# HOW MUCH WATER DOES ALFALFA REALLY NEED?

**Blaine Hanson, Khaled Bali, Steve Orloff, Blake Sanden, Dan Putnam[1]**

## ABSTRACT

Evapotranspiration (ET) of fully-irrigated and deficit-irrigated (no irrigation in July, August, and September) was measured in five alfalfa fields at various locations throughout California. Seasonal ET ranged from 33 to 58 inches, which differed from historical seasonal ET. Deficit irrigation reduced ET, but the ET difference between fully-irrigated and deficit-irrigated alfalfa was site specific. Yields were reduced by deficit irrigation.

**Keywords: a**lfalfa, irrigation, evapotranspiration, water use

## INTRODUCTION

Alfalfa is California's single largest agricultural water user due to the amount grown, typically about 1 million acres, and its long growing season. Seasonal alfalfa water applications generally range from 4,000,000 to 5,500,000 acre-feet. Because of the high water usage, interest exists in better defining the seasonal water use of fully irrigated alfalfa for different climatic areas of California and in midsummer deficit irrigation (no irrigation in July, August, and September) of alfalfa as a strategy for coping with limited water supplies and also as a strategy for providing water for transfer from water-rich areas such as the Sacramento Valley to water-short areas such as the San Joaquin Valley and southern California. In theory, the amount of water available for transfer is the difference between the ET of fully-and deficit-irrigated alfalfa. This midsummer deficit irrigation strategy maintains the relatively high yields of the first part of the year and eliminates irrigations during the summer when yields are small and quality usually is poor.

Previous studies on mid-summer deficit irrigation of alfalfa showed that no irrigation during the midsummer reduced the alfalfa yield, but did not stop all plant growth (Frate et al., 1991, Guitjens, 1993, Ottman et al., 1996, Putnam et al., 2000, Robinson et al., 1994). As a result, some evapotranspiration occurred during the period of deficit irrigation. No information exists on differences in midsummer evapotranspiration amounts between fully-and deficit-irrigated alfalfa.

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This study investigated the seasonal ET requirements of fully-irrigated alfalfa and the effect of midsummer deficit irrigation on yield and evapotranspiration in commercial alfalfa fields at various locations in California.

## METHODS AND MATERIALS

Alfalfa evapotranspiration (ET) was determined at Tulelake (Klamath Basin), Scott Valley (near Yreka in the intermountain area of northern California), Sacramento Valley (near Davis), Kern County (near Buttonwillow), and the Imperial Valley (near Holtville). All sites were commercial fields except for the Tulelake site, which was located at the University of California Intermountain Research and Extension Center, Measurements were made at the Davis site from 2005 to 2008, and at the other sites in 2007 and 2008. The ET was determined using the eddy covariance and surface renewal meteorological methods.

These sites reflect mid-summer climate conditions ranging from warm summer temperatures in the Intermountain areas (Scott Valley, Tulelake) to very hot summer temperatures (Imperial Valley). Border (flood) irrigation was used at the Sacramento Valley, Kern County, and Imperial Valley sites, while sprinkle irrigation was used at the Scott Valley and Tulelake sites, reflecting the irrigation practices of each area. Most of each field was fully irrigated; a section of each field was deficit irrigated during the mid-summer. The fully-irrigated alfalfa was irrigated according to the irrigators' normal practices.

## RESULTS AND DISCUSSION

### *Fully-irrigated Alfalfa Evapotranspiration (ET)*

Daily evapotranspiration of alfalfa is small, generally between 0.05 and 0.1 inches per day, at the start of the crop growing season, which varies depending on climate characteristics, increases with time of year to maximum values between 0.3 and 0.4 inches per day in June/July, and then decreases to small values at the end of the crop season, as shown in Figure 1 for Scott Valley, Imperial Valley, and Sacramento Valley sites. The growing season of Scott Valley is smaller than those of the Sacramento and Imperial Valley due to its altitude (2,700 feet) and northerly location. In the Imperial Valley, alfalfa evapotranspiration from July to September in 2007 was affected by possible heat stress, reflected by daily ET values smaller than reference ET values. Similar behavior occurred in the Imperial Valley 2008 growing season (not shown). Daily ET decreased during the harvest, but increased rapidly with time after the first irrigation after harvest, reaching maximum values just before the next harvest.

Seasonal evapotranspiration ranged from 33 inches (Scott Valley 2008) to 58 inches (Imperial Valley 2007) (Table 1). Seasonal ET values of Scott Valley and Tulelake were greater than the historical ET commonly used for crop water use. Seasonal ET of the Sacramento Valley and Kern County sites was slightly higher than the historical ET, with an average of 53 inches for the three year period for the Sacramento Valley. The seasaonal ET of the Imperial Valley was smaller than the historical value, possibly due to the heat stress.

