INFLUENCE OF IRRIGATION FREQUENCIES AND NITROGEN LEVELS ON THE YIELD AND OTHER AGRONOMIC CHARACTERISTICS OF FORAGE SORGHUM

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FORAGE SORGHUM

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AN ABSTRACT OF THE THESIS OF

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Title: Influence of irrigation frequencies and nitrogen levels on the yield and other agronomic characteristics of forage sorghum.

A field experiment was conducted in the year 1966 at the Agricultural Research and Education Center, of the American University of Beirut located in the Beqa'a plain, Lebanon, to study the influence of four irrigation frequencies and three levels of nitrogen on the yield, protein content, and other characteristics of forage sorghum. The intervals studied were one, two, three, and four weeks, and the levels of nitrogen were 12, 24, and 36 kg per dunum.

The plots were harvested twice. The weekly irrigated plots produced the greatest total yield of dry matter and of protein per dunum. This treatment also produced the thinnest, tallest plants and the highest percentage of leaf plus head.

The plants receiving 36 kg of nitrogen per dunum produced the greatest yield of dry matter and of protein and in addition were taller.

An economic evaluation was carried out in which estimates of the fixed costs of production and of the value of the fodder produced were studied. It was concluded that irrigation at two week intervals and nitrogen levels of 24 kg would be most profitable.

Plants irrigated at weekly intervals had the lowest protein content, but the greatest over-all yield per dunum of protein.

Daily growth curves of the plants prior to the first harvest were found to be linear, whereas weekly growth curves of the same plants as they recovered from harvesting were not.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

I. INTRODUCTION

Increasing population and education in most Middle Eastern countries is increasing the demand for livestock products. Programs concerning improvement of fundamental education, extension, community development, and health and sanitation gradually are changing the diet of the people and more animal products are in demand. Substitutes have never been popular because they lack the superior qualities associated with meat and dairy products.

To increase production of animal products the production of forages must be first increased. Most areas of the Middle East are considered to be arid, irrigation water is limited, and fertilizers are expensive. Therefore proper use of these two important factors is very important in the production of sufficient quantities of high quality forage crops.

Sorghum (*Sorghum vulgare*, Pers.) is known to be a drought resistant crop hence is considered to be suitable to arid regions. This crop yields fairly well under limited moisture conditions, but much higher yields can be obtained under irrigation. Judicious use of fertilizer and water along with other cultural practices should make forage sorghum a crop with great economic potentialities throughout the Middle East.

The Beqa'a Plain of Lebanon receives no rain during most of the normal growing period. In addition the nitrogen content of the soil is relatively low. There is a long growing season with hot summer days of low humidity.

The objective of this experiment was to find out how much nitrogen and irrigation water need to be applied under Beqa'a conditions to obtain economical yields of high quality forage sorghum.

In addition various agronomic data were studied.

II. REVIEW OF LITERATURE

It is known that when nitrogen is applied to most soils, plants make more efficient use of the available moisture. The use of fertilizer enhances plant growth, thereby hastening the depletion of moisture from soils with a limited water supply. A knowledge of the right combination of levels of these two factors is important for maximum forage production.

Optimum intervals between irrigation and optimum levels of nitrogen application vary with soil type, soil fertility, rooting habit of the plant, and climate of the area.

Forage Yield

Irrigation influence. Sorghum is known to be a drought resistant crop, but in many areas of the world there is insufficient rainfall during the growing season to produce maximum yields of forage sorghum without supplementary irrigation.

Several sorghum experiments have been done at the Agricultural Research and Education Center (A.R.E.C.) of the American University of Beirut. The results of these experiments may be summarized as follows:

Qureshi (59) found that plots irrigated at weekly intervals produced a greater amount of forage sorghum per dunum than did those which were irrigated at two, three, or four week intervals. Choudhry (13) reported that weekly irrigation gave a yield of forage sorghum four times that resulting from no irrigation. Sidhu (70) found that grain sorghum plots receiving irrigations at weekly intervals throughout the growing season gave greater yields of stover than did those irrigated bi-weekly. Fuehring et al. (23) showed that the yield of maize was decreased as the interval between irrigation was extended beyond one week. Worzella et al. (79) reported the yields of ten varieties of forage sorghum under irrigation. The average yields for four years ranged from 1.7 to 3.6 tons per dunum.

Many experiments have been done in other parts of the world and their findings can be summarized as follows:

In southern Italy, Carrente and Bertoldi (12) found that although sorghum is resistant to drought, good yields of this crop required irrigation. In Oklahoma, Griffin et al. (26) reported that maximum water use efficiency was obtained by maintaining the water supply in the soil profile above 50 percent of the available moisture level. Bennett et al. (5) in Alabama observed that the yields of sudangrass, millet, and sart sorghum were increased as the available soil moisture was increased. It was also noted that under these conditions the evapotranspiration rate increased.

Ficco (22), in southern Italy, found that sorghum irrigated at 15-day intervals produced from 36,000 to 41,000 kg of green fodder per hectare, but when irrigated at 30-day intervals yielded only 18,500 to 29,100 kg per hectare. Brown et al. (8) at Georgia found that irrigated grain sorghum produced much more dry matter than did non-irrigated. Beckett and Huberty (4) found that in California, even in years of heavy rainfall, three irrigations were required to obtain satisfactorily high yields from sorghum. Gonzales et al. (25) in the Philippines found that increasing the amount of water applied in weekly irrigations increased the yields of grain sorghum. Karper and Quinby (37) found that in Texas irrigated grain sorghum produced from 3000 to 5000 lb of dry matter per acre, but when not irrigated, only a few hundred to 3000 lb were produced. Quackenbush and Throne (57) in Virginia applied three inches of water in one irrigation between the tasseling and milk stages. This was found to increase corn yield 38 bushels over the non-irrigated yield of 65 bushels per acre. Boehle et al. (16) in Pennsylvania found that supplemental irrigation increased yields of several forage grasses.

Denmead and Shaw (17) at Iowa found that corn plants exposed to water stress exhibited a delay in the normal enlargement of plant parts. It was suggested that this delay was a result of the reduced production of dry matter.

Several other researchers, (7, 14, 29, 30, 31, 42, 67, and 79) reported increases in yield resulting from irrigation of crops.

Nitrogen influence. Ott *et al*. (50) found that in Oklahoma an application of 60 lb of nitrogen per acre resulted in an increase of 1.8 tons of forage sorghum per acre. Ram (60) concluded from a greenhouse trial that whether the nitrogen was applied all at once at planting time, or in several increments, the highest yields of dry matter from forage sorghum varieties were obtained with the highest rate tested. Broyles and Fribourg (9), under Tennessee conditions, observed that rates of nitrogen ranging from 0 to 120 lb per acre increased dry matter yields of sudangrass and millet forages. Agabawi and Younies (1) found that in the Sudan, increasing the level of nitrogen up to 140 lb per feddan (one feddan = 0.42 ha) markedly increased the yield of dry matter of sorghum. Jung *et al*. (36) at Virginia reported that higher rates of nitrogen fertilizer increased the dry matter production per acre of sudangrass. Dotzenko (19), at Colorado, studied the response of five levels of nitrogen on grasses and found that increasing the nitrogen rate from 0 to 640 lb per acre increased the forage production.

