IRRIGATION MANAGEMENT PROCEDURES TO MAXIMIZE PRODUCTION OF ALFALFA POPULATIONS SELECTED FOR INCREASED PERFORMANCE UNDER DEFICIT LEVELS OF IRRIGATION

by

Cliff Currier
Assistant Professor
Co-Principal Investigator
Department of Agronomy and Horticulture

Bill Melton
Professor
Co-Principal Investigator
Department of Agronomy and Horticulture

and

John Mayernak
Graduate Student
Department of Agronomy and Horticulture

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ABSTRACT

Availability and cost of irrigation water is a major consideration in crop production in most arid and semi-arid parts of the world. This study was conducted to evaluate selected populations of alfalfa (Medicago sativa L.) for increased performance with deficit levels of irrigation and to determine the effects of irrigation rates and sequences on forage yield and performance of these selected populations.

Selection for increased performance under deficit levels of irrigation increased yield under all irrigation treatments. Forage yields obtained with 20 inches of annual irrigation were reduced approximately 40-45 percent as compared to 40 or 60 inches of irrigation annually. Yields from 40 and 60 inch rates of irrigation were similar with a higher stand density at the end of the third production year in the 40 inch plots. Yields from the early and spread irrigation sequences were similar and indicated that no yield advantage was obtained from the early season applications of irrigation water. However, modifications of seasonal yield patterns, and possible labor savings due to harvest costs, should be investigated further by economic analysis.

Key words: plant populations, water use efficiency, drought, forage, yield, moisture stress

JUSTIFICATION

Water is the most limiting factor to crop production in the world (CAST Report no. 95). The lack of rainfall, inconsistent surface water supplies, depletion of aquifers, increasing costs for pumping, competition for available surface and ground water from industry and urban users, and water-limiting legislation have forced a re-evaluation of cultivar selection and irrigation management schemes for modern crop production.

Alfalfa (*Medicago sativa* L.) is the most important cash crop in New Mexico and is grown on more area than any other irrigated crop (Gerhardt and Hand 1985). Alfalfa is also a high water user, requiring 750 to 900 pounds of water to produce a pound of dry plant material (Bolton 1962, Bula and Massengale 1972). Because of the large area involved in alfalfa production and its high water requirement, a small percentage of water saved in alfalfa production would be a significant quantity. Many research reports have also commented on the apparent drought resistance of alfalfa (Aamodt 1952, Bolton 1962, Bula and Massengale 1972, Carter 1964, Kneebone 1959, Melton et al. 1966). Because of these facts, Wilson et al. (1981) selected alfalfa as a model crop to evaluate the concept of improved productivity with less than optimum levels of irrigation. These workers were successful in demonstrating that "drought productivity" was a viable plant breeding objective as evidenced by the release in 1986 and 1987 of Zia-81 alfalfa germplasm and the cultivar Wilson for increased productivity with deficit levels of irrigation, respectively (Melton et al. 1986, 1987).

However, water requirements of plants are conditioned by both inherent genetic qualities and environmental factors (Kneebone 1959). Therefore, genetic potentials should be matched with irrigation management schemes to maximize production under deficit levels of irrigation. No research information is available on management of deficit levels of irrigation, especially as related to alfalfa genotypes with the potential for increased "drought productivity". Hanson and Sammis (1980) defined a linear relationship between water applied and productivity in terms of consumptive use and water-production functions. However, Wilson et al. (1981) have demonstrated that the slope of the linear function varied with population and age of stand. Sammis (1981) also found that water-production functions varied with each cutting. These complications make it difficult to use this type of information to plan seasonal distributions of irrigation.

Objectives

The objectives of this study were to determine the effects of timing and amounts of flood applied irrigation on forage yield and stand longevity or alfalfa populations selected for increased performance under deficit levels of irrigation.

MATERIALS AND METHODS

The experiment was conducted at the Leyendecker Plant Science Research Center near Las Cruces, NM. Soil type was a Glendale clay loam (mixed, thermic typic torrifluvent). The plot area was laser levelled to a 0 to 1 percent slope. The experiment site occurs at 3881 feet elevation, with 201 frost free days in the growing season, 198 median length days, and an annual precipitation average of 8.2 inches per year.

The genetic materials selected for this study included 13 alfalfa populations selected from the plant breeding program and five cultivars which had previously demonstrated potential for increased performance under deficit levels of irrigation. Detailed descriptions of these genetic sources were provided by Mayernak (1986).

