EFFECT OF IRRIGATION AND NITROGEN ON THE YIELD AND OTHER AGRONOMIC CHARACTERISTICS OF FORAGE SORGHUM

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FORAGE SORGHUM PRODUCTION

QURESHI

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AN ABSTRACT OF THE THESIS OF

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Title: Effect of irrigation and nitrogen on the yield and other agronomic characteristics of forage sorghum.

A one year field experiment was conducted during the year 1965 at the Agricultural Research and Education Center, in the Beqa'a Plain, Lebanon, to determine the effect of four irrigation frequencies and three nitrogen levels on the yield, protein content, and other characteristics of a variety of forage sorghum named White Collier. Irrigation frequencies were floodings given at one week, two week, three week, and four week intervals; and the nitrogen levels were 12 kg, 24 kg, and 36 kg of nitrogen per dunum.

Irrigations applied after every week produced the greatest amount of forage and total protein per dunum. Significantly taller and thinner plants with lengthier internodes, more tillers and leaves per plant with lengthier leaf blades were the results of irrigations given after every week. Plants receiving 36 kg of nitrogen per dunum produced significantly more forage, more total protein, and were taller than were those receiving lesser amounts of nitrogen.

Weekly irrigations and 24 kg of nitrogen per dunum proved to be the best combination for the production of high yields of high quality forage. The greatest response in protein yield was observed from the first increment of 12 kg of nitrogen but the greatest total yield of protein was obtained from 36 kg of nitrogen per dunum, and weekly irrigations.

Plants receiving irrigations after every week were succulent and contained higher moisture, but lower protein and dry matter percentages than did those produced under any of the other irrigation frequencies.

Growth curves of plants getting water after every week were linear and these plants reached the greatest height. Those plants receiving irrigations after every

four weeks were severely affected by water shortage and were the shortest. The growth pattern of these plants showed an increasingly sharp reduction in growth rate one week after irrigation till growth had almost stopped after three weeks had elapsed. After these moisture stressed plants were irrigated, a nearly normal growth course was observed for one week. Then again the sharp reduction in growth rate was experienced.

Cost estimates suggested that irrigations applied every week and the application of 24 kg of nitrogen per dunum would be the most profitable production regime under the conditions of the experiment.

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I. INTRODUCTION

In Lebanon, as in other middle eastern countries, the scarcity of forages has kept animal production to a very low level. As a result, Lebanon is forced to use some of its foreign exchange in importing animal feeds and animal products.

The reasons for poor production of forages are mainly the shortage of irrigation water, the cost of chemical fertilizers, and the high returns possible from other crops. There is a feeling that forage production could be increased through the judicious use of fertilizers and irrigation management practices. Quality and yield are the two main criteria in the production of a forage crop. Both of these characteristics depend to a great extent upon the amounts of water and fertilizer applied to the crop.

Sorghum (Sorghum vulgare, Pers.) is one of the better yielding forage crops in areas of low rain fall because of its drought resistance. If more were known about the irrigation and fertilizer requirements of the crop both quality and yield could be much improved. Under the conditions prevailing in the Beqa'a Plain irrigation coupled with fertilizer should make sorghum a high potential forage crop for the farmers. The high summer temperatures, low daily humidities, and long growing seasons, typical of the Beqa'a Plain, are all favorable to this crop.

Many investigations have shown that the use of more fertilizer where soil fertility is low, and more frequent irrigations where water is a limiting factor, is generally accompanied with higher forage yield. Specific information is lacking as to how much fertilizer and irrigation water need to be applied under Beqa'a conditions in order to obtain higher yields of higher quality forage. To study this problem an experiment was laid out with four irrigation frequencies and three nitrogen rates at the Agricultural Research and Education Center of the American University of Beirut. In addition to forage yield and quality, other agronomic characteristics such as plant height, tillers per plant, length of the internodes, thickness of the stalks, and number of leaves per plant were studied.

II. REVIEW OF LITERATURE

A knowledge of soil moisture and fertilizer requirements is essential for maximum forage production through efficient use of water and plant nutrients. The frequency of irrigation applications, and rates and time of applications of fertilizer vary with soil type, soil fertility, availability of irrigation water, and the climate of the region.

Forage Yield

Irrigation influence: Karper and Quinby (38) observed that although sorghum is commonly grown under rainfed conditions, production was much increased by irrigation. Carrenker and Lillard (10) showed that sudangrass with and without irrigation, yielded 21.4 and 10.1 tons per acre of green matter, respectively. Fresh weights were higher and plants were more succulent with frequent irrigations. Choudhry (12) reported that weekly irrigations gave a yield of forage sorghum four times that of no irrigation, three times that from one irrigation and twice that from two irrigations. Sidhu (71) observed higher yields of grain as well as of stover from weekly irrigated sorghum plots than from plots that received biweekly irrigations. Choudhry (13) reported similar results with corn. Brown <u>et</u> <u>al</u>. (6) obtained significantly more pounds of dry matter of grain sorghum from irrigated plots than from nonirrigated plots. According to Carrenker and Lillard (10), Peterson and Hagan found that frequent irrigations of Ladino clover produced more fresh weight but only slightly more dry matter. Boehle <u>et</u> <u>al</u>. (3) reported that the increase in yield of several forage grasses tested with ~~1.96~~ 9.16 inches of supplementary water was as great as that obtained with 4.35 inches of water. Other investigations by several workers (2, 7, 11, 20, 29, 32, 48, and 49) reported increases in yield from the application of irrigation water.

<u>Nitrogen influence</u>: Burleson <u>et</u> <u>al</u>. (9), under Idaho conditions, were able to produce a significant increase in the yield of forage and grain of sorghum by the application of 60 to 100 pounds of nitrogen per acre. Nevans and Kendall (51) reported that under Illinois conditions frequent yearly heavy applications of barnyard manure resulted in higher forage yields of sorghum for a longer period of time; that is, the benefit was observed to be distributed over the several cuttings made each year. Nelson (50) reported that applications of 80 and 160 pounds of nitrogen increased the sorghum grain yield 31.4 and 40.7 bushels per acre, respectively.

Jung <u>et</u> <u>al</u>. (37) reported that higher rates of nitrogen fertilizer increased the dry matter production per acre of sudangrass. Broyles and Fribourg (8) reported significant increases in the yield of dry matter of sudangrass and millets with an application of 60 pounds of nitrogen per acre. Ram (62) concluded from a greenhouse study that the highest yield of dry matter from two forage sorghum varieties was obtained with the highest rate of nitrogen applied whether at planting or in split applications. Jordon _et al_. (36) reported that the production of dry matter in corn increased with increased nitrogen applications and with heavier plant stands. Several other workers (3, 21, 41, 52, and 66) demonstrated similar increases in yield by the application of nitrogen fertilizers.

Reith and Inkson (67) reported that heavy dressings of nitrogen reduced the percentage of dry matter in the fresh herbage but produced a very large overall increase in the yield of dry matter. Hanway (30) observed that differences in soil fertility resulted in very different rates of dry matter accumulation in the corn plant. The rate of dry matter accumulation was found to be linear over a major part of the growing season on all fertility levels but the rate was different for different fertility levels. Jung _et al_. (37) reported an increased rate of growth of sudangrass from larger applications of nitrogen.

Irrigation and nitrogen influence: Taylor and Slatter (73) stated that the most desirable frequency of irrigation could have maximum benefit to the crop only if a supply of readily available nitrogen were present in the soil. It was also stated that unless enough nutrients were available to the plant, little would be gained by keeping moisture at high levels. Painter *et al.* (55) reported that major benefits from more frequent irrigations and closer spacing resulted only where nitrogen was applied. Quinby and Marion (61) observed that to obtain high yields of forage sorghum under irrigation larger amounts of nutrients would be required.

Porter *et al.* (58) recorded the highest yields of forage sorghum with higher nitrogen levels, higher moisture, and higher planting rates. Doss *et al.* (17) reported that the yield of sart sorghum was increased with increased soil moisture and nitrogen applications. Prato *et al.* (59) showed that forage sorghums gave higher yields where grown under irrigation with high rates of nitrogen fertilizers. Mathers *et al.* (45) obtained greater sorghum grain yields at high moisture levels with 120 pounds of nitrogen than with 60 pounds of nitrogen per acre. Musick *et al.* (49) reported that maximum sorghum grain yield was obtained with adapted hybrids under high levels of irrigation and nitrogen. It was also reported that increasing the number of irrigations from one to four per growing season, increased the average grain yield from 1200 to 1500 pounds per acre. Yields increased steadily at the high moisture levels with increased nitrogen to the maximum application rate (120 pounds per acre) tested. Painter et al. (55) got the highest yield of grain sorghum only when more frequent irrigations and higher rates of nitrogen (240 pounds per acre) were applied. Grimes and Musick (25) reported that grain sorghum yields increased greatly with one additional irrigation and 100 pounds of nitrogen per acre. Paschal and Evans (56) obtained a higher grain yield with thick planting and 240 pounds of nitrogen per acre at high soil moisture levels. The lowest yield was recorded with thin planting and 240 pounds of nitrogen at the lowest moisture level. Gonzales et al. (24) claimed that weekly irrigations of 4.23 centimeters of water resulted in higher grain yields than those obtained from weekly irrigations of 0.72, 1.44, and 2.88 centimeters of water. All treatments received 80 pounds of nitrogen per acre. Rao (65) found that grain sorghum with irrigations at both three-week intervals and weekly intervals gave higher yields from 90 pounds of nitrogen per acre than from 30 or 60 pounds of nitrogen per acre. The response to nitrogen was found independent of that to irrigations. Raney and Manges (64) reported that 125 pounds of nitrogen per acre and a total of

28.8 inches of water applied in five increments, produced a greater yield of corn grain and silage than did the other treatment combinations tested. Higgins and Owens (33) observed that a good yield of corn silage under Idaho conditions could be realized with 100 to 160 pounds of nitrogen per acre and adequate available moisture during the growing period. McMaster et al. (46) reported that 120 pounds of nitrogen per acre resulted in more corn silage than did 60 pounds of nitrogen per acre at medium and high but not at low moisture levels. Schwale (69) found that soil with high water holding capacity and with nitrogen applications produced more bushels of corn per acre than did soil of low water holding capacity with the same amount of nitrogen. Verma and Sherma (75) concluded that applications of 40 and 60 pounds of nitrogen per acre gave significantly increased yields of corn as compared to 20 pounds of nitrogen per acre, but only when large amounts of rainfall were received.

