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Effect of Irrigation Treatments on Alfalfa (*Medicago Sativa* L.) Production, Persistence, and Soil Salinity in Southern California

W. F. Lehman, S. J. Richards,
D. C. Erwin, and A. W. Marsh

UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES

Two experiments were conducted in the Imperial Valley of Southern California to study the effects of irrigation management on alfalfa yield, stand persistence, and soil salinity levels in the root zone.

Irrigation treatments were based on frequency as determined by tensiometers and on duration of irrigation. Soil in Experiment I was mainly clay and clay loam to 3 m. Soil in Experiment II was clay loam, silty clay loam, and clay in the top 1½ m and sandy clay loam and sandy loam in the next 1½ m of depth. Rainfall was negligible.

Frequent short irrigation (FS) or moderate treatment was superior in yield, stand persistence, and hay quality in Experiment I. Phytophthora root rot was found in the frequent long (FL) or wet treatment. In Experiment II yield was similar for all treatments, but an invasion of grass resulting from weaker stands reduced the quality of the hay produced in the FL treatment. Disease incidence was low in the normal short (NS) or dry treatment but relatively high in the other two treatments.

Use of tensiometers at the 30- and 61-cm depth demonstrated the possible use of tensiometers in alfalfa forage production and some of the problems encountered in irrigation.

Soil salinity was inversely related to hours of applied irrigation in both experiments for the 20–45 cm and 45–70 cm depths and for practically all sampling dates during the second year.

In leaching treatments superimposed on Experiment I at the end of the experiment, EC values increased slightly with three 3-hour irrigations. Thirteen irrigations with 24- and 3-hour durations resulted in consistent but similar reductions in soil salinity.

THE AUTHORS:

W. F. Lehman is Associate Agronomist, Imperial Valley Field Station, El Centro.

S. J. Richards is Professor of Soils and Plant Nutrition, Riverside.

D. C. Erwin is Professor of Plant Pathology, Riverside.

A. W. Marsh is Extension Irrigation and Soils Specialist, Riverside.

W. F. Lehman, S. J. Richards,
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Effect of Irrigation Treatments on Alfalfa (*Medicago Sativa* L.) Production, Persistence, and Soil Salinity in Southern California[1]

INTRODUCTION

ALFALFA is one of the largest field crops in the low desert valley areas of California, particularly the Imperial and Palo Verde valleys. In the Imperial Valley alfalfa hay is grown on about 59,535 ha (147,000 acres) annually; alfalfa seed is produced on about 8,505 ha (21,000 acres) of this land during the summer. The value of the alfalfa hay crop is about 21 million dollars, that of the alfalfa seed 2 million dollars (Imperial County Agricultural Commissioner, 1959–1966). In some years alfalfa is the highest valued crop in the Valley, changing places with cotton and lettuce from year to year.

Annual yields of alfalfa in the Imperial Valley average about 13.2 metric tons per ha (5.9 tons per acre). (Imperial County Agricultural Commissioner, 1959–1966). Because of favorable climatic conditions and long season, one might expect the average yields to be higher than they are. Alfalfa stand life ranges from 2 to 5 years, and it is often plowed up after 2 or 3 years of production. The reasons for the relatively short stand life and for the yields somewhat lower than might be expected in this environment are not definitely known. It has been observed that alfalfa is frequently killed as a result of irrigation during hot weather when water stands or the soil is saturated for 36 hours (Erwin, *et al.*, 1959). Even where water does not pond on the ground, evidences of root deterioration have been noted, often accompanied by infection of pathogenic organisms (Erwin, 1954, 1956, 1965, 1966; Smith, 1943, 1945).

Irrigation practices for the production of alfalfa have been summarized (Fortier, 1940, and Stanberry, 1955). In some experiments alfalfa forage yield increased with increased water application. In other experiments alfalfa forage yield increased with increased water application to a certain level, and then decreased as more water was applied. Yield reductions at the high rates of water application were caused by reduction in stand. It was generally concluded that each type of soil and set of conditions require a certain range of soil moisture for maximum alfalfa forage production (Fortier, 1940; Packard, 1917; Stanberry, 1955).

The depth of alfalfa rooting in many soils of Imperial Valley is shallow in comparison with the characteristic deep rooting system which alfalfa has exhibited in other localities or soils (Pack-

[1] Submitted for publication August, 1967.

ard, 1917, and Stanberry, 1955). Preliminary investigations conducted in the area of this study on May 20, 1959, showed that 82, 12, and 6 per cent of the alfalfa roots were found in the 0.3, 0.6, and 0.9 m of soil, respectively. In an investigation made in another location on a 3-year-old stand, 62, 27, and 11 per cent of the alfalfa roots were found in the 0.3, 0.6, and 0.9 m of soil, respectively. Packard (1917) surveyed root depth of three Imperial Valley soils—sand, sandy loam, or fine sandy loam—to a depth of 1.5 and 1.8 m. He found that in these soils 80 to 90 per cent of the fine roots were in the upper 1.2 m. For the fine-textured soils he concluded that the feeding roots are largely on the surface.

In the Imperial Valley alfalfa is commonly grown on fine-textured soils which have limited permeability to water and air. When irrigating with Colorado River water which contains approximately 800 ppm dissolved salts, it is necessary to have some water move downward through the soil profile to provide for leaching the excess salts which concentrate in the root zone as the alfalfa transpires water. Because alfalfa does not tolerate ponding during the summer and leaching may be restricted in the fine-textured soils, a condition is created which is conducive to accumulation of salts in the root zone.

The present experiments were undertaken to study the effects of irrigation management on alfalfa yield, stand persistence, and on soil salinity levels in the root zone. More specifically, an effort was made to learn if a method of irrigation could be developed which would provide for the water needs of alfalfa, avoid situations which cause or predispose plants to attacks of disease organisms, and maintain satisfactory salinity levels. Since preliminary evidence suggests that a successful irrigation management technique might involve short-duration water applications during the hot summer season, a supplementary program to study leaching of salt during the winter months was undertaken as an additional objective of this study.

TABLE 1

ANALYSIS OF WATER SAMPLE FROM ALL-AMERICAN CANAL, COACHELLA BRANCH,* COLLECTED SEPTEMBER 1, 1960

Item	Unit	
Conductivity, EC × 10^6 at 25° C	µmhos/cm	1220
Sodium-adsorption-ratio (SAR)		3.0
Soluble-sodium-percentage (SSP)	per cent	44
Boron.......B	p.p.m.	.14
Dissolved Solids	t.a.f.	1.12
Dissolved Solids	p.p.m.	823
Ratio: ES (p.p.m.)/EC × 10^6 at 25° C		.67
pH		8.0
Calcium.....Ca	meq./l.	4.36
Magnesium..Mg	meq./l.	2.47
Sodium.....Na	meq./l.	5.53
Potassium...K	meq./l.	.09
Sum of Cations		12.45
Carbonate...CO_3	meq./l.	trace
Bicarbonate.HCO_3	meq./l.	2.54
Sulfate......SO_4	meq./l.	6.47
Chloride....Cl	meq./l.	3.36
Fluoride.....F	meq./l.	.03
Nitrate......NO_3	meq./l.	.01
Sum of Anions		12.41

Analyzed by U. S. Salinity Laboratory, and reported as Table 54/60 to Coachella Valley County Water District on November 8, 1960.

* Water in the All-American Canal is diverted from the Colorado River at Imperial Dam and serves both the Imperial and Coachella valleys.

MATERIALS AND METHODS

Two experiments were conducted at two different sites separated from each other by approximately 140 m, both mapped as Imperial silty clay (Strahorn, *et al.,* 1922). Experiment I was conducted from the spring of 1959 to the fall of 1960 followed by a leaching program during the winter of 1960–61. A report from a drainage investigation conducted by the Department of Water

Science and Engineering, University of California, Davis, shows that the soils in the vicinity are mainly clay and clay loam to a depth of 3 m[2]. Over the years of the experiment the water table in this vicinity remained mostly between 1.2 to 1.5 m beneath the soil surface.