Flood irrigation treatments were selected to provide a high stress, moderate stress, and no stress environments and consisted of 20, 40, and 60 inches of moisture, respectively, on an annual basis. Rainfall was subtracted from subsequent irrigations. The high and moderate stress levels of irrigation were subdivided into two sequences with the amounts of irrigation applied either early or spread uniformly over the growing season. The experiment was planted in March 1984. The entire experimental area was uniformly irrigated three times for establishment. A partial set of irrigations was initiated in June 1984 and a complete set of irrigations was initiated in February 1985 and 1986 (table 1). In 1985 and 1986 the 20-inch level, the early sequence had three irrigations prior to the first harvest and two irrigations after the first harvest. The spread sequence received one irrigation before and after the first harvest and one irrigation after each of the next three harvests. In the 40-inch irrigation level, the early sequence received four irrigations before the first harvest and two irrigations between the next three harvests. The spread sequence received two irrigations before the first harvest and two irrigations between the next four harvests. The high irrigation level received four irrigations before the first harvest; two irrigations between harvests; and one irrigation after the last fall harvest. Irrigation water was applied with gated pipe and measured by in-line meters.

The experimental design was a split-plot with four replications. Irrigation treatments were assigned to main plots and alfalfa populations to subplots. Subplots consisted of three rows, five feet in length with a one foot row spacing. Check plots of Mesilla were systemmatically arranged in alternate subplots to facilitate covariance type analysis. Ten border rows of alfalfa surrounded the subplot area in each main plot. Main plots were surrounded by earthen borders and separated by 15 feet of fallow area.

Table 1. Rates and sequences of flood applied irrigation used to evaluate the effects of irrigation management regimes on alfalfa populations selected for increased performance under less than optimum moisture conditions.

Amounts of irrigation--inches per year									
20				40				60	
early		spread		early		spread		spread	
inches	month	inches	month	inches	month	inches	month	inches	month
1985 and 1986*									
				4	Feb.			4	Feb.
4	March			4	March	4	March	4	March
4	April	4	April	4	April	4	April	4	April
4	April			4	April			4	April
-----Harvest 1-----									
4	May	4	May	4	May	4	May	4	May
1984**									
4	May			4	May	4	May	4	May
-----Harvest 2-----									
		4	June	4	June	4	June	4	June
				4	June	4	June	4	June
-----Harvest 3-----									
		4	July	4	July	4	July	4	July
				4	July	4	July	4	July
-----Harvest 4-----									
		4	Aug.			4	Aug.	4	Aug.
								4	Aug.
								4	Sept.
						4	Sept.	4	Sept.
-----Harvest 5-----									
								4	Oct.
Total inches									
20		20		40		40		60	

*Five harvests and a complete set of irrigations were accomplished in 1985 and 1986.

**Four harvests and a partial set of irrigations were accomplished in 1984.

The experiment was planted with the recommended seeding rate of 20 lbs/A. Phosphorus fertilizer (120 lbs P_2O_5/A) and a pre-emergence herbicide, Benefin (at recommended rate) were applied and incorporated into the soil prior to seeding.

Four forage harvests were made in 1984 and five in 1985 and 1986. All plots were harvested when plants in the 60-inch spread treatment were in the one-tenth bloom stage and green weights obtained. Five grab samples were taken from each main plot, weighed, and dried in a forced air dryer for 72 hours at 60C to determine percent dry matter. These values were then used to convert green weights per plot to dry weights. Data were expressed as tons per acre. Stand density was visually estimated as percent cover in each plot at the end of each production year.

Statistical analyses consisted of a regression analysis to adjust subplot yields within each main plot based on the performance of the systematically arranged check subplots. The adjusted subplot values were then analyzed by analysis of variance procedures. Least Significance Difference (LSD) values were used for mean separation. Data from each year were analyzed separately as well as for the three years combined.

RESULTS AND DISCUSSION

1984 - Year of Establishment

Significant differences in forage yield were obtained among irrigation treatments and among alfalfa populations (table 2). The population x irrigation treatment interaction was not significant, indicating that the relative performance of the populations was consistent across irrigation treatments. This response infers that selection for increased performance under deficit levels of irrigation did not interfere with the ability of these populations to respond to more favorable moisture conditions.

