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IRRIGATION AND NITROGEN TREATMENT OF FORAGE CROPS

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Irrigation and Nitrogen Treatment of Forage Crops

G. M. PRINE, F. P. GARDNER, AND C. J. WILLARD[1]

INTRODUCTION

In humid regions rainfall is the principal source of water for plants. Dependence on this free but unpredictable source of water often leads to drought conditions and limited plant growth one or more times during the growing season. Droughts may come during physiologically critical periods or when continued high production is desirable. These factors have provided the impetus for the large increase in supplemental irrigation in the humid states during the past 10 years.

High input cost for irrigating and relatively low economic value of forage crops has tended to limit research on irrigation of forages in humid areas in the past. However, the needs for greater total production and more uniformity in seasonal production have created the need for more information on irrigation of forage crops.

Many investigations have shown the effects of irrigation on forage production in humid regious of the United States (1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15). Yields have varied from less than the unirrigated to several hundred percent greater. Generally small increases in yield from irrigation are reported from well-adapted and well-fertilized forage crops in humid regions. Largest increases in forage production from irrigation have usually occured during seasons with extended periods of drought. Yields during the spring of irrigated alfalfa-bromegrass mixture have been reported to be less than unirrigated when stands were irrigated the previous summer (5). Similarly, irrigation during the previous year reduced yields of irrigated white clover mixtures (10). During a year of extended drought at State College, Mississippi, an irrigated dallisgrass-bermudagrass pasture containing small amounts of hop clover and common lespedeza but without nitrogen fertilization produced 260 percent more forage than unirrigated (7). When 96 pounds of nitrogen was applied in split

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application, the yield increase of irrigated over unirrigated was 355 percent.

Illinois workers (4) reported a longer grazing season, increased carrying capacity, and greater production of beef and of forage on irrigated pastures. Despite these apparent advantages, the researchers concluded irrigation of pasture would give little profit and possibly a loss. Irrigation of pastures for dairy cows has been reported by other investigators to be profitable (14). There seems to be no general agreement on the economic advantage of irrigating forage crops in humid regions.

To obtain information on the irrigation of forage crops, a field investigation was initiated on the Agronomy Farm at Columbus, Ohio, in 1955. The objectives of the investigation were: (1) to determine the effect of irrigation on growth and seasonal production of forage plants and mixtures, (2) to determine the effect of irrigation on certain chemical constituents of forage plants, (3) to determine the effect of irrigation on the botanical composition of forage mixtures and (4) to obtain evidence concerning the economic feasibility of irrigating forage crops.

MATERIALS AND METHODS

This study consisted of two separate experiments each employing a split plot design. Normal rainfall and normal rainfall plus supplemental irrigation were main plot treatments. The experiments were adjacent to each other on a uniform area of Brookston silty clay loam, a humic gley soil, with an available water-holding capacity of two inches per foot of depth. The forages included in the subplots of each experiment, with rates of fertilization and seeding, are given in Table 1.

Experiment I consisted of three replications with the two main plots and each replication separated by a 40-foot alleyway planted in Ranger alfalfa to prevent overthrow of irrigation water from irrigated plots to nonirrigated plots. Both main plot and subplot treatments were randomized. The 6 x 25 foot subplots were superimposed on the main plots in three ten-plot tiers divided by four-foot alleyways. Experiment II was laid out in a similar manner, except it had two replications and the five subplot treatments for each irrigation level were arranged in a single tier.

Both experiments received uniformly 600 pounds per acre of 0-20-20 fertilizer broadcast and harrowed in prior to seeding. All plots were band-seeded on April 2, 1955, without a companion crop

TABLE 1.—The Forage Crops, Rates of Nitrogen Fertilization and Seeding Rates of the 30 Subplot Treatments in Experiment I and 5 Subplot Treatments in Experiment II.

Crops	Nitrogen rates, lb/A annually	Respective seeding rates of crops, lb/A
	Experiment I (Simulated rotation pasture)	
Timothy	0, 60, and 120	4
Orchardgrass	0, 60, 120, and 240	6
Lincoln bromegrass	0, 60, 120, and 240	5
Kentucky bluegrass	0, 60, and 120	5
Ladino clover-timothy	0 and 60	2, 4
Ladino clover-orchardgrass	0 and 60	2, 6
Ladino clover-Lincoln bromegrass	0 and 60	2, 5
Ladino clover-Kentucky bluegrass	0 and 60	2, 5
Empire birdsfoot trefoil-timothy	0	5, 4
Empire birdsfoot trefoil-orchardgrass	0	5, 6
Empire birdsfoot trefoil-Lincoln bromegrass	0	5, 5
Empire birdsfoot trefoil-Kentucky bluegrass	0	5, 5
Ranger alfalfa-timothy*	0	7, 4
Ranger alfalfa-orchardgrass*	0	7, 6
Ranger alfalfa-Lincoln bromegrass*	0	7, 5
Ranger alfalfa-Kentucky bluegrass*	0	7, 5
	Experiment II (Hay)	
Ranger alfalfa	0	10
Ranger alfalfa-Lincoln bromegrass	0	7, 6
Ranger alfalfa-timothy	0	7, 4
Ranger alfalfa-Kenland red clover-Lincoln bromegrass	0	7, 3, 6
Ranger alfalfa-Kenland red clover-timothy	0	7, 3, 4

*One-half pound per acre of Ladino clover seed was seeded with the mixture, but did not result in appreciable amounts of Ladino becoming established.

and with more than 300 pounds per acre of 3-12-12 fertilizer. Plots were irrigated after seeding and generally satisfactory stands were obtained. Perennial weeds were hand-rogued from plots in the fall of 1955 and early spring of 1956 so the plots were pratically weed free at first cutting of the 1956 harvest season.

Plots of Experiment I were harvested monthly during the growing season to simulate rotational grazing. In 1956 and 1957, plots were cut five times, on or about the fifteenth of May, June, July, August and September. Because of late spring in 1958, the first cutting was delayed until May 20. Only four cuttings were made in the 1958 season; no cutting being made in September. Plots of Experiment II were harvested three times annually for hay on or about June 10, July 22 and September 10.

In 1956, the nitrogen fertilizer in Experiment I was applied on three dates—one third on March 13, one third on June 26 after second cutting and one third on August 16 after fourth cutting. In 1957, because of low yields of nitrogen-fertilized grasses in 1956 during the periods when they did not receive nitrogen, one-fourth of the nitrogen was applied after each cutting on May 22, June 18, July 17, and August 16, 1957, and on May 22, June 25, July 31, and September 1, 1958. A uniform broadcast application of 350 pounds per acre of 6.67-16-16 fertilizer was made on all plots of Experiment I and II on March 14 1957, and of 500 pounds per acre of 10-10-10 on April 3, 1958.

In March, 1956, plaster of Paris blocks for moisture determination with platinized stainless steel screen electrodes and five-foot leads were placed at six-inch depths of all treatments containing either bluegrass or Ladino clover or both with no nitrogen in Replications 1 and 3 of Experiment I. At the same time, similar plaster of Paris blocks were placed at 10-, 20-, and 40-inch depths in two locations of bluegrass-Ladino clover with no nitrogen and bluegrass-birdsfoot trefoil plots in the same replications.

In the spring of 1957, plaster of Paris blocks were installed in plots of bromegrass-Ladino clover (no nitrogen) and bromegrass-birdsfoot trefoil treatments in Replications 1 and 3 of Experiment I. One block was installed at each 6-, 10-, 20-, and 40-inch depth in irrigated plots and two blocks at the same depths in the nonirrigated plots. Also, a plaster of Paris block with a ten-foot lead was installed at the 60-inch depth in plots of nonirrigated bluegrass-trefoil and bromegrass-trefoil treatments in Replications 1 and 3 in the spring of 1957.

In Experiment II, plaster of Paris blocks were placed at 6-, 10-, 20-, and 40-inch depths of the pure alfalfa plots. One set of blocks was placed in each irrigated and nonirrigated alfalfa plot of both replications in 1956. In the spring of 1956 an additional set of blocks was installed in the nonirrigated alfalfa plots at the same depths. Also one plaster of Paris block with ten-foot lead was installed at 60-inch depth in each of the two nonirrigated alfalfa plots.

The soil moisture conditions at the location of various plaster of Paris blocks were determined by measuring the electrical resistance of the blocks by an alternating current impedance meter which gave readings in percent available water, as described by Bouyoucos (2). The blocks were read every three or four days from May through September, and more often if rain was expected or irrigation needed before the next scheduled reading.

