REGULATED DEFICIT IRRIGATION of ALFALFA

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ABSTRACT:

Alfalfa is California's single largest agricultural water user due to its large acreage (445,000 ha) and long growing season. A total of 494,000 to 679,000 ha-m (4 to 5.5 million-acre feet) of water are applied to California's alfalfa crop each year, depending on alfalfa acreage of a given year, weather patterns, and method of estimation. Growers normally fully irrigate alfalfa throughout the growing season to maximize yield. However, yields tend to be highest during spring harvests, and lower during summer months. In addition, forage quality of alfalfa tends to be lower during summer months due to the hot weather, resulting price reductions of up to 40%.

The Department of Water Resources has shown interest in deficit irrigation of alfalfa as a source of water available for transfer elsewhere. One strategy is to cutoff irrigation water during July and August when yields are the lowest. The amount of water available for transfer is the difference in the evapotranspiration of an adequately irrigated field and the evapotranspiration of a deficit-irrigated field.

Evapotranspiration (ET) was determined in a commercial field where part of the field was fully irrigated and part was deficit irrigated during the later summer months. The eddy covariance energy balance method and the surface renewal energy balance method were used in the fully irrigated area, and the surface renewal method was used in the deficit irrigated part of the field. Both methods use climatic and soil temperature data to calculate ET.

Results thus far have shown the daily ETc of the fully irrigated area in August to range between 3.5 mm/day to 4 mm/day just after cutting and between 6 mm/day and 7 mm/day after the first irrigation between cuttings. For the deficit-irrigated part of the field, ET ranged between 2 mm/day and 3 mm/day just after cutting, increased to between 5 mm/day and 5.5 mm/day for about 10 days after the first irrigation and then decreased to between 1.5 mm/day and 3 mm/day. ET of the deficit irrigated areas ranged between 1 mm/day and 2 mm/day after the September cutting, whereas, ET of the fully irrigated area was about 3.5 mm/day prior to the next irrigation and then was about 5 mm/day after the irrigation.

INTRODUCTION

Alfalfa is California's single largest agricultural water user due to its large acreage (445,000 ha) and long growing season. A total of 494,000 to 679,000 ha-m (4 to 5.5 million-acre feet**)** are applied to California's alfalfa crop each year, depending on alfalfa acreage of a given year, weather patterns, and method of estimation.

Growers normally fully irrigate alfalfa throughout the growing season to maximize yield. Evapotranspiration (ET) or water use for alfalfa is highest during summer months and lowest during spring and fall months. Yields tend to be highest during spring harvests, and lower during summer months. In addition, forage quality of alfalfa tends to be lower during summer months due to the hot weather, resulting price reductions of up to 40%.

The Department of Water Resources has shown interest in deficit irrigation during the late summer of alfalfa as a source of water available for transfer elsewhere. The amount of transferable water is the difference in the evapotranspiration of a fully-irrigated crop and the evapotranspiration of a deficit-irrigated field. However, little information is available on the evapotranspiration of deficit-irrigated alfalfa during July and August and the effect of deficit irrigation on crop yield and on the yield of subsequent alfalfa crops. This project examines different methods of deficit irrigation and estimates the potential water savings and economic effects of deficit irrigation.

OBJECTIVES

The objectives of this research/demonstration project on controlled deficit irrigation of alfalfa are:

1. Determine the response of alfalfa yield and quality to regulated deficit irrigation to help identify the strategies most appropriate for alfalfa growers to implement for reducing water use of alfalfa.

2. Estimate the potential water savings and the economics associated with different approaches,

3. Estimate the crop evapotranspiration of fully-irrigated alfalfa and deficit-irrigated alfalfa to be used to estimate the water savings that might be used for transfer elsewhere.