Forage yield from the 20-inch irrigation level was reduced by 31 percent as compared to the high irrigation level. Forage yields from the 40- and 60-inch irrigation levels were similar. This result is notable in that similar amounts of forage were produced with a water savings.

Simulation of the early sequence application of deficit levels of irrigation (due to spring planting, see table 1) reduced yields by 44 percent in the 20-inch irrigation level and 20 percent in the 40-inch irrigation level. In both of the early 20- and 40-inch irrigation levels, the reduction in yield was during the latter part of the growing season when irrigation allotments had already been consumed.

Eight of the 13 alfalfa populations selected for increased performance with deficit levels of irrigation yielded significantly higher than the check cultivar Mesilla. The highest yielding selected population exceeded the yield of Mesilla by 16 percent. Three of the cultivars (or germplasms) also exceeded the yield of Mesilla. Rincon, a nondormant cultivar[1], was able to establish faster and utilize limited moisture efficiently because of increased regrowth capabilities. Zia and NC83-2 had been shown to be superior to Mesilla under deficit irrigation in previous studies.

Because of special interest in the performance of the selected populations at the low and moderate irrigation levels, those environments were examined separately. Nine of the selected populations exceeded the yield of Mesilla in the 20-inch early sequence; 10 of the 13 selected populations exceeded the yield of Mesilla in the 20-inch spread sequence; six of the selected populations exceeded the yield of Mesilla in the 40-inch early sequence; nine of the 13 selected populations exceeded the yield of Mesilla

[1]a nondormant cultivar initiates and maintains active growth longer during the frost free period and has a shorter period of quiescence during periods of low temperatures, relative to more dormant cultivars.

Table 2. Total dry matter yield for 18 alfalfa populations from four harvests and five irrigation treatments at Las Cruces, NM, 1984.

Population	Irrigation treatment (inches)					
	20 early	20 spread	40 early	40 spread	60 spread	Mean[1/]
	tons/acre/year					
9S5	1.7	3.7	4.5	5.5	4.5	4.0
9FC8	2.5	4.5	4.7	5.6	5.0	4.5
9D11A	2.6	4.4	4.8	6.4	5.2	4.7
9PEG13	2.1	3.9	4.9	5.4	4.7	4.2
OSGP24	2.1	4.3	4.5	5.6	4.3	4.2
1FC33	2.5	4.4	5.1	6.4	4.9	4.6
1FC34	2.3	4.4	4.0	5.8	5.3	4.4
1FC36	2.5	4.0	4.3	6.1	4.9	4.4
2FC37	2.6	4.3	5.2	6.4	5.2	4.8
3S38	2.6	4.4	5.7	6.0	4.8	4.7
3M39	2.7	4.5	4.5	6.1	5.5	4.7
SCST81	2.6	4.7	5.3	6.4	4.9	4.8
Zia 81	2.7	4.7	5.4	6.8	5.5	5.0
Dawson	2.3	4.2	4.3	4.9	4.0	4.0
Dona Ana	2.0	3.5	4.3	5.5	4.3	3.9
Rincon	2.8	3.9	5.1	6.3	5.5	4.7
Zia	2.5	4.6	5.3	6.7	4.7	4.8
NC83-2	2.5	4.6	4.9	5.8	4.7	4.8
Mesilla (ck)	2.4	4.1	4.6	5.6	4.6	4.3
Mean[1/]	2.4	4.3	4.8	6.0	4.9	4.5
Irrigation level mean	3.4		5.4		4.9	

[1/]LSD(P=0.05) among populations = 0.2 and among irrigation treatments = 0.6.

in the 40-inch spread sequence; and 10 of the 13 selected populations exceeded the yield of Mesilla in the 60-inch sequence. The population 9FC8, which had a high level of performance in the high rate of irrigation and was not among the highest yielding with deficit levels of irrigation. A greater number of populations were superior to Mesilla in the spread sequence than in the early sequence. This was probably due to the short production season and the higher stress level in the early sequence in 1984.

1985 - First Full Production Year

Results from the second year of the test were similar to the first year. Significant differences in yield were obtained among irrigation treatments and among alfalfa populations but again the population x irrigation treatment interaction was not significant (table 3). The lack of an interaction again suggests that selection for increased performance with deficit levels of irrigation did not reduce the ability of these improved populations to respond to higher levels of irrigation.