Capstick *et al*. (11), at Kansas, showed that irrigated grain sorghum had a larger increase in yield from the first increment of nitrogen than from successive additional increments. Summer *et al*. (71) showed that 200 lb of nitrogen per acre is about the optimum when pasturing or green chopping irrigated Piper sudangrass.

Herron and Erhart (32) showed that, under south western Kansas conditions, irrigated grain sorghum usually produced high yields when 90 lb of nitrogen were applied per acre. The greatest response to nitrogen fertilizer was obtained when average yields were less than 55 bushels per acre without fertilization. Porter *et al*. (54), at Texas, showed that higher nitrogen levels produced higher average yields of grain sorghum. Grimes and Musick (27), in Kansas, observed a significant increase in yield of grain sorghum resulting from the application of 80 to 100 lb of nitrogen per acre. Investigation by several other researchers (21, 34, 48, 49, 51, and 74) showed an increase in yield from application of nitrogen.

Combined influence of irrigation and nitrogen. Qureshi (59) at the A.R.E.C. found that weekly irrigation and application of 36 kg of nitrogen per dunum resulted in a significantly greater yield of dry matter of forage sorghum than did other treatment combinations of irrigation frequency and nitrogen level. Taylor and Slater (73) stated that unless enough nutrients are available to the plant, little would be gained by keeping moisture at high levels. Quinby and Marion (58) in Texas found that, to obtain high yields of forage sorghum under irrigation, larger amounts of nutrients would be required. Doss et al. (18) reported that under Alabama conditions the yield of sart sorghum was increased by nitrogen fertilization or by irrigation but that a far greater increase was obtained when both were used. Painter et al. (52) in New Mexico obtained maximum benefits from grain sorghum with more frequent irrigation only where nitrogen was applied. Prato et al. (55) showed that under California conditions irrigated forage sorghum gave higher yields with higher rates of nitrogen fertilizer.

Capstick et al. (11) concluded that in Kansas, the average yield of irrigated grain sorghum was 3776 lb per acre with no irrigation, but 5022 lb per acre with 90 lb of nitrogen per acre. Musick and Grimes (47) at Kansas, reported a maximum sorghum grain yield of 8500 lb per acre was obtained under heavy irrigation and 120 lb of nitrogen per acre. The yield response to nitrogen application was considerably lower where soil moisture was limited. Porter et al. (54) in Texas reported that higher grain sorghum yields depend on high nitrogen rates and moisture levels. Rao (64) at Deccan, India, reported an experiment where two irrigation frequencies (one and three week intervals) were tested in combination with three levels of nitrogen (30, 60, and 90 lb per acre). It was found that at either irrigation frequency the grain sorghum yield was greatest when 90 lb of nitrogen were applied. Raney and

Manges (63) in Kansas observed that when a total of 28.8 inches of water applied at two-week intervals and 125 lb of nitrogen were applied per acre in five increments, a greater yield of corn grain and silage was produced than from other treatment combination. Mathers *et al*. (44) at Bushland, Texas, obtained greater sorghum grain yields at high moisture levels with 120 lb of nitrogen than with 60 lb of nitrogen per acre. Paschal and Evans (53) under northern Mexico conditions, obtained a higher grain yield with 240 lb of nitrogen per acre and high soil moisture levels than with the same rate of nitrogen at low moisture levels. Welch *et al*. (77) at Texas, comparing nitrogen levels of 0, 50, and 100 lb per acre, obtained the maximum yield of grain sorghum with 50 lb of nitrogen. When above average moisture conditions occurred maximum yields were obtained from the 100 lb per acre rate of nitrogen.

Cooper *et al*. (15) at Montana, reported that six different species of forage grasses showed much greater response to high levels of nitrogen when irrigated than when not irrigated. Dotzenko (19) reported that in the Central Great Plains of Colorado, increasing the nitrogen rate from 0 to 640 lb per acre increased the yield of all the six grasses grown under irrigation. McMaster *et al*. (45) in south-eastern Idaho reported that under high moisture conditions, when 120 lb of nitrogen were applied per acre, a higher yield of corn silage was observed than when 60 lb of nitrogen were applied. This increase in yield from the increase in nitrogen applied was not observed under low moisture levels. Schwale (69) in Iowa, found that soils with a high water holding capacity, responded to applications of nitrogen by producing more bushels of corn per acre than did soils with low water holding capacity. Higgins and Owens (33), under Idaho conditions, concluded that a good yield of corn silage with 100 to 160 lb of nitrogen per acre was obtainable when moisture was adequate during the growing period. Lorenze et al. (41) at North Dakota reported that the yields of bromegrass and bromegrass-alfalfa mixtures were doubled by the application of 40 lb of nitrogen, and quadrupled by 200 lb of nitrogen, provided high levels of irrigation were applied.

Protein Yield

In a study of the literature concerning protein yield, the following terminology must be clarified:

a. Crude protein: This includes protein as well as non-protein nitrogenous substances.

b. Nitrogen content: This term is often used to refer to protein as well as non-protein substances such as amino acids and amides.

c. Protein: This term is generally used instead of crude protein for the sake of simplification (46).

Burleson *et al*. (10) in the Rio Grande Valley of Texas found that application of 60 or 120 lb of nitrogen per acre of sorghum resulted in significant increases in both yield and protein content of the grain and forage. Ramig and Smika (62) in Central Nebraska found that nitrogen fertilization increased the crude protein content of sorghum. Cooper *et al*. (15) in Montana, observed that in forage grasses, when nitrogen was applied at the rate of 100 lb per acre, the crude protein content of the herbage was increased in the early part of the season, but this increase was not maintained throughout the rest of the growth period. However, when 400 lb of nitrogen were applied the crude protein level of the herbage remained at the increased level throughout the season.

Broyles and Fribourg (9) at Tennessee, found that when increases in nitrogen ranging from 0 to 120 lb per acre were applied, there was a corresponding increase in nitrogen percentage of the forage of sudangrass and millet. Doss *et al*. (18) at Alabama reported that the nitrogen percentage of sart sorghum increased as soil moisture decreased. It was also found to increase as the rate of nitrogen application was increased. When no nitrogen was applied, the nitrogen percentage in sart sorghum varied from 0.79 percent at low moisture levels to 0.49 percent at high moisture levels. With the addition of 450 lb of nitrogen per acre, the nitrogen percentage of sart sorghum varied from 1.47 percent at low moisture levels to 1.23 percent at high soil moisture levels. Sumner et al. (72) at California, showed that, with Piper sudangrass when nitrogen applications exceeded 200 lb per acre, there was no appreciable increase in yields, but there were relatively high rates of accumulation of nitrate in the harvested forage. Crowford et al. (16) at Ithaca, New York, observed that two of the factors that had major influences on concentration of nitrate in the forage were high nitrogen level and low soil moisture.

Qureshi (59) at the A.R.E.C. reported that weekly irrigated plants of forage sorghum contained a lower percentage of protein, but that the total protein yield was greater compared with those plants that were irrigated less frequently. Sidhu (70) at the A.R.E.C. found that sorghum grains from the plants which were irrigated at two week intervals prior to heading, but at weekly intervals after heading, contained a lower percentage of protein than did those which were from plants irrigated at weekly intervals prior to heading, and bi-weekly thereafter. According to Leopold (40), Koontz and Biddulph found that when plants such as wheat or oats have reached 25 percent of their full size, 90 percent of the total eventual up-take of nitrogen has occurred. For the last 75 percent of their growth, the developing parts of the plants must be supplied with this element principally by retranslocation of that portion already absorbed. Ellis et al. (20) at Kansas, found that a minimum nitrogen content of leaves is associated with maximum forage yields. Bennett et al. (4) at Alabama, reported that in sart sorghum the percentage of nitrogen in plant tissue decreased with increasing soil moisture, but that the total uptake was usually greater with irrigation.