The second experiment was conducted from the spring of 1961 to the fall of 1962. The drainage survey indicated that the top 1.5 m of soil in this area consisted of clay loam, silty clay loam, and clay. The 1.5–3 m depth was a mixture of sandy clay loam and sandy loam. The water table has been approximately 1.5 m beneath the surface most of the time.

Water used for irrigation was obtained from the Colorado River diverted at Imperial Dam and transported through the All-American Canal. Salt concentrations of Colorado River water in the All-American Canal have increased gradually with the years, but larger changes have occurred at different seasons within a year. During the years of this experiment, the average $EC \times 10^6$ for periodic samples analyzed at the U. S. Salinity Laboratory was 1180 μmhos/cm at 25° C. Three analyses taken during the first half of the year averaged 1100 μmhos/cm, while analyses during the last half of the year averaged 1260 μmhos/*cm*. A complete analysis of the water for one period is shown in table 1.

Rainfall during the period of Experiments I and II was 5.94 and 6.10 cm, respectively. This rain fell in 18 different days in Experiment I and 20 in Experiment II. The amount of rain that fell in a day was usually very low. Rainfall of only 0.25 cm or less was recorded on 13 days in Experiment I and 15 days in Experiment II.

Both irrigation experiments were seeded with Moapa alfalfa in the fall of the year. Plot size was 4.6 × 91.4 m in Experiment I and 9.1 × 91.4 m in Experiment II. Each plot was surrounded by borders 30 to 46 cm high and 91 cm wide at the base which permitted ponding to a depth of several centimeters for a controlled period of time. Each plot had inlet and outlet controls. Surface drainage was fairly rapid when the outlet was opened, so that the rate of recession about equaled the rate of advance.

Two tensiometer locations, each with a 30- and a 61-cm tensiometer, were established on each plot. Deeper tensiometer installations were unnecessary because of the limitation of rooting depth. The tensiometer locations were equidistant from the ends of the plots and 30.5 m apart within one plot. Readings were taken between 7:30 and 8:00 a.m. each morning. Data from tensiometers located in soil which had dried beyond the functioning limits of the tensiometer were recorded at the highest limit reached. This figure was recorded until the plots were irrigated. Data from tensiometers not functioning properly because of mechanical failure were eliminated from the averages.

Three irrigation treatments replicated three times were applied to both experiments in a randomized block design. Differential treatments were started April 9, 1959, after two cuttings in Experiment I, and on June 3, 1961, after three cuttings in Experiment II. They were:

Normal Short (NS)—irrigate when 30-cm tensiometers read 70 to 80 centibars (cb); hold water on plots for 3 hours.

Frequent Short (FS)—irrigate when 30-cm tensiometers read 30 to 35 cb; hold water on plot 3 hours.

Frequent Long (FL)—irrigate as FS except hold water on plot 6 hours.

The indicated duration was lengthened 1 to 2 hours on plots when soil suctions for the 61-cm tensiometers indicated that a dry soil layer was developing. Treatments FS and FL were always

[2] Drainage investigation on Imperial Valley Field Station, March 1958, by L. G. Wilson.

irrigated at the same time because experience had shown it would be impractical or very difficult to use three different irrigation schedules during the summer months. Irrigation water availability and the requisite soil drying before cutting produced some periods which were drier than the desired treatment values.

The lack of metering equipment and control of irrigation water eliminated any attempt to learn the quantity of water applied or the quantity of water moving downward in the soil profile.

Two areas in each plot, 1.1 × 15.2 m in Experiment I and 1.1 × 9.1 m in Experiment II, were cut for yield measurements. The centers of the cut areas were located in the center of the plot near each tensiometer location. A 2–3 kg sample of hay was taken from each cut and oven-dried in a forced-air oven set at about 77° C to determine percentage of moisture. Green forage was then converted to tons per acre of oven-dry hay.

Stand counts were made after a spring and fall cutting in two 61 × 61 cm squares in each plot. Subsequent counts were made within the same location inside the area cut for yield.

The thin stand in the FL treatment in Experiment I was renovated lightly and reseeded on November 23, 1959. An extra irrigation was given this treatment in an effort to establish the stand.

During both experiments, soil samples were taken in the spring, midsummer, and fall at the 0–5, 5–20, 20–45, and 45–70 cm depths. The surface layer was sampled at three locations and the deeper layers at two locations per plot. Locations for all soil sampling were noted and subsequent sampling locations moved to new sites. Electrical conductivity of the saturation soil extract expressed as mmhos/cm was used as the index to soil salinity (Richards, 1954).

Following Experiment I, three winter leaching treatments were carried out from November 1960 to February 1961. The treatments again were specified on the basis of number and duration of irrigations as follows: three 3-hour irrigations; thirteen 3-hour irrigations; and thirteen 24-hour irrigations. One plot from each treatment of the preceding irrigation experiment was assigned by lot to each of the three leaching treatments. Soil sampling for salinity measurements was used to evaluate the effects of the leaching treatments.

Inspection of randomly selected areas were made periodically to evaluate the response of the irrigation treatments on the major root diseases on alfalfa. Disease reactions were determined from inspection of the roots.

Analysis of variance was calculated where applicable. Percentages were converted to degrees of an angle for analysis.

RESULTS

Yield

Significant differences were found among the averages for hay yield in Experiment I (figure 1). Considerably more hay was produced by the frequent short irrigations (FS) than by either of the other two treatments in the experiment. By observing the individual cut information in figure 1, it will be noted that the NS treatment produced less hay than either of the other two treatments in most of the cuttings. Increased amounts of water applied in the FS and FL treatments seemed to have a beneficial effect on the June 12, 1959, cutting whereas the NS treatment was adversely affected by the new irrigation regime. This was also true in the third cutting in Experiment II. The FL treatment appeared to have been adversely affected after the July 9, 1959, cutting and was unable to recover.

The total cumulative yields for the three irrigation treatments in Experi-

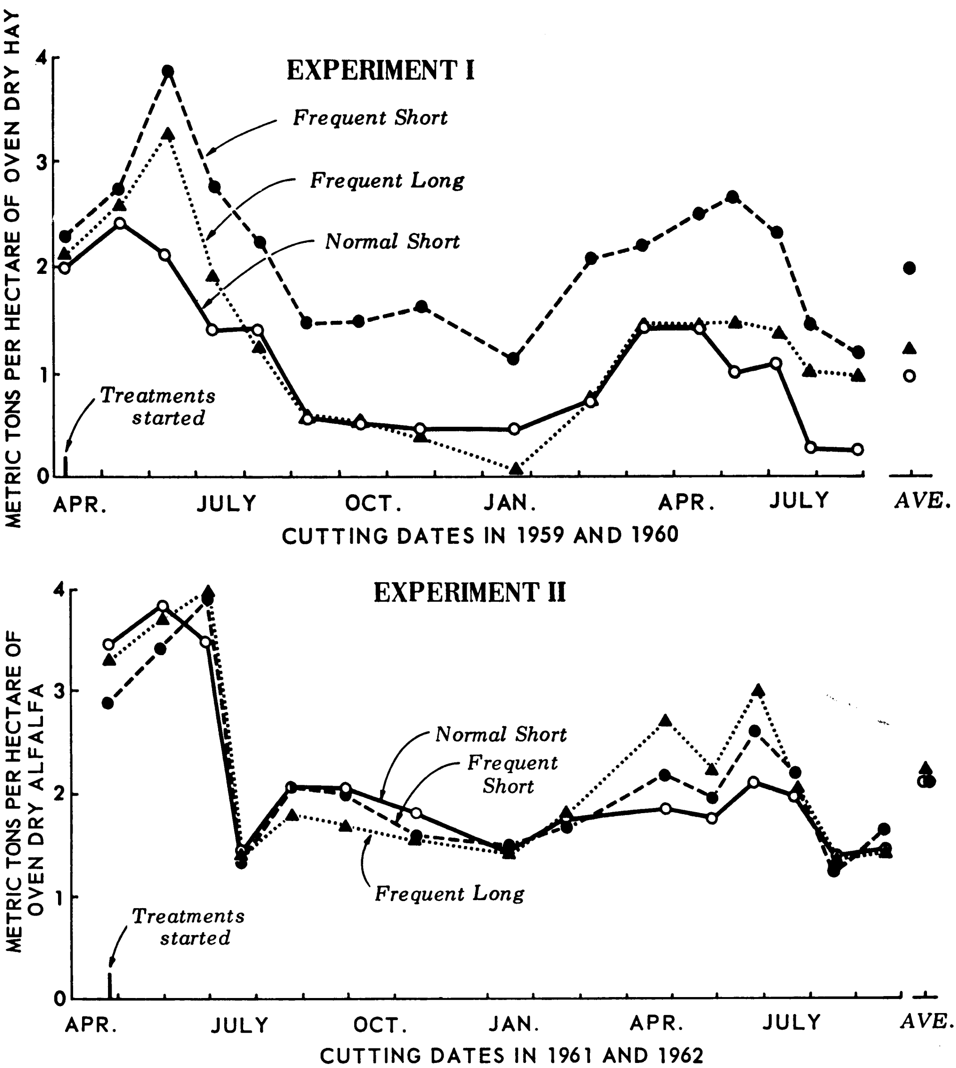

Fig. 1. Alfalfa hay yield by cutting date for two experiments with three irrigation treatments each.