In order to facilitate adequate irrigation for the many species and treatments involved in the investigation, an arbitrary criterion for determining when to irrigate was established. Irrigation water was applied when a majority of the blocks at the six-inch depth of the irrigated plots gave a reading of 10 percent available moisture on the meter and blocks at the 10-inch depth of irrigated bluegrass-Ladino (no nitrogen) and bluegrass-trefoil gave readings of less than 50 per cent available moisture. One and one half inches of water were needed to bring the soil back to field capacity when water was depleted to the above degree.

Thornthwaite and Mather (13) gave evidence that when soil water is maintained at the optimum that evapotranspiration is similar for all kinds of vegetation. Therefore, it was believed that irrigating to suit the needs of Ladino clover and bluegrass, both rather shallow-rooted and heavy users of water from upper soil levels, would also furnish adequate water for the other species involved. The blocks in nonirrigated plots served as checks to irrigation and gave information on water removed at various depths of nonirrigated treatments. Because Experiments I and II could not be irrigated separately, Experiment II received irrigation similar to Experiment I.

In a laboratory test, where plaster of Paris blocks were placed in soil from the 6- to 12-inch level of the experimental area, it was found that the permanent wilting point (PWP) of the soil (16.2 percent water by weight) was at a reading of approximately 10 percent available moisture on the meter scale. The 50 percent available water reading on the meter scale was approximately the halfway point in moisture between the permanent wilting point (determined on pressure membrane apparatus at 15 atmospheres pressure) and field capacity (29.1 percent moisture by weight determined on tension table at one third atmosphere tension). The moisture meter gave rather variable readings from block to block when plaster blocks were in soil near or at field capacity. At high moisture levels soil temperature also caused considerable fluctuation in meter readings. However, as the soil became drier and approached permanent wilting point the variation in readings between blocks became small and temperature caused only negligible changes in readings.

The amount of irrigation water applied was determined by placing open-topped quart cans at various locations on the plots and measuring the depth of water in the cans immediately after irrigation. As there was some variation in the distribution of water to the plots, the inches of water supplied was assumed to be the average depth of the one third of cans with least amount of water in them. In general, there was little variation in water level of cans with the lower amounts of water. Therefore, all irrigated areas received at least the amount of water reported but some areas unavoidably got more.

The plots were harvested by cutting a 3 x 21-foot strip through the center of each plot with a sickle-bar mower approximately two inches above the ground. The green weight yield of forage was determined immediately in the field and a subsample taken for determination of dry weight and chemical analysis.

The percentage of various species in forage of the various mixtures was estimated before each cutting of Experiment I. The estimates were made at separate times by two persons in as unbiased a manner as possible. In 1956 and 1957 the same persons made the estimates each time. In 1958, it was necessary to use different persons.

The crude protein content of nitrogen-fertilized pure grass treatments was determined for individual cuttings in two replications of Experiment I in 1956, 1957, and 1958.

Rainfall and Irrigation

A graphic presentation of daily rainfall and irrigation applied to irrigated plots from April through September for the years 1956, 1957, and 1958 is given in Figure 1. The precipitation, deviation from normal precipitation, and amounts of irrigation water applied to irrigated plots for months April through September, during the same three years are presented in Table 2. The driest summer was in 1956 when rainfall in June, July, August, and September was below normal. During this growing season 6.55 inches of irrigation water were applied. The first irrigation of 1.25 inches applied on June 16 had little effect as it rained every day for the next five days for a total of 1.9 inches, which was enough to bring all plots back to field capacity without irrigation. Rainfall did not coincide with the other four irrigations during this season. The fall of 1956 was very dry and had many sunny days. The first sufficiently severe freeze to damage the crops in this experiment was on November 22.

In 1957, rainfall was adequate until the middle of July. The rainfall of July and August was less than in 1956, but the soil entered July at field moisture capacity. A total of 5.4 inches of water was applied in four irrigations. The last irrigation of 0.60 inch on September 10 was cut short by rain, which over a several day period, amounted to 1.82 inches. Other irrigations were not followed immediately by rainfall.

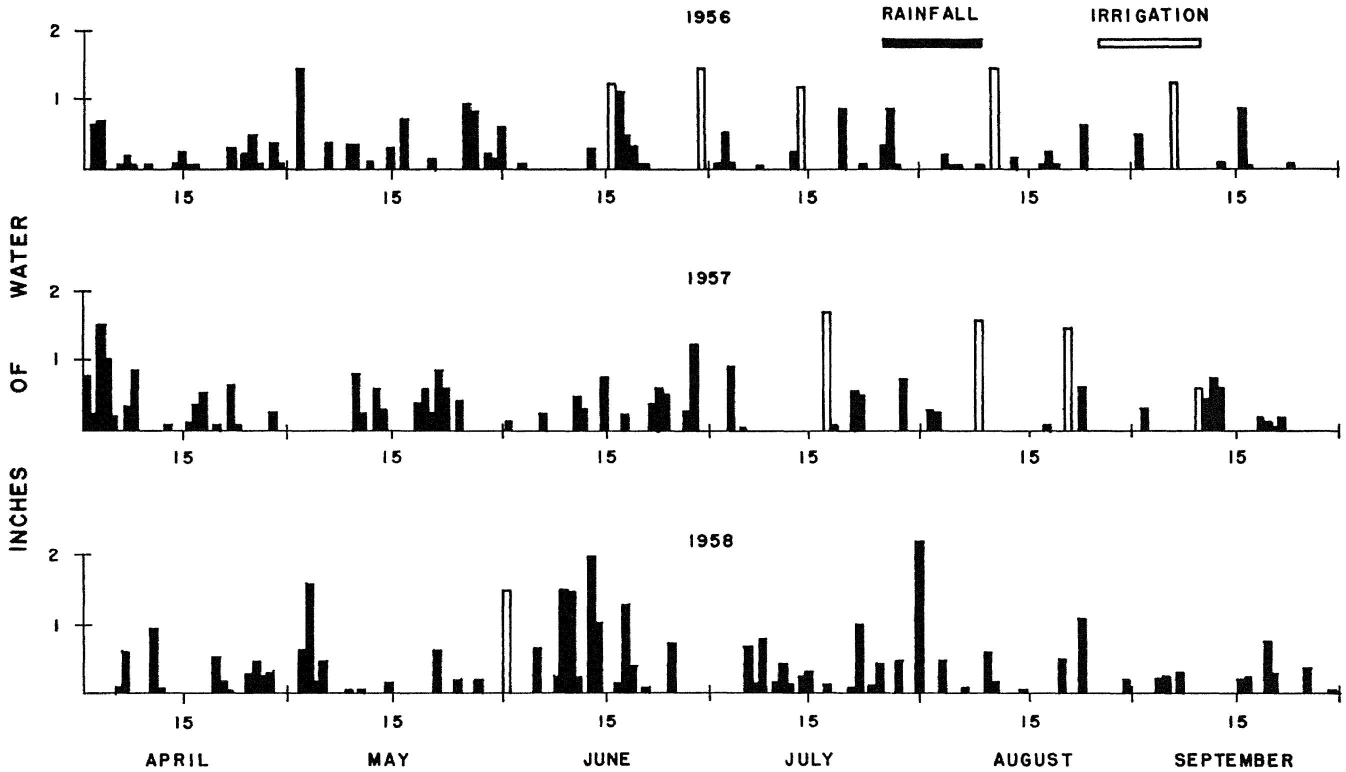

Fig. 1.—The daily rainfall at the Agronomy farm, Columbus, Ohio, and irrigation water applied to irrigated plots for April through September in 1956, 1957, and 1958.

TABLE 2.—The Monthly Precipitation, Deviation From Normal Precipitation, and Irrigation Water Applied to Irrigated Plots in the Irrigation Study at the Agronomy Farm, Columbus, Ohio.

Month	Precipitation	Inches of water Deviation from normal	Water applied to irrigated plots	Precipitation plus irrigation
		1956		
April	3.18	— 0.01	0.00	3.18
May	6.13	+ 2.90	0.00	6.13
June	2.21	— 1.45	2.65	4.86
July	3.13	— 0.40	1.20	4.33
August	1.91	— 1.10	1.45	3.36
September	1.66	— 0.92	1.25	2.91
Total	18.22	— 0.98	6.55	24.77
		1957		
April	6.79	+ 3.60	0.00	6.79
May	5.00	+ 1.77	0.00	5.00
June	5.20	+ 1.54	0.00	5.20
July	2.76	— 0.77	1.70	4.46
August	1.17	— 1.84	3.10	4.27
September	2.63	— 0.05	0.60	3.23
Total	23.55	+ 4.35	5.40	28.95
		1958		
April	3.72	+ 0.53	0.00	3.72
May	4.24	+ 1.01	0.00	4.24
June	10.58	+ 6.92	1.50	12.08
July	7.39	+ 3.86	0.00	7.39
August	3.33	+ 0.32	0.00	3.33
September	2.99	+ 0.41	0.00	2.99
Total	32.25	+13.05	1.50	33.75

The 1958 growing season had heavy and well-distributed rainfall so no irrigation was applied except for one and one half inches on June 2. This application was followed by heavy rainfall so that it was not effective.