Table 1. Seasonal ET of the fully-irrigated alfalfa and historical ET for the experimental sites.

| Site | Seasonal ET (inches) | Historical ET (inches) |
|---|---|---|
| Imperial Valley | 58 (2007) | 76 |
| Kern County | 56(2007) | 49 |
| Davis | 50 (2005)<br>54 (2006)<br>55 (2007) | 49 |
| Scott Valley | 39 (2007)<br>33 (2008) | 33 |
| Tulelake | 41(2007)<br>35 (2008) | 33 |

### *Crop Coefficients*

Crop ET commonly is estimated by multiplying the CIMIS reference crop ET by crop coefficients. Alfalfa crop coefficients were calculated for each site and compared with the historical crop coefficients (Table 2). Coefficients were not calculated for Scott Valley, where CIMIS reference crop ET was not available. Crop coefficients were the smallest just after a harvest and largest just before harvest.

Table 2. Crop coefficients of alfalfa.

| Site | Average | Minimum | Maximum |
|---|---|---|---|
| Davis 2005 | 0.92 | 0.49 | 1.14 |
| Davis 2006 | 0.94 | 0.56 | 1.11 |
| Davis 2007 | 1.04 | 0.65 | 1.33 |
| Kern 2007 | 1.01 | 062 | 1.25 |
| Imperial Valley 2007 | 0.80 | 0.43 | 0.99 |
| Tulelake 2007 | 0.99 | 0.50 | 1.30 |
| **Historical (Doorenbos and Pruitt, 1977)** | | | |
| Humid[1] | 0..85 | 0.50 | 1.05 |
| Dry[1] | 0.95 | 0.40 | 1.15 |
| Strong wind | 1.05 | 0.30 | 1.25 |

[1] light to moderate wind conditions

### *Mid-summer Deficit Irrigation*

Mid-summer deficit irrigation reduced the ET, but the amount of reduction varied considerably between the experimental sites. ET differences between fully-and deficit-irrigated alfalfa during the periods of mid-summer deficit irrigation ranged from 0.2 to 9 inches (Table 3). The 2007 value for Tulelake reflects the influence of shallow groundwater, which contributed to the ET of the deficit irrigated alfalfa, while the 2008 value reflected deficit irrigation from the first of June to the end of the crop season. The difference for Kern County reflects the fact that there was only one month of deficit irrigation. The largest differences were found for Sacramento Valley. ET

values of the fully-irrigated alfalfa during the period of deficit irrigation were similar for Imperial Valley, Sacramento Valley, and Tulelake.

***Yield***

Actual yield differences between fully–and deficit-irrigated alfalfa during the period of deficit irrigation ranged from 0.4 (Tulelake 2007) to 2.78 tons per acre (Sacramento Valley 2006). The small Tulelake difference reflects the shallow ground water contribution. The differences for Kern County reflect the one month of deficit irrigation. However, experience has shown that a yield of 0.5 tons per acre or smaller is not economical to harvest. Yields smaller than 0.5 tons per acre were excluded in the practical yield differences. The practical yield differences represent the economical yield loss to the grower.

Table 3.ET differences between fully-and deficit-irrigated alfalfa and fully-irrigated ET during the periods of deficit irrigation.

| Site | | ET differences (inches) | Full ET during period of deficit irrigation (inches) |
|---|---|---|---|
| Imperial Valley | 2007 | 2.4 | 22.5 |
| Kern County | 2006 | 1.8 | 8.9 |
| | 2007 | 1.7 | 14.0 |
| Sacramento Valley | 2005 | 9.4 | 23.4 |
| | 2006 | 7.4 | 21.2 |
| | 2007 | 4.7 | 18.7 |
| Scott Valley | 2007 | 2.0 | 10.6 |
| | 2008 | 3.1 | 12.6 |
| Tulelake | 2007 | 0.2 | 18.6 |
| | 2008 | 4.3 | 24.7 |

Table 4. Total yield difference between fully-and deficit-irrigated alfalfa.

| Site | | Actual yield difference (tons per acre) | Practical yield difference* (tons per acre) |
|---|---|---|---|
| Imperial Valley | 2007 | 1.66 | 1.66 |
| Kern County | 2006 | 0.66 | 1.03 |
| | 2007 | 0.85 | 1.16 |
| Sacramento Valley | 2005 | 1.37 | |
| | 2006 | 2.78 | 3.95 |
| | 2007 | 3.74 | 4.59 |
| Scott Valley | 2007 | 0.82 | 1.38 |
| Tulelake | 2007 | 0.4 | 0.4 |

* adjusted for yields smaller than 0.5 tons per acre (not considered economical to harvest)

## CONCLUSIONS

These ET measurements generally showed seasonal ET values that are higher than the historical seasonal ET values. The exception was Imperial Valley where the 2007 seasonal value was considerably smaller than the historical value. Average crop coefficients were similar to the historical values except for Imperial Valley. Mid-summer deficit irrigation reduced the ET during the period of deficit irrigation, but the differences in ET between fully-irrigated and deficit-irrigated alfalfa were site specific. Yields were also reduced by deficit irrigation.

