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Alfalfa Responses to Irrigation Treatment and Environment[1]

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ABSTRACT

Water management is critical for maximum production of alfalfa (*Medicago sativa* L.) with under irrigation resulting in loss of production and over irrigation resulting in a loss of stand. The purpose of this study was to determine the optimum irrigation rates under high evaporative demand. Growth of alfalfa was evaluated on replicated plots (6 × 6 m) established on a fine textured soil (Typic Torrifluvent, clayey over loamy, montmorillonitic, calcareous hyperthermic family) and differentially irrigated from July 1975 to January 1978. The irrigation treatments were applied at 56, 66, 75 (best estimate of E_t, and 84% of pan evaporation (E_p) and described as dry, semidry, optimum and wet, respectively. Alfalfa yields increased with increase in water applied. Irrigation at 84% E_p for leaching did not enhance yield over the optimum water treatment possibly because of reduced stand from waterlogging. The protein concentration of alfalfa was higher in dry than in wet treatments in March and November. During the summer, plant temperatures in the dry treatment were up to 7 C higher than in the wet treatment.

***Additional index words:* *Medicago sativa* L., Plant temperature, Plant height, Forage yield, Protein concentration, Stand density.**

ALFALFA (*Medicago sativa* L.) is an important crop in the Desert Southwest because annual yields and quality are good, markets are close, and the crop is well suited to efficient rotation practices. Proper irrigation of alfalfa is often a critical factor in the success of the crop. Over or under irrigation can reduce yield, quality, stand longevity, and ultimately, economic returns. The attendant dangers of "scalding" or plant stand losses from flooding injury caused by slow water infiltration accentuates the problem (Stanberry, 17).

Several researchers have studied the water use efficiency (WUE) of alfalfa. Joy et al. (10,11) and Delaney et al. (3) showed that WUE was greater under low than under high water regimes. Conversely, Bauder et al. (1) measured a greater WUE in North Dakota for irrigated plots compared to plots under natural rainfall. In most of these studies, WUE was highest when the water supplied to plants by irrigation, rain, or ground water approximated evapotranspiration for the environmental area (6).

In several studies (2,12,16,18) alfalfa growth was related to amount and frequency of irrigation and proximity of water table. Measurement of changes in soil water has been used as criterion for refining estimates of water use (4,11,14,16). Pan evaporation (E_p) has also been used for irrigation scheduling (7,14).

Scrutiny of environmental effects on alfalfa growth and quality has increased in recent years (8,9,15). Stanberry (17) reported that under similar temperatures alfalfa growth was poorer in late than in early summer. He attributed late summer yield reductions to cumulative effects of high temperature and other stresses that decrease WUE.

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The objectives of this study were to evaluate alfalfa for (i) the yield response to irrigation treatments based upon pan evaporation values when water was non-limiting; and (ii) the differences in plant height, stand density, protein concentration, and leaf temperature as a function of irrigation regimes and in relation to time.

MATERIALS AND METHODS

Alfalfa field plots were established in November 1974 at the Imperial Valley Conservation Research Center on a fine textured soil (Typic Torrifluvent, clayey over loamy, montmorillonitic, calcareous, hyperthermic family). The experimental design was a split-plot, randomized complete block with five replications. The six irrigation regimes comprised the main plot treatments and the two cultivars the subplot treatments.

Borders were put up to form a series of 6 × 6 m plots. Plots were arranged in two rows (separated by 6 m) with 3 m between plots within the row. Plastic waterlines (5 cm diam) and outlets were installed to supply plots with metered amounts of water.

The plot area was pre-irrigated, disked, floated, and bordered lengthwise. Superphosphate was broadcast at the rate of 225 kg P/ha to insure adequate P. Soil K levels are high in the Imperial Valley so K was not applied. Two alfalfa cultivars, Mesa Sirsa and Salton were seeded in November 1974 so that each occupied one-half of a plot. Mesa Sirsa is a common commercial variety and Salton is considered tolerant to adverse waterlogging during high temperatures that are common in the summer (13).

Alfalfa was harvested at the 1/10 bloom stage. Yields of each cultivar were measured from a m^2 area which was cut at the 5 cm height with hedge clippers. The forage was dried in an oven (50 C) and weighed. Reported yields contain 10% moisture. The balance of the plot and surrounding bulk areas were harvested at the same time as the yield samples. Yield samples harvested 9 March, 23 May, 18 July, and 22 Nov. 1977 were analyzed for protein (Kjeldahl method) and samples harvested on 23 May were analyzed for acid detergent fiber (5). Water use efficiency was calculated as the amount of alfalfa produced (10% moisture) per ha cm of water applied.