ment II were not significantly different. Observed plant vigor together with yield data for individual cuttings made in April through June, 1962 (figure 1) indicated that the alfalfa in the FS and FL treatments benefited from the larger water application made during this period.

STAND COUNT

Number of alfalfa plants in 30 square cm for four dates in each of the two experiments is shown in table 2. Plant number decreased between each of the dates when counts were taken in Experiment I except in the FL treatment. The stand increased in the FL treatment plots because they were reseeded in November to increase the thin stand. The FS treatment had the best stand

TABLE 2

NUMBER OF ALFALFA PLANTS IN 30 SQUARE CM FOR FOUR DATES IN EACH OF TWO EXPERIMENTS

Treatment	Number of plants per 30 square cm				
	Experiment I date counted				
	5-22-1959	9-18-1959	5-19-1959	10-12-1960	Average*
NS	41.7	11.6	4.6	0.3	14.5
FS	50.2	26.8	15.1	5.3	24.3
FL	50.1	6.9	8.1	1.0	16.5
Ave.*	47.3	15.1	9.3	2.2	
	Experiment II date counted				
	5-31-1961	10-2-1961	6-22-1962	10-9-1962	Average†
NS	15.0	15.4	7.7	4 2	10.6
FS	15.1	16.6	10.9	3.9	11.6
FL	14.5	14.1	7.2	1.2	9.2
Ave.†	14.9	15.4	8.6	3.1	

* Significant at the 5 per cent level.
† Significant at the 1 per cent level.

through the entire test. This probably contributed to the higher forage yields also found in the FS treatment in this experiment. In Experiment II little or no loss of stand occurred during the first summer. There was some loss during the winter but the greatest loss was through the second summer. Stands were similar in the NS and FS treatments through the test but slightly lower for the FL treatment.

PERCENTAGE OF GRASS IN ALFALFA STAND

Two grass species are responsible in reducing alfalfa hay quality in the low desert areas of southern California. Canary grass (*Phalaris minor* Retz.) is an important weed during the winter and early spring months and water grass (*Echinochloa colonum* (L) Link) is important during the summer and early fall. Percentage of grass in alfalfa hay at cutting dates when grass was an important component is found in table 3. Grass concentration changed through the season. These changes were due primarily to a species change and the density or vigor of the alfalfa stands. Weeds were relatively unimportant in the stand during most of the first year of growth. The first grass recorded was in September in the first experiment. This was water grass which died as the weather cooled. Canary grass was found in both experiments in March and April, but decreased in importance and died as the warm weather approached and higher yields were obtained. Grass again increased in the later summer when the stands weakened.

In Experiment I grass percentage was low for the FS treatment through the entire test but relatively high for the other two treatments. In Experiment II sufficient grass occurred in four cuttings to be recorded. The percentage values for the NS and FS treatments were similar in all four cuttings. When compared to the NS and FS treatments, the FL treatment had approximately twice as much grass in every cutting.

Grass percentage should be considered with yield information because of its influence upon quality and value. Yield was low and grass percentage was

TABLE 3
PERCENTAGE OF GRASS IN ALFALFA HAY AT CUTTING DATES WHEN GRASS WAS AN IMPORTANT COMPONENT IN THE HAY

Treatment	Experiment I cutting date									
	9-9-1959	3-9-1960	4-13-1960	5-16-1960	6-8-1960	7-5-1960	7-28-1960	8-29-1960	10-14-1960	Ave.†
	percentage of grass									
NS	47.3	30.0	17.3	10.0	10.0	17.3	25.7	60.3	78.0	32.9
FS	0.0	1.7	0.0	0.0	0.0	0.0	0.0	7.3	13.0	2.4
FL	48.7	16.7	46.7	5.0	4.7	25.7	50.7	77.0	74.7	38.9
Ave.†	32 0	16.1	21.3	5.0	4.9	14.3	25.5	48.2	55 2	
	Experiment II cutting date									
	4-27-1962	7-20-1962	8-16-1962	9-20-1962						Ave.*
	percentage of grass									
NS	13.3	1.7	12.3	26.3						13.4
FS	16.7	2.3	8.3	38.0						16.3
FL	32.3	15.7	38.0	65.3						37.8
Ave.†	20.8	6.6	19.5	43.2						

* Significant at the 5 per cent level.
† Significant at the 1 per cent level.

high in the NS and FL treatments in Experiment I. Thus, a loss was sustained in two areas in these treatments. For the FS treatment in Experiment I hay yields were comparatively high and grass was low for most cuts. In Experiment II total yield was slightly higher for the FL treatment but the larger quantity of grass reduced the quality of this yield.

ALFALFA DISEASES

Percentage of alfalfa plants with Rhizoctonia root canker (Erwin, 1956; Smith, 1943, 1945) lesions and xylem necrosis (commonly called scald) found in Experiment II are shown in table 4. Percentage of roots with Rhizoctonia root canker and xylem necrosis increased with irrigation frequency and time of application. A very low percentage of roots was found with the two diseases in the NS treatment. The incidence of disease in the FS treatment was three times that of the NS and the FL was four times that of the NS.

TABLE 4
PERCENTAGE OF ALFALFA PLANTS WITH RHIZOCTONIA ROOT CANKER LESIONS AND XYLEM NECROSIS FOUND IN THREE IRRIGATION TREATMENTS SEPTEMBER 11, 1961

Treatment	Plants with Rhizoctonia root canker*	Plants with Xylem necrosis†
	per cent	*per cent*
NS	4.6	6.3
FS	14.2	20.1
FL	19 7	23.8

* Significant at the 5 per cent level.
† Significant at the 1 per cent level.

Samples were taken May 15, 1962, in nine locations in each treatment to determine incidence of *Phytophthora megasperma* (Erwin, 1954, 1965). No Phytophthora lesions were found on roots from the nine locations in the NS treatment. Typical lesions were found in four of the nine locations in the FS treatment and two of the nine locations in the FL treatments.

TABLE 5

IRRIGATION FREQUENCY AND TENSIOMETER READINGS AT THE TIME OF IRRIGATION THROUGH TWO ALFALFA EXPERIMENTS WITH THREE IRRIGATION TREATMENTS EACH

Item	Experiment I Treatments			Experiment II Treatments		
	NS	FS	FL	NS	FS	FL
Average number of irrigations per cutting...	2.0	3.2	3 1	2.4	2.9	2.9
Average number of days between irrigations for the months of:						
May, June, July, August..........	11.5	8.0	8.0	10.6	8 6	8 6
March, April, September, October......	14.0	11.5	11.5	14.3	12.1	12.1
November, December, January, February..........	42.7	22.7	22.7	33.7	28.0	28.0
Average tensiometer readings at time of irrigation in centibars:						
30-cm tensiometer..........	54	50	25	69	48	46
61-cm tensiometer..........	25	18	9	17	11	11

IRRIGATION

Irrigation frequency is shown in table 5. In Experiment I the FS and FL treatments were irrigated about one more time per cutting than the NS treatment and 0.5 times more per cutting in Experiment II.

