Application of additional irrigation water increased hay yields, but water in excess of about 2 feet did not appear to be particularly beneficial, according to recent tests at Davis. Adding the depth of initial soil moisture storage, and assuming an irrigation efficiency of 70%, the total annual water requirement of alfalfa under these conditions is about 4½ acre-feet. When water supplies are deficient, a good crop can be maintained with less than 8 inches of water applied, if the soil moisture reservoir is full in the spring. If about 2 feet of water is available for the hay crop, there appears to be little difference between applying water early or in equal amounts throughout the season.

Water *supply and irrigation effects* on Alfalfa

J. R. DAVIS · A. W. FRY · L. G. JONES

Although alfalfa hay is not a high income crop for California ranchers, it has a relatively high water requirement and usually occupies some of the best irrigated soils. In times of water shortages or high water costs, ranchers are forced to make decisions about irrigating a relatively low-value crop that occupies good soil, knowing however, that the decision may influence more than one year's yields. The decision usually involves proportioning the available water, and deciding whether to apply water at each cutting or early in the season—or perhaps not to irrigate at all late in the season.

Alfalfa irrigation systems are usually designed to achieve a fairly uniform distribution of water from the upper to the lower end of the field. Most growers also recognize that certain deviations from uniform water distribution may result in a more economical irrigation system. The question then is: how much deviation from uniform water distribution will allow the greatest net returns?

An alfalfa irrigation project was initiated at Davis in 1961, on Yolo silty clay loam soil with the objective of determining the yield and quality of alfalfa hay produced under different irrigation systems. One of the irrigation treatments represented a good, desirable irrigation practice: depths of water applied at each irrigation were designed to replace the soil moisture used since the last irrigation, and to maintain adequate soil moisture at all times. All other treatments were then irrigated at exactly the same time, but with different depths of water as summarized below:

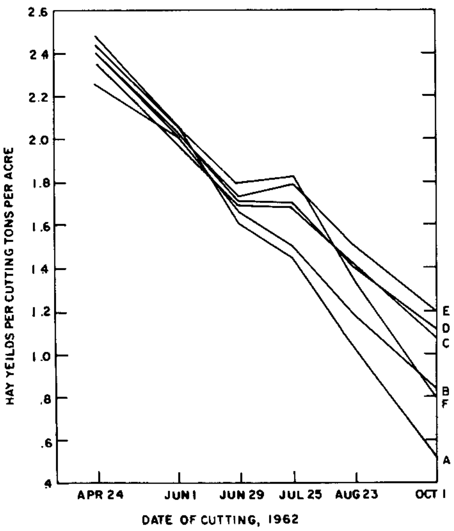
- A Depth of water applied = 25% of treatment D
- B Depth of water applied = 50% of treatment D
- C Depth of water applied = 75% of treatment D
- D Depth of water applied to maintain good soil moisture conditions and to replace soil moisture used since the previous irrigation
- E Depth of water applied = 150% of treatment D
- F Depth of water applied = 200% of treatment D for the first two irrigations, and no water applied after the third cutting at the end of June
- G Depth of water applied = treatment D, but with no winter irrigation
- H Depth of water applied = treatment C, but with no winter irrigation

Plots established

A randomized plot design with six replications of each treatment was selected for the field study. Each plot was 20 × 50 ft. and was surrounded by earth levees with a plastic film core. The plastic film, extending about 2 feet below the soil surface, was to reduce moisture movement from one plot to another. Before seeding, all plots were leveled to a flat grade, and water was applied at each irrigation by quick flooding through a meter.

Early in 1961, a good stand of Lahontan alfalfa was established, and all plots were maintained at the same soil moisture level during the year. The differential treatments were started in 1962, after good uniform stands had been obtained. At all times, cultural practices such as fertilization, insect and rodent control were maintained. Good winter rainfall during 1961–62 filled the soil moisture profile to a depth of at least 10 feet, so no winter irrigation was necessary in the spring of 1962. Thus, treatments G and H were equivalent to treatments D and C, respectively.

All 48 plots were harvested on the same morning, using a 12 ft. wide swather to cut a 12 ft. × 20 ft. area in the center of each plot. All hay was immediately weighed and samples were taken for moisture content and hay quality.