Stand density and plant heights were measured in two replications only. Plant density counts were made 3 Feb. 1976, 7 Jan. 1977, and 6 Dec. 1977, and consisted of all living crowns within two areas (0.077 m^2 each) in each plot. Plant heights were measured at six locations within each plot on 27 Aug. 1975, 13 May 1976, 6 Apr. 1977, 18 May 1977, 20 June 1977, 11 July 1977, and 22 Nov. 1977.

Leaf temperatures were measured 2 to 9 August and 30 Nov. to 9 Dec. of 1977 to evaluate differences which occurred during the two seasons. Plant temperatures were measured during the test periods between 1300 and 1400 hours with a Telatemp Infrared Thermometer Model AG42[3].

The amount of irrigation water applied was based on pan evaporation (E_p) from a class A weather pan. Previous lysimeter studies in the Imperial Valley have shown that 75% of E_p is a good approximation of alfalfa evapotranspiration (E_t) and this was used as our optimum treatment. The class A weather pan was located about 1 km from the experimental area in a 4 × 4 m area planted to grass. The optimum treatment was irrigated when E_p values indicated a 50% reduction in the available soil moisture (ASM) to the 75-cm depth (which contained most of the roots). Available soil moisture was equal to 16.4 cm (0 to 75-cm depth) for this soil. For 3 days after harvest the E_p value was halved to adjust for reduced evaporative surface.

Treatments received 56, 66, 75, or 84% E_p and were defined as dry, semidry, optimum, and wet, respectively. The study also included two winter leaching (WL) treatments where less water was applied in the summer but extra water in the winter so that the total of applied water was equal to 66 or 75% of the E_p on an annual basis. All plots were irrigated the same (at 75% E_p) until July 1975 when differential irrigation treatments were initiated. All plots were irrigated on the same day but with differing amounts of water.

The time that water stood on the plots was measured for irrigations applied in 1975 (23 September), 1976 (9 March, 15 April, 12 May, 8 July, 20 July, 12 August, 9 December), and 1977 (2 June, 25 July, 3 August, 12 August).

RESULTS AND DISCUSSION

High temperatures in the summer resulted in high evaporation rates (E_p = 10 cm/week) and resulted in frequent irrigations (Fig. 1). There were only two large

[3] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of a product by the USDA, and does not imply its approval to the exclusion of other products that may also be suitable.

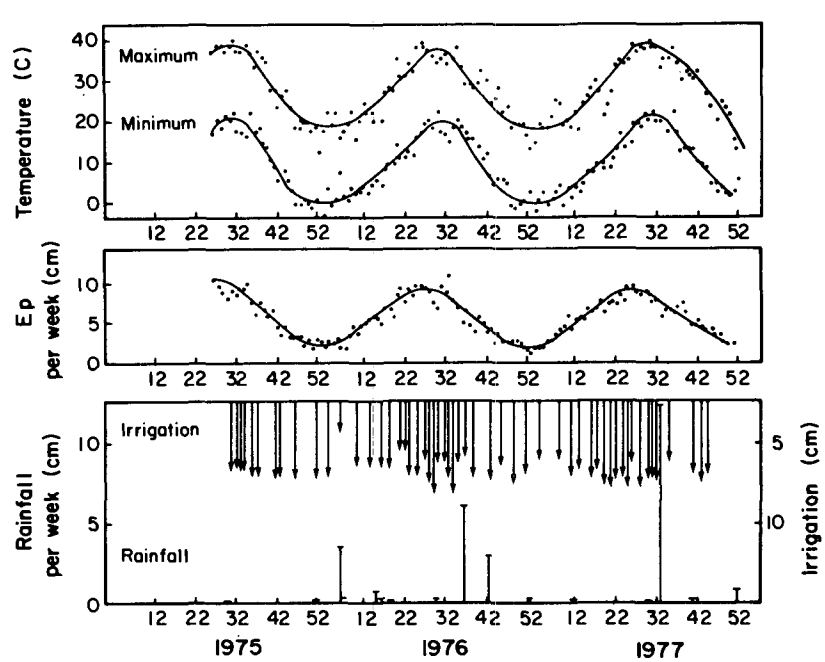

Fig. 1. Weekly totals and distribution of rainfall, E_p, irrigations [for optimum treatment (0.75 E_p)].

rains during the 2½ years of the test (10 Sept. 1976 and 16 Aug. 1977). Irrigation intervals were lengthened to 1 month under low temperatures.

The cultivar responses were not significantly different so the data presented are an average of the two.

