Alfalfa Responses to Irrigation Treatment and Environment¹

T. J. Donovan and B. D. Meek²

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 X 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 \( E_p \), 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 water use efficiency as a function of irrigation regimes and in relation to time. 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-m areas which were cut at the same time as the yield samples. Yield samples were analyzed for protein (Kjeldahl method) and samples harvested at the same time as the yield samples were analyzed for acid detergent fiber (ADF) and neutral detergent fiber (NDF).

Alfalfa field plots were established in November 1974 and consisted of all living crowns (10% moisture) per ha cm of water applied. The plot area was pre-irrigated, disked, floated, and bordered lengthwise. Superphosphate was broadcast at the rate of 5 kg in 6 cm diam) and outlets 6 m between 6 m X 6 m plots. All plots were irrigated the same (at 75 cm depth) for this soil. For 3 days after harvest the E, value was halved to adjust for reduced evaporative surface. Available soil moisture was equal to moisture (ASM) to the 75-cm depth (which contained most of the roots). Available soil moisture was halved to adjust for reduced evaporative surface. Available soil moisture was used as our optimum treatment. The class was defined as dry, semidry, optimum, and wet, respectively. The study included two winter leaching (WL) treatments where less water was used as our optimum treatment. The class was located about 4 km from the experimental area in a non-limnic, 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-m areas which were cut at the same time as the yield samples. Yield samples were analyzed for protein (Kjeldahl method) and samples harvested at the same time as the yield samples were analyzed for acid detergent fiber (ADF) and neutral detergent fiber (NDF).

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rains during the 2% 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\% \text{EP}) and semidry (66\% \text{EP}) than in the optimum (75\% \text{EP}) 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 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 \text{EP}, 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>
<thead>
<tr>
<th>Water Application Treatment</th>
<th>Annual Water Application</th>
<th>Water Use Efficiency (g/kg)</th>
<th>Total Yield (tl/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>56 cm</td>
<td>162</td>
<td>110 a*</td>
</tr>
<tr>
<td>Semidry</td>
<td>66 cm</td>
<td>187</td>
<td>117 a</td>
</tr>
<tr>
<td>Optimum</td>
<td>75 cm</td>
<td>211</td>
<td>121 a</td>
</tr>
<tr>
<td>Wet</td>
<td>84 cm</td>
<td>236</td>
<td>109 a</td>
</tr>
<tr>
<td>Semidry (WL)</td>
<td>56 cm</td>
<td>192</td>
<td>121 a</td>
</tr>
<tr>
<td>Optimum (WL)</td>
<td>75 cm</td>
<td>214</td>
<td>115 a</td>
</tr>
</tbody>
</table>

* 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.

\text{EP} = \text{Percent of pan evaporation.}

\text{WUE} = \text{Mean of 1976 and 1977 includes rainfall above 1.25 cm per event.}

\text{Oven dry alfalfa weights with 10\%.}

\text{Total yield accumulated from August 1975 to January 1978.}

\text{WL treatments winter leaching and summer water depletion.}
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% of Eₚ in this experiment there was a 16% loss in yield. The relationship (yield = -3.73 + 0.120 Eₚ) 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.