The average number of days between irrigations in the two experiments differed only during the winter months. During May, June, July, and August the NS treatment was irrigated about every 11 days, and the other two treatments about every eight days. Irrigations through the months of March, April, September, and October were 14 days apart for the NS treatment, and 12 days apart for the FS and FL treatments.

The interval between the few irrigations made during the winter months was three to four times longer than it was during the summer months, probably because of rainfall, humidity, and temperature.

The observed suctions shown in table 5 for Experiment I differed considerably from the suctions prescribed for the treatments. In Experiment II the observed suctions were very close to those prescribed. Considerable variability was found among the six tensiometers in a treatment because some areas in the treatments would dry more rapidly than others. Seldom were all tensiometers in a treatment at the maximum range at the time of irrigation.

The average readings for the 61-cm tensiometers given in table 5 relate to conditions just prior to irrigation. As will appear in selected tensiometer records, readings at this depth approach zero following irrigations and remain relatively low during irrigation intervals. For the fine-textured soils, such readings could indicate adverse root environment due to lack of aeration.

The amount of rainfall per day was very low (less than 0.25 cm) on most days when rainfall was recorded. Only one rain was of sufficient magnitude (2.41 cm) to lower suctions in Experiment I. In Experiment II, three rains of 1.04, 1.04, and 2.06 cm affected the tensiometer readings. One of the 1.04 cm rains which fell in August affected the tensiometers in only one treatment.

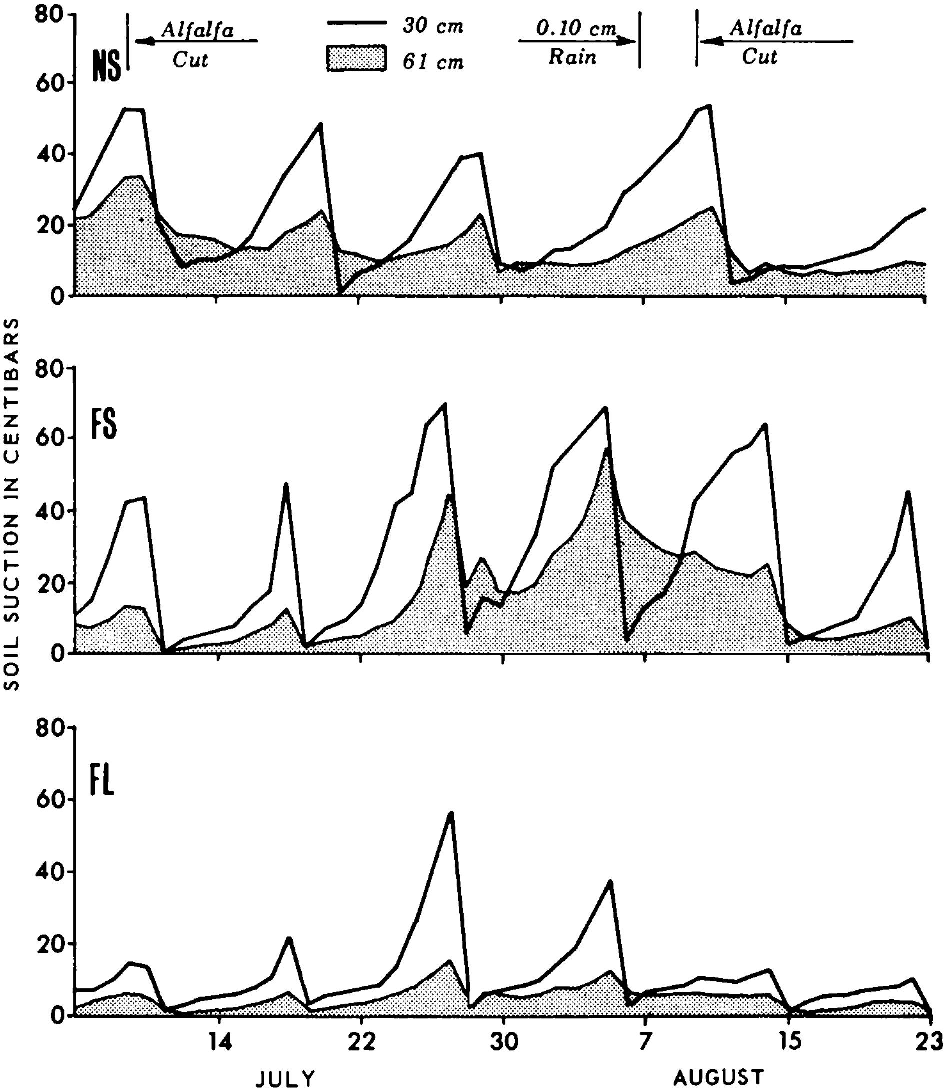

Fig. 2. Soil suction records at 30- and 61-cm depths from July 6 to August 23, 1959, for three irrigation treatments in alfalfa irrigation Experiment I. Timing of irrigations is indicated by a sharp decline of the 30-cm records to a near 0 suction.

From this it appears that rainfall had little direct effect on the results of this study.

Selected tensiometer records obtained during the summer and winter for the two experiments are shown in figures 2 to 6. Records selected show some of the special problems encountered as well as typical results. Problems such as coordinating the prescribed irrigation schedule with cutting, "water out" periods, and other factors occurred in both trials and are easily pinpointed in graphs of the 30-cm tensiometer records. For example, a mistake in plot irrigation is readily shown in figure 4 on July 1. The FS and FL treatments should have been irrigated on this date instead of the NS. The effect of rain is shown for December 14 in figure 6 NS and for August 23 in

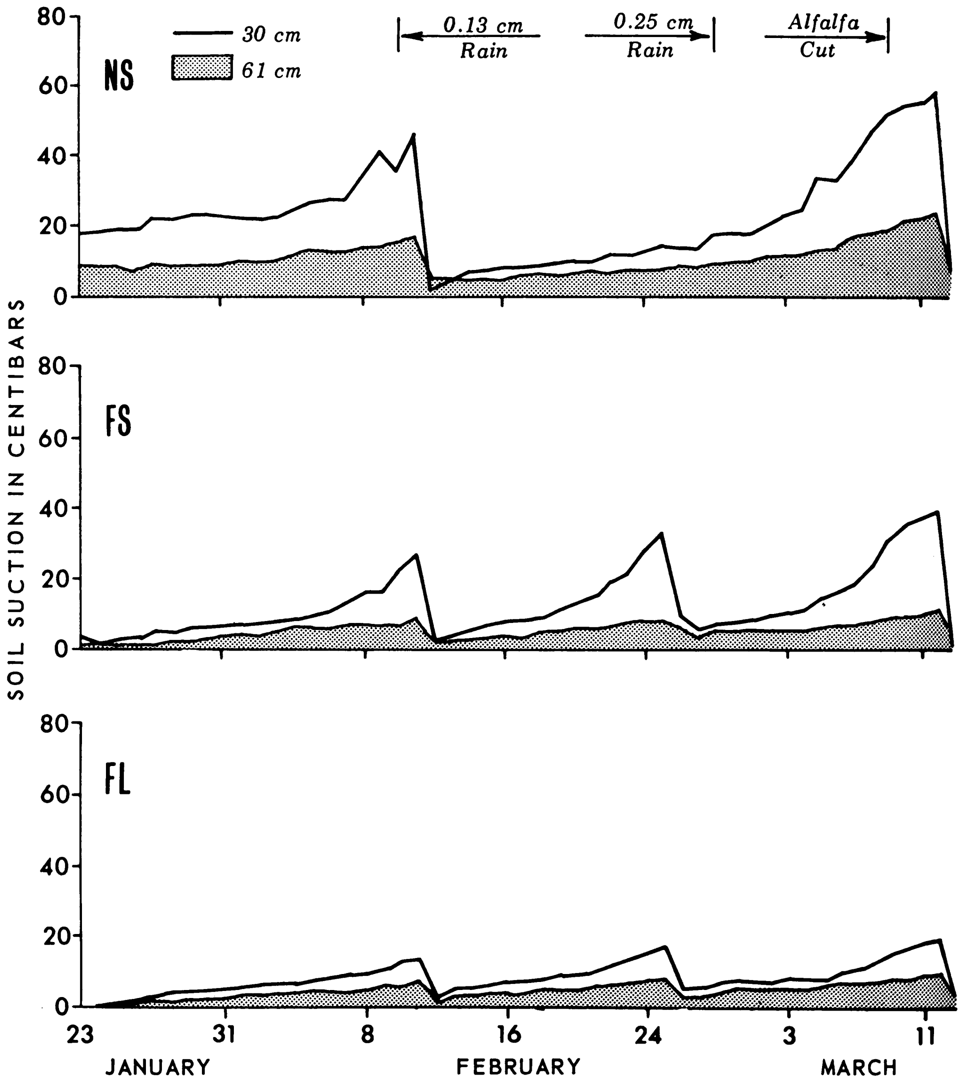

Fig. 3. Soil suction records at the 30- and 61-cm depths from January 23 to March 13, 1960, for three irrigation treatments in alfalfa irrigation Experiment I.