The effect of irrigation treatments on plant temperatures was much greater in August than in November-December (Fig. 2). Plant temperatures in August were higher in the dry (56% E_p) and semidry (66% E_p) than in the optimum (75% E_p) treatment for −1, 4, and 7 days after irrigation. In August 1977, 7 days after irrigation, plant temperatures were 7 C higher in the dry compared to the optimum treatment.

Low water availability produced short plants with higher leaf temperatures than the optimum treatment. As would be expected, the short plants tended to have a high concentration of protein. Leaf temperatures should be further evaluated for effects on yield and as an index for scheduling irrigation.

Plant height was 26% less in the dry than in the optimum treatment (average of all sampling dates) (Fig. 3). The optimum (not shown, but would be a horizontal line at 100%) and wet (84% E_p) treatments had similar plant heights. Statistical differences in plant height between the optimum and dry treatments were much greater in 1977 than in 1975 or 1976.

Total yield did not differ significantly between the optimum and wet treatment (Table 1). Total yields were 33 and 16% lower in the dry and semidry treatments, respectively, than the optimum treatment, with applied water deficits of 25 and 12.5%. Winter leaching (WL) did not significantly improve yield when compared to the optimum water management treatment. Harvest yields were high in June and July, reaching 4 tons/ha per cutting (Fig. 4). The optimum and wet treatments had similar yields until the large rain in August 1977. After the rain of 12.3 cm the yields of the wet treatment were significantly lower because waterlogging caused a loss of stand.

When the water was applied at levels greater than E_t to achieve leaching, yield was either unaffected or reduced. This wet treatment reduced salinity (data not shown) in the top 30 cm of soil, but some plants died and that loss apparently offset any benefits of reduced salinity. Findings of our study indicate that clay soils in the Desert Southwest, that are cropped with alfalfa, cannot be leached without a loss of plant stand. Such soils, therefore, should be leached before planting to reduce the effect of salinity during the 3 or 4 years that alfalfa is grown.

Table 1. Mean annual water application and water use efficiency for 1976 and 1977 and total yields for the six irrigation treatments on alfalfa.

	Water† application treatment	Annual‡ water application	WUE§ 1976	WUE§ 1977	Total yield¶ 2½ years
		cm	— kg/ha cm —		t/ha
Dry	56	162	110 a*	93 bc	36.8 d
Semidry	66	187	117 a	103 ab	45.9 c
Optimum	75	211	121 a	108 a	54.6 a
Wet	84	236	109 a	88 c	53.3 a
Semidry (WL)#	56	192	121 a	108 a	47.1 bc
Optimum (WL)	75	214	115 a	106 a	51.7 ab

* Treatment means followed by the same letter within a column are not significantly different (0.05) from each other by the Duncan's Multiple Range Test.
† Percent of pan evaporation.
‡ Mean of 1976 and 1977 includes rainfall above 1.25 cm per event.
§ Water use efficiency based on oven dry alfalfa weights with 10% moisture.
¶ Total yield accumulated from August 1975 to January 1978.
# WL treatments winter leaching and summer water depletion.

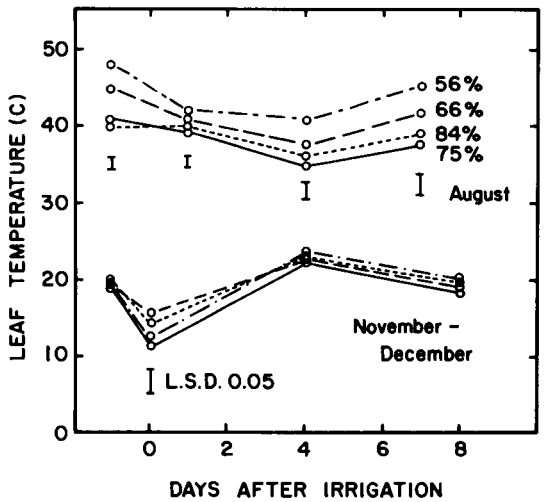

Fig. 2. Alfalfa leaf temperature (measured with infrared thermometer) in relation to four water application treatments (56, 66, 75, and 84% of E_p) in August and November-December 1977.

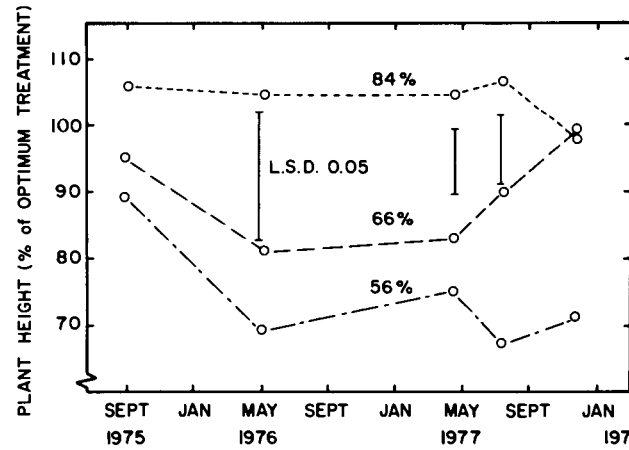

Fig. 3. Plant height (% of optimum treatment) as influenced by water application treatments (56, 66, 75, and 84% of E_p) (the 75% water application treatment could be represented by a horizontal line at 100% plant height).