Dotzenko (18) reported that higher rates of nitrogen applications increased the yield of all the six grasses grown in an irrigated trial. Lorenz et al. (42) reported that the yields of bromegrass and bromegrass-alfalfa were doubled by the application of 40 pounds of nitrogen per acre, tripled by 80 pounds of nitrogen, and quadrupled by 200 pounds of nitrogen, provided high levels of irrigation were applied. Yields at medium and high moisture levels were similar and were significantly higher than at low moisture levels. Cooper *et al.* (14) in Montana, reported that all the six forage grasses under study showed much greater response to high levels of nitrogen when irrigated than when not irrigated. Doss *et al.* (17) stated that in the case of sart sorghum, response to irrigation increased as the rate of nitrogen application increased.

Protein Yield

The term "nitrogen content" is used to mean the nitrogen present in protein form as well as that in other simpler nonprotein substances such as amino acids and amides. The term "crude protein" is used for proteins as well as for other nonprotein nitrogenous substances. The term protein is generally used for crude protein for the sake of simplification (47, pp. 10-12).

Doss *et al.* (17) reported that the nitrogen content of sart sorghum varied inversely with the moisture regimes and directly with the rates of nitrogen applied. When no nitrogen was applied, the nitrogen content in sart sorghum varied from 0.79 per cent at low moisture levels to 0.57 per cent at high moisture levels. With the addition of 240 pounds of nitrogen per acre, the nitrogen content of sart sorghum varied from 1.47 per cent at low moisture levels to 1.23 per cent at high soil moisture levels. Broyles and Fribourg (8) found that the percentage of nitrogen in the harvested forage of sudangrass and millet increased as the nitrogen application was increased from 0 to 60, and to 120 pounds of nitrogen per acre. Cooper et al. (14) and Dotzenko (18) reported that under irrigated conditions, increasing the increment of nitrogen increased the nitrogen content of the forage grasses tested. Jung et al. (37) reported that the crude protein content of sudangrass was increased markedly by nitrogen fertilization.

Burleson et al. (9) concluded that for sorghum applications of 60 or 120 pounds of nitrogen per acre increased the protein content of both grain and forage. According to Boyd et al. (5), Stephens et al. found that the protein content of sorghum grown with the water table at a depth of 36 inches was approximately eight per cent. With the water table at 24 inches, the protein content was six per cent and when the water table was maintained at 12 inches, the protein content was only three per cent. Choudhry (12) reported that the weekly irrigated plants of forage sorghum contained a smaller percentage of protein, while sorghum less frequently irrigated had a greater percentage of protein. In contrast, the total protein content increased according to the increase in the number of irrigations. Nelson (50) reported that the protein content of grain sorghum grown under irrigation increased with the increase in the increment of nitrogen fertilizer applied. Ramage et al. (63) reported that the protein content of grasses ranged from 12 to 20 per cent as the nitrogen application was increased from 50 to 400 pounds per acre. Davis et al. (15) found that the protein content of alfalfa forage tended to be less as the amount of water applied was increased. Similar results were reported by several other workers (19, 58, 60, and 66).

Genter et al. (22) reported that the protein content of corn grain was significantly greater under conditions of drouth than under good growing conditions. Under drouth conditions applications of nitrogen were found to have no effect on protein content. In contrast, Zuber et al. (79) found that with irrigated corn, the protein content of both grain and stover was increased with increased amounts of nitrogen applied. Kessler et al. (40) reviewed Stocker who reported that plants may continue to absorb nitrogen from the soil even under water stress conditions, resulting in an increased total nitrogen in the aerial parts of these plants.

Plant Height

Brown et al. (6) reported that sorghum plants grown on nonirrigated plots were approximately seven inches shorter than those grown at medium moisture levels and fourteen inches shorter than those grown at high moisture levels. Choudhry (12) found that the tallest plants were produced by weekly irrigations and the shortest plants resulted from no irrigation. Porter et al. (58) found no significant effect of nitrogen levels and planting rates on the height of grain sorghum plants grown under irrigation. Ram (62) reported that in a glass house experiment, the tallest forage sorghum plants were produced where the highest rate of nitrogen was applied.

MacGillivray (43) reported that high moisture levels produced taller corn plants than did the medium levels, and that the shortest plants were obtained where no irrigation was applied. Similar results were reported by other workers (15, 32, and 44).

Tillers per Plant

Choudhry (12) found a small but significant increase in the number of tillers per plant produced in weekly irrigated as compared to nonirrigated plots. Similar results were also reported by Sidhu (71) for grain sorghum and by Choudhry (13) for hybrid corn. Jung et al. (37) reported that tillering in sudangrass, sorghum, and millet was greatly increased by nitrogen fertilization. Two tillers per plant were obtained with zero nitrogen, but this number of tillers increased to 20 per plant when the nitrogen was applied at the rate of 300 pounds per acre.

Length of the Internodes

Howe and Rhoades (35) stated that low soil moisture levels produced shorter corn plants because of the shorter internodes. Denmead and Shaw (16) observed that shorter internodes were among the most apparent effects of low moisture supply during the growing period of corn. The same effect was also reported by Choudhry (12) in the case of forage sorghum.

Thickness of the Stem

Choudhry (12) reported that the thickness of the forage sorghum stalk varied directly with frequency of irrigation. The thickest plants were obtained from non-irrigated, and the thinnest from weekly irrigated plots. The same observation was reported by Sidhu (71) in the case of grain sorghum. It was reported by Zeevart (78) that the action of growth retardants on the plant resulted in thicker stems. It was stated that in the treated plants, the cortex and pith constituted a larger portion of the stem cross section.

Number of Leaves per Plant

Choudhry (12) found that the greatest number of leaves per plant of forage sorghum was produced in weekly irrigated plots. Hagan et al. (28) reported that the most frequently irrigated plots of Ladino clover produced more and larger leaves per plant.

Length and Width of the Leaves

Denmead and Shaw (16) reported that the leaf area of corn plants was decreased when moisture stress was applied during the vegetative stage of growth.

Growth Rate

Denmead and Shaw (16) observed that the rate of stem elongation of corn declined when available soil moisture was depleted by 75 per cent and continued to decline as the wilting point was approached. After watering, these moisture-stressed plants maintained a slow growth rate for one to three days and then elongation continued at the same rate as that of the non-stressed plants. Kemper et al. (39) observed that the growth rate of corn decreased with decreased moisture level. Jung et al. (37) reported that a higher level of nitrogen fertilization resulted in an increased rate of growth. Jordon et al. (36) reported that the growth curve of corn plants fertilized with nitrogen was nearly linear until the plants attained their full height. The growth curves for 60 and 120 pounds of nitrogen per acre were almost alike but differed from that of the untreated plots in being curvilinear.

From the review of literature presented in this section, it can be concluded that amounts of both water and nitrogen affect the forage yields of sorghum. Water was found to be more important than nitrogen. Water deficiency causes slow growth, poor plant structure, and poor yields, even though significant amounts of nutrients are available to the plants. More frequent irrigations result in increased yields provided sufficient nutrients are available in the soil. Proper combinations of irrigation frequency and amounts of nitrogen in most cases result in increased forage yields.

III. MATERIALS AND METHODS

An irrigation and fertilizer experiment on forage sorghum was conducted during the year 1965 at the Agricultural Research and Education Center of the American University of Beirut situated in the Beqa'a Plain, Lebanon. The trial was located on a clay type soil calcarious in nature with pH 8.0. The soil was analysed after the crop was harvested. The total nitrogen was determined by modified Kjeldahl method (34) and the available phosphorous was determined by a method described by Olsen et al. (53). The total nitrogen ranged from 0.12 to 0.15 per cent, and the available phosphorous from 10.4 to 15.6 parts per million. The detailed analysis is presented in Table 11 of the appendix. The history sheet of the experimental plot showed that alfalfa for hay was grown for three years prior to being plowed in 1963. This was followed by a crop of wheat in 1963-64.

For the present experiment a good seed bed was prepared and the land was levelled to facilitate more uniform distribution of irrigation water to the plots. A variety of forage sorghum named White Collier, which gave high yields of forage during four years of testing (77), was used for this experiment.

Twelve kilograms of nitrogen per dunum[1] in the form of ammonium sulphonitrate and 20 kilograms of P_2O_5 per dunum in the form of super phosphate were broadcast and disked into the soil prior to seeding. The experiment was laid out in a split plot design with four replications. The main plots consisted of the irrigation frequencies and the subplots of nitrogen levels. Each subplot consisted of six rows, each spaced 50 centimeters apart and five meters long. The details of the experiment are as follows:

<u>Irrigation frequencies</u> (main plots):

All plots were sprinkler irrigated for five weeks. Thereafter the furrow flood method was used, where water was applied through gated pipes. The four irrigation frequencies studied and their symbols are listed as follows:

Symbol	Frequency
1. I_1[2]	Irrigation after every week
2. I_2	Irrigation after every two weeks
3. I_3	Irrigation after every three weeks
4. I_4	Irrigation after every four weeks

At each irrigation, sufficient water was applied

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1. Dunum = 1000 square meters.