4. Identify deficit irrigation strategies and management practices that will minimize yield loss and plant mortality.

PLAN OF ACTION

COMMERCIAL FIELD EXPERIMENT

Two sites have been selected in Yolo County for a farm level demonstration. Deficit irrigation is being imposed on selected checks in each field. The experimental design is a randomized complete block design, with 3 irrigation treatments and 4 replications. The three irrigation treatments are: 1) Full irrigation treatment 2) Deficit irrigation for short period, (1 month) 3) Deficit irrigation for long period (2 months). Data collected are yield, yield quality parameters, soil water potential, and applied irrigation water. Flood irrigation is used by both growers, the normal irrigation method of alfalfa in the Sacramento/San Joaquin Valley.

At one site, evapotranspiration of the full treatment is being determined. The Bowen Ratio energy balance method (Todd et al. (2000) was used in 2004, but because of problems with this method, the eddy covariance or correlation energy balance method (Kizer and Elliott, 1991; Tanner et al., 1985) and the surface renewal energy balance method (Spano, 1997) are being used in 2005. The surface renewal system is installed in the deficit-irrigated field. Canopy coverage was also measured with a digital, infrared camera in both the full-and deficit-irrigated treatments. Crop coefficients are calculated as the ratio of crop ET to reference crop ET, provided by the California Irrigation Management Information System.

UC DAVIS EXPERIMENT

In addition to the farm sites, an experiment has been established at UC Davis which includes varieties and irrigation treatments using a randomized block split plot design with four replicates. Plots were established in the fall of 2002. The irrigation treatments are the main treatments and varieties are the secondary treatments. The irrigation treatments are:

1. Full irrigation according to normal grower practice on check-flood fields,
2. Ceasing irrigation during 4 weeks in August,
3. Ceasing irrigation for 8 weeks during July and August, and
4. Reducing irrigations from 2-3 per month to 1 per month during the months of June, July and August.

Different varieties are used in the subplots. Data collected include applied water and yield for all plots, and yield quality and soil water potential on selected plots. A cutting schedule is being used that reflects farm-level conditions. Yield quality parameters include acid detergent fiber (ADF), neutral detergent fiber (NDF) and crude protein (CP).

RESULTS

COMMERCIAL FIELD EXPERIMENT

The 2004 alfalfa evapotranspiration (ETc) data showed small ETc values on about day of year (DOY) 100 and DOY130, the result of the harvest or cutting (Fig. 1). After a cutting, ETc increased with time to maximum values, which occurred just before the next cutting. At the same time, both canopy coverage and plant height also were the smallest just after a cutting and increased with time after cutting (Fig. 2).

The ETc data in Fig. 1 were determined with the Campbell Scientific Bowen Ratio energy balance method. The method resulted in reasonable values until after about DOY180. Thereafter, the BR latent heat flux density data, used to calculate daily ETc, became very erratic. The main reason for this behavior was felt to be caused by the dew point temperature measurements. The BR method requires water vapor pressure data at two elevations above the canopy. The difference between the two measurements is used to calculate the latent heat flux density. The Campbell Scientific BR system measures the dew point temperature at the two elevations and converts those data into water vapor pressure. The dew point temperatures are measured by drawing in samples of air through tubing at each elevation and flowing the air through a chilled mirror hygrometer. This method worked quite well for calculating ETc of tomatoes in the Westlands Water District (Fresno County), but apparently, the climatic conditions at this alfalfa field resulted in condensation in the tubing. Thus, no differences in dew point temperatures could be detected until about mid-day, resulting in unreliable data. Because of this problem, the 2005 ETc data were determined with the Campbell Scientific eddy covariance (EC) energy balance system and with the surface renewal (SR) energy balance method, developed at UC Davis.

The 2005 data showed increasing ETc and reference crop ET (ETo) with day of year up to about DOY130 (Fig. 3). Considerable variability occurred in the data due to the highly variable climate behavior during the first part of the year. However, just after a cutting, small values of ETc occurred, as did in 2004, and then ETc increased with time after cutting until the next cutting. This pattern is very obvious after DOY180, but is less so earlier in the year because of the day-to-day climate variability. However, it can be seen that while ETc was small on about DOY110 and DOY 146, high ETo values occurred for both time periods, indicating that the small ETc values were due to cutting. Cumulative ETc as of September 9, 2005 was 946 mm (37 inches).

Canopy coverage and plant height data have been collected during 2005. Those data will be evaluated this fall.