RESULTS AND DISCUSSION

EXPERIMENT I

Dry Matter Production

The annual and average dry matter production for irrigated and unirrigated forage crops in Experiment I, managed as simulated rotationally grazed pasture, are presented in Table 3. The largest increases in forage yield from irrigation were obtained in 1956, the year with the longest dry period. In 1956, the average gain of all treatments from irrigation was 1640 pounds of dry matter per acre.

The average dry matter gain from irrigation over the three harvest seasons of this study varied from an increase of 2310 pounds per acre per year for the Ladino-timothy mixture receiving no nitrogen to a loss of 420 pounds on the alfalfa-bluegrass plots (Table 3). The average annual gain from irrigation for all forage crops for the three seasons was only 650 pounds of dry matter per acre.

Nitrogen fertilization of pure grasses increased yields with and without irrigation. However irrigation in addition to high nitrogen fertilization increased yields up to 3000 to 4000 pounds per acre on orchardgrass and bromegrass in 1956. Irrigated grasses gave 25 or more pounds of forage increases for each pound of nitrogen applied over the three year test period. Irrigated orchardgrass and bromegrass yielded nearly as much dry matter per pound of nitrogen at the 240 pound rate in 1956 and 1957 as at the lower rates. In 1958, the overall response to irrigation was a loss of 230 pounds of dry matter and the response to nitrogen fertilization was less than before. The larger amount of nitrogen applied in the basic fertilizer to all plots in 1958 was probably a factor in the lower gains in yields of grasses per pound of additional nitrogen applied at high nitrogen rates.

Larger increases in dry matter yield from irrigation would be expected on soils with lighter texture and lower water-holding capacities than the Brookston silty clay loam on which this investigation was conducted. Luetkemeier and Kohnke (6) got only a small increase in corn yields from irrigation on a similar Brookston soil in Indiana during two years not having extremely droughty conditions, but they got large increases in corn yields from irrigation of nearby light-textured Plainfield sand in one year and Fox loam the next year. This same relationship should hold for forage crops.

Averaging the gains from irrigation (Table 3) of timothy, orchardgrass, bromegrass, and bluegrass, at 0, 60, and 120 pounds of nitrogen per acre showed that timothy was most responsive to irrigation with an average annual gain from irrigation of 900 pounds per acre, while that of orchardgrass, bromegrass, and bluegrass was 360, 110, and 10 pounds per acre, respectively.

Ladino clover gave the largest response to irrigation among the legumes. Ladino-grass mixtures receiving no nitrogen yielded an average of 1740 pounds per acre per annum more when irrigated. The gain from irrigation of Ladino-grass mixtures was reduced to 1200 pounds per acre per year when 60 pounds of nitrogen was applied annually. Mixtures employing the drought-tolerant legumes, birds-

TABLE 3.—The Dry Matter Production of Irrigated and Unirrigated Forage Crops Managed as Simulated Rotation Pasture During a Three-Year Period at Columbus, Ohio.

Crop	Pounds nitrogen per acre	Yield of dry matter, pounds per acre, with and without irrigation								
		1956		1957		1958		Average annual		
		Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated	Gain from irrigation
Timothy	0	1,640	2,250	2,830	2,560	6,160	6,160	3,540	3,660	120
	60	2,430	5,070	4,830	4,730	6,550	7,170	4,450	5,660	1,210
	120	4,110	6,580	5,680	6,850	8,660	9,100	6,150	7,510	1,360
Orchardgrass	0	1,740	2,470	2,570	3,050	6,060	6,520	3,460	4,010	550
	60	2,940	4,140	4,890	4,640	7,950	7,990	5,260	5,590	330
	120	4,560	5,540	6,190	6,530	9,730	9,000	6,830	7,020	190
	240	6,040	9,400	9,010	10,770	9,570	10,690	8,210	10,290	2,080
Bromegrass	0	1,760	2,650	2,690	2,710	6,570	5,900	3,670	3,750	80
	60	2,920	4,480	4,980	4,680	7,890	6,820	5,260	5,330	70
	120	4,200	6,510	6,810	6,360	9,560	8,230	6,860	7,030	170
	240	5,400	9,350	9,970	9,500	10,450	9,410	8,610	9,420	810
Bluegrass	0	1,610	1,970	2,520	1,950	5,710	5,140	3,280	3,020	— 260
	60	1,950	3,300	4,670	3,820	7,590	7,430	4,740	4,850	110
	120	3,450	4,890	6,030	6,260	9,100	7,940	6,190	6,360	170
Ladino-timothy	0	4,720	7,360	4,220	7,950	6,740	7,320	5,230	7,540	2,310
	60	5,520	7,120	6,510	8,450	7,490	7,890	6,510	7,820	1,310
Ladino-orchardgrass	0	4,830	5,800	4,660	7,230	6,680	7,800	5,390	6,940	1,550
	60	5,570	8,160	6,510	7,340	8,610	7,800	6,900	7,770	870
Ladino-bromegrass	0	5,850	7,580	5,310	7,470	7,210	7,110	6,120	7,390	1,270
	60	6,050	8,710	7,290	8,990	8,480	8,280	7,270	8,660	1,390
Ladino-bluegrass	0	4,470	6,090	3,770	5,820	6,050	7,910	4,760	6,610	1,850
	60	5,350	8,180	5,550	6,060	7,000	7,320	5,970	7,190	1,220

TABLE 3. (Continued)—The Dry Matter Production of Irrigated and Unirrigated Forage Crops Managed as Simulated Rotation Pasture During a Three-Year Period at Columbus, Ohio.

Crop	Pounds nitrogen per acre	Yield of dry matter, pounds per acre, with and without irrigation								
		1956		1957		1958		Average annual		
		Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated	Gain from irrigation
Trefoil-timothy	0	4,300	5,600	7,560	7,090	8,520	8,140	6,790	6,940	150
Trefoil-orchardgrass	0	4,420	4,670	6,770	6,680	9,730	8,800	6,970	6,720	— 250
Trefoil-bromegrass	0	3,850	4,980	6,550	7,300	8,510	7,470	6,300	6,920	620
Trefoil-bluegrass	0	4,020	5,500	6,370	6,380	8,980	7,860	6,460	6,580	120
Alfalfa-timothy	0	9,770	11,180	9,890	11,650	10,710	8,930	10,120	10,590	470
Alfalfa-orchardgrass	0	10,220	10,780	9,620	8,950	10,370	9,610	10,070	9,780	— 290
Alfalfa-bromegrass	0	9,380	11,130	10,300	10,760	9,590	8,910	9,760	10,270	510
Alfalfa-bluegrass	0	9,050	9,930	8,950	7,300	8,910	8,420	8,970	8,550	— 420
Mean		4,740	6,380	6.100	6,660	8,170	7,940	6,340	6,990	650
Average gain from irrigation		1,640*		560		— 230		650		
LSD .05 for crops-nitrogen values at the same level of irrigation		1,310		1,520		1,850		1,180		
LSD .05 for irrigation values at the same crop-nitrogen level		1,200		1,300		NS		990		

*Significant at .05 level.

foot trefoil and alfalfa, gave annual average yield increases of 160 and 50 pounds of dry matter per acre, respectively, from irrigation.

Examination of data showed that total annual production figures did not reveal certain important effects of irrigation on the forage crops. Yield advantages as a result of irrigation during drought periods were being masked by yields during periods when irrigation was not applied. The yields of all treatments during the dry periods of 1956 and 1957 are given in Table 4. The dry period in 1956, when irrigation was effective, covered the last three cutting periods. In 1957, the dry period was shorter, consisting of the last two cutting periods, but drought conditions were more intense than in 1956. Consequently many treatments gave similar dry matter increases from irrigation for each of the two years.