Genter et al. (24) at Virginia, found that with hybrid corn the protein percent was significantly higher under drought conditions than under good growing conditions. Zuber et al. (80) at Missouri, showed that when more than 50 lb of nitrogen were applied per acre the crude protein in irrigated corn increased both in the grain and in the stover. Reichman et al. (65),under South Dakota conditions, observed that when nitrogen and phosphorous were applied to the soil, the percentage of both in corn leaves, grain, and stover was increased. Prince (56) at South Carolina, found that there was a direct relationship between the amount of nitrogen applied to the soil and crude protein content of the corn. Increasing the rate of nitrogen applied resulted in an increased percentage of crude protein. Ramage et al. (61) in New Jersey, reported that when nitrogen application was increased from 50 to 400 lb per acre, the protein content of grasses was increased from 12 to 20 percent.

Plant Height

Choudhry (13) at the A.R.E.C. reported that irrigated forage sorghum plants were taller than when non-irrigated. The tallest plants were produced under weekly irrigation and shortest under no irrigation. Brown *et al*. (8) at Georgia, showed that when rainfall was not adequate, the growth rate of grain sorghum was increased by irrigation. Plants in non-irrigated plots were fourteen inches shorter than those that were grown at high moisture levels. Thurman *et al*. (75) at Arkansas, reported that sorghum plants were taller where they were grown under irrigation.

Ram (60) from a glasshouse experiment, found that the tallest forage sorghum plants were produced where the highest rate of nitrogen was applied. Qureshi (59) at the A.R.E.C. reported that the tallest plants of forage sorghum were obtained under weekly irrigation and a nitrogen rate of 36 kg per dunum.

Macgillivray (43) at California, observed that the tallest corn plants were produced under high moisture level and the shortest plants resulted from no irrigation. Investigation by other workers (17, 36, and 66) showed similar results.

Thickness of the Stem

Qureshi (59) at the A.R.E.C. reported that stem thickness of forage sorghum was directly related to irrigation frequency. The thinnest stems were obtained under weekly irrigation and the thickest were produced by plants irrigated at four-week intervals. The nitrogen rate influenced slightly the stem thickness. Choudhry (13) at the A.R.E.C. found that non-irrigated plots of grain sorghum produced plants with the thickest stems, but the thinnest were produced under weekly irrigation. Sidhu (70) at the A.R.E.C. observed that weekly irrigated plots produced thinner stems in grain sorghum than did plots irrigated bi-weekly.

Percentage of Leaf plus Head

Choudhry (13) at the A.R.E.C. observed that under weekly irrigations more leaves were produced by forage sorghum plants than when the interval between irrigations was increased. According to Leopold (40), Magness et al. observed that in mature leaves, wilting was associated with a depletion of the carbohydrate reserves of the leaf. If wilting was severe enough, leaf senescence followed even though the water supply was later restored. Hagan et al. (28) in Davis, California, reported that more and larger leaves were produced by Ladino clover plants growing in the most frequently irrigated plots. Arney (2) from a greenhouse trial found that in strawberry plants, the leaf production rate was reduced under dry condition.

According to Whyte *et al.* (78) Ripperton and Takahashi in Hawaii found that application of nitrogen to kikuyu grass (*Pennisetum clandestinum*, Hochst.) encouraged the formation of coarse, stemmy growth, but when unfertilized, the grass remained fine and leafy. Battikhah (3) reported that, under Lebanese conditions, banana plants fertilized by nitrogen produced more leaves in less time than did those plants not fertilized.

Growth Rate

Qureshi (59) at the A.R.E.C. reported that the growth rate of forage sorghum was markedly affected by irrigation frequencies. Irrigation at one week intervals resulted in a linear growth rate, whereas the effect of the other irrigation treatments were non-linear. According to Leopold (40), Gates demonstrated that the degree of growth inhibition was approximately related to the degree of wilting occurring, and that the growth inhibition may persist for several days after the wilting experience. Jung *et al.* (36) at Virginia, observed that the growth rate of sudangrass increased with a higher level of nitrogen fertilizer.

Denmead and Shaw (17) at Iowa, observed that under moisture stress the growth rate of corn declined. After watering, one to three days were required for stressed plants to recover and again elongate with the same rate as that of the non-stressed plants. Kemper (38) at Colorado, reported that a decrease in moisture level showed a decline in the growth rate of corn plants.

III. MATERIALS AND METHODS

An experiment was conducted in 1966 at the A.R.E.C., situated 80 kilometers east of Beirut in the Beqa'a plain, to study the effect of nitrogen fertilizer and irrigation on forage sorghum.

The design of the experiment was a split plot. The main plots were irrigation frequencies and the sub plots were the nitrogen levels. There were four replicates. There were six rows per plot, each five meters long and the distance between them was 50 cm.

The climate of the experimental area is semi arid with an average rainfall of about 400 mm, nearly all of which is received during the period from October to May. No rainfall is received from June through September which is the main growing season for summer annual crops. According to Fuehring et al. (23) the soil of the area is a calcareous clay type with a marked tendency to shrink and crack on drying and its pH is approximately eight. It has relatively good permeability, but is low in organic matter, nitrogen, and phosphorous. The area has a long growing season with high temperatures and low air humidity during the day which accentuates evapo-transpiration. During the growing season of this experiment the maximum temperature recorded was 38°C in August and the minimum

-0.7 occurred in May. During this period the distribution of rainfall was as follows: 2.6 mm in May; no rain in June, July, or August; 0.9 mm in September; and in October, prior to the date of the final harvest, 24.9 mm were received.

In April when the seedbed was prepared 12 kg of nitrogen per dunum[1] in the form of ammonium sulphonitrate were broadcast and worked into the soil with a light disking. On May 4 seed of the variety Beefbuilder was planted with a Planet Jr. planter at a heavy rate of seeding. When the plants were about eight to ten centimeters in height they were thinned by hand to obtain a stand 8 cm apart within the rows. Weeds were controlled by hand where necessary.

Irrigation

A sprinkler system of irrigation was followed for the first 6 weeks after planting. The water applied was measured and found to be 1.5 acre inches for each time of irrigation. Later, furrows were opened between the rows and from then on irrigation was done according to a schedule made for the four irrigation frequencies as follows:

I_1 - Irrigation at one week intervals.

I_2 - Irrigation at two week intervals.

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1. One dunum = 1000 square meters.

I_3 - Irrigation at three week intervals.

I_4 - Irrigation at four week intervals.

This procedure was followed till October 22, the date of the second harvest of all the plots.

The irrigation was done by means of gated pipes and the amount of the water running into each furrow was adjusted so that at each irrigation the moisture content of the soil was brought to field capacity.