Forage yield from the 20-inch irrigation level was reduced by 45 percent as compared to the 60-inch irrigation level. Forage yield from the 40-inch irrigation level was similar to that obtained from the 60-inch irrigation level. Using 40 inches of irrigation to produce the same amount of yield resulted in a water savings of 33 percent.

Yields produced in the early sequences were similar to the spread sequences. Observations of yield distributions during the growing season indicated that early season yields were higher with early applications of irrigation water but that seasonal yield distribution pattern was more uniform with the spread sequences. Proper interpretation of these data will require an economic analysis and evaluation of subsequent years performance.

Table 3. Total dry matter yield for 18 alfalfa populations from five harvests and five irrigation treatments at Las Cruces, NM, 1985.

Population	Irrigation treatment (inches) 20 early	20 spread	40 early	40 spread	60 spread	Mean[1/]
	--tons/acre/year--					
9S5	5.5	6.1	11.3	10.2	9.6	8.5
9FC8	5.3	6.2	11.4	12.2	11.1	9.2
9D11A	6.1	6.0	12.5	13.3	12.1	10.0
9PEG13	4.8	6.5	11.5	10.0	11.4	8.9
0SGP24	5.4	6.7	11.0	11.3	11.0	9.1
1FC33	5.9	5.9	11.8	11.9	11.5	9.4
1FC34	5.5	7.0	11.5	11.5	11.9	9.5
1FC36	5.6	7.0	11.2	11.5	11.7	9.4
2FC37	5.6	6.6	11.7	11.9	10.9	9.3
3S38	6.5	6.7	11.9	11.3	10.4	9.4
3M39	5.8	7.3	11.1	11.4	11.5	9.4
SCST81	5.0	6.5	11.7	12.4	11.0	9.3
Zia 81	5.6	8.1	11.3	12.3	12.2	9.9
Dawson	4.6	6.5	10.2	10.2	8.1	7.9
Dona Ana	4.7	5.6	10.3	10.0	10.7	8.3
Rincon	5.6	5.8	10.9	11.1	11.3	8.9
Zia	7.9	7.8	11.8	12.0	10.9	10.1
NC83-2	5.5	5.5	11.0	11.3	10.5	8.7
Mesilla (ck)	5.4	5.8	10.7	10.5	10.0	8.5
Mean[1/]	5.6	6.5	11.3	11.4	11.0	9.2
Irrigation level mean	6.1		11.3		11.0	

[1/]LSD(P=0.05) among populations = 0.6 and among irrigation treatments = 1.9.

The mean yield of populations for all irrigation treatments showed that eleven of the 13 selected alfalfa populations significantly exceeded the yield of Mesilla. The highest yielding population exceeded the average yield of Mesilla by 16 percent. Within specific irrigation sequences, the fewest number of elite populations occurred in the 20 inch-early sequence. Only 9D11A and 3S38 were higher yielding than Mesilla (by 20 percent) in this treatment. As the stress level decreased and the length of the production season increased, the number of selected populations exceeding the yield of Mesilla increased: nine of 13 in the 20-inch spread; 10 of 13 in the 40-inch early; 11 of 13 in the 40-inch spread; and 11 of 13 in the 60-inch treatment. These results verify that selection for increased performance under deficit levels of irrigations was effective and that evaluations would probably be most effective under a moderate stress environment.

<u>1986 - Third Production Year</u>

Significant differences in forage yield were obtained among irrigation treatments and alfalfa populations but the interaction between irrigation treatments and populations was not significant (table 4).

Forage yields from the 40- and 60-inch irrigation levels were similar and significantly higher than the 20-inch irrigation level. The 20-inch level of irrigation yielded 23 percent less than the high rate of irrigation. The timeliness and amount of rainfall in 1986 benefited the low rates of irrigation compared to the previous two years (tables 2, 3, and 4). The difference in yield could also have been higher due to Phytophthora root rot, caused by <u>Phytophthora</u> <u>megasperma</u> Drechs. f. sp. <u>medicaginis</u> Kuan and Erwin, which seriously damaged plots in the 60-inch irrigation level.

Yields from the early and spread irrigation sequences were similar during the third year of the test.

Table 4. Total dry matter yield for 18 alfalfa populations from five harvests and five irrigation treatments at Las Cruces, NM, 1986.