During the dry periods the largest increase in dry matter production, slightly over 3000 pounds per acre, was obtained from orchardgrass and bromegrass receiving 240 pounds of nitrogen per acre annually. The grasses under heavy nitrogen fertilization and in mixture with Ladino clover gave the largest response to irrigation. The yields from unirrigated alfalfa-grass mixtures during dry periods compared favorably with these irrigated grasses at 240 pounds per acre of nitrogen. The common practice of utilizing alfalfa-grass meadows for supplementary grazing after one or two crops of hay are removed would appear to be sound and dependable except during seasons with extremely long periods of drought.

The gain or loss of dry matter during the first cuttings of 1957 and 1958 as a result of irrigating the previous summer is also shown in Table 4. The loss in yields from the first cuttings following irrigation in the previous summer was frequently a large share of the gain from irrigation made the year before. This reduction in yield of irrigated crops was mainly during the first cutting. A reduced yield of irrigated forages during the first cuttings of 1957 cancelled much of the gain from irrigation during the summer of 1957 and even resulted in lower total season dry matter production with some forages than when not irrigated. In 1958, most of the irrigated forages had lower seasonal dry matter yields than the unirrigated principally as a result of lower first cutting yields.

Irrigation had the effect of shifting forage production so that a greater percentage of the total production was made during the dry summer months. This might be well for the livestock producer because it is during the summer and not spring that he usually needs additional production from his pasture or meadow.

The causes for the poor growth in the spring of forages that had been irrigated the summer before would seem to be different for the different crops. With the grasses, it seems that drought prevented the utilization of a large share of the nitrogen applied, so that it remained in the soil to stimulate growth the next spring. This seems fairly clear from the fact that the loss from irrigation the year before increases regularly (bluegrass is a non-significant exception) as the amount of nitrogen applied increases (Table 4). Even through nitrogen applications were the same for both irrigated and unirrigated plots, the unirrigated plots started out with more nitrogen available the next spring, as shown significantly in Table 5. Nitrogen analyses of the four grasses, timothy, orchardgrass, bromegrass and bluegrass, when grown in pure stand at the several nitrogen rates, indicated that much of the nitrogen not removed in top growth of irrigated grasses in the summer was available for growth and removed in top growth the following spring(Table 5). The stimulating effect of extra nitrogen on grasses is well recognized. Additional nitrogen would have to be applied to produce the same growth from irrigated forages, especially those containing grasses only.

This difference in nitrogen uptake by irrigated and unirrigated grasses is probably only one factor contributing to reduced growth of irrigated forages in the spring. Favorable conditions for growth of irrigated plants in the dry periods of summer probably resulted in carbohydrates being utilized in top growth instead of going to storage as food reserves in the roots. Low food reserve storage in the irrigated plants would result in poor growth the next spring.

This lack of root reserves was probably the dominant factor in the poorer yield of legumes, especially alfalfa. The fact that alfalfa is injured less by frequent cutting in dry seasons or under dry conditions than in wet has long been known (16, 17). In these tests, during the dry periods the forage plants on irrigated plots appeared younger and more vigorous than plants on the unirrigated plots. Birdsfoot trefoil and Ladino clover did not bloom as profusely on irrigated as unirrigated plots.

Protein Content and Protein Yields of Grasses

The average crude protein contents of the four grasses in pure stand are given in Table 6. The average protein contents over the growing season in 1956, 1957 and 1958 were generally very similar whether irrigated or not irrigated. Only small differences existed in the seasonal protein content of the various grasses at the same level

TABLE 4.—The Dry Matter Gains From Irrigation of Simulated Rotationally Grazed Forage Crops During Dry Periods in 1956* and 1957* and the Gains or Losses During the First Cuttings of 1957 and 1958 Following Irrigation the Previous Year.

Crops	Pounds nitrogen per acre	Pounds per acre of dry matter gained or lost from irrigation during					
		Dry season of 1956	1st cutting of 1957	Dry season of 1957	1st cutting of 1958	Average of dry seasons	Average of 1st cuttings
Timothy	0	650	—900	470	110	560	—400
	60	2100	—1090	1380	380	1740	—360
	120	2510	—1270	2520	190	2520	—540
Orchardgrass	0	640	—70	550	330	600	130
	60	1140	—980	1050	—380	1100	—680
	120	1520	—1020	1810	—820	1670	—920
	240	3190	—1550	3020	980	3110	—290
Bromegrass	0	680	—430	530	—690	610	—560
	60	1190	—1260	1310	—1110	1250	—1190
	120	1890	—1820	1580	140	1740	—840
	240	3060	—2990	3050	—920	3050	—1960
Bluegrass	0	330	—820	260	—310	300	—570
	60	1110	—1450	690	—620	900	—1040
	120	1210	—1070	1340	—1430	1280	—1250
Ladino-timothy	0	2670	400	2020	160	2350	280
	60	2320	—830	2570	210	2450	—310
Ladino-orchardgrass	0	1670	—220	1740	390	1710	90
	60	2360	—930	1690	—770	2020	—850
Ladino-bromegrass	0	2300	—820	1360	—580	1830	—700
	60	2540	—970	1670	—1330	2110	—1150
Ladino-bluegrass	0	2060	370	1140	130	1600	250
	60	2480	—460	960	—940	1720	—700

TABLE 4. (Continued)—The Dry Matter Gains From Irrigation of Simulated Rotationally Grazed Forage Crops During Dry Periods in 1956* and 1957* and the Gains or Losses During the First Cuttings of 1957 and 1958 Following Irrigation the Previous Year.

Crops	Pounds nitrogen per acre	Pounds per acre of dry matter gained or lost from irrigation during					
		Dry season of 1956	1st cutting of 1957	Dry season of 1957	1st cutting of 1958	Average of dry seasons	Average of 1st cuttings
Trefoil-timothy	0	1570	— 680	850	— 300	1210	— 490
Trefoil-orchardgrass	0	980	— 420	940	— 40	960	— 230
Trefoil-bromegrass	0	1210	— 250	930	— 90	1070	— 170
Trefoil-bluegrass	0	1330	— 580	800	— 370	1070	— 480
Alfalfa-timothy	0	1330	110	1520	— 940	1430	— 420
Alfalfa-orchardgrass	0	460	— 940	710	— 470	590	— 710
Alfalfa-bromegrass	0	1320	— 430	740	— 110	1030	— 270
Alfalfa-bluegrass	0	720	— 860	410	— 160	570	— 510
Mean		1620	— 810	1320	— 310	1470	— 560

*The dry period in 1956 was the three month period from June 15 to September 15 and yields are for the cuttings made in July, August and September. The dry period in 1957 was the two month period from July to September 15 and yields are for the cuttings made in August and September.

TABLE 5.—The Average Nitrogen Recovered in Harvested Top Growth of Bromegrass, Orchardgrass, Bluegrass and Timothy During Selected Periods as Affected by Irrigation and Nitrogen Fertilization.

Pounds nitrogen per acre	Irrigated	The average pounds per acre of nitrogen in grasses harvested					
		1956 season	First cutting of 1957	1956 season plus first cutting of 1957	Last four cuttings of 1957 season	First cutting of 1958	Last four cuttings of 1957 season plus first cutting of 1958
0	No	33	34	67	13	88	101
	Yes	47	26	73	21	88	109
60	No	57	53*	110	40	108	148
	Yes	94*	31	125	54	89	143
120	No	97	62*	159	68	124*	192
	Yes	130*	32	162	96*	97	193

*Significantly different at 05 level from corresponding value at other irrigation level for the same level of N.

TABLE 6.—The Crude Protein Content of Irrigated and Unirrigated Grasses Receiving Various Rates of Nitrogen, 1956 through 1958.

Grass	Pounds nitrogen per acre	Per cent protein: 1956 Not irrigated	1956 Irrigated	1957 Not irrigated	1957 Irrigated	1958 Not irrigated	1958 Irrigated	3 year average Not irrigated	3 year average Irrigated
Timothy	0	12.6	12.9	11.1	12.0	12.9	12.5	12.2	12.5
	60	12.7	15.3	12.3	12.4	14.0	13.2	13.0	13.6
	120	13.9	14.2	12.9	13.3	14.4	13.8	13.7	13.8
Orchardgrass	0	15.9	14.4	11.7	11.9	12.9	11.8	13.5	12.7
	60	14.5	14.4	11.7	12.2	15.3	14.8	13.8	13.8
	120	14.7	14.1	13.3	12.5	15.2	13.4	14.4	13.3
	240	17.1	19.4	15.7	15.3	18.3	15.6	17.0	16.8
Bromegrass	0	13.5	14.3	13.0	13.6	14.2	16.1	13.6	14.7
	60	15.4	15.1	13.4	14.1	15.6	15.6	14.8	14.9
	120	16.0	16.1	13.9	14.7	16.0	16.8	15.3	15.9
	240	18.8	17.5	15.6	16.8	18.0	16.6	17.5	17.0
Bluegrass	0	12.1	11.7	11.1	11.7	14.7	15.0	12.6	12.8
	60	13.9	14.6	11.8	12.8	15.2	14.2	13.6	13.9
	120	14.1	14.3	13.1	13.9	16.0	16.3	14.4	14.8
Average all grasses	0	12.6	13.3	11.7	12.3	13.7	13.9	13.0	13.2
	60	14.1	14.9	12.3	12.9	15.0	14.5	13.8	14.1
	120	14.7	14.7	13.3	13.6	15.2	14.6	14.5	14.5
Average bromegrass and orchardgrass	240	17.8	18.5	15.7	16.1	18.2	16.1	17.3	16.9

of irrigation and nitrogen fertilization. The average protein contents of grasses were increased by nitrogen fertilization. However, the seasonal increases were small, usually not over one per cent protein for each 60 pounds per acre increase in nitrogen applied.