2. I_1 is used as check for irrigation comparisons.

to return the moisture content of the soil to field capacity. The field capacity was determined by taking soil samples 24 hours after irrigation. It was found that the soil had a field capacity of about 31 per cent moisture.

Nitrogen rates (subplots):

A uniform application of 12 kg of nitrogen was made at planting time. Two subsequent side dressings were made according to nitrogen levels. These nitrogen levels and their symbols are listed as follows:

	Symbol	Rate
1.	F_1[1]	12 kg of nitrogen per dunum applied at planting time
2.	F_2	24 kg of nitrogen per dunum applied in two equal portions
3.	F_3	36 kg of nitrogen per dunum applied in three equal portions

The first portion of 12 kg of nitrogen was applied to all the plots at the time of seed bed preparation in April. The second portion of 12 kg per dunum was applied as a side dressing to the F_2 and F_3 plots on the 28th of June. The third portion of 12 kg per dunum was applied as a second side dressing to the F_3 plots. In the case of the I_1 plots this second side dressing was made on July 23. For the I_2 and I_3 plots the date was July 31, and for the I_4 plots, August 13.

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1. F_1 is used as check for fertilizer comparisons.

This difference in application dates occurred because of the irrigation frequencies. In each case, the fertilizer was applied to a plot just before irrigation was given.

The planting was done with a Planet Jr. planter on April 26. On this date the air temperature was 26° C. All plots were seeded thickly and later, when the plants were 6-8 centimeters in height, were thinned by hand to a uniform population of approximately 80 plants per 5-meter row. Weeding was done by hand with nursery equipment during the early stages of growth. As the sorghum plants grew larger, they were able to compete successfully against the weeds.

The furrows for the flood irrigation were opened on June 15 and the irrigation treatments commenced on June 18 and continued thereafter, according to each appropriate schedule, until harvest time. The total number of irrigations given to each irrigation treatment was 16 for I_1, 11 for I_2, 10 for I_3, and 8 for I_4. Since there were 5 sprinkler irrigations given uniformly to all treatments during the seedling establishment stage, that is, prior to beginning the various irrigation frequencies, there were only 11, 6, 5, and 3 flood irrigations given during the main growth stage of the plants. The amount of water applied by the sprinkler was the same in all the treatments and was measured to be 1.5 acre inches of water per irrigation. The amount of irrigation water applied per irrigation by the furrow method was measured by collecting the water in buckets as it was let into the plot from the gated pipe. The total quantity of water thus applied both by sprinkler and furrow method in each case was as follows:

Treatment	Sprinkler	Furrow	Total (acre inches)
I_1	(5 x 1.5)	(11 x 2.20)	31.70
I_2	(5 x 1.5)	(6 x 2.68)	23.58
I_3	(5 x 1.5)	(5 x 2.87)	21.85
I_4	(5 x 1.5)	(3 x 3.03)	16,59

Seed germination and early crop growth was very slow which delayed the opening of furrows for the commencement of irrigation frequencies. The slow growth occurred possibly as a result of low temperatures following planting. Low temperatures continued after planting time up to May 12. During the growing period of the crop the maximum temperature ranged from 32° C in the last days of May to 34° C in August, while the minimum temperatures varied from -1° C in the second week of May to 10.9° C in August. Rainfall during the growing period was distributed as follows: 11.1 mm was recorded just one day after planting in April, 3 mm in May, 3 mm in June, no rainfall in July or August and 23.2 mm in September when the crop was still in the field. On June 28, Dipterex 0.15 per cent was sprayed to control leaf hoppers (Cicedellidae). This spray damaged the plants, having a burning effect on the tips of the leaves. Damage was more pronounced in the I_3 and I_4 treatments. On July 19, to control aphids (Aphididae), the crop was again sprayed with Metasytox at the rate of one ml per liter of water.

Data were recorded on growth rate, plant height, number of tillers and leaves per plant, length of the internodes, length and width of the leaves, thickness of the stem, and forage yield.

Weekly growth observations were recorded by taking the height of four randomly selected plants in each treatment. Small stakes were driven into the ground beside these plants to form a constant platform for taking height measurements. The height of the individual plant was recorded by measuring from the platform to the tip of the last leaf fully extended. Leaves per plant were counted at the time of harvest from five randomly chosen plants in each treatment. The thickness of the stem was measured from the central portion of the stalk. The length of the leaf was measured from the collar of the leaf to the tip of the leaf.

To obtain plot yields the outer two rows on each side of the plot and one-half meter at each end was left as border. Therefore the area harvested per plot was two four-meter long rows spaced fifty cm apart. The I_1

treatments were harvested on September 3, when heading was almost complete in all the treatments. The I_2 treatments were harvested on September 10 although it was observed that heading was not complete in all the treatments. The I_3 and I_4 treatments were harvested on September 17, when it was noted that the plants had made no further growth for several weeks. After harvesting of each treatment, irrigation was applied immediately in an attempt to stimulate new growth. It was observed after one month that there was not sufficient regrowth to cut for forage and, therefore, a second cut was not taken. This poor regrowth was a result of the low temperatures experienced in September.

After harvest, the green weight was recorded and a representative sample of one kilogram from each treatment was cut by a cutting machine. The chopped samples were placed in cloth bags and stored for approximately 40 days for air drying. The air dry weight of each sample was recorded and a representative sample from this material was taken to determine the dry matter content and for chemical analysis. The samples were placed in an oven at 75° C for 48 hours (68). A representative subsample of about 15 grams from each treatment was ground in a Willey Mill using a 40 mesh sieve. Duplicate chemical determinations for nitrogen content were made on each sample by the modified Kjeldahl method (34). The amount of nitrogen was multiplied by the factor 6.25 and the results were expressed as percentage of crude protein (47). Total yield of protein per dunum was also calculated.

Statistical methods appropriate to the split plot design were used to analyse the data (72). However, in the analysis of variance the error term for irrigation was reduced by one because of the difficulty experienced with randomization of the irrigation treatments. In the flood system of irrigation used, it is not possible to use a different randomization in all the replicates. This is so because the water must run across all the plot area at each irrigation. Therefore all replicates must have the same order of irrigation treatments as that of replicate one.

In order to find out the most economical rate of nitrogen fertilization, the value of green forage was estimated. The prices used were 3.6 L. piasters per kg of green forage and 115 L. piasters per kg of nitrogen[1].

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1. Information obtained through personal communication with Dr. Knud V. Rottensten, Professor and Head of the Division of Animal Production and Protection, Faculty of Agricultural Sciences, American University of Beirut, Beirut, Lebanon.

IV. RESULTS AND DISCUSSIONS

This study was conducted during the year 1965 at the Agricultural Research and Education Center, in the Beqa'a Plain, Lebanon, to study and evaluate the effects of four irrigation frequencies and three nitrogen rates on the yield and other characteristics of forage sorghum. The data concerning the various characters studied are summarized and reported in Tables 1-10.

Forage Yield

The data for forage yield in terms of dry matter are summarized in Table 1. It can be seen from the data that the yield of dry matter decreased as the interval between irrigations was increased from one to four weeks. The greatest dry matter yield (1637 kg per dunum) was obtained from the plots irrigated after every week, and the lowest (1307 kg per dunum) from the plots irrigated after every four weeks. Irrigations given after every two weeks resulted in yields 240 kg per dunum less than the check (I_1) plots and this difference was highly significant. It was observed that irrigations given after every three weeks resulted in almost the same dry matter yield as irrigations after every two weeks.

Table 1. Effect of irrigation frequencies and nitrogen applications on the yield of forage sorghum (expressed in kg of dry matter per dunum).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	1455.0	1310.0	1282.5	1272.5	1330.0
F_2	1685.0	1432.5	1427.5	1335.0	1470.0
F_3	1777.5	1455.0	1495.5	1320.0	1512.5
Irrigation means	1637.5	1397.5	1402.0	1307.5	

LSD	5%	1%
Irrigation	88.2 kg/dunum	128.3 kg/dunum
Nitrogen	52.1 " "	70.6 " "
Irrigation x nitrogen	149.1 " "	200.0 " "

Analysis of Variance

Source	D.F.	M.S.
Replication	3	0.5945*
Irrigation	3	3.8321**
Error (a)	8[1]	0.1417
Nitrogen	2	2.3327**
Irrigation x nitrogen	6	0.2170*
Error (b)	24	0.0820

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

* Significant at 5% level.

** Significant at 1% level.

Yields from plots irrigated after every four weeks were very low, and the difference between this treatment and the check treatment was highly significant. This yield from the I_4 plots was also significantly different from the I_2 and I_3 treatments.

The maximum dry matter yield achieved under a weekly irrigation regime could be attributed to the fact that maximum plant growth and development took place as a result of readily available moisture in the vicinity of the plant roots. The plants also did not suffer from serious water stress at any stage of the growth period. These results are in agreement with the findings of many workers (6, 10, 12, 38, 48, and 71), where it was shown that more irrigations resulted in greatly increased yields of forage sorghum.

The dry matter yields were also greatly influenced by nitrogen applications. The greatest dry matter yield (1512 kg per dunum) was obtained by the application of 36 kg of nitrogen per dunum. The first increment of 12 kg of nitrogen resulted in an increased yield (182 kg per dunum) of dry matter over the check (F_1), but this rate of increase was not maintained through the addition of another increment of 12 kg of nitrogen. This second increment resulted in an increase of only 42 kg of dry matter as compared to the yields from the first increment. Statistically, the differences between the effects of F_2 and F_3 and those of the check (F_1) were highly significant, and the difference between the F_2 and F_3 was significant. These results are confirmed by the findings of other workers (8, 9, 37, 50, and 62).