Population	Irrigation treatment (inches)					
	20 early	20 spread	40 early	40 spread	60 spread	Mean 1/
	tons/acre/year					
9S5	7.1	8.4	10.9	10.1	8.6	9.0
9FC8	6.3	8.9	11.4	11.2	10.5	9.7
9D11A	7.9	8.5	12.8	12.4	12.8	10.9
9PEG13	6.0	9.0	11.4	10.2	10.9	9.5
OSGP24	6.3	9.0	12.4	11.3	10.3	9.9
1FC33	6.7	8.3	10.9	11.8	9.0	9.3
1FC34	7.2	8.5	11.1	11.3	10.1	9.6
1FC36	8.1	8.1	10.3	11.9	10.5	9.8
2FC37	7.6	9.0	11.6	11.8	10.1	10.0
3S38	8.0	9.2	12.5	12.1	10.8	10.5
3M39	7.0	10.2	11.3	11.8	10.9	10.2
SCST81	7.0	8.9	12.0	13.0	11.1	10.4
Zia 81	7.8	9.5	12.2	11.6	12.0	10.6
Dawson	5.4	8.0	10.1	9.0	7.2	7.9
Dona Ana	6.2	7.6	10.9	10.4	10.7	9.2
Rincon	7.9	8.2	11.2	10.9	9.8	9.6
Zia	8.1	10.1	13.2	13.0	11.6	11.2
NC83-2	6.6	7.9	11.4	11.1	9.2	9.2
Mesilla (ck)	6.9	8.0	10.3	9.6	8.0	8.6
Mean 1/	7.1	8.7	11.5	11.4	10.3	9.8
Irrigation level mean	7.9		11.4		10.3	

1/ LSD(P=0.05) among cultivars = 0.6 and among irrigation treatments = 1.4.

Eleven of the 13 selected populations significantly exceeded the forage yield of Mesilla when averaged across irrigation treatments. The highest yielding selected population (9D11A) exceeded the average yield of Mesilla by 27 percent. Again, as the stress level increased, the number of selected populations exceeding the yield of Mesilla decreased. In the 20-inch early irrigation sequence, only five of the 13 selected populations exceeded the yield of Mesilla while eight exceeded the yield of Mesilla in the 20-inch spread sequence. In the 40 and 60-inch of irrigation levels, all but one population exceeded the yield of Mesilla. Zia and Rincon were the higher yielding cultivars in all irrigation treatments.

Combined Data For Three Years

The combined analysis showed significant differences among irrigation treatments, alfalfa populations and years. The only significant interactions were years x irrigation treatments and years x alfalfa populations (table 5 and figures 1 and 2). The performances of the alfalfa populations were relatively consistent across irrigation treatments indicating that alfalfa populations could be developed which would have increased performance under all rates and sequences of irrigation.

The interaction between years and irrigation treatments was due to two factors: (1) yields increased more between the first and second year of the stand at the higher irrigation levels, and (2) yields from the low irrigation level increased in the third year at the higher irrigation levels (figure 1). A part of this yield response could be attributed to a large amount of winter precipitation between the second and third year of the stand which probably benefited the low irrigation level more than the plots which had received higher amounts of irrigation.

