Nicolaus CIMIS station, so a nearby source of ET_o was available.

SUMMARY OF 2000 RESEARCH ACCOMPLISHMENTS BY OBJECTIVE:

Methods and Materials

Crop evapotranspiration is typically approximated as the product of ET_o and a crop coefficient (K_c) factor. ET_o, which approximates the evapotranspiration of an irrigated pasture, is intended to account for variations in weather and the K_c factor accounts for biological, ecophysiological, and agronomic differences between the crop and the reference evapotranspiration. The K_c factor is determined as the ratio ET_c/ET_o using simultaneous measurements or estimates of ET_o and measured ET_c.

In this experiment, ET_c was measured using the surface renewal (SR) method. The method has been thoroughly described in Paw U and Brunet (1991), Paw U et al. (1995), Snyder et al. (1996), and Spano et al. (1997). Temperature data were collected using a frequency of $f=$ 4 Hz with 76.2 μm diameter thermocouples. Following the approach of Van Atta (1977), the second, third, and fifth powers of a structure function are used to estimate a and $l+s$ (Snyder et al., 1997). The structure function is calculated using time lags of r = 0.25 and 0.50 s. During half-hourly periods, H is estimated using:

$$H = \alpha \rho C_p \frac{a}{l+s} z \qquad (1)$$

where ρ is the air density, C_p is the specific heat of air at constant pressure, z is the measurement height, α is a weighting factor, which accounts for differential heating below the measurement height, and $a/(l+s)$ is the product of a/l and the relative time for heating ($l/l+s$). To determine α, the surface renewal H values assuming α=1.0 (H_R) are compared with H values from a sonic anemometer (H_{EC}) mounted above the canopy top. The correction for unequal heating (α) is calculated as the slope through the origin of a regression of H_{EC} versus H_R. In this experiment, we found different calibrations for the case when $H_R<0$ (Fig. 1) and when $H_R\geq 0$ (Fig. 2). Note that $H_R<0$ typically occurs during the afternoon and nighttime, and $H_R\geq 0$ typically occurs during the morning.

Sensible heat flux density data from the SR measurements are used with measured net radiation (R_n) and soil heat flux density or conductive heat exchange (G) to estimate latent heat flux density (λE) or crop evapotranspiration (ET_c) using the energy balance equation ($ET_c=\lambda E=R_n-G-H$). The G term was estimated from the volumetric heat capacity of the water and changes in water temperature. The change in soil water temperature was measured using shielded thermistors placed at the water-soil interface and mounted at about 2.54 cm (1 inch) below the water surface using a floating device. Daily ET_o and ET_c rates were calculated by summing the hourly data. Then daily K_c values were calculated as