figure 5 NS. The long period between irrigations at the time of cutting and the drying beyond the prescribed limits are shown in figure 5 as well as some of the other figures. The reduced demand for water after a cutting is shown to some degree in most graphs. However, in these graphs where averages are used this is often confounded by the fact that some tensiometers in the average have reached the maximum. This reduced demand was best demonstrated by individual tensiometers which had not reached the maximum reading. The differences between winter and summer irrigations are evident when the appropriate figures are compared.

One problem encountered in Experiment I and not in Experiment II was water penetration. Examples of this are demonstrated best in graphs of the 61-cm tensiometer records and sometimes by the 30-cm tensiometers in figures 2 to 4. No average suctions of 0 were reached by the 61-cm tensiometers in treatment NS from about May to September 1959 and March to the end of the trial in 1960. Occasionally the area around the 61-cm tensiometer would begin to dry in the FS treatment. However, this soil could usually be wet by holding the water on the plots 1 to 2 hours longer for a few irrigations. As shown by a mistake in plot irrigation in figure 4 FS, one long interval between irrigations could be enough to start drying a layer in the soil. In farm practice this could happen between cuttings.

Water would often continue to penetrate and wet the 61-cm tensiometer from two to four days after an irrigation. As shown in figure 4 FS July 22 to

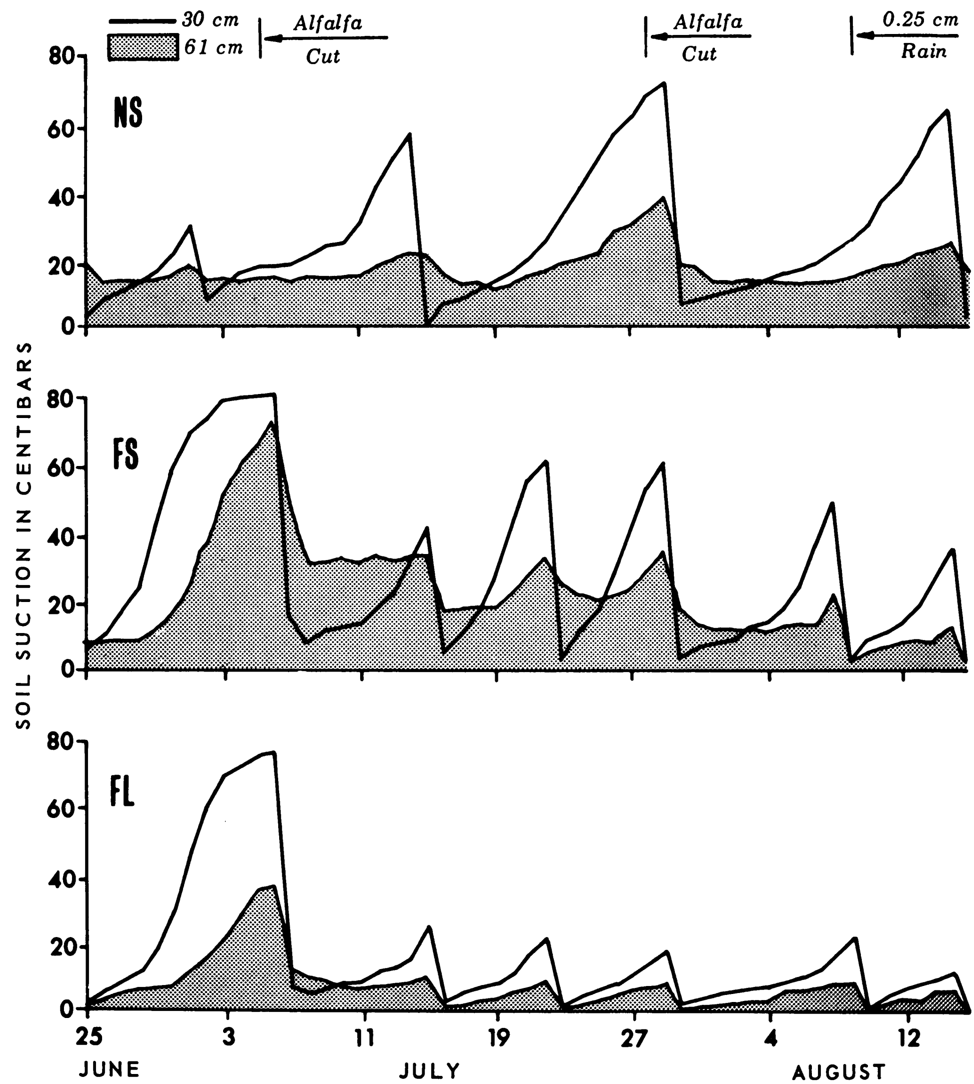

Fig. 4. Soil suction records at the 30- and 61-cm depths from June 25 to August 16, 1960, for three irrigation treatments in alfalfa irrigation Experiment I. NS was irrigated in June when FS and FL treatments were supposed to have been irrigated.