The field capacity of the soil was measured by taking soil samples from six locations at the bottom of the furrows of each irrigation treatment 24 hours after each irrigation. The amount of water applied per irrigation by the furrow method was measured by inserting a flowmeter in the pipe bringing water to the plots. The number of irrigations by the furrow method were 18 for I_1, 9 for I_2, 6 for I_3, and 4 for I_4. The amounts of water that were applied by both the sprinkler and furrow methods during the whole growing season were as follows:

Treatment	Sprinkler	Furrow	Total acre inch
I_1	(6 x 1.5)	(18 x 2.65)	56.70
I_2	(6 x 1.5)	(9 x 2.76)	33.84
I_3	(6 x 1.5)	(6 x 2.85)	26.10
I_4	(6 x 1.5)	(4 x 3.10)	21.40

Nitrogen

There were three rates of nitrogen applied as subplots to the main plots. These were as follows:

N_1 - 12 kg of nitrogen per dunum.

N_2 - 24 kg of nitrogen per dunum in two equal portions.

N_3 - 36 kg of nitrogen in three equal portions.

The first 12 kg were broadcast over the whole experimental area prior to planting time. The first increment of 12 kg for the N_2 and N_3 plots was applied as a side dressing approximately four cm deep, on the following dates:

I_1 - June 24	I_3 - July 8
I_2 - June 30	I_4 - July 15

These dates were determined according to the irrigation frequencies of the main plots, the fertilizer being applied just prior to an irrigation in each case. The dates of application of the second increment for the N_3 plots were as follows:

I_1 - July 23	I_3 - July 29
I_2 - July 29	I_4 - August 12

Two cuttings were obtained from each treatment. The first cut was taken when most of the plants in a plot were fully headed out. The dates of harvesting for the different irrigation treatments were as follows:

I_1 - August 17	I_3 - September 13
I_2 - August 24	I_4 - September 16

All treatments were harvested a second time on October 22 after it was clear that no further growth would occur because of the coolness of the season.

To eliminate border effect, one half meter at each end of the rows was discarded, and only the two central rows of each plot were harvested. A one kg representative sample was taken for the determination of the dry matter and protein content of the forage materials produced from each plot. These samples were chopped into pieces three to five cm long and were dried in the open air in a cloth sack for about 40 days. Prior to determining the percentage of crude protein in these samples, they were placed in an oven for 48 hours at 75°C (68). Then a 15 g representative sample was ground in a Willey mill (a 40 mesh sieve was used), and the crude protein content was determined by the modified Kjeldahl method (35).

To observe the rate of growth in each irrigation treatment, daily height measurements were made on four representative plants during the period July 1 to July 31. To ensure that the height was determined accurately a small stake was fixed in the ground close to each plant and used as a base for the daily measurements. The plants were measured as fully extended to the tip of the tallest leaf. Prior to the second cut the heights of the same plants were measured at weekly intervals.

Three plants from each plot were selected at random, and from them the following agronomic details were determined: Thickness of the stems at the level of the second internode from the ground; percentage of leaf plus head; and plant height at harvesting time.

The field was inspected for pests during the growing season, but no evidence of infection or damage was observed.

To analyse the data, statistical methods appropriate to the split plot design were employed (39 and 70).

It was intended to determine the residual effects of the treatments on a following wheat crop, but events beyond the control of the author prevented this.

IV. RESULTS AND DISCUSSION

This experiment was conducted to determine the influence of four irrigation frequencies and three nitrogen levels on yield, protein content, and other agronomic characteristics of forage sorghum. The summarized data are presented in Tables 1-8.

Forage Yield

The total yield per plot, expressed as kg of dry matter per dunum, is summarized in Table 1. As the irrigation intervals were increased from one week to two, three, or four weeks, the yield decreased. The highest yield of dry matter was obtained from plots irrigated at one week intervals, and the lowest yield was from the plots that were irrigated after every four weeks. The differences between I_1 (weekly irrigated plots) and other irrigation treatments were significant statistically. The large differences between the yields of the I_1 and the other irrigation frequencies were caused by the moisture stress suffered by the plants watered at other than one week intervals. In the I_3 and I_4 treatments, firing of the tips of the leaves was observed prior to the first harvest.

The plants in the I_3 and I_4 plots did not produce a

Table 1. Effect of four irrigation frequencies and three levels of nitrogen on the total yield of forage sorghum (total of two harvests), expressed in kg of dry matter per dunum.

Nitrogen levels	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
N_1	2299.0	2001.7	1534.2	1180.1	1753.7
N_2	2678.2	2185.8	1605.8	1280.3	1934.7**
N_3	2830.5	2257.1	1615.1	1262.6	1991.2**
Irrigation means	2602.5	2147.8**	1585.0**	1237.5**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	62135
Irrigation	3	4353548**
Error (a)	8[1]	76248
Nitrogen	2	250347**
Irrigation x Nitrogen	6	46031*
Error (b)	24	15839

L.S.D.	5%	1%
Irrigation	260.3 kg/dunum	379.0 kg/dunum
Nitrogen	91.6 " "	124.1 " "
Irrigation x Nitrogen	183.3 " "	N.S.

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

* Significant at 5% level.

** Significant at 1% level.

measurable amount of new growth until approximately one week after being harvested. This delay in recovery was a direct result of the depletion of soil moisture by the plants in these plots. Growth in these plots was slow until the first irrigation, according to the schedule for each treatment, replenished the soil moisture supply.

Nitrogen increments also resulted in increased yield. The greatest amount of dry matter was obtained from the N_3, or 36 kg of nitrogen per dunum, treatment. The least was obtained from the N_1, or 12 kg of nitrogen per dunum treatment. The differences between the yields of the N_1, N_2, and N_3 treatments were significant statistically, although the difference between the yields of the N_2 and N_3 treatments was not. The first increment of nitrogen (an addition of 12 kg per dunum) caused an increase in the yield of dry matter equal to 181.0 kg per dunum, while the second increment increased the yield only 56.5 kg per dunum. From this it may be inferred that the first increment was used more efficiently by the plants than was the second. This was probably because, as is commonly known, the supply of nutrients must be proportional to the available moisture. Where the water was a limiting factor plants were not able to utilize large amounts of nutrients. When moisture supplies were adequate, an improvement in nutrient supply was observed to increase the water-use efficiency of the plants. Also, as stated by Leopold (40), Koontz and Biddulph found that some types of plants usually absorb most of the entire amount of nitrogen that is absorbed during the early stages of growth. Consequently, perhaps for this reason, these sorghum plants were able to utilize the first increment of nitrogen more efficiently than the second because the second increment was applied after this peak absorption stage had passed.

Considering the response of the plants to the combined effects of the two treatments nitrogen and irrigation, it can be concluded that the greatest yield was obtained from weekly irrigations and 36 kg of nitrogen per dunum, the I_1N_3 combination, the least from the I_4N_1 combination. In the I_1 treatment the increase in dry matter produced by the first 12 kg increment of nitrogen was 379.2 kg per dunum, but was only 152.3 kg from the second increment of nitrogen. When the irrigation intervals were extended to two, three, or four weeks, similar increases in yield were not observed from the same nitrogen increments. This agrees with the known closure of the stomata of plants under water stress, which results in a decrease in photosynthesis and a slower growth rate. In all the irrigation treatments the first increment of fertilizer caused a much greater increase in yield than did the second increment. In addition, the increase in dry matter resulting from the addition of the second increment was not significant statistically. Therefore, the best combination of irrigation and nitrogen treatment is I_1 (weekly irrigation) and N_3 (36 kg of nitrogen per dunum).