$$K_c = \frac{ET_c}{ET_o} \qquad (2)$$

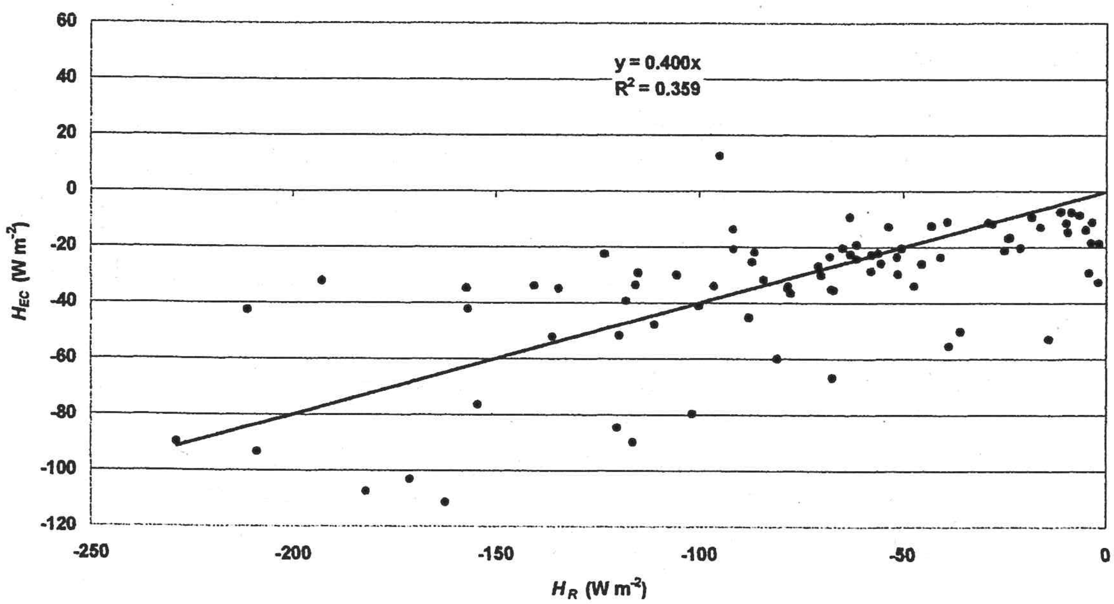

Figure 1. Sonic anemometer H versus the SR sensible heat flux density (H_R) with $\alpha = 1.0$ when $H_R < 0$. Then H is then estimated as $H = 0.400 \times H_R$ whenever $H_R < 0$.

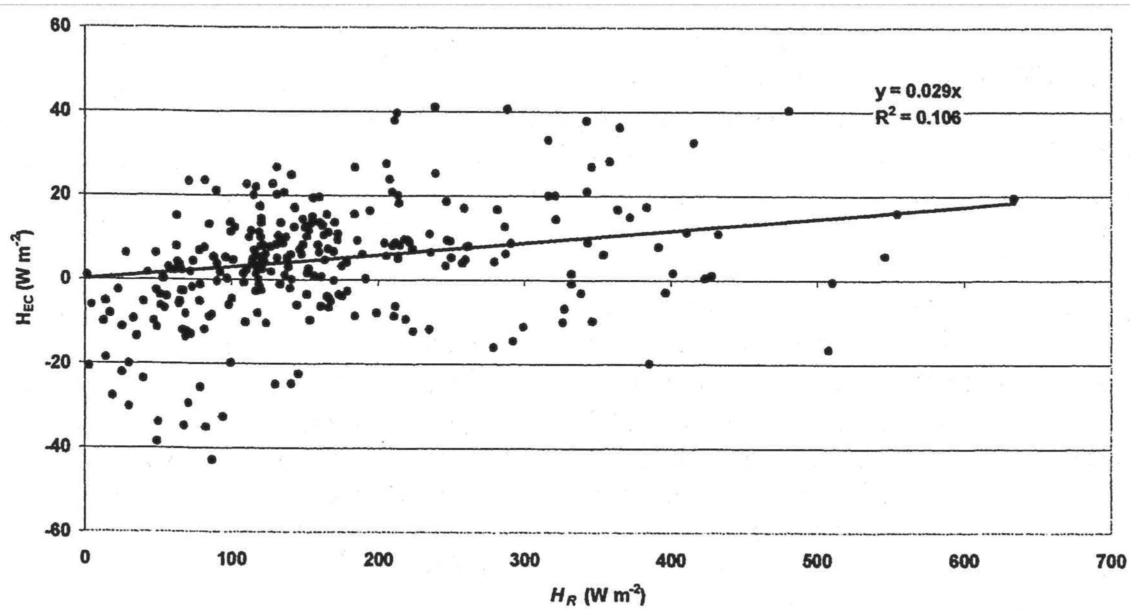

Figure 2. Sonic anemometer H versus the SR sensible heat flux density (H_R) with $\alpha = 1.0$ when $H_R \geq 0$. Then H is then estimated as $H = 0.029 \times H_R$ whenever $H_R \geq 0$.