The interaction between irrigation and nitrogen was significant at the 5% level. That is, the influence of irrigation frequencies was not maintained at the same rate when the second variable, nitrogen levels, was introduced. The highest dry matter yield was achieved where 36 kg of nitrogen was applied and plants were irrigated after every week. The lowest yield was obtained from the plots that received 12 kg of nitrogen and irrigations after every four weeks.

Dressings of plants with further nitrogen increments under water stress conditions did not prove as useful as in the case where plants were irrigated after every week. The dry matter yield increased from 1455 kg from the I_1xF_1 combination to 1777 kg per dunum from the I_1xF_3 combination. In contrast, where irrigations were applied at either three- or four-week intervals, an equal amount of nitrogen did not result in a significant increase in the dry matter yield. This could be explained in the light that the nutrients were utilized efficiently where the water was available throughout the growing season and the plants did not suffer from any water stress.

In the case where irrigations were applied after every week, the addition of the first increment of nitrogen resulted in an increase of 230 kg of dry matter; but the same increment, when applied where irrigations were given after every four weeks, resulted in an increase of only 63 kg of dry matter per dunum. Therefore, it may be concluded that water stress and not nitrogen was limiting the yield increases.

The greatest response occurred from the first increment of 12 kg of nitrogen under weekly irrigations. The second increment of 12 kg of nitrogen did not result in any significant increase in the dry matter yield under any of the irrigation treatments. These results are in line with those obtained by other workers (17, 25, 59, 61 and 64). It may, therefore, be suggested from these results that irrigations after every week and 24 kg of nitrogen per dunum are optimum, under the conditions of this experiment, for optimum forage yield.

Protein Percentage

Quality of forages and feeds is determined by the nutrients they supply. Among these nutrients protein content is of great importance and it is commonly stated that fodders with a high protein content have superior feeding value.

An examination of the data presented in Table 2 indicates that the protein percentage in the sorghum plants was markedly affected both by irrigation frequencies and by nitrogen rates. The protein percentage varied inversely with the irrigation frequencies and directly with the nitrogen rates. The protein content ranged from 5.40 per cent (I_1 plots) to 6.30 per cent (I_4 plots). All the irrigation treatments I_2, I_3, and I_4 differed highly significantly from the check (I_1) treatment. As for the effect of nitrogen rates, the protein content varied from 5.95 per cent (F_1 plots) to 6.41 per cent (F_3 plots).

The interaction between irrigation and nitrogen was found highly significant. The plants with the greatest protein content were grown under monthly irrigations and 24 kg of nitrogen per dunum, and the plants with lowest protein content were produced under weekly irrigations and 12 kg of nitrogen per dunum.

Plants irrigated at either one- or two-week intervals showed a significant increase in the protein percentage when the second increment of 12 kg of nitrogen was added. However, little response to this increment was observed at I_3 and I_4 irrigation frequencies. As the time between irrigations was increased beyond two weeks, further applications of nitrogen did not result in any significant increase in the protein content of the forage.

Table 2. Effect of irrigation frequencies and nitrogen applications on protein percentage of forage sorghum.

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	5.40	5.72	6.04	6.62	5.95
F_2	5.74	5.96	6.28	6.69	6.17
F_3	6.30	6.52	6.27	6.53	6.14
Irrigation means	5.81	6.07	6.20	6.61	

LSD	5%	1%
Irrigation	0.22 per cent	0.32 per cent
Nitrogen	0.15 " "	0.20 " "
Irrigation x nitrogen	0.42 " "	0.57 " "

Analysis of Variance

Source	D.F.	M.S.
Replication	3	0.0164
Irrigation	3	1.3340**
Error (a)	8[1]	0.0539
Nitrogen	2	0.8289**
Irrigation x nitrogen	6	0.2490**
Error (b)	24	0.0419

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

** Significant at 1% level.

The high protein percentage in the plants irrigated after every 3 or 4 weeks is probably due to the fact that dry matter production was restricted by the water stress applied resulting in a high concentration of nitrogenous compounds in the plant per unit of dry matter. Another possible explanation of high nitrogen content in the plants can be given from the results of Kessler et al. (40) where it was shown that nitrogen uptake may continue even under water stress conditions. The low protein percentage of weekly irrigated plants was probably due to the fact that plants did not suffer from any prolonged water shortage during the growing period. Thus, these plants grew vigorously utilizing the nitrogen available in the soil and producing a greater amount of herbage.

Protein Yield

The effect of irrigation frequencies and nitrogen rates on the total protein yield can be seen from the data recorded in Table 3. It is revealed that as the irrigation frequencies were decreased from I_1 to I_2, I_3, and I_4, the protein yield was also decreased significantly. There were no significant differences between the I_2, I_3, and I_4 treatments, but all differed highly significantly from the check (I_1) treatment. Plants irrigated after every week contained a lower percentage

Table 3. Effect of irrigation frequencies and nitrogen applications on the protein content of forage sorghum (expressed as total yield of protein in kg per dunum).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	78.57	76.44	76.15	77.43	77.19
F_2	96.65	86.13	89.51	83.47	88.94
F_3	111.36	91.72	90.11	82.36	93.89
Irrigation means	95.53	84.76	85.26	81.09	

LSD	5%	1%
Irrigation	5.33 kg/dunum	7.75 kg/dunum
Nitrogen	3.02 " "	4.09 " "
Irrigation x nitrogen	8.53 " "	11.56 " "

Analysis of Variance

Source	D.F.	M.S.
Replication	3	137.5661*
Irrigation	3	461.2193**
Error (a)	8[1]	32.0249
Nitrogen	2	1183.1200**
Irrigation x nitrogen	6	141.8150**
Error (b)	24	17.0758

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

* Significant at 5% level.

** Significant at 1% level.

of protein than did those irrigated after every two, three, or four weeks. However, as the total dry matter produced from I_1, that is from weekly irrigations, was higher, the total yield of protein per dunum was higher.

Nitrogen increments also resulted in higher protein yields. The first increment of 12 kg of nitrogen increased the protein yield by 11 kg per dunum and the second increment resulted in an increase of only five kg of protein per dunum. Both increases differed highly significantly from the check (F_1).

The highly significant interaction between irrigation and nitrogen confirms the present findings concerning dry matter yields and protein percentage in the plants, where the increases observed were the results of proper combinations of the two treatments. The greatest protein yield was recorded from the I_1xF_3 plots and the lowest yield of protein was from the I_3xF_1 and I_4xF_1 plots. Except for the I_1 plots, the second increment of nitrogen did not result in any significant increases in protein yield at the other irrigation intervals tested. These results closely resemble the work of many other authors (14, 17, 18, 22, and 50).

Tillers per Plant

The data in Table 4 show the effect of irrigation and nitrogen on the tillers per plant. It may be seen

Table 4. Effect of irrigation frequencies and nitrogen applications on the number of tillers per plant of forage sorghum.

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	1.48	1.50	1.35	1.31	1.41
F_2	1.49	1.48	1.40	1.29	1.41
F_3	1.54	1.51	1.38	1.31	1.43
Irrigation means	1.50	1.50	1.38	1.30	

LSD	5%	1%
Irrigation	0.14	N.S.
Nitrogen	N.S.	N.S.
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	0.0084
Irrigation	3	0.0859*
Error (a)	5[1]	0.0125
Nitrogen	2	0.0023
Irrigation x nitrogen	6	0.0015
Error (b)	16	0.0010

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

* Significant at 5% level.

that tillering under the conditions of this experiment was not much affected by any of the above two treatments. Although plants irrigated weekly produced significantly more tillers per plant than did those irrigated after every three or four weeks, the practical significance is so low that it is of little importance agronomically. More nitrogen applications also had little influence on the number of tillers per plant.

This lack of influence of the irrigation and fertilizer treatments on tiller numbers is in disagreement with the findings of many authors (12, 13, 37, and 71). This difference is perhaps a result of the early irrigation and fertilizer treatments applied uniformly to the plots. All the plots had received a preplanting application of 12 kg of nitrogen and for the first five weeks after planting all the plots received weekly sprinkler irrigations. This period probably was sufficient for the formation of tiller initials to be completed. Subsequent treatment variables, therefore, did not affect the tillering capacity to any significant extent. Another reason possibly was that the plants were spaced very closely and did not have sufficient space for the tillers to develop. Finally, low tillering might be a characteristic of variety.

Plant Height

Plant height is one of the important characteristics that have a close relation with forage yield. Five plants from each treatment were selected randomly at harvest time and were measured from the base to the tip of the top leaf. The same five plants were used for subsequent observations on stalk diameter, internode length, and length and width of the leaves. It can be seen from the data in Table 5 that plots irrigated after every week produced significantly taller plants than those irrigated after every two weeks. These plants were taller than those irrigated after every three weeks and in turn, these were taller than those irrigated after every four weeks. Therefore, the shortest plants resulted from plots irrigated after every four weeks. Similarly, more nitrogen applications resulted in increased plant height. The addition of 12 kg of nitrogen over the check (F_1) resulted in taller plants and the height was further increased by the addition of the second increment of 12 kg of nitrogen. Both increases significantly differed from the check (F_1). In the absence of any significant interaction, it may be said that irrigation frequency and nitrogen applications affected plant height independently. These results are in agreement with those reported by many workers (6, 12, 43, 58, and 62).