Fig. 4 shows the effect of deficit irrigation on alfalfa ETc. Deficit irrigation started on July 25. It was desired to start the deficit irrigation at the end of June, but we failed to communicate this to the irrigator, which resulted in July irrigations. After the July 25 cutting, ETc of the deficit irrigated part of the field was less than that of the fully irrigated field and eventually decreased to values between 1 and 2 mm/day. Cumulative ETc between July 25 and September 9 was 254 mm for the fully irrigated treatment and 128 mm for the deficit irrigated treatment.

No trend with time was found for the crop coefficients of the fully-irrigated treatment prior to DOY100, although considerable variation in the coefficients occurred due to climate variability (Fig. 5). After DOY100, a strong pattern occurred with crop coefficients just after cutting ranging between 0.4 and 0.5 and then increasing to values between 1.0 and 1.2.

Yields in the two commercial fields are shown in Tables 1 and 2. Yields were substantially reduced by the deficit irrigation. There was some recovery in yield due to the fall irrigation, but yields of that treatment were still smaller than those of the fully-irrigated treatments. The difference in applied water between the fully irrigated treatment and the deficit –irrigated treatments was 853 mm for the mid-summer cutoff and 599 mm for the mid-summer cutoff followed by a fall irrigation for Site C (location of the ETc experiment). Data on applied water at the other site was only recently received.

UC DAVIS EXPERIMENT

Seven cuttings were conducted and fifteen irrigations were applied from beginning of April to beginning of October in 2004.

Seasonal amounts of irrigation water applied to each treatment over the season are in Table 3. The July cutoff resulted in a reduction of 838 mm of water, and the August Cutoff resulted in a reduction of 432 mm of water compared to the fully irrigated treatment. The July cutoff treatment, with irrigation in the fall (September), resulted in a reduction of 406 mm.

Table 4 shows no significant differences in yield before the deficit treatments were applied prior to the July 6 harvest. After July 6, the irrigation water was cutoff for treatments 2 and 4. After the treatments were imposed in July, significant yield differences were seen between the control plots and deficit-irrigated plots (treatments 2 and 4) at the 95% level of confidence. These differences due to irrigation were seen in the last 3 harvests of the year, resulting in an over-all significant reduction in yield for the year (Table 4). The yield in the control (fully irrigated) plots reflects the yield levels commonly observed in field plot studies on the UC Davis campus. It should be noted that yield measurements from small-plot studies such as these are typically 20-40% higher than the yield commonly found in commercial fields. The average yield level in Yolo County for alfalfa is approximately 16.8 Mg/ha. This is largely due to the fact that the UC Davis soil is a class 1 soil; near zero harvest losses (5-20% harvests losses are common); no deteriorated sections of fields (as can occur in commercial fields); and more flexibility to obtain timely harvests than growers have.

FUTURE RESEARCH

The ETc measurements of 2005 will continue until the end of October or November. Thereafter, the eddy covariance and surface renewal instruments will be removed and installed in another field. Measurements will be made in the new field into the fall of 2006. The UC Davis experiment will also be continued in 2006. Data from 2005 will continue to be evaluated.

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Table 1. Yield (Mg/ha) for cuttings 5 and 6 for the Site G commercial field in 2004.

Treatment	Yield (Mg/ha)		
	Cutting 5	Cutting 6	Total
Full irrigation	2.46	1.90	4.39
Cutoff in mid-summer	0.85	0.52	1.39
Mid-summer cutoff with fall irrigation	0.83	1.03	1.84
LSD (0.05)	0.43	1.37	1.75

Table 2. Yield (Mg/ha) for cuttings 4, 5 and 6 for the Site C commercial field in 2004.

Treatment	Yield (Mg/ha)			
	Cutting 4	Cutting 5	Cutting 6	Total
Full irrigation	3.49	3.02	1.90	8.42
Cutoff in mid-summer	0.78	0.56	0.94	2.26
Mid-summer cutoff with fall irrigation	0.60	0.36	2.15	3.14
LSD (0.05)	0.63	0.38	1.39	1.25

Table 3. Seasonal amount of applied irrigation water (mm) for each treatment of the UC Davis experiment in 2004.