The small increases in protein content coupled with large increases in dry matter as the nitrogen rate increased resulted in greatly increased yields of crude protein per rate (Table 7). The average protein yield for 120 pounds of N per acre, over four grasses for three years was double the yield with no nitrogen.

The avreage protein yield of bromegrass and orchardgrass receiving 240 pounds nitrogen per acre over the three years was 1630 pounds per acre. This was three times the average protein yield of these two grasses without nitrogen. Overall, the influence of nitrogen was very similar on each of the grasses, each additional increment of nitrogen resulting in substantial increases in crude protein production per acre. There were no consistent differences in protein yields of the four grasses at the same nitrogen and irrigation level.

The protein production by cuttings for the grasses in 1956 and 1957 is given in Table 8. The yields in the dry season are also totaled to give the protein production from the yields in Table 4.

It is clear that protein production follows yield, but with more contrast between high nitrogen fertilization and none, because of the increased protein from high amounts of nitrogen.

In longtime practice, irrigation will increase protein production in proportion to yield and no more.

Legume Percentage and Performance

The average estimated percentages of legumes in the forage of each grass-legume mixture for the 1956, 1957, and 1958 growing seasons are shown in Table 9. Ladino clover was favored by irrigation and generally constituted a greater portion of the total from irrigated clover-grass mixtures than from unirrigated mixtures. The Ladino clover-grass mixtures receiving no additional nitrogen beyond basic fertilizer usually contained more clover than mixtures receiving 60 pounds per acre of nitrogen. The lack of persistence practically eliminated Ladino clover from all mixtures by 1958 except with timothy and bromegrass, irrespective of irrigation treatment.

Birdsfoot trefoil seemed well adapted to both irrigated and unirrigated conditions. The percentage of birdsfoot trefoil in mixtures tended to hold steady or increased each year for the three year period. This was due to development of larger trefoil plants with each succes-

TABLE 7.—Crude Protein Production of Irrigated and Unirrigated Grasses Receiving Various Rates of Nitrogen, 1956 through 1958.

		Pounds per acre of protein							
	Pounds	1956		1957		1958		3 year average	
Grass	nitrogen per acre	Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated	Not irrigated	Irrigated
Timothy	0	170	290	320	260	800	770	430	440
	60	270	720	530	510	920	950	570	730
	120	550	880	720	820	1300	1380	860	1030
Orchardgrass	0	260	310	280	330	780	770	440	470
	60	430	570	590	540	1220	1180	750	760
	120	680	750	770	730	1480	1210	980	900
	240	980	1770	1430	1570	1750	1670	1390	1670
Bromegrass	0	210	380	310	350	930	950	480	560
	60	440	640	660	640	1230	1070	780	780
	120	690	930	970	820	1530	1390	1060	1050
	240	1050	1680	1570	1500	1880	1570	1500	1580
Bluegrass	0	170	190	270	220	840	770	430	390
	60	260	420	570	430	1150	1060	660	640
	120	510	680	770	830	1430	1300	900	940
Average all grasses	0	200	290	300	290	840	810	450	480
	60	350	590	590	530	1130	1070	690	730
	120	610	810	810	800	1430	1320	950	980
Average orchardgrass and bromegrass	240	1020	1730	1500	1530	1810	1620	1450	1630

TABLE 8.—The Yield of Crude Protein Per Acre in Averaged Grass Treatments Harvested Monthly as Affected by Irrigation and Nitrogen Fertilization During 1956 and 1957 at Columbus.

Crops averaged	Pounds nitrogen per acre	Year	Irrigated	Pounds protein per acre at cutting made about 15th day of: May	June	July	August	September	Dry season* total	Total protein
Timothy	0	1956	No	77	67	41	13	5	59	200
Orchardgrass			Yes	92	61	59	41	41	141	290
Bromegrass		1957	No	216	39	31	9	2	11	300
Kentucky bluegrass			Yes	159	34	29	40	27	67	290
Timothy	60	1956	No	145	67	65	37	38	130	350
Orchardgrass			Yes	202	68	140	59	118	317	590
Bromegrass		1957	No	333	96	99	42	21	63	590
Kentucky bluegrass			Yes	193	76	75	113	73	186	530
Timothy	120	1956	No	352	78	79	45	55	179	610
Orchardgrass			Yes	326	70	172	67	174	413	810
Bromegrass		1957	No	383	152	161	55	56	111	810
Kentucky bluegrass			Yes	206	124	137	160	174	334	800
Orchardgrass	240	1956	No	533	125	134	113	115	362	1020
Bromegrass			Yes	707	112	391	111	406	908	1730
		1957	No	671	316	370	85	59	144	1500
			Yes	277	275	304	344	332	676	1530

*July, August, and September in 1956; August and September in 1957; to compare with Table 4.

sive year. A good stand of birdsfoot trefoil was obtained at seeding but many of the plants were small and lacked vigor during the 1956 season and some did not grow large until after the 1957 season. Only in 1958 were yields indicative of a vigorous stand of birdsfoot trefoil in mixture with grasses.

Cutting alfalfa five times a year is too frequent for best maintenance of stand and vigor of alfalfa in central Ohio. Alfalfa plants became weaker over the course of this experiment. Irrigation tended to further weaken the alfalfa plants and the stand on irrigated plots became thinner than on unirrigated plots. Bromegrass and timothy were least competitive of the four grasses with alfalfa regardless of irrigation treatment, as evidenced by the percentage of alfalfa in the mixtures (Table 9). Even though alfalfa in irrigated bluegrass and orchardgrass was rather thin by 1958, alfalfa still made up a large portion of the forage produced.

TABLE 9.—The Average Percentage of Legumes in Irrigated and Unirrigated Legume-Grass Mixtures Cut to Simulate Rotationally-Grazed Pasture at Columbus, Ohio.

Mixture	1956 Irrigated		1957 Irrigated		1958 Irrigated	
	No	Yes	No	Yes	No	Yes
Ladino-timothy	11	43	4	48	22	14
Ladino-timothy plus 60 lb/A N	13	13	1	20	6	18
Ladino-orchardgrass	18	23	1	32	0	3
Ladino-orchardgrass plus 60/A N	14	15	0	4	0	0
Ladino-bromegrass	53	50	1	46	13	8
Ladino-bromegrass plus 60 lb/A N	40	51	0	4	1	21
Ladino-bluegrass	28	40	0	12	0	8
Ladino-bluegrass plus 60/A N	40	37	0	4	0	0
Trefoil-timothy	32	31	61	46	55	42
Trefoil-orchardgrass	21	18	40	27	38	15
Trefoil-bromegrass	25	29	34	57	39	36
Trefoil-bluegrass	32	36	45	36	48	38
Alfalfa-timothy	90	92	82	79	74	57
Alfalfa-orchardgrass	78	65	69	47	40	28
Alfalfa-bromegrass	88	86	85	78	74	48
Alfalfa-bluegrass	86	81	77	47	57	36

No Ladino clover was apparent on any of the alfalfa-grass plots in 1956 though one half pound per acre of Ladino clover seed was sown with these mixtures at seeding. Ladino clover failed to establish on any of the unirrigated alfalfa grass plots during the three harvest years. A sparse stand of Ladino-clover did develop on the irrigated alfalfa-grass plots late in 1957 and in 1958, especially on plots containing timothy and bromegrass. However, Ladino clover did not make a substantial contribution to yields on any of the irrigated alfalfa-grass plots.