Table 5. Effect of irrigation frequencies and nitrogen applications on the height of forage sorghum plants (in cm).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	244.1	225.9	203.5	186.9	215.3
F_2	252.4	232.3	210.8	192.7	222.1
F_3	257.0	237.0	211.2	194.6	224.9
Irrigation means	251.5	231.7	208.5	191.4	

LSD	5%	1%
Irrigation	14.5 cm	22.8 cm
Nitrogen	2.3 cm	4.2 cm
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	215.5741
Irrigation	3	6223.0042**
Error (a)	5[1]	143.6467
Nitrogen	2	292.3781**
Irrigation x nitrogen	6	3.2973
Error (b)	16	6.4455

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

** Significant at 1% level.

Length of the Internodes

Internodes from the middle part of the five selected plants from each treatment were measured and the data are summarized in Table 6. Significant differences were observed in the length of the internodes as a result of irrigation frequencies. The plants getting water after every week produced the internodes of greatest length and the plants receiving water after every four weeks produced the shortest internodes. All irrigation treatments I_2, I_3, and I_4 differed highly significantly from the check (I_1). Irrigation treatments I_3 and I_4 produced internodes of approximately the same length and these were significantly shorter than those of the plants irrigated more frequently. These effects of irrigation on the internode length are in agreement with the results obtained by (12, 16, and 35).

Nitrogen applications did not result in any significant increase in the length of the internodes. There was no significant interaction between irrigations and nitrogen applications. The greater internode length of the plants irrigated after every week was obtained as a result of continuous cell elongation.

Table 6. Effect of irrigation frequencies and nitrogen applications on the length of the internode of forage sorghum plants (in cm).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	20.7	17.6	14.5	13.2	16.5
F_2	21.6	17.2	14.7	13.1	16.6
F_3	21.3	18.7	14.8	12.8	16.9
Irrigation means	21.2	17.8	14.7	13.0	

LSD	5%	1%
Irrigation	2.4 cm	3.8 cm
Nitrogen	N.S.	N.S.
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	0.0453
Irrigation	3	117.7965**
Error (a)	5[1]	0.3971
Nitrogen	2	0.5303
Irrigation x nitrogen	6	0.6578
Error (b)	16	0.3043

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

** Significant at 1% level.

Thickness of the Stalk

Cattle relish thin and succulent plants of forage sorghum as against thick and stiff plants. The thickness of the stalk from the central part of the same five selected plants from each treatment was measured at harvest time and the data are presented in Table 7. A study of the data reveals that thinner stalks were produced from the plots irrigated after every week as compared with those irrigated less frequently. There were no significant differences in the thickness of the stalks grown under the I_1 or I_2 levels, but both were significantly different from I_3 and I_4.

The thicker stalks of the plants obtained from the I_3 and I_4 treatments were probably caused by the water stress these plants experienced. During these periods of water stress cell elongation apparently was hampered. However, cell multiplication in the secondary meristems at the nodes seemed to be stimulated and thicker stems resulted. In experiments with chemical growth retardants (78) similar results were noted where inhibition of cell elongation was accompanied by excessive thickening of the cortex region.

Nitrogen applications did not result in any significant increase in the thickness of the stalk. The

Table 7. Effect of irrigation frequencies and nitrogen applications on stalk thickness of forage sorghum plants (in cm).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	1.12	1.14	1.17	1.22	1.16
F_2	1.13	1.13	1.19	1.16	1.16
F_3	1.13	1.13	1.19	1.21	1.17
Irrigation means	1.13	1.14	1.18	1.21	

LSD	5%	1%
Irrigation	0.03 cm	0.05 cm
Nitrogen	N.S.	N.S.
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	0.00322
Irrigation	3	0.01657**
Error (a)	5[1]	0.00072
Nitrogen	2	0.00034
Irrigation x nitrogen	6	0.00004
Error (b)	16	0.00015

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

** Significant at 1% level.

interaction between irrigation and nitrogen application was also found nonsignificant.

Number of Leaves per Plant

A greater amount of leafy material renders the forage more palatable and nutritive for the animals. To determine the number of leaves per plant, the same five selected plants were taken and leaves were counted. It is apparent from the data presented in Table 8 that significantly more leaves per plant were produced when plants were irrigated after every week than those irrigated after every three or four weeks. There were no significant differences in the number of leaves per plant of I_1 and I_2 but both were significantly different from I_3 and I_4. Vigorous plant growth and development at the I_1 level is responsible for more leaves per plant. These results are in conformity with other workers (12 and 28). The effect of nitrogen on leaf number per plant was found nonsignificant and so also was the interaction between irrigation and nitrogen application.

Length and Width of the Leaves

The size of the leaves is also an important character which contributes towards the yield and quality of the forage plant. The leaves are the seat of manufacture of plant food and greater size will mean

Table 8. Effect of irrigation frequencies and nitrogen applications on the number of leaves per plant of forage sorghum.

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	8.58	8.42	8.17	8.17	8.34
F_2	8.92	8.67	8.17	8.42	8.55
F_3	9.08	8.42	8.25	8.25	8.50
Irrigation means	8.86	8.50	8.20	8.28	

LSD	5%	1%
Irrigation	0.39	N.S.
Nitrogen	N.S.	N.S.
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	0.0468
Irrigation	3	0.7986*
Error (a)	5[1]	0.1063
Nitrogen	2	0.1458
Irrigation x nitrogen	6	0.0555
Error (b)	16	0.0885

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

* Significant at 5% level.

formation of more food for the plant. To determine the size of the leaves, the same five selected plants from each treatment were measured. The leaf length was recorded from the collar to the tip of each leaf. The width was recorded across the middle of the leaf blade. The data for these two observations are summarized in Tables 9 and 10. It can be seen that the longest leaves were produced by plants irrigated after every week. Significantly shorter leaves were obtained from the plots which were subjected to water stress conditions. Nitrogen applications did not produce any significant effect on this character. The width of the leaves was little influenced by either irrigation or nitrogen applications.

Growth of the Plants

The effect of irrigation frequencies on plant growth is shown in Figure 1. It can be seen from the curves that for the plants grown under the I_1 treatment, the growth pattern was in a normal linear fashion, showing that moisture was continuously available to these plants.

The plants irrigated after every two weeks showed little disturbance in growth rate. One week after irrigation the growth rate of these plants had decreased, but growth recommenced its normal course when irrigation was applied a week later according to schedule.

Table 9. Effect of irrigation frequencies and nitrogen applications on the leaf length of forage sorghum plants (in cm).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	90.1	80.8	76.7	70.3	79.5
F_2	92.5	79.3	75.9	70.7	79.6
F_3	91.6	80.8	75.3	69.8	79.4
Irrigation means	91.4	80.3	75.1	70.3	

LSD	5%	1%
Irrigation	3.1 cm	6.3 cm
Nitrogen	N.S.	N.S.
Irrigation x nitrogen	N.S.	N.S.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	16.1724
Irrigation	3	721.3820**
Error (a)	5[1]	11.0492
Nitrogen	2	0.1059
Irrigation x nitrogen	6	2.4205
Error (b)	16	2.2527

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

** Significant at 1% level.

Table 10. Effect of irrigation frequencies and nitrogen applications on the leaf width of forage sorghum plants (in cm).

Nitrogen rates	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
F_1	4.95	4.80	5.09	5.32	5.04
F_2	4.96	4.83	4.77	5.55	5.03
F_3	5.04	4.73	4.72	5.37	4.97
Irrigation means	4.98	4.79	4.86	5.41	

All results are nonsignificant.

Analysis of Variance

Source	D.F.	M.S.
Replication	2	0.0012
Irrigation	3	0.7068
Error (a)	5[1]	0.3706
Nitrogen	2	0.0182
Irrigation x nitrogen	6	0.0521
Error (b)	16	0.0286

1. The number of degrees of freedom for error "a" has been reduced by one because of confounding of the irrigation treatments.