Protein Percentage of the First Harvest

Protein is a most valuable feed material and high quality forages contain greater amounts of protein. In Table 2 the data for percentage of protein in the dry matter from the first harvest is presented. It can be seen that protein percentage is related to irrigation frequencies and to nitrogen levels. The protein content decreases as the interval between irrigations decreases, but increases with increasing nitrogen levels. The protein content ranged from 5.08 percent in the I_1 treatment to 6.78 percent in the I_4 plots. The difference between I_1 and I_2 was not statistically significant but the differences between I_1 and I_3, and between I_1 and I_4 were highly significant. The higher protein percentage in the plants irrigated at three or four week intervals is a result of water stress experienced by these plants resulting in slow growth, limiting the retranslocation of inorganic nitrogenous materials to new growth areas. This caused a higher concentration of nitrogenous compounds per unit of dry matter in the plants. Water stress, preventing cell elongation although having little effect on cell multiplication,

Table 2. Effect of four irrigation frequencies and three levels of nitrogen on protein percentage of forage sorghum (first harvest).

Nitrogen levels	Irrigation frequencies I_1	I_2	I_3	I_4	Nitrogen means
N_1	4.63	4.44	5.23	5.76	6.01
N_2	4.97	5.91	6.15	7.44	6.11*
N_3	5.64	6.24	6.50	7.13	6.38*
Irrigation means	5.08	5.53	5.96**	6.78**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	1.87
Irrigation	3	6.24**
Error (a)	8[1]	0.375
Nitrogen	2	5.27*
Irrigation x Nitrogen	6	1.45
Error (b)	24	1.29

L.S.D.	5%	1%
Irrigation	0.58	0.84
Nitrogen	0.82	N.S.
Irrigation x Nitrogen	N.S.	N.S.

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

* Significant at 5% level.

** Significant at 1% level.

resulted in these plants having a nearly normal number of cells. Since each cell would be relatively small, the ratio of the cytoplasmic contents of these cells to the non-nitrogen containing parts would be higher than that of plants with cells of normal size. Plants suffering from water stress have been known to develop more extensive root systems, thereby being better able to absorb greater amounts of nitrogen as well as water from the soil. Perhaps in this case, the I_3 and I_4 plants had developed such root systems resulting in inordinately high levels of nitrogen. Since only crude protein content was determined, the high level found from these treatments may have been partly a result of this absorption and accumulation of nitrogen beyond the immediate needs of the plants concerned.

In the case of weekly irrigation, the plants did not suffer from a lack of moisture, so grew vigorously, and normal retranslocation of nitrogen took place from areas of early concentration to areas of new growth. This resulted in a lower overall protein percentage, but a greater overall yield of protein.

The effect of nitrogen on the protein was also evident. There was an increase from 5.01 percent for the plants receiving the N_1 treatment to 6.38 percent for those at the N_3 level. The differences between N_1 and N_2 and between N_1 and N_3 were significant statistically. The increase in percentage of protein probably resulted from the greater availability of nitrogen in the vicinity of the roots of the plants receiving the higher rates of this nutrient.

The interaction between irrigation and nitrogen was not significant statistically.

Protein Percentage in the Second Cut

In Table 3, it can be seen that in the second cut, as in the first, the percentage of protein is inversely related to irrigation frequency and directly related to nitrogen levels. However, the rate of increase in percentage, especially in the case of the I_3 and I_4 treatments, is higher than in the first harvest. The reason for this could be that plants, in the early stages of growth, contain higher percentages of nitrogenous materials and that these plants when harvested were in an earlier stage of growth when compared with the stage of the first cut.

Application of nitrogen increased the percentage of protein in the second cut as in the first. The rate of increase in protein percentage, as a result of the second increment of nitrogen, was greater than that of the first cut. The reason could be that since less nitrogen had been applied to the N_1 and N_2 plots, little or none would be left after the first harvest. However, as more had been applied to the N_3 plots, more would be left after

Table 3. Effect of four irrigation frequencies and three levels of nitrogen on the protein percentage of forage sorghum (second harvest).

Nitrogen levels	Irrigation frequencies I_1	I_2	I_3	I_4	Nitrogen means
N_1	4.72	5.07	8.53	9.13	6.86
N_2	5.47	5.90	9.08	10.80	7.81**
N_3	5.61	7.12	11.83	13.44	9.50**
Irrigation means	5.26	6.03	9.81**	11.12**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	1.61
Irrigation	3	97.51**
Error (a)	8[1]	1.003
Nitrogen	2	28.66**
Irrigation x Nitrogen	6	2.68**
Error (b)	24	0.29

L.S.D.	5%	1%
Irrigation	0.94363	1.3725
Nitrogen	0.3922	0.5312
Irrigation x Nitrogen	0.2492	0.3375

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

* Significant at 5% level.

** Significant at 1% level.

the first harvest, and consequently a greater response was observed.

Concerning the interaction between irrigation and nitrogen, the greatest protein percent was obtained from the I_4 and N_3 combination of treatments. The lowest protein percent was produced by the N_1 and I_1 combination of treatments. The rate of increase in nitrogen percentage due to the addition of the second nitrogen increment was higher than that of the first cut in all irrigation treatments, except for I_1. The reason for failure of the plants in I_1 to maintain the response to nitrogen exhibited by those of the other irrigation treatments could be a result of the high rate of uptake from those plots prior to the first harvest. In these plots, so much of the nitrogen had been absorbed that little was left for support of the regrowth.

Protein Yield

In Table 4 may be found the data concerning the influence of irrigation frequencies and nitrogen levels on total yields of protein in forage sorghum. It is clear that as irrigation intervals were increased the total protein yield decreased. The greatest yield of protein resulted from the I_1 or weekly irrigation treatment and the lowest from the I_4 or irrigation at four week intervals treatment.

Table 4. Effect of four irrigation frequencies and three levels of nitrogen on the protein content of forage sorghum (expressed as total protein in kg per dunum for two harvests).

Nitrogen levels	Irrigation frequencies I_1	I_2	I_3	I_4	Nitrogen means
N_1	109.0	98.7	84.7	63.7	88.8
N_2	136.9	123.0	99.7	89.0	112.1**
N_3	160.6	136.6	114.4	92.7	126.1**
Irrigation means	135.5	119.5*	99.6**	81.8**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	6504.33**
Irrigation	3	150.66
Error (a)	8[1]	239.85
Nitrogen	2	4880.00**
Irrigation x Nitrogen	6	292.00**
Error (b)	24	66.58

L.S.D.	5%	1%
Irrigation	14.60	21.23
Nitrogen	5.95	8.06
Irrigation x Nitrogen	11.86	16.07

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

* Significant at 5% level.

** Significant at 1% level.

Although the percentage of protein in the plants grown under the I_1 treatment was lower than that of all other irrigation treatments, these plots produced more protein per dunum since they also produced so much more dry matter. The difference between I_1 and I_2 was statistically significant, and the differences between I_1 and I_3, and between I_1 and I_4 were highly significant. The reason for these significant differences was the relatively lower yields of the I_3 and I_4 plots, even though, as discussed above, the percentage of nitrogen was higher in these plants.

An increase in the level of nitrogen resulted in a higher protein yield, the N_1 plots producing only 88.8 kg of protein per dunum, where the N_3 plots produced 126.1 kg. The first increment of nitrogen increased the yield of protein by 23.3 kg per dunum but the second increment only 14.0 kg per dunum.