The experiment was conducted in Sutter County near the Nicolaus CIMIS station. The SR weather station was set up in a rice paddy on June 4, 2000 when the plants were just beginning to emerge from the water. The SR weather station consists of a CR10X data logger, a net radiometer, a soil heat flux plate, and two water proof thermistors. The net radiometer has an output in millivolts and it has a daytime calibration ($R_n = 9.17$ W m^{-2} mV^{-1}) and a nighttime calibration ($R_n = 11.25$ W m^{-2} mV^{-1}). A soil heat flux plate was buried in the soil at 2 cm depth. The sensor outputs a millivolt reading and the calibration for the soil heat flux sensor was G=44.5 W m^{-2} mV^{-1}. The thermistors are excited with 2500 mV and the output is read in millivolts and converted to temperature in degrees Celsius (°C).

The surface renewal measurements are calibrated by comparing with sensible heat flux density data from a sonic anemometer. The sonic anemometer was set up on June 18, 2000. However, the thermocouple was broken on the sonic anemometer and it was replaced on June 25, 2000. Data were collected from June 25 to 30 to calibrate the SR method. On July 19, two broken thermocouples were replaced on the SR station. The thermocouples were damaged on July 15, so H was estimated using a missing data function during that period. The missing data function

$$H = 1.01(R_n - G) \qquad (3)$$

was determined by regression of all of the existing λE data versus $R_n - G$ (Fig. 3). On August 17, one broken thermocouple was replaced. During the period when it was broken, H was estimated from the other thermocouple. The net radiometer was bent downward slightly to the southwest for part of the time between July 25 and August 17. The sensor was re-leveled on August 17.

Although the water depth varied somewhat during the season (Table 1), a fixed value of 10 cm was used to calculate energy storage in the water for the G calculation. Variations in the water depth were not anticipated and a method to obtain continuous water depth measurements is needed to improve estimates in the future. The water was drained from the field and the weather station was removed from the field in mid-October.

Table 1. Water depths, canopy heights, and percentage ground cover observations.

Date	Water depth (cm)	Canopy height over water (cm)	Ground Cover (%)
June 4	10		
June 18	10	10	
June 25	20	15	60-70
June 30	15	20-25	70-80
July 19	10	33	100
July 25	10	50	100
August 17	15	60	100

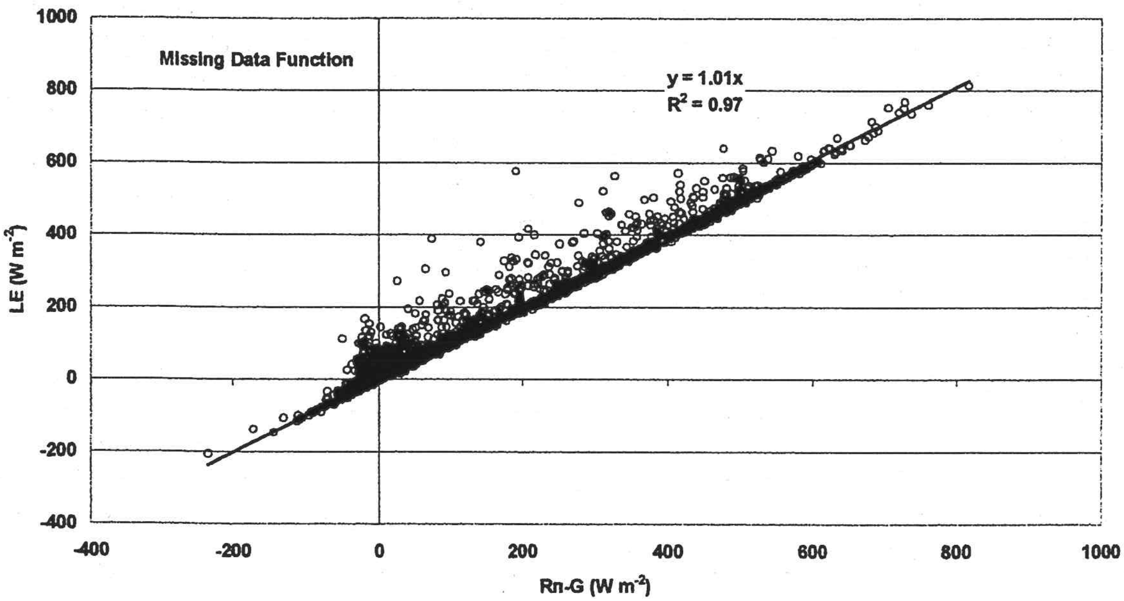

Figure 3. Latent heat flux density plotted versus net radiation minus soil heat flux density. LE was calculated as the residual of the energy balance equation using H determined using the SR method. The equation LE = 1.01 x (Rn – G) is used to estimate LE when H cannot be calculated due to missing thermocouple data.