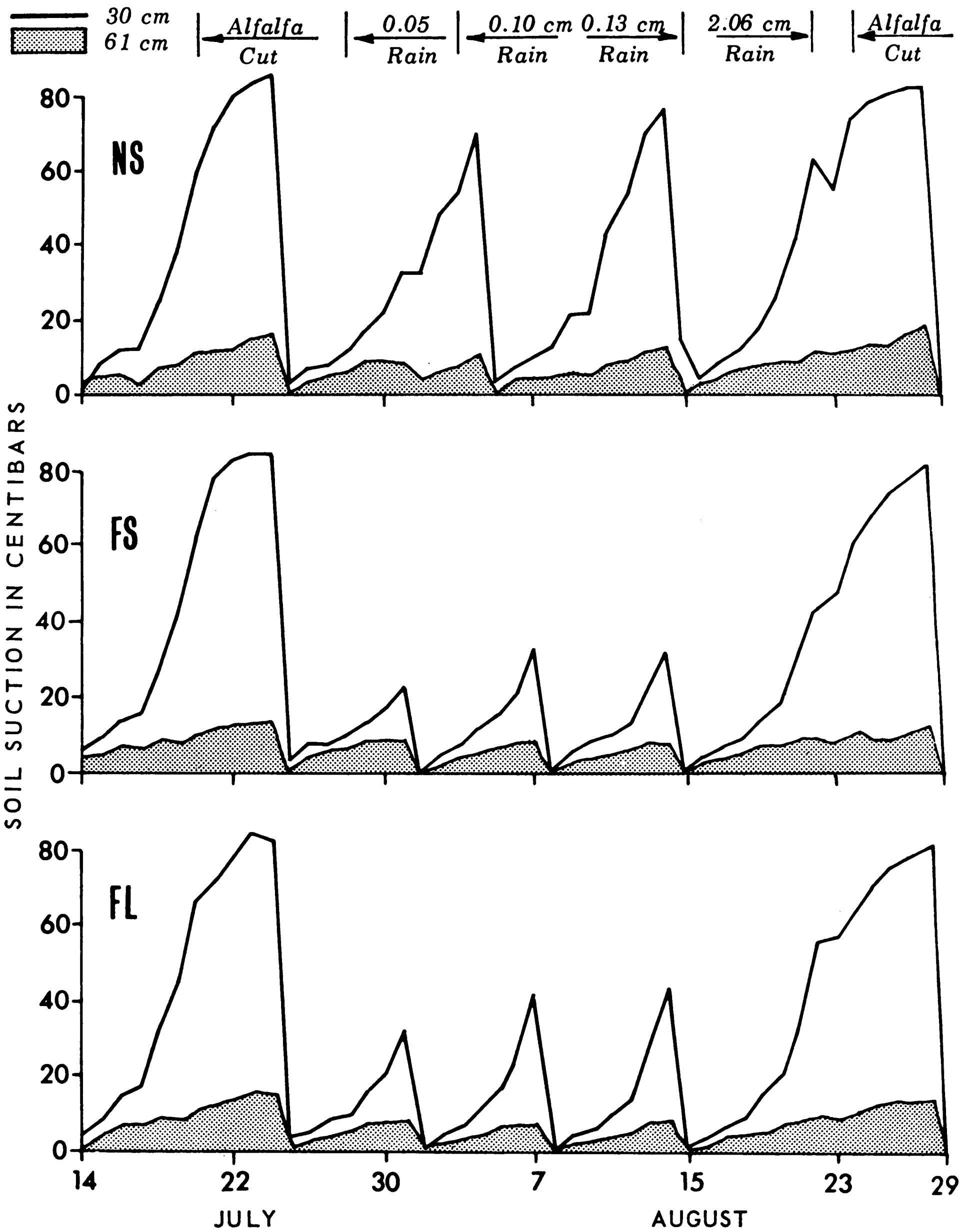

Fig. 5. Soil suction records at the 30- and 61-cm depths from July 14 to August 29, 1961, for three irrigation treatments in alfalfa irrigation Experiment II.

29, 1960, this would often form a U-shaped curve on the graph.

The FL treatment was saturated to the 30- and 61-cm depths after almost every irrigation.

Another difference between the two experiments was the difficulty in applying the prescribed amounts of water in Experiment I. Even though the interval was usually longer in the NS treatment, the tensiometer readings were often lower than the FS treatment at the time

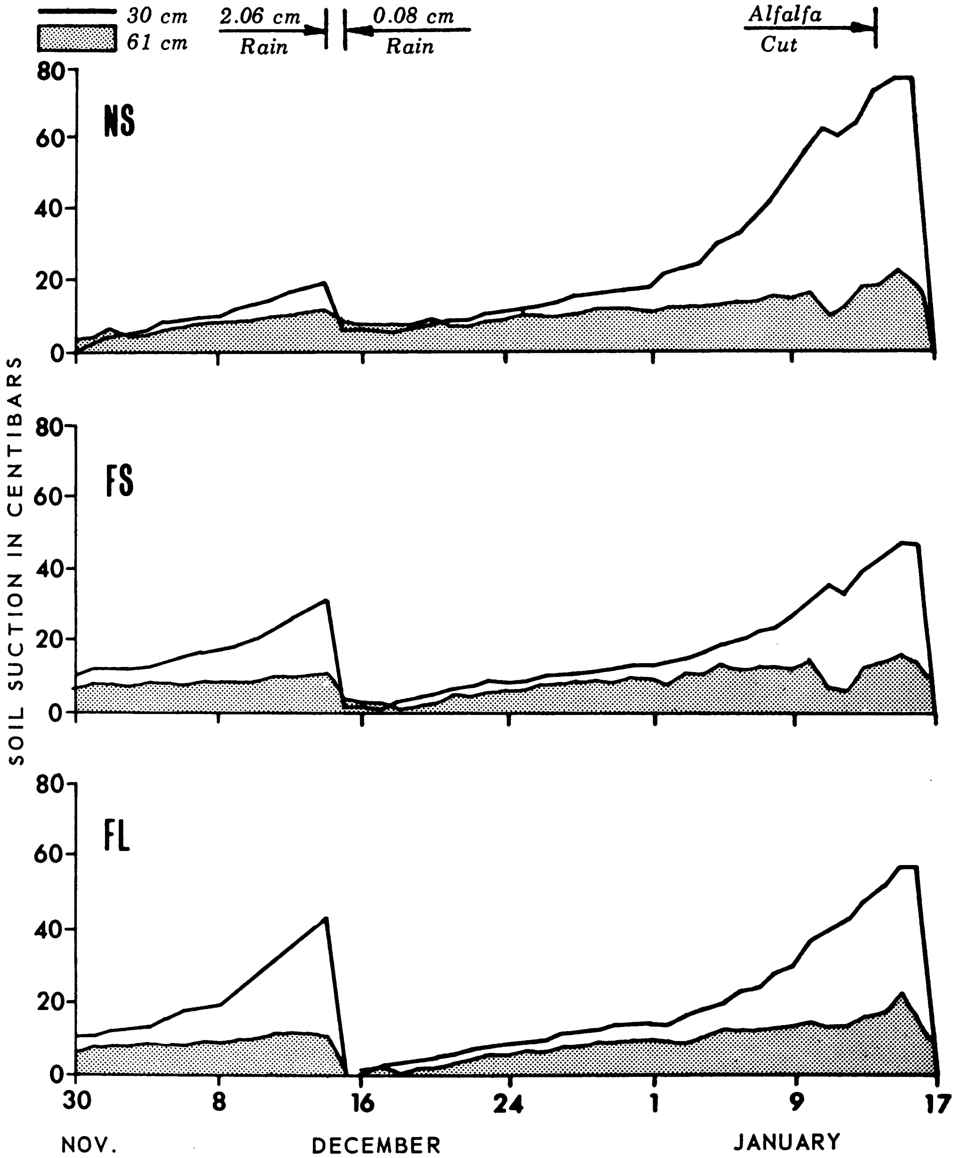

Fig. 6. Soil suction records at the 30- and 61-cm depths from November and December, 1961, and January, 1962, for three irrigation treatments in alfalfa irrigation Experiment II. Timing of irrigations is indicated by a sharp decline of the 30-cm records to a near 0 suction except December 14 in the NS treatment.

of irrigation. Suctions for the FL treatment were very low even though it was irrigated at the same time as the FS treatment. The demands for water by the treatments seem to be a reflection of the amount of plant growth in each treatment.

SALINITY TRENDS

Figures 7 and 8 show the salinity trends resulting from the three irrigation management treatments for Experiments I and II, respectively. Each plotted point is the average for two sampling locations on each of three replicated plots. Soil salinity studies vary greatly because of local soil and plant variations which influence water transfer. No attempt has been made to show statistical significance, but the trends indicated by the treatment averages for the two lower soil sampling depths are, with only one exception, consistent with the applied treatments. In terms of the total length of time for which irrigation water is held on the plots, the treatments can be arranged in order of increasing leaching potential as NS, FS, and FL. For the 20–45 and 45–70 cm soil depths and for practically all of the sampling dates during the second year, the EC values are inversely related to hours of applied irrigation. The one exception is on the August 1960 sampling date for the 20–45 cm soil depth. This consistency is noteworthy since the initial sampling for both experiments show no correlations with treatment response.

As an overall range, the EC values for Experiment II, figure 8, are lower than for Experiment I, figure 7. The possible explanation is that the soil for Experiment II had more favorable water transport properties and hence similar irrigation treatments with the same irrigation water quality resulted in somewhat faster leaching. In Experiment I, the EC values for all of the treatments are higher than are recommended for good alfalfa production (Richards, 1954). Salinity trends were somewhat more favorable under treatment FL. However, such a treatment might be considered an extreme or costly irrigation management. Nevertheless, treatments similar to FL may be required for salinity control under the existing soil, water, and climate conditions.

WINTER IRRIGATION TO ACHIEVE LEACHING

The EC values in figures 7 and 8 obtained to show soil salinity trends indicate in general that soil salinity values are higher than desirable for alfalfa (Richards, 1954). Irrigation treatment FL was considered to be a treatment which could not be exceeded during summer months for promoting leaching without causing undue adverse biological effects on the plants. A possible alternative was proposed to carry out a leaching program during the winter months when lower air and soil temperatures might make it feasible to irrigate more frequently or for longer durations. Thus leaching might be promoted more readily when irrigation water is withdrawn from the soil at a slower rate by the transpiring crop and conditions are less favorable for pathogens.