Treatment	Applied Water (mm)
Full Irrigation	1,371
July Cutoff	533
August Cutoff	940
July Cutoff; Sep. irrigation	965

Table 4. Average yield (Mg/ha) vs. irrigation strategy for each cutting date of the UC Davis experiment in 2004.

Treatment	Apr 5	May 9	Jun 4	Jul 6	Aug 4	Aug 31	Sep 30	Total
Full	3.1584	4.3456	4.2336	4.9504	4.5472	4.592	3.9648	29.792
Jul. cutoff	3.2704	4.256	4.0544	4.5248	1.904	1.0304	0.2688	19.2864
Aug. cutoff	3.1584	4.5472	4.5024	5.1744	4.5248	4.0768	1.7472	27.7088
Jul. cutoff; Sep. irrig.	3.1584	4.48	4.4576	5.3088	2.4864	1.5232	4.032	25.424
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LSD (0.05)					0.18144	0.18368	0.17472	0.80192

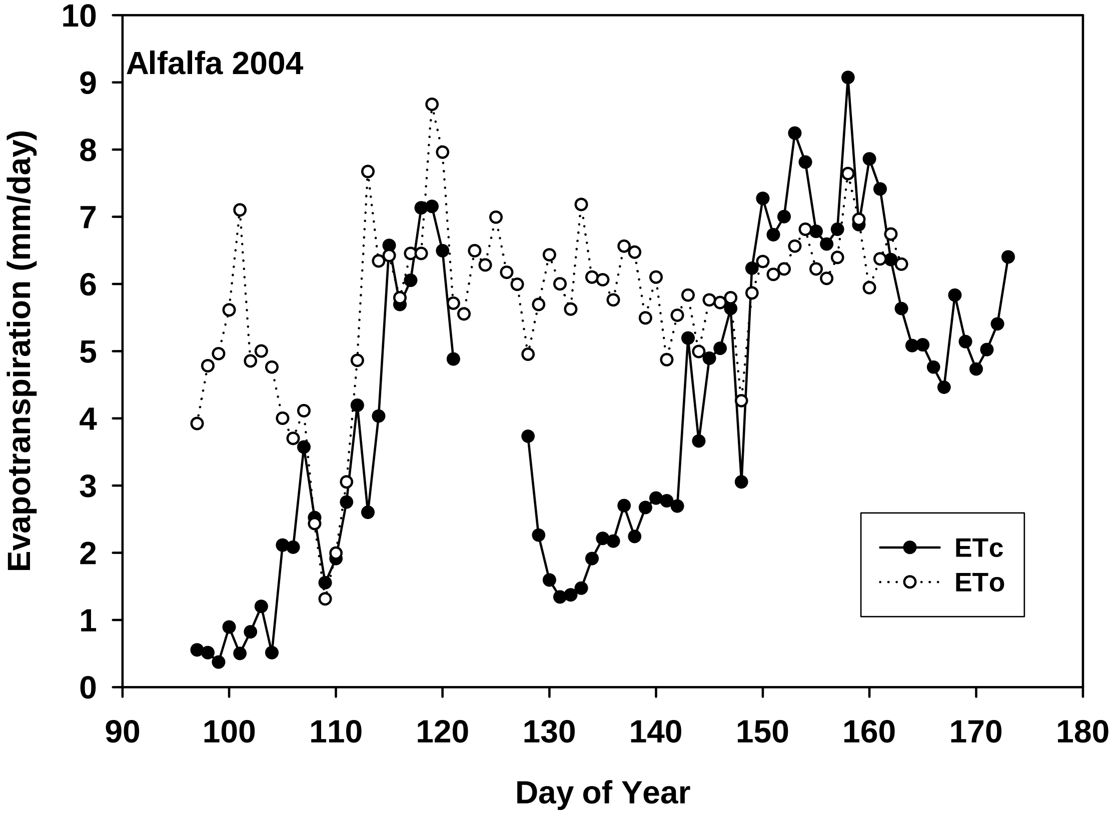

Fig. 1. Daily alfalfa evapotranspiration and reference crop evapotranspiration of a commercial field in 2004.