EXPERIMENT II

The amount of dry matter produced in 1956, 1957 and 1958 by various alfalfa mixtures managed as hay, with and without irrigation, is presented in Table 10. The average annual increase in yield from irrigation was only 1270 pounds per acre. The value of this forage would have to be high to pay for costs involved in irrigating plus a reasonable return. As this split plot experiment had only two replications and considerable variation existed, these data should be considered preliminary.

The hay yields for each cutting (Table 11) show that alfalfa mixtures cut three times annually as a hay crop had no reduction in yield during the first cutting or during the entire wet season of 1958 as a residual effect of previous irrigations. In 1958, when all irrigated alfalfa-grass mixtures of Experiment I yielded less than nonirrigated mixtures, the irrigated mixtures of Experiment II had equal or better yields than nonirrigated. This evidence suggests that proper management, i.e. less frequent cutting, of forage crops can eliminate the detrimental effects of irrigation noted in Experiment I.

SOIL MOISTURE STUDIES

The percent available soil moisture as determined from meter readings of gypsum blocks in plots of nonirrigated Ladino clover-bluegrass and birdsfoot trefoil-bluegrass in Experiment I and alfalfa in Experiment II for months of May through September in 1956 are shown in Figures 2, 3, and 4, respectively. Similar soil moisture data for the 1957 season are given in Figures 5, 6, and 7. In addition during the 1957 season, available soil moisture was studied in plots of nonirrigated Ladino clover-bromegrass and birdsfoot trefoil-bromegrass (Figures 8 and 9). There was essentially no Ladino clover in nonirrigated Ladino clover-grass mixtures in 1957 so data for Ladino clover-bluegrass in Figure 5 and Ladino clover-bromegrass in Figure 8 should be considered as pure grass.

TABLE 10.—The Drymatter Production of Irrigated and Unirrigated Hay Mixtures at Columbus, Ohio, for Three Growing Seasons.

Hay mixtures	Pounds per acre drymatter											
	1956			1957			1958			3 year average		
	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation
	No	Yes		No	Yes		No	Yes		No	Yes	
Alfalfa, alone	9,580	10,410	830	8,770	10,410	1,640	10,630	13,440	2,810	9,660	11,420	1,760*
Alfalfa-bromegrass	11,010	12,590	1,580	10,630	12,630	2,000	12,410	12,840	430	11,350	12,690	1,340
Alfalfa-timothy	10,670	12,910	2,240	9,290	9,750	460	11,930	11,940	10	10,630	11,530	900
Alfalfa-red clover-bromegrass	10,230	11,830	1,600	9,950	11,560	1,610	11,710	12,850	1,140	10,630	12,080	1,450*
Alfalfa-red clover-timothy	9,880	10,460	580	9,510	10,900	1,390	13,150	13,910	760	10,850	11,760	910
Overall average	10,270	11,460	1,370	9,630	11,050	1,420	11,970	13,000	1,030	10,620	11,900	1,270*

*Significant at .05 level.

TABLE 11.—The Average Drymatter Yield of Each of the Three Cuttings of Irrigated and Nonirrigated Hay Mixtures Over Three Growing Seasons at Columbus, Ohio.

	Pounds per acre yield of drymatter for cutting[1]											
	One			Two			Three			Total		
	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation	Irrigated		Increase from irrigation
Mixtures	No	Yes		No	Yes		No	Yes		No	Yes	
Alfalfa, alone	4,510	5,110	600	2,930	3,480	550	2,220	2,830	610	9,660	11,420	1,760*
Alfalfa-bromegrass	5,600	5,970	370	3,490	3,820	330	2,260	2,890	630	11,350	12,690	1,340
Alfalfa-timothy	4,860	4,790	—70	3,530	3,700	170	2,240	3,040	800	10,630	11,530	900
Alfalfa-red clover-bromegrass	5,350	5,740	390	3,390	3,590	200	1,890	2,750	860	10,630	12,080	1,450*
Alfalfa-red clover-timothy	5,400	5,580	180	3,370	3,620	250	2,080	2,550	470	10,850	11,760	910
All	5,140	5,440	300	3,340	3,640	300	2,140	2,810	670	10,620	11,900	1,270*
Percent of total seasonal yield	48.4	45.7		31.5	30.6		20.2	23.6				

[1]Cuttings were made approximately June 10, July 22 and September 10 of each growing season.

*Significant at .05 level.

In general, the moisture block studies substantiated what is already known; that is, that the forage crops studied had different depths of effective root activity. For example, bluegrass has a shallower root system than bromegrass (Figures 5 and 8) so did not remove moisture to as great a depth as bromegrass. Due to the greater soil volume from which to draw water, bromegrass was more drought resistant than bluegrass.

For legumes a similar relationship existed. Ladino clover used water principally in the upper 20 inches of soil while birdsfoot trefoil and alfalfa obtained moisture from the 60-inch depth, the deepest placement of moisture blocks. The greater volume of soil from which to obtain moisture would be expected to give these latter crops great drought resistance. However, there was another advantage for growing the deep rooted crops alone or in mixture with shallow rooted crops. During several dry periods bluegrass growing in combination with birdsfoot trefoil on unirrigated plots did not wilt for several days after bluegrass growing alone or in combination with Ladino clover. The moisture blocks in the bluegrass-trefoil plots showed more available soil moisture at the 10 and 20-inch depths than the blocks in bluegrass-Ladino clover at the same depths but less available moisture

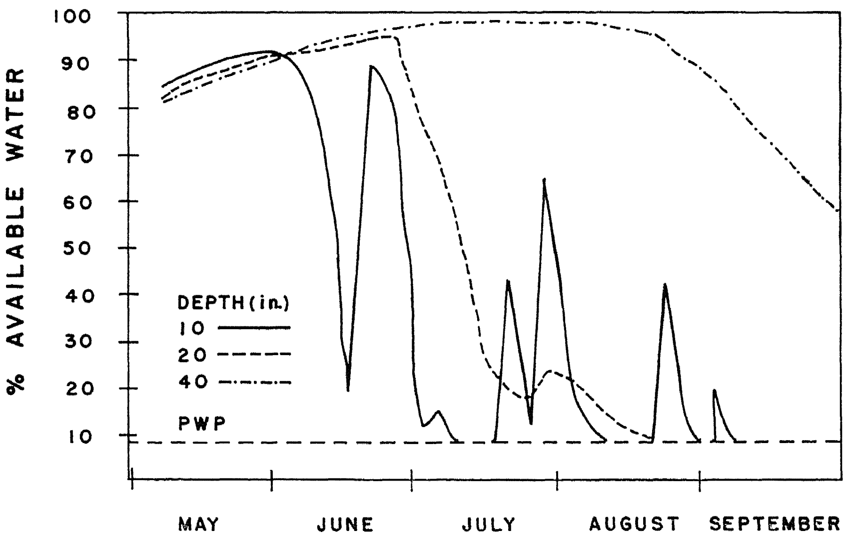

Fig. 2.—The percent available water (meter reading) in the soil at the 10-, 20-, and 40-inch depths of unirrigated Ladino clover-bluegrass plots from May through September in 1956.

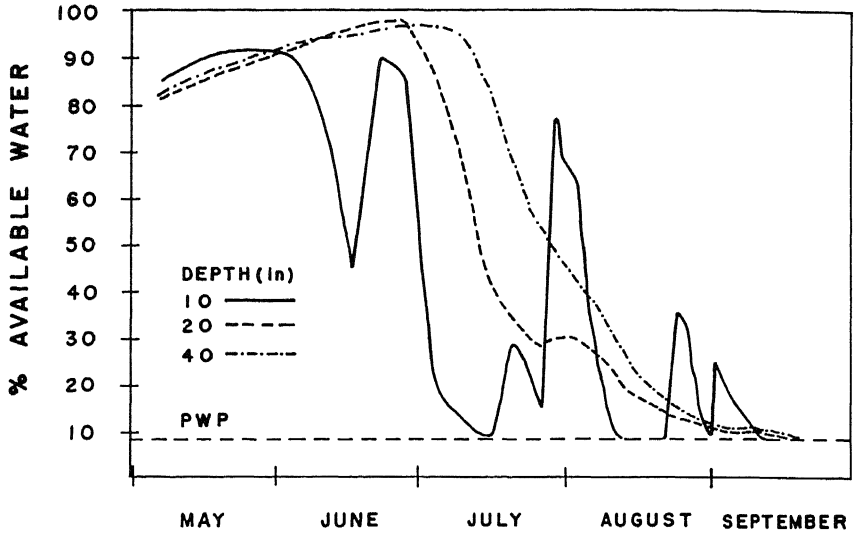

Fig. 3.—The percent available water (meter reading) in the soil at the 10-, 20-, and 40-inch depths of unirrigated birdsfoot trefoil plots from May through September in 1956.