From November 1960 to February 1961 three leaching treatments were carried out on the plots formerly used for Experiment I. The treatments were again specified on the frequency or number of irrigations and the duration of each irrigation when applied. The treatments were specified as follows: three irrigations for 3-hours duration (this might be considered a continuation of the NS irrigation treatment); 13 irrigations for 3 hours; and 13 irrigations for 24-hours duration. One plot from each of the irrigation treatments was assigned by lot to each of the leaching treatments. The response to the leaching treatment was measured by taking soil samples for EC evaluation of the saturated extract at the end of the experiment for comparison with the values at the end of irrigation Experiment I.

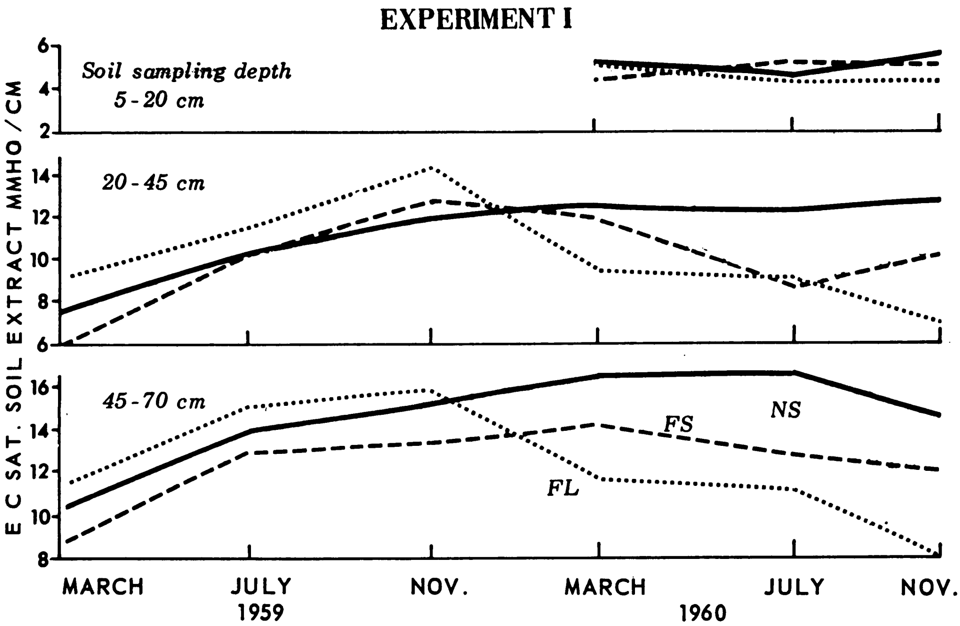

Fig. 7. Soil salinity trends during Experiment I as measured by the electrical conductivity at 25° C of the saturate extracts of soil samples taken from the three depths of the indicated dates during the experiment. Each plotted point is an average of two sampling locations per plot and three replicated plots. See text for the irrigation treatments specified by NS, FS, and FL, respectively.

Table 6 shows the averages for individual plots. The surface samples, 0 to 5 cm, were replicated three times; the deeper soil samples only twice. For each plot, the initial EC is given and then the difference in EC represented by a plus or minus value found after the leaching treatment. In spite of the large initial variability among plots, the trends are reasonably consistent. In nearly every case, the treatment with only three irrigations showed a small increase in EC values of all depths. In both the treatments where 13 irrigations were given, a consistent lowering of the EC values was found for all soil depths.

Of considerable interest is the fact that the 13 irrigations with 24-hour durations resulted in no greater reductions of soil salinity than when the same number of irrigations was applied for only three hours. This appears to represent an unusually severe instance of a soil in which the infiltration rate falls to an insignificantly low value after 3 hours. This soil also has the observed property of cracking as drying occurs, so that much of the initial infiltration of water takes place in the crack and after water is applied, the cracks are "closed" by swelling.

DISCUSSION

Results for the two experiments differ to some degree for most components.

In Experiment I the FS treatment was superior in almost all components measured. Stands in this treatment were vigorous through the entire test. Competition with weeds was good. Salt balance at end of test was acceptable. On the other hand, the NS treatment appeared to be in need of water through the entire test. This was especially true during the winter months. Salinity in-

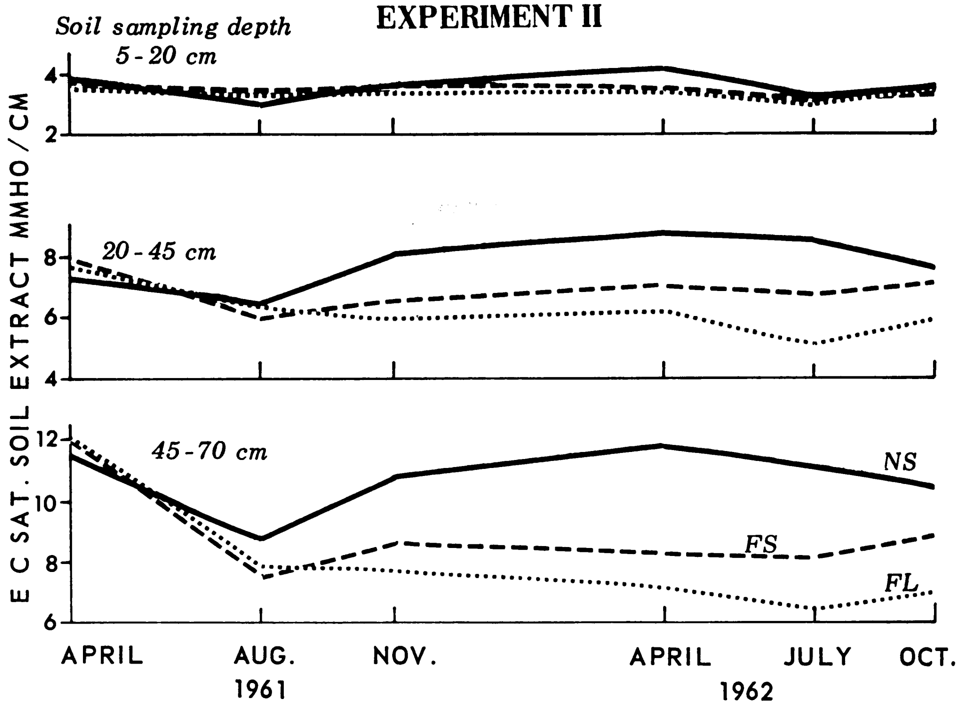

Fig. 8. Soil salinity trends during Experiment II as measured by the electrical conductivity at 25° C of the saturate extracts of soil samples taken from the three depths of the indicated dates during the experiment. Each plotted point is an average of two sampling locations per plot and three replicated plots. See text for the irrigation treatments specified by NS, FS, and FL, respectively.

creased in the soil profile through the life of the test. Stands were weak and unable to compete with weeds. The FL treatment was equally poor. Yield was good for the first few cuttings, but stands started to thin at the time of the July cutting. This appeared to be associated with the larger amounts of water being applied. The plants were light yellow and weak. Root rot was found in two of the three replications. Stands were almost depleted at the end of the first year. The replanting done only on this treatment was partially successful, but the stands were again depleted the next summer. Yields appeared fair but much of the hay removed was grass. However, soil salinity was lowest in this treatment at the end of the trial.

In Experiment II the NS treatment appeared superior when all factors are considered. However, it appeared that slightly more water might have been helpful during the later winter and early spring months. The FS treatment was similar to the NS treatment for stand and grass percentage, but the disease incidence was higher in the FS treatment. The FL treatment was definitely the poorest treatment. Stand counts were slightly lower. Much of the yield in four cuttings was grass and the disease incidence was high.

Observed suctions differed from prescribed suctions in Experiment I but were similar to prescribed suctions in Experiment II. Part of the discrepancy between observed and prescribed suctions was due to the fact that 80 to 85 cb is the maximum range of the tensiometer. Once the maximum was reached it was recorded until the next irrigation.