Water transfer amounts based on ET differences are not practical because of the site-specific responses, which cannot be predicted. Although ET occurred during the periods of deficit irrigation, the source of this water used by the crop was stored soil moisture from the earlier irrigations, prior to the start of deficit irrigation. Also, this crop water use did not contribute to economical yield levels. The exception was at Tulelake where crop water use of the shallow ground water maintained high yields of the deficit-irrigated alfalfa. Water transfer amounts should be based on the ET of fully irrigated alfalfa during the period of mid-summer irrigation, which can be estimated as the product of crop coefficients and CIMIS reference crop ET. This ET also more fully reflects the reduction in applied water during the deficit irrigation period.

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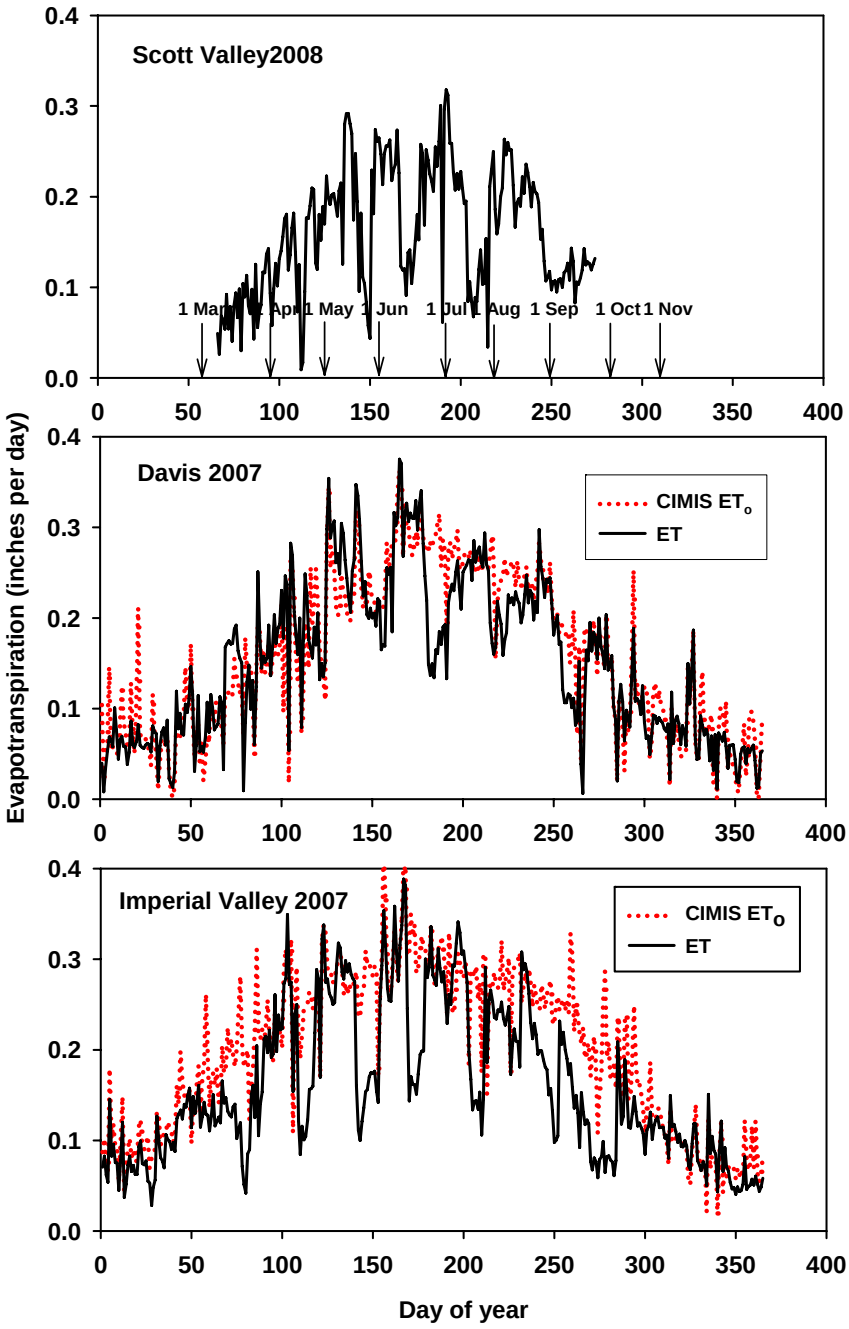


Figure 1. Daily evapotranspiration of alfalfa for Scott Valley (2008), Sacramento Valley (2007), and Imperial Valley (2007). CIMIS $ET_o$ is the CIMIS reference crop ET, defined as the ET of a well-watered grass.