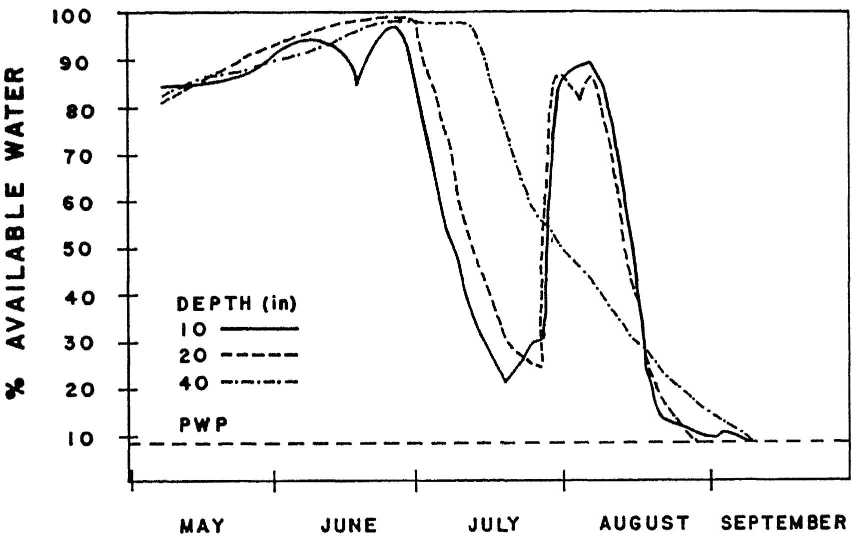

Fig. 4.—The percent available water (meter reading) in the soil at the 10-, 20-, and 40-inch depths of unirrigated alfalfa plots (cut as hay) from May through September in 1956.

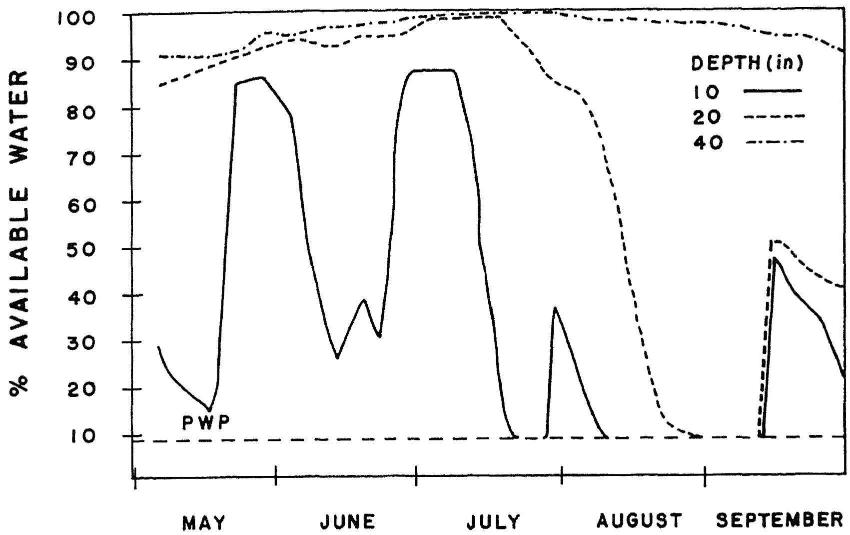

Fig. 5.—The percent available water (meter reading) in the soil at the 10-, 20-, and 40-inch depths of unirrigated Ladino clover-bluegrass plots from May through September in 1957.

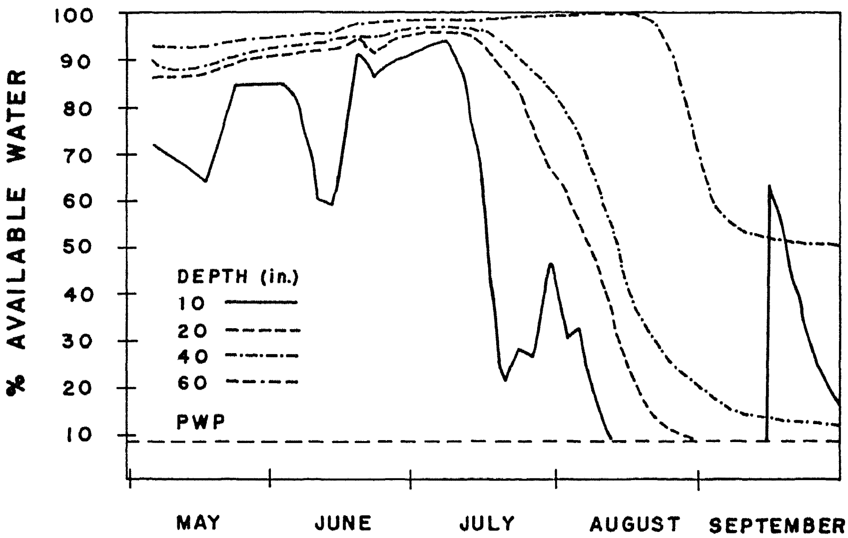

Fig. 6.—The percent available water (meter reading) in the soil at the 10-, 20-, 40-, and 60-inch depths of unirrigated birdsfoot trefoil-bluegrass plots from May through September in 1957.

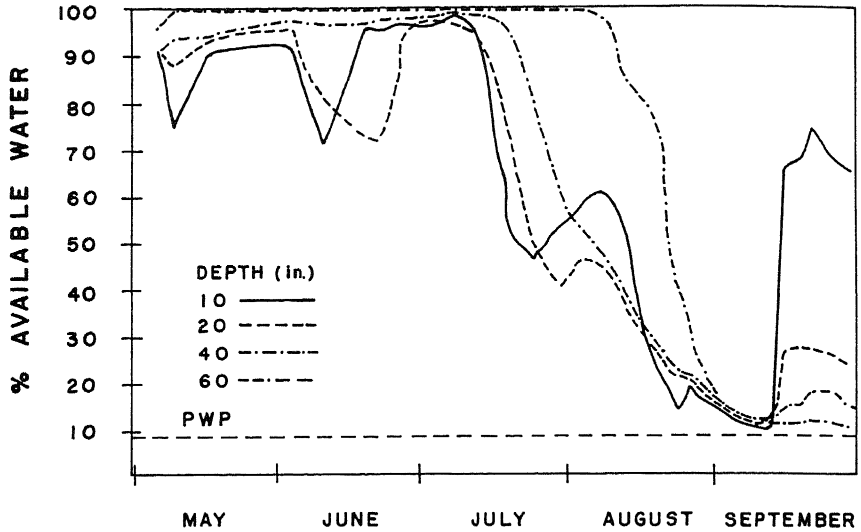

Fig. 7.—The percent available water (meter reading) in the soil at the 10-, 20-, 40-, and 60-inch depths of unirrigated alfalfa plots (cut as hay) from May through September in 1957.

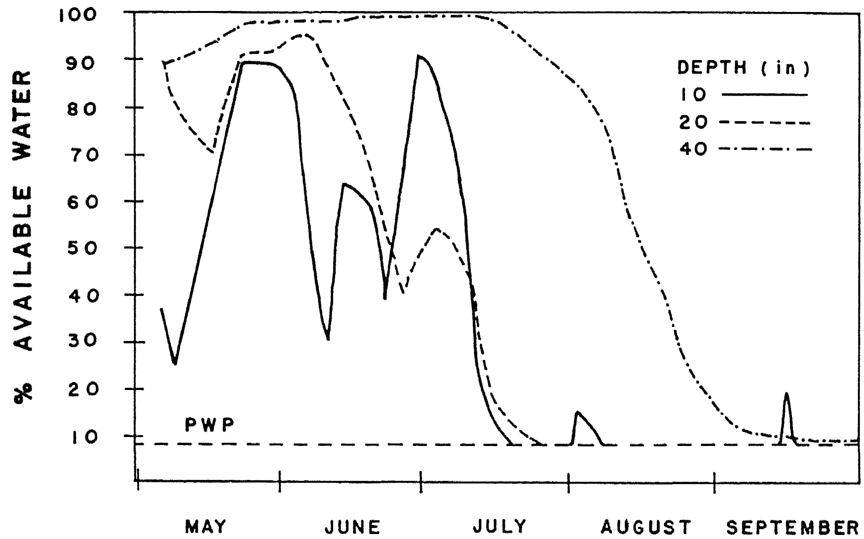

Fig. 8.—The percent available water (meter reading) in the soil at the 10-, 20-, and 40-inch depths of unirrigated Ladino clover-bromegrass plots from May through September in 1957.