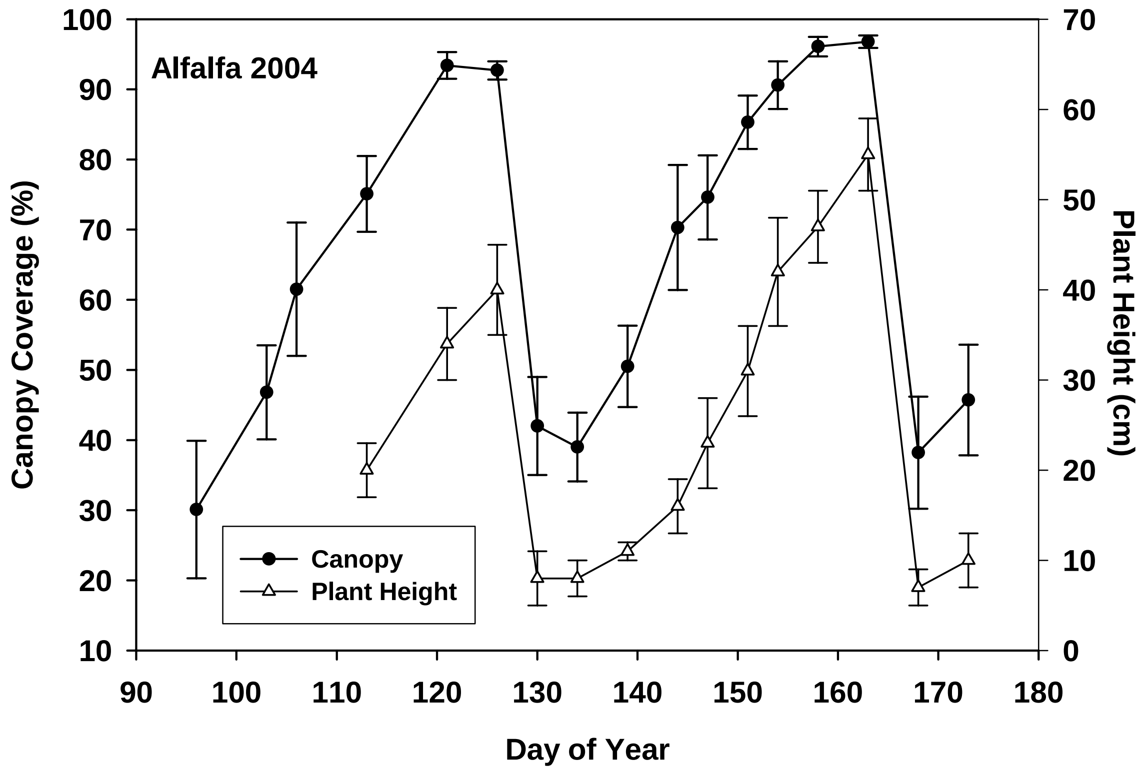

Fig. 2. Canopy coverage and plant height (cm) with time of a commercial field in 2004.