The interaction between irrigation and nitrogen was highly significant. The first increment of nitrogen resulted in a significant increase in the yield of protein in all irrigation treatments. The second increment caused a further significant increase in all irrigation treatments, except in the I_4 treatment. This failure of the plants in the I_4 plots to respond to the extra nitrogen was probably a result of their inability to utilize the second increment of nitrogen because of the limited growth possible under these extreme moisture stress condition. However, the protein percentage in these plants was the highest of all the treatments.

Percentage of Leaves plus Heads (First Cut)

One of the characteristics of high quality hay is its leafiness. Considering the irrigation frequencies, it can be seen in Table 5 that the percentage of total dry matter contained in the leaves plus head decreased as the irrigation interval was increased. The highest percentage of leaves was obtained under the I_1 irrigation frequency, and the lowest under the I_4 irrigation frequency. The difference in leaf percentage between the I_1 and other irrigation frequencies was highly significant. The higher rate of growth and development due to availability of moisture throughout the growing period of the I_1 plots probably is responsible for the high percentage of leaves in the dry matter yield. In addition, plants in these plots produced bigger and more fully developed heads.

Increasing the rate of nitrogen application did not change significantly the percentage of leaves plus head. The interaction between irrigation and nitrogen was significant for the leaf percentage data.

Table 5. Effect of four irrigation frequencies and three levels of nitrogen on percentage of leaves plus heads in forage sorghum (first harvest).

Nitrogen levels	Irrigation frequencies I_1	I_2	I_3	I_4	Nitrogen means
N_1	25.20	23.15	20.10	17.72	21.54
N_2	25.75	23.90	19.07	18.85	21.89
N_3	25.75	23.20	20.90	18.37	22.05
Irrigation means	25.56	23.41**	20.03**	18.31**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	20.73**
Irrigation	3	138.66**
Error (a)	8[1]	2.16
Nitrogen	2	0.295
Irrigation x Nitrogen	6	1.796
Error (b)	24	2.30

L.S.D.	5%	1%
Irrigation	1.38%	2.01%
Nitrogen	N.S.	N.S.
Irrigation x Nitrogen	N.S.	N.S.

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

* Significant at 5% level.
** Significant at 1% level.

Stem Thickness

The measurements of stem thickness are summarized in Table 6. It can be seen that the thinnest stems were produced under I_1, the weekly irrigation treatment. The differences in thickness of stem between the I_1 and the other irrigation treatments were significant.

The different nitrogen levels did not result in any significant difference in thickness of stem. The interaction between irrigation and nitrogen level was not significant.

The reason for the thicker stems under moisture stress conditions may be that cell elongation was reduced, leaving thicker cell walls resulting in thicker stems. However, under a weekly irrigation frequency, where the plants suffered no water stress, cell elongation was normal, resulting in thin tall stems.

Plant Height (Determined prior to the First Harvest)

From the data in Table 7 it can be seen that plant height responded significantly to different irrigation frequencies. Less frequent irrigation resulted in shorter plants. The differences between the heights of the I_1 plants and those of the other irrigation treatments were highly significant. Nitrogen application had no significant

Table 6. Effect of four irrigation frequencies and three levels of nitrogen on stem thickness of forage sorghum (in cm).

Nitrogen levels	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
N_1	1.68	1.71	1.75	1.79	1.73
N_2	1.72	1.73	1.75	1.91	1.78
N_3	1.72	1.82	1.88	1.91	1.83
Irrigation means	1.71	1.75*	1.79*	1.87*	

Analysis of variance

Source	D.F.	M.S.
Replication	3	0.0133
Irrigation	3	0.0533*
Error (a)	8[1]	0.0112
Nitrogen	2	0.040
Irrigation x Nitrogen	6	0.0066
Error (b)	24	0.0120

L.S.D.	5%	1%
Irrigation	0.0315	N.S.
Nitrogen	N.S.	N.S.
Irrigation x Nitrogen	N.S.	N.S.

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

* Significant at 5% level.

Table 7. Effect of four irrigation frequencies and three levels of nitrogen on the height in cm of forage sorghum plants. Measurements made prior to the first harvest.

Nitrogen levels	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
N_1	270.75	223.75	180.25	173.50	212.06
N_2	275.25	225.00	193.75	177.25	217.81
N_3	286.50	233.75	191.75	172.75	221.18*
Irrigation means	277.50	227.50**	188.58**	174.50**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	645
Irrigation	3	25537**
Error (a)	8[1]	313.75
Nitrogen	2	340.5*
Irrigation x Nitrogen	6	92.33
Error (b)	24	71.08

L.S.D.	5%	1%
Irrigation	16.70 cm	24.29 cm
Nitrogen	6.07 cm	N.S.
Irrigation x Nitrogen	N.S.	N.S.

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

* Significant at 5% level.

** Significant at 1% level.

effect on plant height. The interaction between irrigation and nitrogen application also was not significant where the character plant height is considered.

Plant Height (Determined prior to the Second Harvest)

These data are presented in Table 8. The tallest plants were produced under the I_1 treatment and the shortest under the I_4 treatment. The differences between I_1 and I_3, and between I_1 and I_4 were highly significant statistically. However, the difference between I_1 and I_2 was not significant. The plants under the I_3 and I_4 treatments were much shorter at this harvest than they were at the time of the first harvest. These plants failed to grow taller because their first harvest date was about three weeks later than that of the I_1 and I_2 plots. In addition, regrowth of these I_3 and I_4 plants did not commence until they were irrigated three weeks after the first harvest. Thus these plants were forced to try to make their recovery later in the season, when cooler temperatures hindered rapid growth.

Nitrogen applications again resulted in an increase in the height of the plants in the second cut. The differences between the plants receiving the N_1 and N_2 treatments and between those receiving the N_1 and N_3 treatments were highly significant. These differences probably were a

Table 8. Effect of four irrigation frequencies and three levels of nitrogen on the height of forage sorghum plants in cm. Measurements made prior to the second harvest.

Nitrogen levels	Irrigation frequencies				Nitrogen means
	I_1	I_2	I_3	I_4	
N_1	133.50	133.75	63.75	42.75	93.56
N_2	166.00	173.25	71.25	50.25	112.06**
N_3	203.50	180.50	83.25	67.00	133.56**
Irrigation means	167.83	158.33	72.75**	53.33**	

Analysis of variance

Source	D.F.	M.S.
Replication	3	331.96**
Irrigation	3	40967.91
Error (a)	8[1]	354.83
Nitrogen	2	6412**
Irrigation x Nitrogen	6	545*
Error (b)	24	164.44

L.S.D.	5%	1%
Irrigation	17.79	25.89
Nitrogen	9.27	12.55
Irrigation x Nitrogen	18.66	N.S.

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

* Significant at 5% level.

** Significant at 1% level.

result of the effect of the nitrogen still available in the N_2 and N_3 plots.

The interaction between irrigation and nitrogen was significant. The tallest plants were produced under the I_1 and N_3 combination, and the shortest under the I_4-N_1 combination.

An interpretation of these data indicates that for this second harvest at least, there was little difference between the effects of the irrigation treatments I_1 and I_2 on plant height.