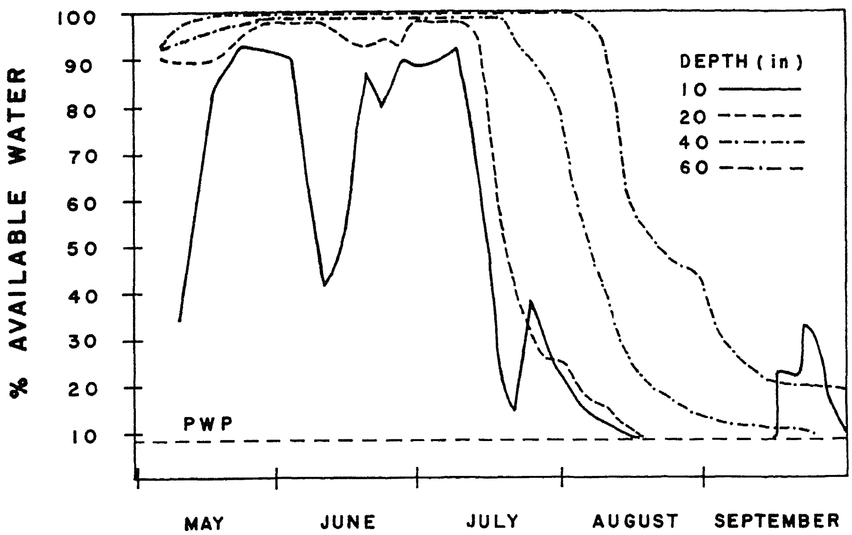

Fig. 9.—The percent available water (meter reading) in the soil at 10-, 20-, 40-, and 60-inch depths of unirrigated birdsfoot trefoil-bromegrass plots from May through September in 1957.

at the 40-inch depth. The evapotranspiration from vegetation tends to be the same regardless of the depth of root system under adequate soil moisture conditions (13). Therefore, the shallow rooted forage crop would tend to remove moisture more rapidly from the small volume of soil occupied by its roots. The same amount of water would be removed from soil by the roots of the deep-rooted forage crop or mixture but less from each depth because of the greater soil volume involved. The result would be that under continuing drought conditions, soil under the shallow-rooted crops would reach the permanent wilting point (PWP) faster than under the deep-rooted crops. Also rain penetrated to greater depths under the deep-rooted crops than under the shallow-rooted crops. The end result of these advantages is that deep-rooted forage crops tend to maintain a satisfactory level of soil moisture over a higher percentage of their root system for longer periods of time than shallow-rooted crops. The deep-rooted forage crops would need less frequent irrigation as compared to shallow-rooted crops but more water would need to be applied per irrigation.

During the dry years in 1956 and 1957 the soil moisture under nonirrigated alfalfa managed as hay did not approach the permanent wilting point at the 6, 10, 20, 40, or 60-inch depths until late in August or early in September. Then all depths reached the permanent wilting point within a few days of each other. Thus a long drought can be serious with deep-rooted forage crops. Also, light rains would give less relief to these crops if during a drought soil for a large portion of the root system is near the permanent wilting point. The rains would bring adequate moisture to a much smaller portion of the total root system of the deep-rooted crops than the shallow-rooted crops. The deep-rooted crops still removed moisture from the lower depths even through rains had brought shallow-depths of surface soil to field capacity.

GENERAL DISCUSSION

The problem of irrigating forage crops in humid areas is a complex one. Yields of forage crops can be increased during dry periods. Often quality of forage can be improved, as when white clover is better maintained in irrigated white clover-grass mixtures. The data from these experiments show that the magnitude of increase in quantity and quality from irrigation depends upon the forage species or mixtures used. These factors affect the response to irrigation: Previous and current management; fertility, available water storage, and physical characteristics of soil; length of drought periods; climatic factors affecting evapotranspiration; and management and utilization of the irrigated forage crop. Better methods of managing irrigated forage crops in humid regions are used to maximize the gain from irrigation.

The cost of applying irrigation water, value of increased quantity and quality of forage produced and such additional benefits as longer grazing season, more uniform carrying capacity, and dependable forage supply will determine whether irrigation can be used profitably. It appears that the good production of well-managed, drought-resistant forage crops, such as alfalfa, birdsfoot trefoil, and bromegrass, during periods of normal drought, makes the need for widespread irrigation of forage crops in Ohio questionable.

The advantages of applying nitrogen fertilization to grasses were demonstrated in this study. Increasing the rate of nitrogen fertilization increased the yield of dry matter and protein and often the protein percentage of grasses. Nitrogen fertilization was complementary to irrigation during the dry periods in summer so that the largest increases in dry matter production occurred at the highest nitrogen rates on grasses. Irrigation of grasses in pure stand without proper fertilization, especially nitrogen would certainly have little merit.

SUMMARY

Experiment I compared irrigation and nonirrigation on timothy, orchardgrass, bromegrass, and bluegrass, grown in pure stand with several rates of nitrogen fertilization and in mixtures with alfalfa, birdsfoot trefoil, and Ladino clover. Plots were cut monthly during the growing season to simulate rotational grazing. Experiment II studied irrigation of alfalfa alone and mixed with timothy and bromegrass both with and without red clover, cut three times yearly for hay.

The yield increases from irrigation varied widely with species and frequency of cutting. Nitrogen fertilized grasses and Ladino clover-grass mixtures gave the largest increases in yields from irrigation. Timothy and Ladino clover were the species most responsive to irrigation. Average annual dry matter gains for three years from irrigation of the thirty forage combinations of Experiment I varied from a loss to more than one ton per acre.

Irrigated forages were more productive than nonirrigated forages during the dry part of summer but under the conditions of the test were less productive in the early spring period following irrigation. The nonirrigated grasses yielded more than irrigated in the spring because of the carryover of unused nitrogen. Alfalfa especially, and probably the other crops, were weakened by irrigation reducing carbohydrate storage for the roots.

The yields of dry matter and protein and protein content of grasses were progressively increased as the level of nitrogenous fertilizer was raised. Nitrogen and irrigation were complementary during the drought period in 1956 and 1957 when bromegrass and orchardgrass receiving 240 pounds per acre of nitrogen gave the largest gains from irrigation in Experiment I. The average protein yield of the four grasses was doubled by 120 pounds nitrogen per acre.

Birdsfoot trefoil grew satisfactorily under both irrigated and nonirrigated conditions. Ladino clover was most favorably maintained under irrigation. Alfalfa decreased in vigor and stand with frequent cutting under irrigation especially in mixture with bluegrass and orchardgrass. The good production of nonirrigated alfalfa-grass mixtures during dry periods indicated the value of drought resistant forage crops to bridge most droughts.

The data suggest that irrigation would be of greatest value during abnormally long periods of low rainfall and high evapotranspiration on soils of low water-holding-capacity. To gain the maximum benefit

from irrigation of forages in humid regions, varieties adapted to irrigated conditions should be found and proper management of irrigated forage crops must be determined. It appears that the economic feasibility of irrigating forage crops in Ohio is questionable. Certainly all other methods of increasing yields, such as fertilization and management, must be taken care of first.

Five alfalfa mixtures in Experiment II were cut as hay under normal rainfall and normal rainfall plus supplementary irrigation. The 3-year average gain for irrigation was 1280 pounds per acre. Irrigated alfalfa managed as hay did not show a yield decrease in the following spring, as happened in Experiment I.

Gypsum moisture blocks were placed at 6, 10, 20, 40, and 60-inch soil depths in selected nonirrigated plots. More favorable soil moisture conditions were maintained over a longer period of time, when birdsfoot trefoil (deep-rooted) was grown in mixtures with bluegrass (shallow-rooted) than when bluegrass was grown with Ladino clover (shallow-rooted). The deep roots of the birdsfoot trefoil removed less moisture from the upper soil, as it obtained much of its water requirement from deeper in the soil profile.

Deep-rooted, drought resistant alfalfa and birdsfoot trefoil removed soil moisture slowly and rather uniformly from 6, 10, 20, 40, and 60-inch depths. The presence of some available soil water throughout the root zone of these crops for long dry periods seems to be a primary reason for their good growth during droughts. However, in unusually long droughts growth of these deep rooted crops was reduced. This uniform depletion of water from a large volume of soil suggests that infrequent heavy irrigations would suffice for alfalfa and birdsfoot trefoil.

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