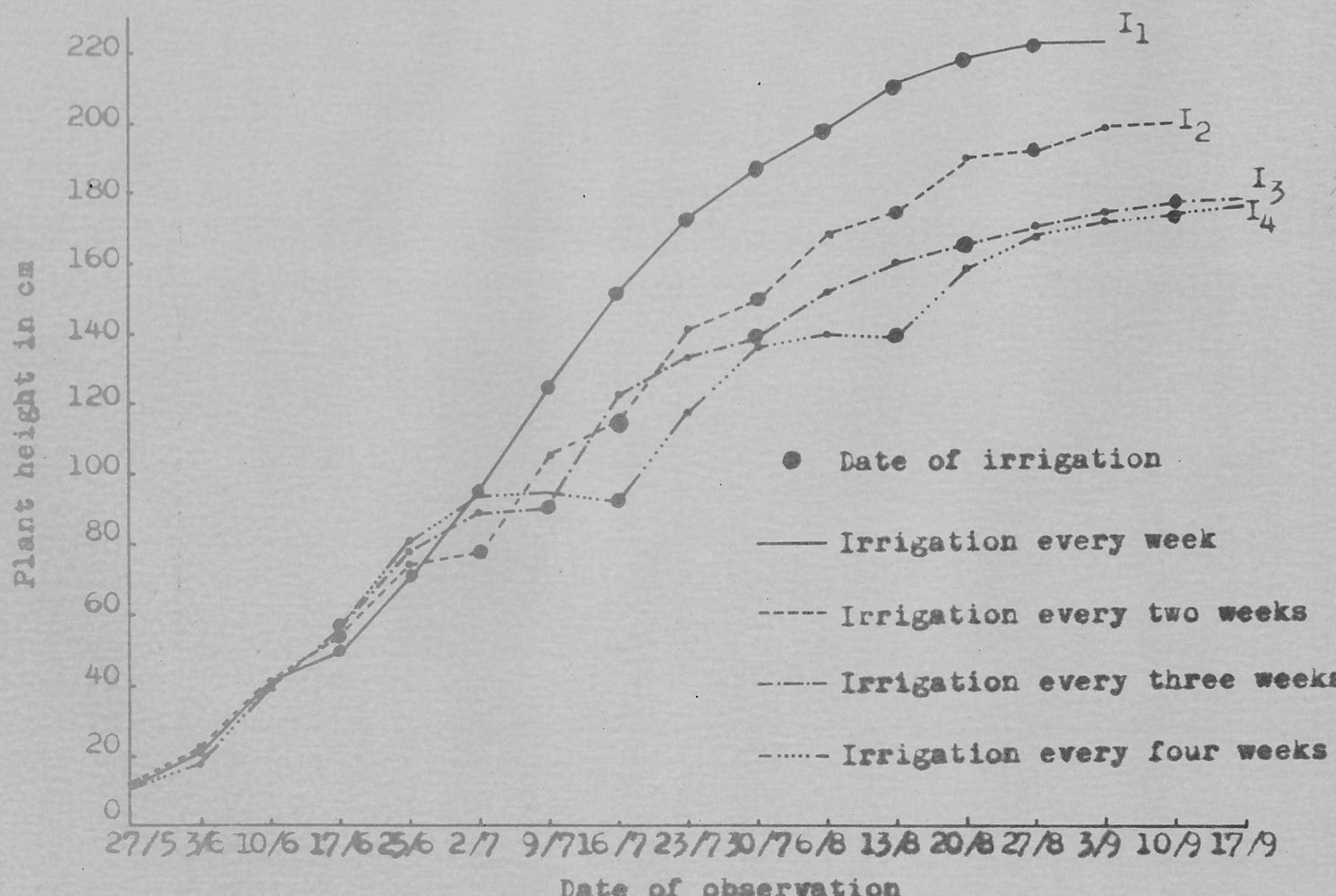

Figure 1. Effect of irrigation frequency on the height of forage sorghum plants (average of 4 selected plants).

Growth was greatly reduced where the plants were subjected to intervals as great as three or four weeks between irrigations. Plants receiving water after every 3 weeks had almost stopped their growth in the third week, the leaves had begun to roll and the tips had dried. This effect was very severe in the I_4 plots, where after three weeks the plants appeared severely wilted, the tips were completely dried, and much of the dried portion was lost. This is shown by depressions in the growth curve of I_4, during the fourth week. After the water was applied to the I_3 and I_4 plants, they recovered to a large extent exhibiting normal growth rates for as long as water remained available.

These effects were very severe during the middle of the growing season when the plants were young; but as the plants neared maturity or maximum development, the severity was less pronounced. A study of Figure 1, therefore, leads to the conclusion that for the plants to grow normally and vigorously, weekly irrigations seem to be essential. Further, irrigations at two-week intervals may not be too deleterious to forage yield and quality.

Economic Evaluation

Gross returns from the irrigation and nitrogen treatments were estimated and are presented in the form of bar graphs in Figure 2. It can be seen that, under the weekly irrigation frequency, the expenditure of only 13.80 L.L. for an additional increment of nitrogen increased the gross returns from 271.00 L.L. to 312.00 L.L., a difference of 42.00 L.L. When the second increment of nitrogen was added, the increase was from 312.00 L.L. to 331.00 L.L., a difference of 19.00 L.L. This indicates that the second increment of nitrogen did not result in as great a difference as did the first increment of nitrogen.

Under the I_2 irrigation frequency, the first increment increased the gross return from 231.00 L.L. to 251.00 L.L., a difference of 20.00 L.L. When the second increment of 12 kg of nitrogen was applied, the increased return amounted to only 2.00 L.L. This shows that this second increment is not at all profitable, because it does not even return the cost of the increment (13.80 L.L.). Almost the same effect was maintained at I_3 irrigation frequency, but at the I_4 irrigation frequency even the first increment of 12 kg nitrogen proved to be nonprofitable.

Therefore, from this evaluation, it can be suggested that weekly irrigations and 24 kg of nitrogen per dunum is the best combination for the highest gross returns per dunum.

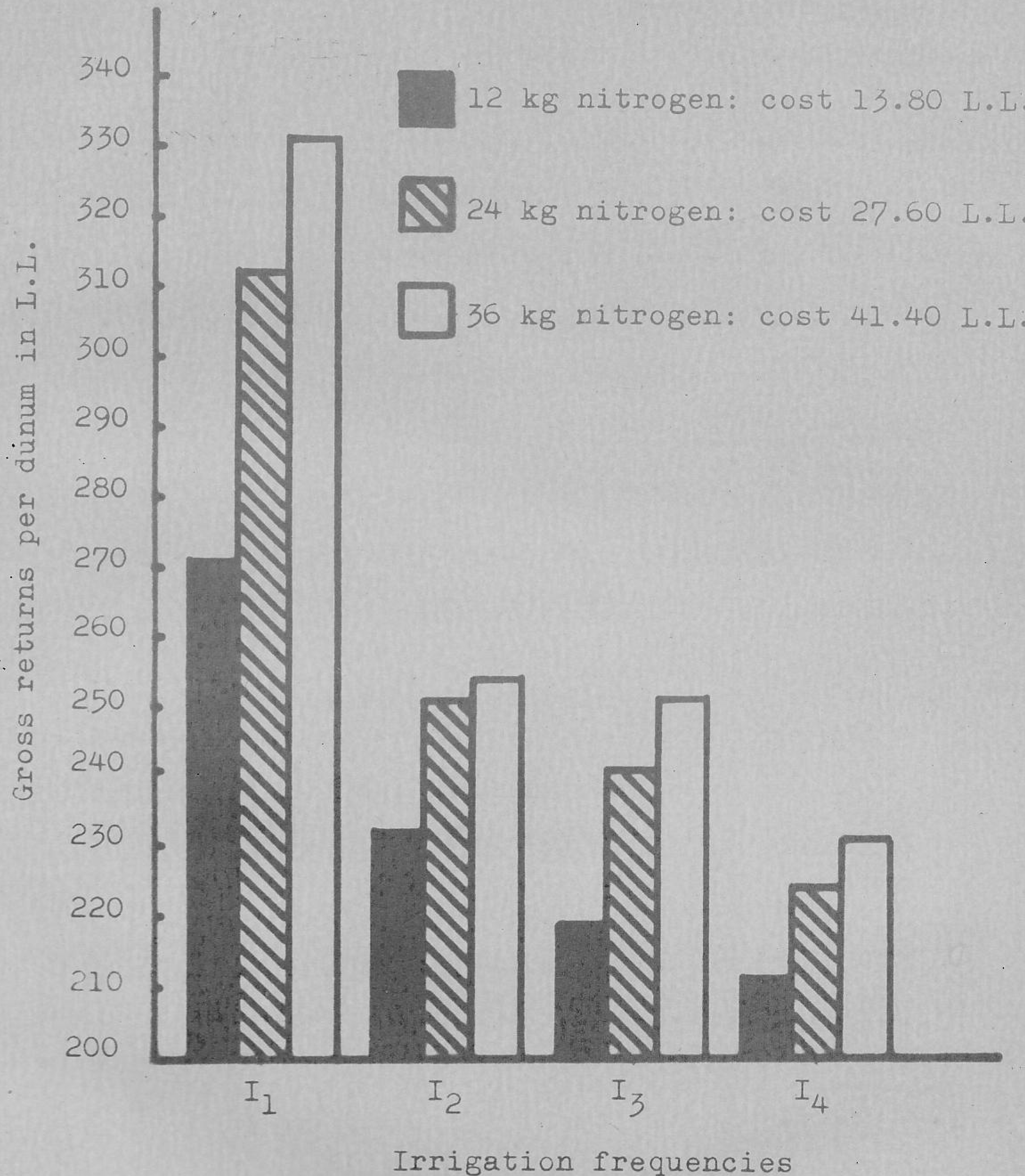

Figure 2. Estimated gross returns from the irrigation and nitrogen treatments tested.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A field experiment was conducted during the 1965 growing season at the Agricultural Research and Education Center, Lebanon, to determine the effect of four irrigation frequencies and three nitrogen levels on forage yield, protein content, protein yield, and other characteristics of a forage sorghum. The variety White Collier was used. The experiment was laid out in a split plot design. The irrigation frequencies and nitrogen levels were:

Irrigation frequencies

- I_1 Irrigations once each week
- I_2 Irrigations every two weeks
- I_3 Irrigations every three weeks
- I_4 Irrigations every four weeks

Nitrogen levels

- F_1 12 kg of nitrogen per dunum applied at planting time.
- F_2 24 kg of nitrogen per dunum, 12 kg at planting time and an increment of 12 kg as a side dressing.
- F_3 36 kg of nitrogen per dunum, 12 kg at planting time and as two subsequent 12 kg side dressings.

Forage yields were significantly different for different irrigation frequencies. Irrigations after every week resulted in the highest dry matter yield of the irrigation frequencies tested. Nitrogen rates also affected the forage yield directly. Both F_2 and F_3 treatments resulted in forage yields significantly higher than that of the check (F_1). The significant interaction indicates a relationship between irrigation frequencies and nitrogen rates.

The I_1xF_1 combination of treatments produced significantly less forage yields than did the I_1xF_2 or I_1xF_3 combinations. The latter two were not significantly different from each other.