Hay yields

The results of this study are shown on the graph and are also listed below:

Treatments	Total Hay Yield Tons/Acre	Total Water Applied* Inches	Yield per acre-foot** Applied Tons/ac/ft.
A	9.10	7.87	13.9
B	9.59	15.75	7.3
C & H	10.19	23.62	5.2
D & G	10.38	31.51	4.0
E	10.49	47.28	2.7
F	10.24	27.44	4.5

* Exclusive of soil moisture storage at the beginning of the season, which would total about 15 to 18 inches of water.

** All yields are based on hay of 12% moisture content.

Although these data were not analyzed statistically, it is apparent that essentially no yield differences existed between treatments C, D, E and F, but that a total yield difference of at least one ton per acre of hay occurred between treatment A and these four treatments. Treatment F, which involved only two irrigations (the last one occurring after the second cutting) still yielded as high as treatments C or D, which received five irrigations.

Reasons for these results lie primarily in the amount of moisture retained in the soil throughout the season. As seen on the graph, all yields were about the same through the third cutting on June 29. The extraction of soil moisture from treatments A and B through June far exceeded the application of water, however, causing a yield decline to appear. This would indicate that in a normal year, the first two cuttings of alfalfa may not be influenced a great deal by irrigation, but that an increasing lack of soil moisture in the top 3 to 4 ft. depth of soil would soon decrease crop growth. In the case of treatment F, each of the two irrigations added almost 14 inches of water to the soil profile and yield decreases would not be expected until after the fourth cutting.

Hay quality

Hay quality was affected by irrigation treatment. Protein and carotene contents tended to be lower as the depth of water applied increased. For the drier treatments (A and B), protein and carotene percentages increased slightly throughout the season, probably because the leaf-to-stem ratio increased as plant growth was slowed down. Based particularly on the protein content, the hay quality was improved by the same soil moisture stresses that reduced yields. Analyses of fiber content, which would aid in this discussion, were not completed at the time of this writing.

Economic considerations

A tentative economic analysis and an evaluation of alternative decisions the rancher could make, if water were deficient or water costs were high, is possible from the data already presented. The table included to illustrate such an analysis was based on a roadside value of hay at $20 per ton. Using treatment E, which had the highest yields as a base, the table shows the gains or losses in annual income per acre for various prices of water, should the total depth of water applied be decreased from 47.28 inches.

The underlined values in the table are those which would result in the greatest net gain in income. For example, if the total cost of water application were $1 per acre foot, an annual seasonal application of about 4 feet of water (treatment E) would be the best; any lesser depth would result in a loss of income. On the other hand, if the total cost of water were $20 per acre foot, then reducing applications from 4 feet to 8 inches would save almost $38 per acre, per year, even though the yield would decrease.

This table illustrates a demand schedule for water as a function of price or cost of water application, and shows that the magnitude of probable water demands generally decreases as the price of water increases: a twofold increase in cost from $10 to $20 per acre foot would create a threefold decrease in water applied (23.62 inches to 7.87 inches); however, a twofold increase from $2.50 to $5.00 per acre foot would have no effect on demand. Analyses such as these must be available for other locations and additional crop years, however, before good generalizations can be made.

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GAINS (+) OR LOSSES (–) OF ALFALFA INCOME PER ACRE ANNUALLY AS A FUNCTION OF WATER APPLIED AND WATER COST

Changes in Depth of Water Applied	Cost of Applying Water, per Acre Foot*					
	$1.00	$2.50	$5.00	$10.00	$20.00	$30.00
From E to F	$– 3.35	$– 0.87	$+ 3.26	$+11.53	$+28.06	$+44.59
E to D	– 0.89	+ 1.09**	+ 4.37**	+10.94	+24.08	+37.22
E to C	– 4.03	– 1.07	+ 3.86	+13.72**	+33.44	+53.16
E to B	–15.37	–11.43	– 4.86	+ 8.28	+34.56	+60.84
E to A	–24.52	–19.59	–11.38	+ 5.04	+37.88**	+70.72**

* These costs include capital, labor, power, water and all other irrigation costs.

** Underlined values offer greatest net gain in income.