Growth Rate (Prior to the First Harvest)

The effect of irrigation frequencies on the daily rate of growth of the sorghum plants is shown graphically in Figure 1. It can be seen that growth was greatly influenced by irrigation intervals. The nitrogen level was the same for all irrigation treatments until July 23, when the weekly irrigated plots received the third portion of nitrogen.

In the weekly irrigated plots there was a more rapid rate of growth for the three or four days following an irrigation than during the last two days of the week, but the growth was continuous and did not completely stop. Plants receiving water at two week intervals started to grow rapidly the second day after an irrigation, but then the rate of growth decreased until it had stopped two or

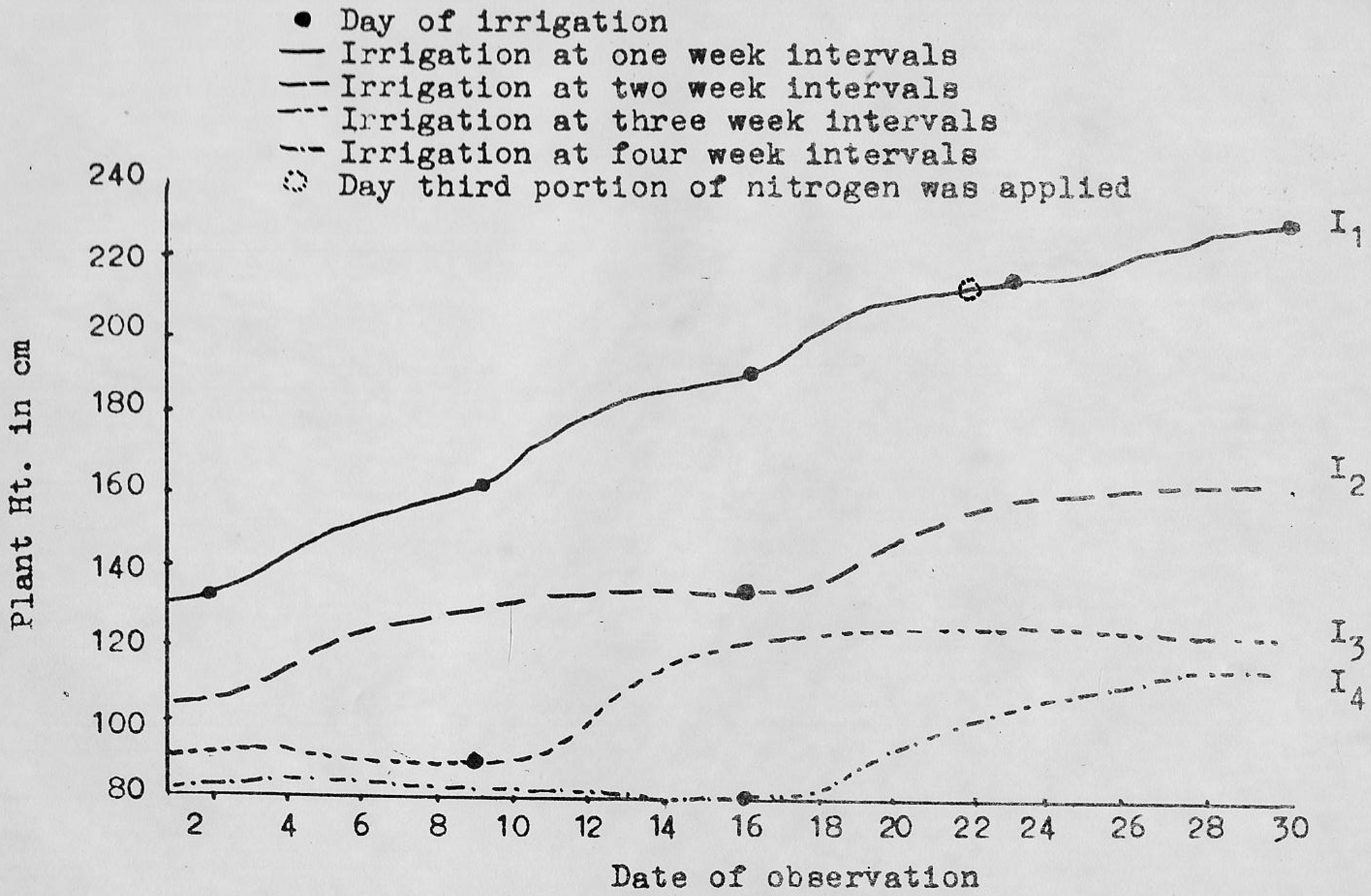

Figure 1. Effect of irrigation frequencies on the growth rate of sorghum plants. Measurements were made daily during July 1966, on four plants from each irrigation treatment.

three days before the next scheduled irrigation. The plants receiving water at three or four week intervals had stopped their growth at the end of the second week, the leaves had begun to roll, the tips had dried, wilting occurred, and the dried tips were lost. The depressions in the I_3 and I_4 curves were the result of this damage to the plants. After water was applied to the I_3 and I_4 plots, the plants did not recover and start to grow for two days.

Growth Rate (Prior to the Second Harvest)

Figure 2 shows the effect of irrigation frequencies on the weekly growth rate of the same plants as those measured prior to the first harvest. The curves are more linear for all irrigation treatments than for those of the first cut. Because of the cool temperatures through this period the rate of growth was very slow, and growth had almost stopped by the time of the second harvest. The I_3 and I_4 treatments did show a measurable amount of growth for only about one week after the first cut. The reason for such limited growth was that these plots were under a high moisture stress, and also daily temperatures were too low for optimum growth of sorghum.

It may be concluded from this study that, under the conditions of the Beqa'a, continuous rapid growth of sorghum plants cannot be obtained unless weekly irrigation is