Both irrigation frequencies and nitrogen rates affected markedly the protein percentage of the plants as well as the total protein yield. Plants getting irrigations after every week contained a lower percentage of protein than did those irrigated at two-, three- or four-week intervals, but total yields of protein were higher because of the higher total forage yields. Nitrogen rates had a direct effect upon both protein percentage and protein yield. Increasing the nitrogen rates from F_1 to F_2 and F_3 resulted in increases in both protein percentage and protein yield.

Tillers per plant were affected by irrigation frequencies but were not influenced by nitrogen rates.

Plants irrigated after every week produced more tillers per plant than did those irrigated after every three or four weeks.

Plant height was affected significantly both by irrigation frequencies and nitrogen rates. The tallest plants resulted from the plots irrigated after every week. Nitrogen rates had a direct influence on plant height. The tallest plants were produced where 36 kg of nitrogen per dunum had been applied.

Length of the internodes and thickness of the stalk were affected by irrigation frequencies but not by nitrogen rates. Longer internodes and thinner stalks resulted from the plots irrigated after every week, while shorter internodes and thicker plants resulted from the plots irrigated after every three or four weeks.

The length and number of leaves per plant were both influenced by irrigations but neither were influenced by nitrogen rates. The treatment I_1 produced the lengthiest and greatest number of leaves per plant. The width of the leaves was not affected by irrigation frequencies nor by nitrogen rates.

Growth rate was influenced markedly by the irrigation frequencies. The growth curve of plants getting water after every week was linear, while for those getting water after every three or four weeks, the curves were markedly nonlinear. The growth almost stopped in the third week, leaves were rolled, tips were withered, completely wilted, and broken away affecting the plant height. Even these plants regained their normal growth course after the irrigation was applied. The severity of the effect of water stress diminished as the plants approached maturity. Nitrogen levels affected the growth rate of the plants under the I_1 and I_2 irrigation frequencies. However, at the I_3 and I_4 frequencies, the moisture stress of the prolonged intervals between irrigations prevented any response to nitrogen.

In brief, on the basis of this one year of investigation, the following conclusions can be made:

i. Irrigations given after every week produced the greatest amount of dry matter and protein yield per dunum, most tillers per plant, and the tallest plants. This treatment also resulted in thinner stalks with longer internodes, more leaves per plant, and longer leaf blades.

ii. Nitrogen at the rate of 36 kg per dunum was found to result in the highest yield of dry matter and of protein per dunum, and in the tallest plants. The amount of increase in forage yield resulting from the second increment of nitrogen was not as great as the increase from the first increment. Tillers per plant, length of internodes, thickness of stalks, number of leaves per plant, and length and width of the leaf were influenced only slightly by the nitrogen rates.

iii. Growth rate was affected markedly by irrigation frequencies. Nitrogen rates affected the growth rate at I_1 and I_2 irrigation frequencies but not at the I_3 or I_4 irrigation frequencies.

From this it appears that irrigations after every week and application of 24 kg of nitrogen per dunum, 12 kg at planting time and 12 kg as a side dressing 1½ months after planting, resulted in significantly greater dry matter and protein yields. More tillers per plant, taller plants with thin stalks and longer internodes, and plants with more leaves were also the result of this combination.

It was also indicated that, under the conditions of this experiment, irrigations every week and 24 kg of nitrogen would give the highest gross return per unit area of land.

Under situations where a farmer has too little water available for weekly irrigation, low yields of sorghum forage can be expected. Furthermore, the increased yield from the addition of nitrogen fertilizers was not profitable except where weekly irrigation was practiced.

SELECTED BIBLIOGRAPHY

1. Beckett, S. H., and M. R. Huberty. Irrigation investigations with field crops at Davis, and at Delhi, California. Calif. Agric. Expt. Sta. Bul. 450, 1928.

2. Bennett, O. L., B. D. Doss, D. A. Ashley, V. J. Kilmer, and E. C. Richardson. Effect of soil moisture regimes on yield, nutrient content, and evapotranspiration for three annual forage species. Agron. J. 56, 195, 1964.

3. Boehle, J. Jr., L. T. Kardos, and J. B. Washko. Effect of irrigation and deep fertilization on yield and root distribution of selected forage crops. Agron. J. 53, 153, 1961.

4. Bordade, V. N. A note on Jowar (Sorghum vulgare). Sorghum Newsletter 6, 20, 1963.

5. Boyd, F. T., V. E. Green, and H. L. Chapman Jr. Production of sorghum forage and grain in South Florida. Florida Agric. Expt. Sta. Bul. 628, 1961.

6. Brown, A. R., C. Cobb, and E. H. Wood. Effect of irrigation and row spacing on grain sorghum in the Piedmont. Agron. J. 56, 506, 1964.

7. Brown, D. A., and R. H. Benedict. Increasing crop yields through irrigation. Agric. Expt. Sta. Univ. Kansas, No. 3, April 1964.

8. Broyles, K. R., and H. A. Fribourg. Nitrogen fertilization and cutting management of sudan-grass and millets. Agron. J. 51, 277, 1959.

9. Burleson, C. A., W. R. Cowley, and G. Otey. Effect of nitrogen fertilization on yield and protein content of grain sorghum in the lower Rio Grande valley of Texas. Agron. J. 48, 524, 1956. X

10. Carrenker, J. R., and J. H. Lillard. Irrigation practices for pasture and forage crops. Water, Yearbook of Agriculture, USDA. 1955.

11. Carrente, V., and P. Bertoldi. Trials with grain and fodder sorghum. Ann. Sper. Agric. 14, 797, 1960. Abstracted in Field Crops Abstracts (1339). Vol. 15, No. 3, August 1962.

12. Choudhry, M. R. Effect of supplementary irrigation on yield and other characteristics of forage sorghum. M.S. Thesis. American University of Beirut. Beirut, Lebanon. 1964.

13. Choudhry, N. H. Effect of irrigation schedule and plant population on the yield and other characteristics of hybrid corn. M.S. Thesis. American University of Beirut. Beirut, Lebanon. 1965.

14. Cooper, C. S., M. G. Klages, and J. S. Schaeffer. Performance of six forage grass species under different irrigation and nitrogen treatments. Agron. J. 54, 283, 1962.

15. Davis, J. R., W. A. Fry, and L. G. Jones. Water supply and irrigation effect on alfalfa. Calif. Agric. 17 (March), 4, 1963.

16. Denmead, O. T., and R. H. Shaw. The effect of soil moisture stress at different stages of growth on the development and yield of corn. Agron. J. 52, 272, 1960.

17. Doss, B. D., D. A. Ashley, O. L. Bennett, R. M. Patterson, and L. E. Ensminger. Yield, nitrogen content, and water use of sart sorghum. Agron. J. 56, 589, 1964.

18. Dotzenko, A. D. Effect of different nitrogen levels on the yield, total nitrogen content and nitrogen recovery of six grasses grown under irrigation. Agron. J. 53, 131, 1961.

19. Ellis, B. G., C. J. Knauss, and F. W. Smith. Nutrient content of corn as related to fertilizer application and soil fertility. Agron. J. 48, 455, 1956.

20. Ficco, N. Three years trial on irrigating with brackish water. Genio rur. 24, 753, 1961. Abstracted in Field Crops Abstracts (1128). Vol. 15, No. 2, May 1962.

21. Garg, D. K., and K. Kayande. Effect of nitrogen and phosphorous singly and in combination with varying row spacing on the yield of Jowar. Madras Agric. J. 49, 258, 1962. Abstracted in Field Crops Abstracts (1721). Vol. 16, No. 4, November 1963.

22. Genter, C. F., J. F. Eheart, and W. N. Linkous. Effect of location, hybrid, fertilizer, and rate of planting on the oil and protein content of corn. Agron. J. 48, 63, 1956.

23. George, M. H., and A. B. Erhart. Effect of nitrogen and phosphorous fertilizers on the yield of irrigated grain sorghum in south-western Kansas. Agron. J. 52, 499, 1960.

24. Gonzales, T. T., P. B. Aldaba, and B. Andes. Irrigation studies on sorghum at the Lamo Experiment Station. Sorghum Newsletter 6, 42, 1963.

25. Grimes, D. W., and J. T. Musick. How plant spacing, fertility and irrigation affect grain sorghum production in south-western Kansas. Kan. Agric. Expt. Sta. Bul. 414, 1959.

26. Grimes, D. W., and J. T. Musick. Effect of plant spacing, fertility and irrigation management on grain sorghum production. Agron. J. 52, 647, 1960.

27. Grimes, D. L., and G. A. Reichman. Fertilizers increase crop nutrient content. Crops and Soils 14 (March-April), 18, 1962.

28. Hagan, R. M., M. L. Peterson, R. P. Upchurch, and L. G. Jones. Relationship of soil moisture stress to different aspects of growth in Ladino clover. Soil Sci. Soc. Am. Proc. 21, 360, 1957.

29. Hanks, R. J., and C. B. Tanner. Water consumption by plants as influenced by soil fertility. Agron. J. 44, 98, 1952.

30. Hanway, J. J. Corn growth and composition in relation to soil fertility. I. Growth of different plant parts and relation between leaf weight and grain yield. Agron. J. 54, 145, 1962.

31. Haynes, J. L. The effect of availability of soil moisture upon vegetative growth and water use in corn. J. Am. Soc. Agron. 40, 385, 1948.

32. Hearn, A. B., and R. A. Wood. Irrigation control experiments on dry season crops in Nyasaland. Emp. J. Expt. Agric. 32, 1, 1964.

33. Higgins, R. E., and E. W. Owens. Producing field corn in Idaho. Idaho Agric. Exten. Ser. Bul. 402, 1963.

34. Horwitz, W. (Editor). Official Methods of Analysis. Association of Official Agricultural Chemists, Incorporated. Washington, D.C., 9th ed., 1960.