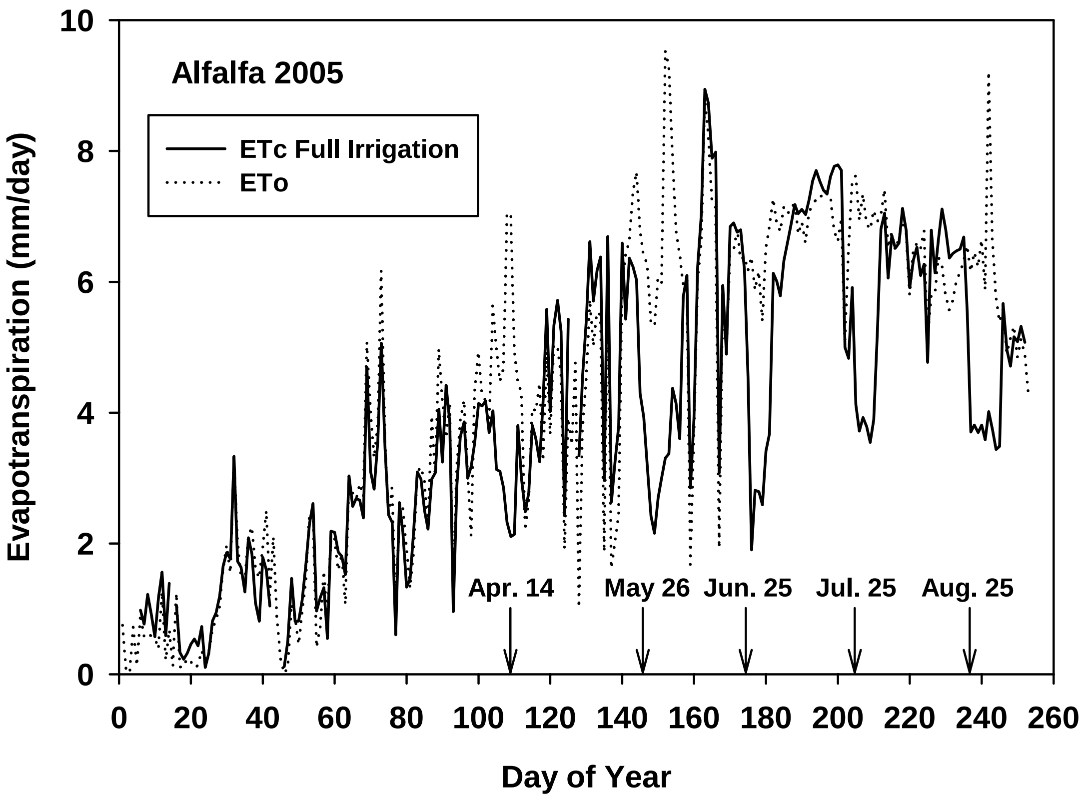

Fig. 3. Daily alfalfa and reference crop evapotranspiration with time of a commercial field in 2005. The arrows with the dates are the cutting or harvest times.