TABLE 6

RESPONSE TO LEACHING TREATMENTS CARRIED OUT FROM NOVEMBER 1960 TO FEBRUARY 1961. THE EC OF THE SATURATED SOIL EXTRACT IN MMHOS/CM IS GIVEN FOR EACH PLOT AT THE END OF THE FIRST IRRIGATION EXPERIMENT PRIOR TO LEACHING, AND THE DIFFERENCE IN EC VALUES BY THE END OF THE WINTER LEACHING PERIOD

Preceding plot treatment		Leaching traetments					
		3 irrigations 3 hours each		13 irrigations 3 hours each		13 irrigations 24 hours each	
		EC	Diff.	EC	Diff.	EC	Diff.
	0–5 cm sampling depth						
NS		11.8	+1.1	4.7	−3.1	5.4	−3.7
FS		2.2	+1.4	2.1	−0.4	2.0	−0.7
FL		2.6	+0.8	2.8	−1.4	3.0	−0.9
	Ave. Diff.		+1.1		−1.6		−1.8
	5–20 cm sampling depth						
NS		8.4	+0.5	3.4	−1.2	4.6	−2.1
FS		6.0	+1.0	5.3	−1.9	4.0	−1.0
FL		2.8	−0.2	2.5	−1.2	7.3	−1.1
	Ave. Diff.		+0.4		−1.4		−1.4
	20–45 cm sampling depth						
NS		13.4	−0.3	14.2	−9.2	10.6	−4.3
FS		11.9	+0.7	9.4	−2.8	9.9	−3.9
FL		6.3	+0.5	5.0	−1.5	9.4	−1.2
	Ave. Diff.		+0.3		−4.5		−3.1
	45–70 cm sampling depth						
NS		15.6	+0.9	13.5	−5.0	14.3	−4.3
FS		14.6	−1.2	10.4	−2.4	11.4	−2.8
FL		7.3	+1.3	6.2	−1.2	11.2	−1.5
	Ave. Diff.		+0.3		−2.9		−2.9

Since the NS treatment was designed to be irrigated at the upper limits of the tensiometer, the average may tend to be lower than the prescribed suctions but never higher than 80 to 85 cb. On the other hand, the FS and FL treatments which were designed to be irrigated at 30 to 35 cb might tend to be higher since suctions well beyond this could be recorded. Other factors which resulted in discrepancies between observed and prescribed suctions were: soil heterogeneity which resulted in differences in water holding capacity and plant growth; stand differences which affected water loss through transpiration; factors that might influence stand life; and adjustment of the irrigation schedule to meet the cutting schedule or to meet the irrigation district's "water out" period.

The basic difference between the two trials was water permeability of the soils and sub-surface drainage.

These results suggest a narrow optimum range between the application of too little and too much irrigation water on alfalfa. The NS treatment in Experiment I was given too little water, whereas the FL treatment received too much water in both experiments. The differences obtained between the two trials indicate that soil type will be important when deciding on the irrigation schedules to be used. Sub-surface drainage and permeability as well as slope of the land should be important variables to consider. Optimum range may be very narrow in soils similar to those found in Experiment I and greater in the more permeable, well-drained soils. From this it appears it would be difficult to recommend a set irrigation schedule for a specific field or group of fields.

Tensiometers may be more difficult to manage in alfalfa fields than in other crops (Richards and Marsh, 1961). The main reason is that the fields must be harvested several times a year. Tensiometers must be protected to prevent damage during harvest operations. This requires either an above-ground enclosure which may be a nuisance or an underground emplacement with protective coverage. Devices for the latter have become available since this experiment was conducted. In addition, the tensiometers must be read frequently, especially during the summer, and kept in an operating condition. These instruments would be of value in many alfalfa fields. However, the extra work involved in reading and maintaining them may discourage many potential users.

Even though tensiometers may not be generally accepted, they would have definite value in certain alfalfa fields where:

1. Grower's experience or knowledge is limited and a means to evaluate the effects of irrigation is useful.
2. Problems of root and water penetration exist.
3. Unknown dry layers or perched water tables might develop.
4. Excessive soil wetness may occur and persist after irrigation.

Experience obtained in this trial indicates that tensiometers can be helpful, but they must be used along with other criteria generally used in determining an irrigation date. Some of these are crop response, prior personal experience in irrigating alfalfa, and knowledge of the area and the field. Because of soil differences many tensiometers should be used until representative tensiometers can be isolated. Defective tensiometers should not be used. In this trial tensiometers were at times suspected of being defective, but generally the tensiometers were found to be in working condition and correctly reflected true water condition of the soil in which they were placed. The only problem was that the soil was actually wetter or drier than anticipated.

Soil salinity is an ever-present problem in the low desert valleys of southern California and should be given important consideration in every irrigation program. It has been shown that salts can build up in the Imperial Valley under minimum water application represented by treatment NS. An acceptable salt balance was maintained by applying more water in the FS and FL treatments. When EC values are held approximately constant, it indicates that some water in excess of the crop requirement is moving below the root zone to carry enough salts to balance the salts introduced with the irrigation water. If upward capillary movement of water occurs during irrigation intervals, then this must be counterbalanced by downward movement following each irrigation.

Plant loss and disease incidence were high in both experiments for the FL treatment and to a lesser degree for the FS treatment in Experiment II. Most of the plant loss due to Rhizoctonia and scald occurred during the summer. From the results of this test it appears water should be used carefully during the summer. It may be necessary to supply only enough water for the plant and little, if any, extra for leaching during this time. The best time for applying extra water for leaching might be during the cool winter months. Since Phytophthora root rot is caused by the water mold *Phytophthora megasperma* and because its temperature relations appear to be limited to the fall, winter, and spring seasons (Erwin, 1966), some caution should be observed even during these cooler months.

Optimum irrigation management seems to fall between two limits. Enough water must be used to maintain a favorable salt balance and economic yields and yet too much water or holding the water on the plants for too long a time would result in increased plant loss or disease incidence. In order to achieve this balanced irrigation program for widely varying soil types, it appears that tensiometer records and repeated soil salinity measurements should prove helpful.

LITERATURE CITED

ERWIN, D. C.
1954. Root rot of alfalfa caused by *Phytophthora cryptogea*. Phytopathology **44**: 700–04.
1956. Important diseases of alfalfa in southern California. Plant Disease Rptr. **40**: 380–83.
1965. Reclassification of the casual agent of root rot of alfalfa from *Phytophthora cryptogea* to *P. megasperma*. Phytopathology **55**: 1139–43.
1966. Varietal reaction of alfalfa to *Phytophthora megasperma* and variation in virulence of the casual fungus. Phytopathology **56**: 653–57.

ERWIN, D. C., B. W. KENNEDY, and W. F. LEHMAN
1959. Xylem necrosis and root rot of alfalfa associated with excessive irrigation and high temperatures. Phytopathology **49**: 572–78.

FORTIER, S.
1940. Irrigation practices in growing alfalfa. U. S. Dept. Agr. Farmers Bul. **1630**.

IMPERIAL COUNTY AGRICULTURAL COMMISSIONER
1959–1966. Annual reports.

PACKARD, W. E.
1917. Irrigation of alfalfa in Imperial Valley. Univ. of Calif. Press Bul. **284**.

RICHARDS, L. A.
1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A., Agr. Handbook **60**.

RICHARDS, S. J. and A. W. MARSH
1961. Irrigation based on soil suction measurements. Soil Sci. Soc. Amer. Proc. **25**: 65–69.

SMITH, D. F.
1943. Rhizoctonia root canker of alfalfa (*Medicago sativa*). Phytopathology **33**: 1081–85.
1945. Parasitism of *Rhizoctonia solani* from alfalfa. Phytopathology **35**: 832–37.

STANBERRY, C. O.
1955. Irrigation practices in growing alfalfa. Water, Yearbook of Agr. 1955. U. S. Govt. Printing Office, Washington, D.C. Pp. 435–43.

STRAHORN, A. T., E. B. WATSON, A. E. KOCHER, E. C. ECKMANN, and J. B. HAMMON
1922. Soil survey of the El Centro area, California. U.S.D.A., Govt. Printing Office, Washington, D.C.

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