35. Howe, O. W., and H. F. Rhoades. Irrigation practice for corn production in relation to stage of plant development. Soil Sci. Soc. Am. Proc. 19, 94, 1955.

36. Jordon, H. V., K. D. Laird, and D. D. Ferguson. Growth rates and nitrogen uptake by corn in a fertilizer spacing experiment. Agron. J. 42, 261, 1950.

37. Jung, G. A., B. Lilly, S. C. Shih, and R. L. Reid. Studies with sudangrass. Effect of growth stage and level of nitrogen fertilizer upon yield of dry matter; estimated digestibility of energy, dry matter and protein; amino acid composition; and prussic acid potential. Agron. J. 56, 533, 1964.

38. Karper, R. E., and J. R. Quinby. Sorghum - its production, utilization and breeding. Econ. Bot. 1, 355, 1947.

39. Kemper, W. D., C. W. Robinson, and H. M. Golus. Growth rates of barley and corn as affected by changes in soil moisture stress. Soil Sci. 91, 332, 1961.

40. Kessler, D., B. Chen, and S. P. Monselise. Studies on water regime and nitrogen metabolism of citrus seedlings grown under water stress. Plant Physiol. 39, 379, 1964.

41. Kurtkoti, F. B., and C. B. Diverkar. Improved methods of Jowar cultivation. Mysore Agric. J. 34, 5, 1959. Abstracted in Field Crops Abstracts (1141). Vol. 13, No. 3, August 1960.

42. Lorenz, R. J., C. W. Carlson, G. A. Rogler, and H. Holmen. Bromegrass and bromegrass-alfalfa yields as influenced by moisture levels, fertilizer rates, and harvest frequency. Agron. J. 53, 49, 1961.

43. MacGillivray, J. H. Effect of irrigation on the growth and yield of sweet corn. Proc. Am. Soc. Hort. Sci. 54, 330, 1949.

44. MacKay, D. C., and C. A. Eaves. The influence of irrigation treatment on yield and fertilizer utilization by sweet corn and snap beans. Can. J. Pl. Sci. 42, 219, 1962.

45. Mathers, A. C., F. G. Viets Jr., M. E. Jensen, and W. H. Sletten. Relationship of nitrogen and grain sorghum yield under three moisture regimes. Agron. J. 52, 443, 1960.

46. McMaster, G., J. G. Walker, and W. Owens. Irrigation and fertilization of field corn grown for silage in south-eastern Idaho. Idaho Agric. Expt. Sta. Bul. 113, 1961.

47. Morrison, F. B. Feeds and Feeding. Morrison Publishing Company. Ithaca, New York, 22nd ed., 1956.

48. Musick, J. T., and D. W. Grimes. Water management and consumptive use of irrigated grain sorghum in western Kansas. Kan. Agric. Expt. Sta. Bul. 113, 1961.

49. Musick, J. T., D. W. Grimes, and G. M. Herron. Irrigation water management and nitrogen fertilization of grain sorghum. Agron. J. 55, 295, 1963.

50. Nelson, C. E. Effect of spacing and nitrogen application on yield of grain sorghum under irrigation. Agron. J. 44, 303, 1952.

51. Nevans, W. B., and K. A. Kendall. Sorghums and soybeans as silage crops for milk production. Univ. Illinois Agric. Expt. Sta. Bul. 578, 1954.

52. Norman, R. M., and C. H. Hsi. Fertilizer tests at New Mexico. Sorghum Newsletter 6, 35, 1963.

53. Olsen, S. R., C. U. Cole, F. S. Watanabe, and L. A. Dean. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. U. S. Department of Agriculture Cir. 939, 1954.

54. Owens, F. W., and R. D. Ensign. Field corn production in Idaho. Idaho Agric. Expt. Sta. Bul. 310, 1959.

55. Painter, C. G., and R. W. Leamer. The effect of moisture, spacing, fertility, and their interrelationship on grain sorghum production. Agron. J. 45, 261, 1953.

56. Paschal, J. L., and C. F. Evans. Economic interpretation of yield data from a nitrogen rate experiment with irrigated grain sorghum. Soil Sci. Soc. Am. Proc. 18, 454, 1954.

57. Pitman, D. W., and G. Stewart. Twenty eight years of irrigation experiments near Logan, Utah. Utah Agric. Expt. Sta. Bul. 219, 1930.

58. Porter, K. B., M. E. Jensen, and W. H. Sletten. The effect of row spacing, fertilizer, and planting rate on the yield and water use of irrigated grain sorghum. Agron. J. 52, 431, 1960.

59. Prato, J. D., V. L. Marble, D. G. Smeltzer, and G. F. Worker, Jr. Sorghum forages for silage in California. Calif. Agric. 17 (October), 10, 1963.

60. Prince, A. B. Effects of nitrogen fertilization, plant spacing, and variety on the protein composition of corn. Agron. J. 46, 185, 1954.

61. Quinby, J. R., and P. T. Marion. Production and feeding of forage sorghum in Texas. Texas Agric. Expt. Sta. Bul. 965, 1960.

62. Ram, A. Effect of nitrogen fertilization on yield and nitrogen content of forage sorghum varieties. Diss. Abstr. 20, No. 10, 3917, 1960. Abstracted in Field Crops Abstracts (657). Vol. 14, No. 2, May 1961.

63. Ramage, C. H., C. Eby, R. E. Mather, and E. R. Purvis. Yield and chemical composition of grasses fertilized heavily with nitrogen. Agron. J. 50, 59, 1958.

64. Raney, R. J., and H. Manges. Results from the Concordia, Kansas irrigation experiments fields. Kan. Agric. Expt. Sta. Bul. 421, 1960.

65. Rao, N. G. P. Irrigation, and fertility studies at Deccan, India. Sorghum Newsletter 5, 64, 1962.

66. Reichman, G. A., D. L. Grunes, C. W. Carlson, and J. Elessi. Nitrogen and phosphorous composition and yield of corn as affected by fertilization. Agron. J. 51, 575, 1959.

67. Reith, J. W. S., and R. H. E. Inkson. The effect of fertilizers on herbage production. J. Agric. Res. 56, 17, 1961.

68. Schmidt, W. H., and W. L. Collville. Forage yield and composition of Teosinte, corn, and forage sorghum grown under irrigation. Agron. J. 55, 327, 1963.

69. Schwale, G. O. Research on irrigation of corn and soybeans at Conesville and Ankeny, Iowa. Iowa Agric. Expt. Sta. Res. Bul. 458, 1958. Abstracted in Field Crops Abstracts (624). Vol. 12, 1959.

70. Shealey, A. L., W. G. Kirk, and R. M. Crown. Comparative feeding value of silages made from napiergrass, sorghum, and sugar cane. Univ. Florida Agric. Expt. Sta. Bul. 538, 1941.

71. Sidhu, N. A. Effect of irrigation schedule and plant population on grain yield and other characteristics of grain sorghum. M.S. Thesis. American University of Beirut. Beirut, Lebanon. 1965.

72. Snedecor, G. W., and W. G. Cochran. Statistical Methods. The Iowa State University Press, Ames, Iowa, U.S.A., 5th ed., 1956.

73. Taylor, S. A., and C. S. Slater. When to irrigate and how much water to apply. Water, Yearbook of Agriculture, USDA. 1955.

74. Thomas, W. Effect of applied nitrogen and sulphur on yield and protein content of corn. Agron. J. 51, 572, 1959.

75. Verma, R. D., and J. C. Sherma. Effect of different doses of nitrogen and phosphorous placed and broadcast, and of row spacing on maize. Ind. J. Agric. Sci. 28, 13, 1958.

76. Victor, I. M., and D. G. Shockley. Irrigation of hay and pasture crops in Idaho. Idaho Agric. Expt. Sta. Bul. 249, 1955.

77. Worzella, W. W., S. Abu Shakra, and D. W. Bray. Forage production trials in the Beqa'a, Lebanon, 1958-63. Publication No. 25. Faculty of Agricultural Sciences, American University of Beirut. Beirut, Lebanon. 1964.

78. Zeevaart, J. A. A. Effect of growth retardant CCC on floral inhibition and growth in Pharbitis nil. Plant Physiol. 39, 402, 1964.

79. Zuber, M. S., G. E. Smith, and C. W. Gehrke. Crude protein of corn grain and stover as influenced by different hybrids, plant populations, and nitrogen levels. Agron. J. 46, 257, 1954.

APPENDIX

Table 11. Average values of the pH and chemical analysis of the soil samples taken from 30 cm depth, after harvest of the crop.

Treatment	pH	Total nitrogen (%)	Available phosphorous (ppm)
I_1 F_1	8.00	0.1221	10.4
I_1 F_2	7.90	0.1326	10.8
I_1 F_3	8.30	0.1346	9.6
I_2 F_1	7.90	0.1275	12.4
I_2 F_2	7.95	0.1322	11.2
I_2 F_3	7.95	0.1386	10.8
I_3 F_1	8.30	0.1304	10.4
I_3 F_2	7.85	0.1278	10.0
I_3 F_3	7.90	0.1473	11.6
I_4 F_1	7.90	0.1361	28.8
I_4 F_2	7.85	0.1373	14.8
I_4 F_3	8.25	0.1487	15.6
Average	7.96	0.1346	13.03

Table 12. Average monthly temperatures and precipitation at the Agricultural Research and Education Center, Beqa'a Plain, Lebanon, for the growing season of 1965.

Months	Temperature °C	Rainfall (mm)
April	9.2	48.7
May	14.0	3.0
June	25.7	3.0
July	22.5	0.0
August	23.7	0.0
September	20.2	23.2
October	13.2	46.8