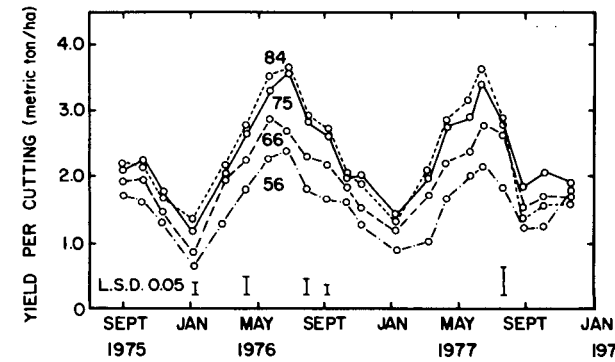

Fig. 4. Alfalfa yields per cutting in relation to four water application treatments (56, 66, 75, and 84% of E_p).

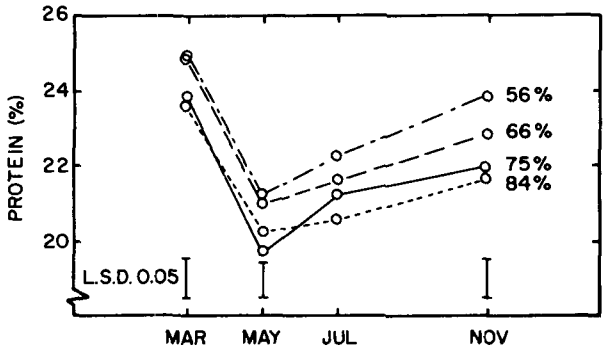

Fig. 5. Protein concentration (a measure of quality) in 1977 in relation to four water application standard treatments. (56, 66, 75, and 84% of E_p).

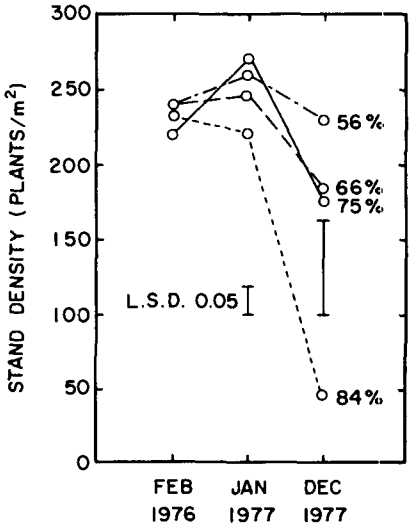

Fig. 6. Stand density (persistence of alfalfa under four different water application treatments (56, 66, 75, and 84% of E_p).

Our results differ from those of Bauder (1) who measured a 10% deficit in annual alfalfa yield when the available water was 12% below the rate at which water was not limiting. When water was reduced from 75 to 66% E_p in this experiment there was a 16% loss in yield. The relationship (yield = $-3.73 + 0.120\ E_t$) between yield (at 0% moisture for 1976 and 1977) and evapotranspiration was calculated for this study and showed that 8.3 cm of water was necessary to produce 1 ton/ha of alfalfa. This data is similar to that obtained by Sammis (16). Alfalfa in the Imperial Valley is grown primarily for its vegetative forage and the relationship between water applied and yield was found to be linear as previously shown by Bauder (1) and Sammis (16).

Water use efficiency for the wet and dry treatments was decreased in 1976 and 1977 (Table 1) compared to the optimum treatment. The reduction was statistically significant in 1977 but not in 1976.

Protein concentration of forage was higher for the dry than for the optimum or wet treatments in cool (March and November) but not in warm months (May and July) (Fig. 5). Acid detergent fiber averaged 17.1% for the dry, 20.6% for the optimum and 23.2% for the wet treatment. The plants tended to have shorter, finer stems in the dry and semidry than in the optimum and wet treatments.

Stand density changed with time and differed markedly between the dry and wet treatments by the end of the experiment (Fig. 6). The rain of August 1977 caused the loss of some plants in the wet treatment.

Average infiltration times for irrigations were 18, 23, and 25 h for the semidry, optimum, and wet treatments, respectively.

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