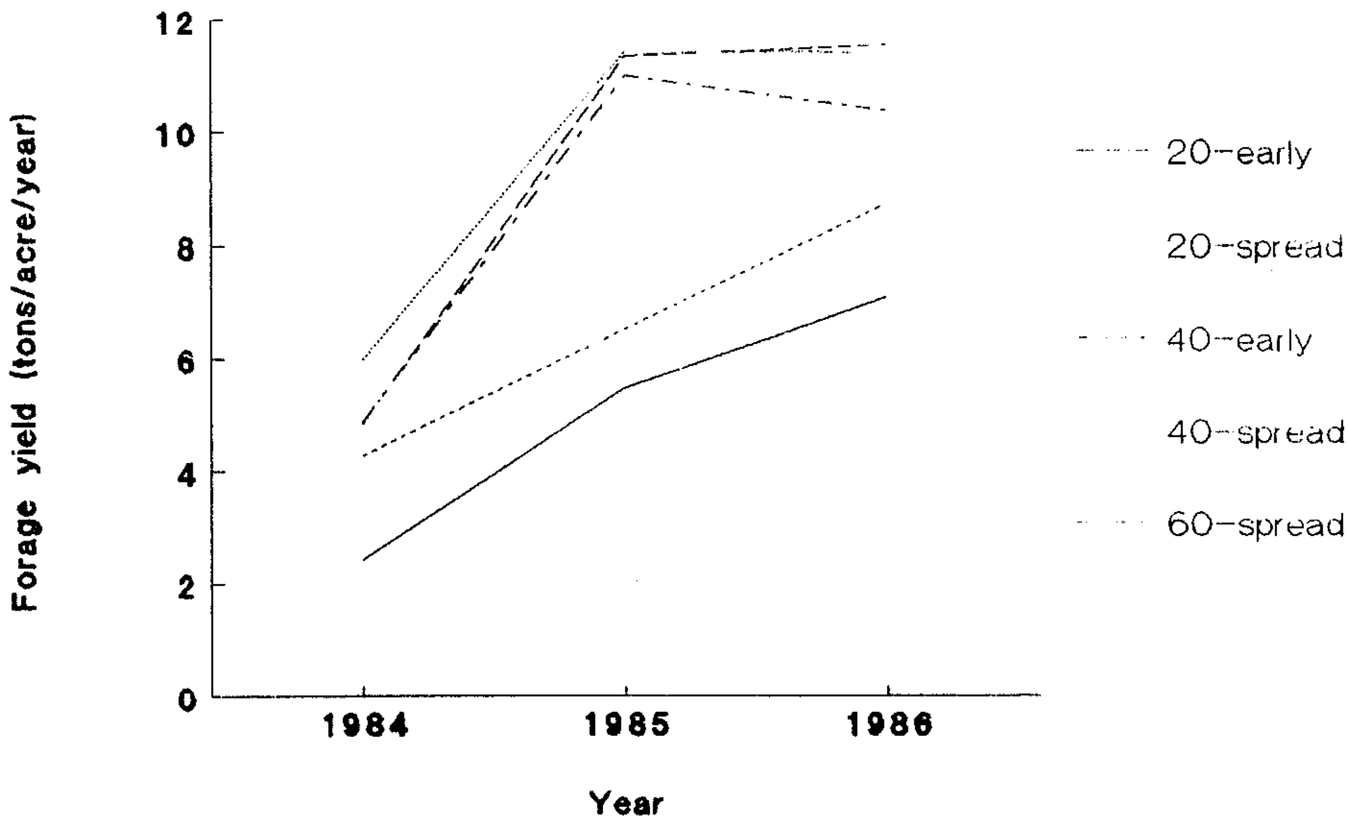

Fig. 1. Forage yield from irrigation sequences across years.

The interaction between alfalfa populations and years was also significant (figure 2). This interaction was due to the higher yielding selected populations increasing in average yield in the third year of the test whereas others decreased (i.e. Dawson) or remained stable between the second and third production year.

Forage yields more than doubled between the year of establishment and the second and third production season (tables 2, 3, and 4). This is a normal reaction to age of stand in alfalfa.

Table 5. Average dry matter per year of 18 alfalfa populations over five irrigation treatments at Las Cruces, NM, 1984, 1985, and 1986.

Population	Irrigation treatment (inches)					
	20 early	20 spread	40 early	40 spread	60 spread	Mean1/
	tons/acre/year					
9S5	4.8	6.1	8.9	8.6	7.8	7.2
9FC8	4.7	6.5	9.2	9.7	8.9	7.8
9D11A	5.5	6.3	10.0	10.7	10.0	8.5
9PEG13	4.3	6.5	9.3	8.5	9.0	7.5
0SGP24	4.6	6.7	9.2	9.4	8.5	7.7
1FC33	5.0	6.2	9.3	10.0	8.5	7.8
1FC34	5.0	6.6	8.9	9.5	9.1	7.8
1FC36	5.4	6.4	8.6	9.8	9.0	7.8
2FC37	5.3	6.6	9.5	10.0	8.7	8.0
3S38	5.7	6.8	10.0	9.8	8.7	8.2
3M39	5.2	7.3	9.0	9.8	9.3	8.1
SCST81	4.9	6.7	9.7	10.6	9.0	8.2
Zia 81	5.4	7.4	9.6	10.2	9.9	8.5
Dawson	4.1	6.2	8.2	8.0	6.4	6.6
Dona Ana	4.3	5.6	8.5	8.6	8.6	7.1
Rincon	5.4	6.0	9.1	9.4	8.9	7.8
Zia	6.2	7.5	10.1	10.6	9.1	8.7
NC83-2	4.9	6.0	9.1	9.4	8.1	7.5
Mesilla (ck)	4.9	6.0	8.5	8.6	7.5	7.1
Mean1/	5.0	6.5	9.2	9.6	8.7	7.8
Irrigation level mean	5.7		9.4		8.7	

1/LSD(P=0.05) among alfalfa populations = 0.2 and among irrigation treatments = 2.4.