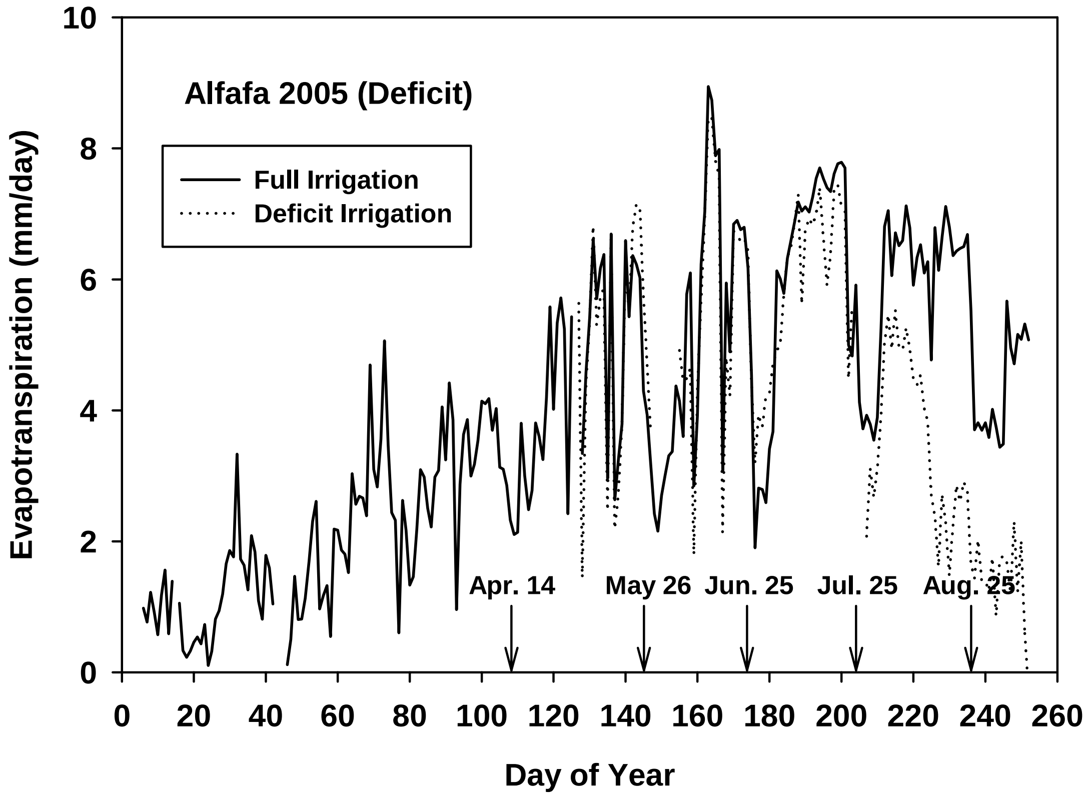

Fig. 4. Daily alfalfa evapotranspiration of fully irrigated and deficit irrigated alfalfa in a commercial field in 2005. Deficit irrigation started on July 25. The arrows with the dates are the cutting times.

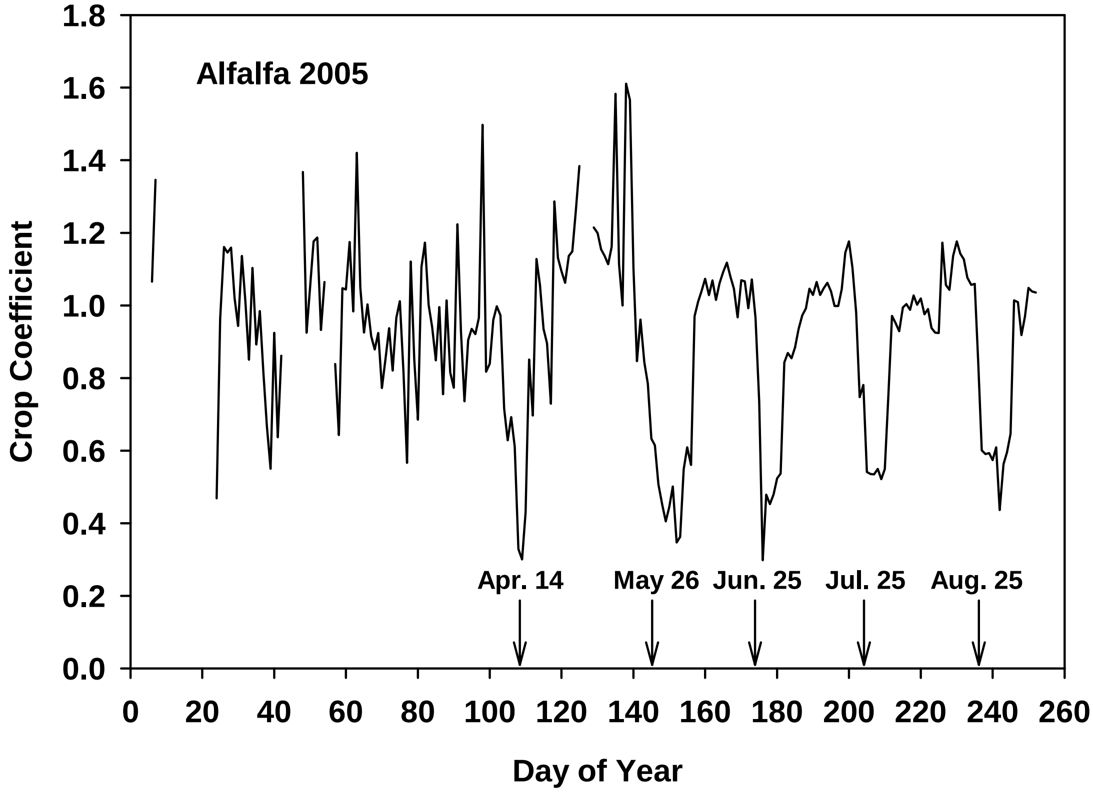

Fig. 5. Daily crop coefficients of alfalfa in a commercial field in 2005. The arrows with the dates are the cutting times.