Results and Discussion:

A plot of the daily ET_c and ET_o rates during the season is shown in Fig. 4. When the canopy was small at the beginning of the season, ET_c was considerably higher than ET_o. During the middle of the season, the ET_c was about 9% higher than ET_o, and late in the season, the ET_c dropped below ET_o as senescence occurred. These changes are even more evident in the K_c curve shown in Fig. 5. The K_c values decreased from the June 4 start date until about June 25 when the canopy reached about 65% ground cover. Then the K_c remained relatively fixed at K_c=1.09 from June 25 through October 15 as shown in Fig. 6. This is considerably smaller than K_c values reported in earlier literature. The K_c then dropped to about 0.9 at the end of the season.

Cumulative ET_o and ET_c from June 5 through the end of the season are plotted in Fig. 7. The total cumulative ET_c of 800 mm is equal to 31.5 inches for the season, which is considerably lower than the 42 inches reported as the water use for rice.

Conclusions

Based on surface renewal ET_c measurements, the total seasonal water use was about 75% of what is typically reported in the literature. The K_c values started at about 1.30 and decreased to about 1.09 when the canopy reached about 65% ground cover. During the main part of the season, the K_c values remained at about 1.09 and then dropped to about 0.90 at the end of the season. Because the results were so different from earlier reports, we feel that the experiment should be repeated one more season to confirm the results.

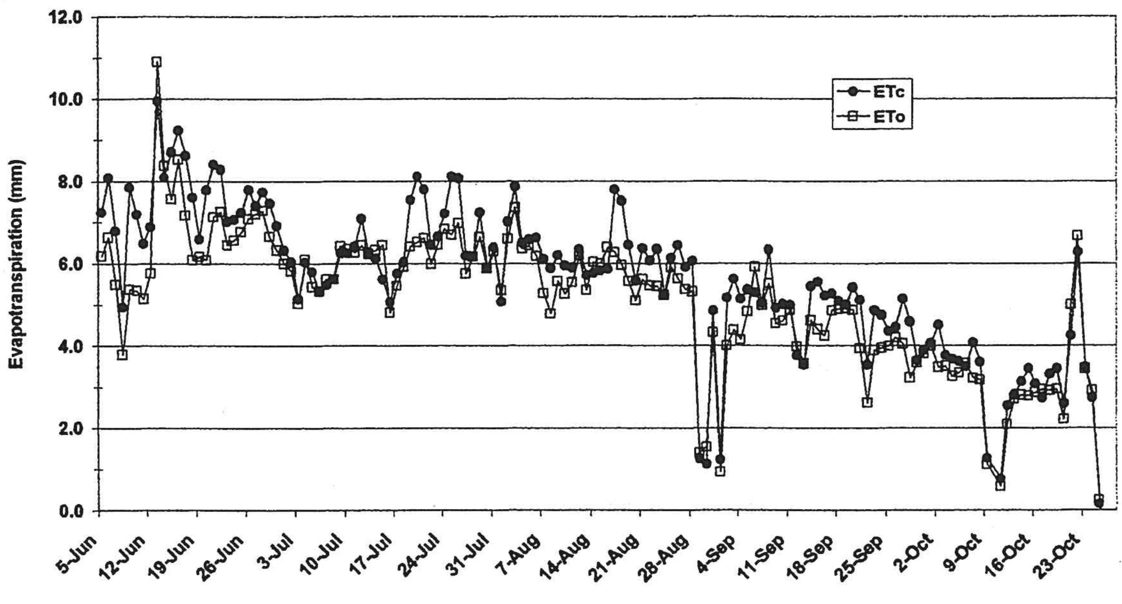

Figure 4. Crop evapotranspiration (ET_c) and reference evapotranspiration (ET_o) for rice grown during the 2000 season near Nicolaus, California