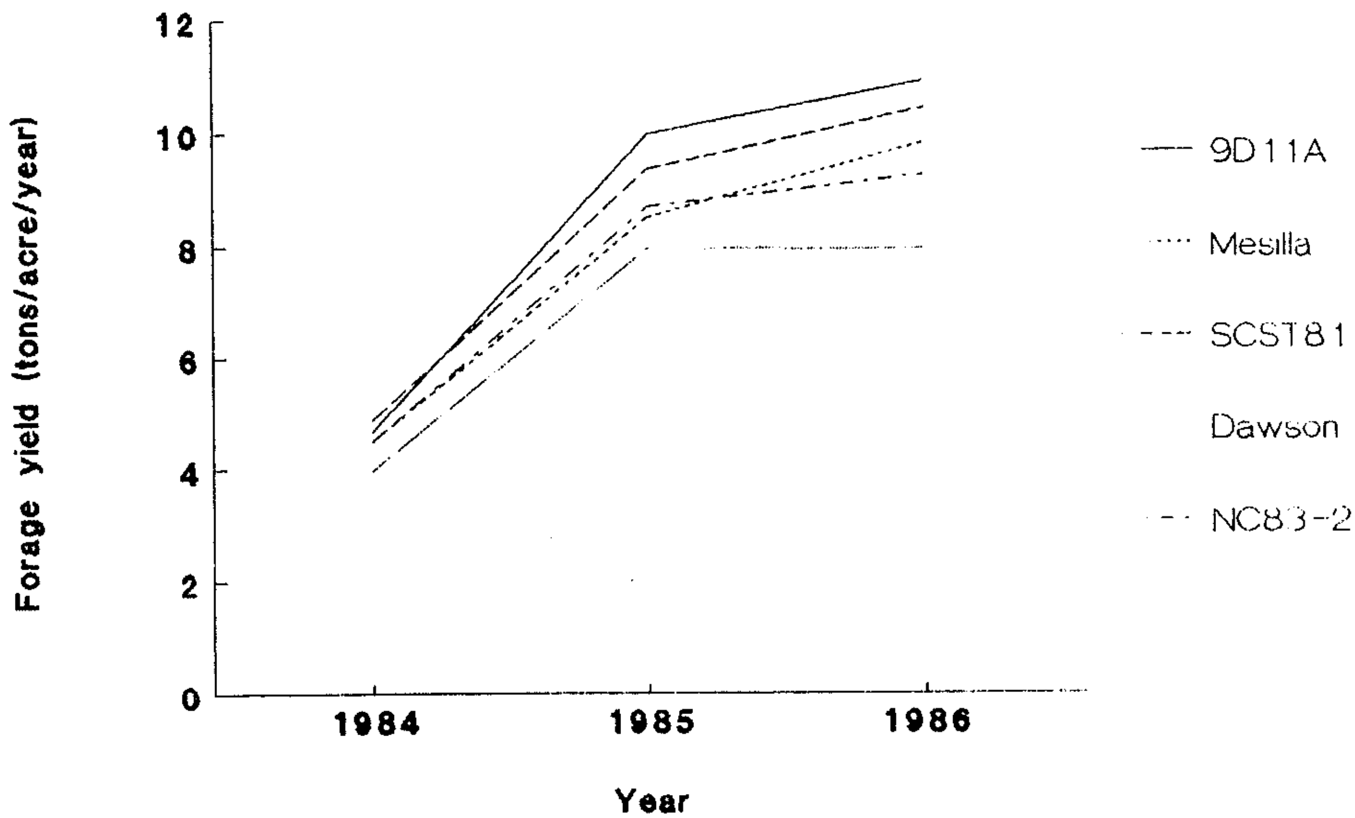

Fig. 2. Forage yield of alfalfa populations in three successive years when averaged across irrigation treatments.

Over the three year period, forage yields from the 40-inch irrigation level were slightly higher than obtained from the 60-inch irrigation level when averaged across irrigation treatments (table 5). This finding indicated that less water was required for maximum yield than previously considered at this location and soil environment. The difference between the 40- and 60-inch irrigation level would represent a water savings of 33 percent. Forage yield was reduced by 39 percent by a 50 percent reduction of irrigation between the 40- and 20-inch irrigation levels. Phytophthora root rot was prevalent in the 60-inch irrigation level plots and barely noticeable at the 40 or 20-inch irrigation levels. This effect on yield in future years would be considerable and would certainly affect stand longevity.

Over the three-year-period, there were no differences in yield between the early and spread sequences. Observations on individual harvest yields did indicate that yield distributions during the season were different. The significance of variability in yield patterns will require further analysis to determine if crop value and labor savings will affect economic returns or water-use efficiencies.

Twelve of the 13 selected populations significantly exceeded the forage yield of the check cultivar Mesilla over the three year period (table 5). The highest yielding selected populations (9D11A and Zia 81) exceeded the yield of Mesilla by 20 percent when averaged over years and irrigation treatments. Within the individual irrigation sequences, six of the 13 selected populations exceeded the yield of Mesilla in the 20-inch early sequence, while almost all of the selected populations exceeded the yield of Mesilla in the other sequences. The selected population 9S5 was similar to Mesilla in forage yield in the 20-inch spread and 40-inch spread sequences.

Stand Density

Stand density was similar among the alfalfa populations but declined as age of stand increased (table 6). The only significant difference in stand density due to irrigation treatment was at the end of the third growing season. The highest stand density was in plots which received the lowest amount of irrigation and stand density declined as the rate of irrigation increased. This finding was very significant in that it indicated that excess irrigation on fine-textured soils and diseases, principally Phytopnthora root rot, were more damaging to stand maintenance than water stress at the lower irrigation levels.

Table 6. Visual estimates of stand density taken at the end of each production year as affected by irrigation treatments.

Irrigation treatment	Stand density 1984	1985	1986
	------------% stand[1/]-----------		
20 inch - early	76	69	68
20 inch - spread	73	68	78
40 inch - early	75	52	53
40 inch - spread	78	61	59
60 inch - spread	69	53	25
Mean[2/]	74	61	57

[1/]Stand density was measured as a visual estimate of cover in each plot.
[2/]LSD(P=0.05) among years = 8; among irrigation treatments in 1986 = 10.

CONCLUSIONS

The findings from this study were significant in several areas:

1. Selection for improved forage yield in alfalfa under deficit levels of irrigation was effective.

2. Selection for improved forage yield in alfalfa under deficit levels of irrigation improved performance under all irrigation treatments.

3. The same, or slightly higher, level of forage yield was obtained from 40 inches of irrigation as with the 60 inches of irrigation, which gave a water savings of 33 percent.

4. Forage yields with only one-half as much water (20 versus 40 inches) were reduced approximately 40 percent indicating a non-linear response curve to water application rate.

5. Yields were slightly lower for the early than for the spread sequence of irrigations at both the 20- and 40-inch irrigation levels. These differences were not statistically significant and indicated that irrigation may be applied early in the season if necessary. In some situations, early application of irrigation may produce a savings of water, labor, and/or harvesting expense without sacrificing yield.

6. Loss of stand due to severe drought stress was less than losses due to excess water stress and diseases at the higher rates of irrigation.

Application of Findings

Selection for improved performance under deficit irrigation levels is a viable system of improving forage yields under all irrigation treatments. It would be reasonable to assume that very quantitative traits like yield and water stress tolerance could be improved even further with more cycles of selection and/or more sophisticated genotypic selection procedures. This work should be continued as this is the only successful alfalfa breeding program in the United States to improve water stress tolerance.

Irrigation management did affect yield levels and, in this environment, showed that yield could be maintained and stand life increased by using less water (40 inches instead of 60 inches). The overall similarities in yield between the early and spread irrigation sequences indicated that no yield advantage was obtained by the early season water applications. However, modifications of seasonal yield patterns and possible labor savings due to fewer harvests with the early season irrigations could affect the economics of the alfalfa cropping system and should be examined from an economic standpoint.

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