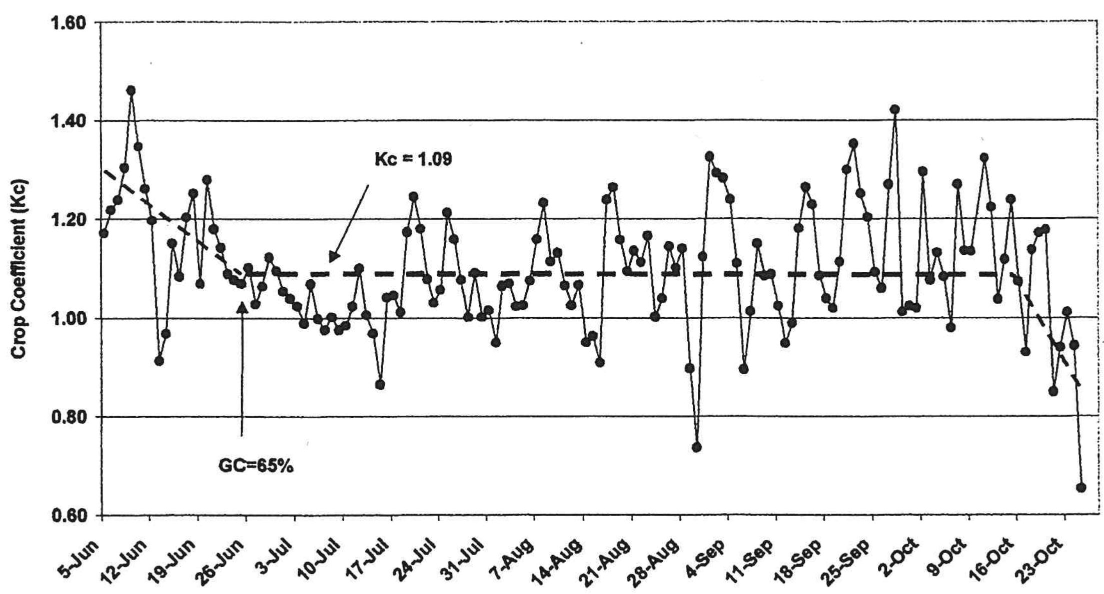

Figure 5. Crop coefficient (Kc) versus date for rice grown during the 2000 season near Nicolaus, California

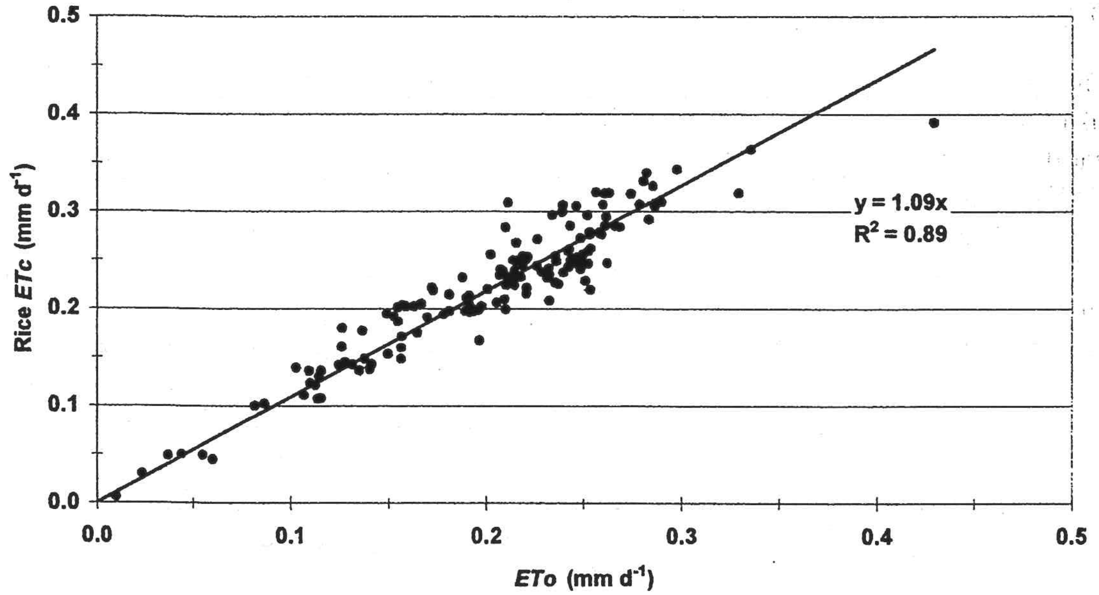

Figure 6. Graph of daily ET_c versus ET_o from the period June 29-October 15 for the 2000 rice growing season.

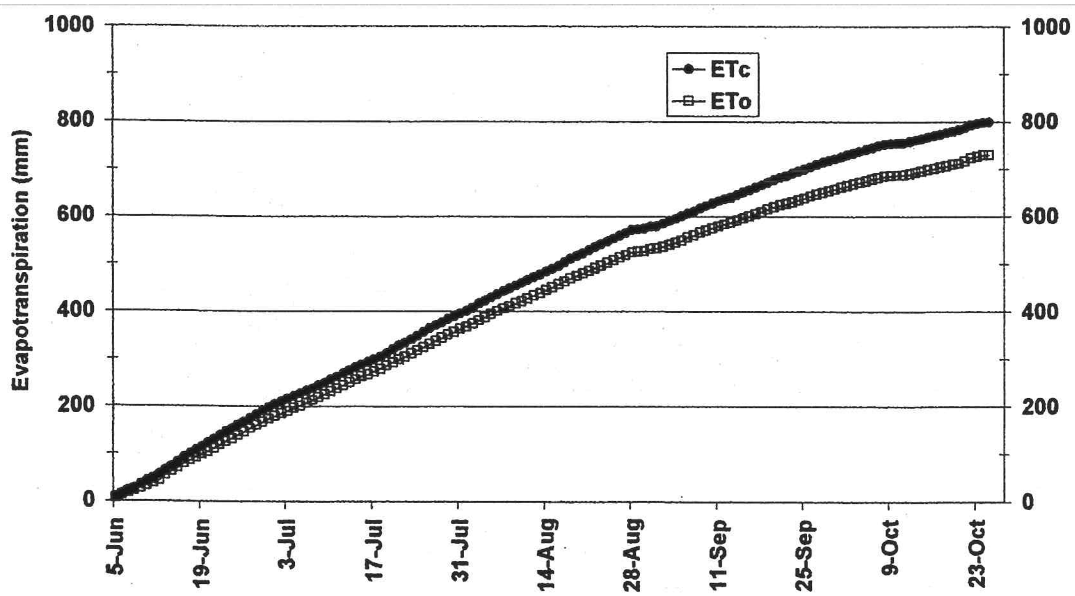

Figure 7. Cumulative crop evapotranspiration and cumulative reference evapotranspiration during the 2000 growing season for rice grown near Nicolaus, California

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PUBLICATIONS OR REPORTS: None at this time

GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

An experiment was conducted in Sutter County to measure crop evapotranspiration (ET_c) of rice and to determine crop coefficient (K_c) values relative to reference evapotranspiration (ET_o) from the California Irrigation Management Information System (CIMIS). The surface renewal method, which uses high frequency temperature data, and energy balance measurements of net radiation and soil (and water) heat flux density were used to determine ET_c. The total seasonal water use (31.5 inches) was about 75% of what is typically reported for California (42.0 inches). The K_c values started at about 1.30 and decreased to about 1.09 when the canopy reached about 65% ground cover. During the main part of the season, the K_c values remained at about 1.09 and then dropped to about 0.90 at the end of the season. Because the results were so different from earlier reports, we feel that the experiment should be repeated one more season to confirm the results.