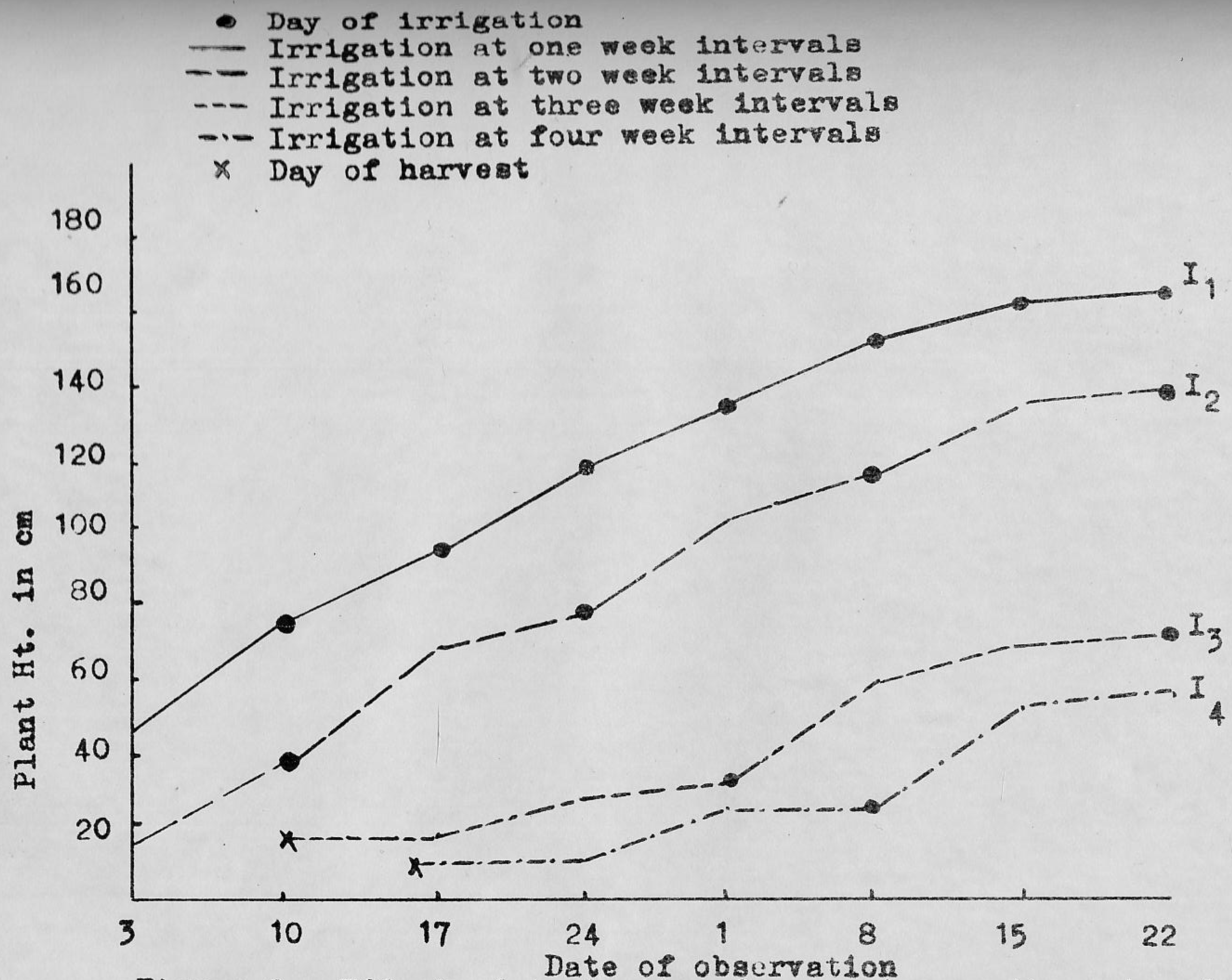

Figure 2. Effect of irrigation frequencies on the rate of regrowth after harvesting of forage sorghum. Measurements were made at weekly intervals. The plants selected were the same as those measured in July.

practised.

Economic Evaluation

It can be seen in Table 9 that under a weekly irrigation frequency, the expenditure of LL 12 for additional nitrogen (first increment) increased the monetary return from LL 218 to LL 244, a difference of LL 26. However, the second increment of nitrogen increased the return by only LL 3. This indicates that the second increment of nitrogen was not so profitable as the first.

Under the I_2 irrigation frequency the first increment of nitrogen increased the net return from LL 188 to LL 194 a difference of LL 6. However, application of the second increment resulted in a reduced profit. In the case of I_3 and I_4 the addition of the first and second increments resulted in serious decreases in return when the cost of the fertilizer was subtracted. On the basis of the above finding the best combination of irrigation frequency and nitrogen level is I_1 and either N_2 or N_3 where water is available for weekly irrigation.

Another evaluation was made on the basis of units of irrigation. If the amount of water available to a farmer for irrigation is fixed, but there is available extra land for him to rent, it may be possible for him to increase his fodder production by increasing his land area and decreasing his irrigation frequency. If the frequency of

Table 9. Estimated gross returns, above the nitrogen cost (LL)[1] from the four irrigation and three nitrogen treatments.

Nitrogen levels	Irrigation frequencies			
	I_1	I_2	I_3	I_4
N_1	218	188	141	106
N_2	244	194	136	103
N_3	247	190	125	90

Value of sorghum estimated at LP[2] 10 per kg of dry matter[3].

Value of nitrogen estimated at LL 1 per kg of nitrogen[4].

1. LL stands for Lebanese Pounds.
2. LP stands for Lebanese Piasters.
3. Value determined by private communication with Dr. K.V. Rottensten, Head of the Animal Production and Protection Division, Faculty of Agricultural Sciences. American University of Beirut.
4. Value determined by private communication with Dr. H.D. Fuehring, Head of the Soils and Irrigation Division, Faculty of Agricultural Sciences. American University of Beirut.

irrigation is changed from weekly intervals to two, three, or four week intervals, then two, three, or four times as much land can be irrigated with the same amount of water. This amount of water can be referred to as a unit of irrigation. To convert the monetary returns obtained from the irrigation frequencies tested, to an irrigation unit basis, each was multiplied by an appropriate factor, as follows:

1. The return from the I_2N_1 frequency as found in Table 9 to be LL 188 was multiplied by two since twice as much land could be irrigated with a unit of irrigation. Thus 2 x 188 = LL 376, the monetary return from the sorghum produced by irrigation at two week intervals. The return from the I_2N_2 frequency, LL 195 in Table 10, becomes 2 x 194 = LL 388, and the return for the I_2N_3 frequency, LL 190 in Table 9, becomes LL 380.

2. Similarly, the returns from the I_3 frequency given in Table 9 are multiplied by a factor of three, and the returns from the I_4 frequency given in Table 9 are multiplied by a factor of four.

These new estimates of returns, based on those possible from a unit of irrigation are summarized in Table 10. It can be seen from this evaluation that the returns from the I_3 and I_4 frequencies of irrigation appear to be more profitable than those from the I_1 or I_2 frequencies. However, in this unit of irrigation system of evaluation,

Table 10. Estimated returns (LL) less the nitrogen cost from the four irrigation and three nitrogen treatments based on a unit of irrigation[1].

Nitrogen levels	Irrigation frequencies			
	I_1	I_2[2]	I_3[3]	I_4[4]
N_1	218	376	423	424
N_2	244	388	408	412
N_3	247	380	375	360

1. The unit of irrigation is the amount of water that was applied to plots under the weekly irrigation treatment.
2. Since twice the land area can be irrigated with a unit of irrigation if the interval between irrigations is doubled the net return from the I_2 treatment given in Table 10 has been multiplied by two.
3. Since three times the land area can be irrigated with a unit of irrigation the net return from the I_3 treatment given in Table 10 has been multiplied by three.
4. Since four times the land area can be irrigated with a unit of irrigation the net return from the I_4 treatment given in Table 10 has been multiplied by four.

the fixed costs for production must also be considered. When two, three, or four times as much land and fertilizer are used to exploit fully the irrigation unit, these fixed costs will also be increased by factors of two, three, or four respectively.

The fixed costs have been estimated as follows[1]:

1.	Land preparation	LL 5.00
2.	Planting	LL 4.00
3.	Land rent	LL31.00
4.	Labor for harvesting	LL 8.00
5.	Labor for fertilizer application	LL 1.50
6.	Seed cost	LL 0.50
	Total LL	50.00 per dunum

This total of LL 50 is the estimate of the total expenses of production (less cost of irrigation and nitrogen) of one dunum of sorghum under Beqa'a conditions. To determine a final evaluation of the monetary returns from this nitrogen and irrigation experiment, the data in Table 11 were adjusted and summarized as follows:

1. From each of the returns listed under I_1, the fixed cost of LL 50, 51.5 and 53 was subtracted, respectively. The differences between these fixed cost estimates are due to the cost of application of the first and second increments of nitrogen.

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1. These estimates prepared in private consultation with Dr. G. Ward, Head of Agricultural Economics and Rural Sociology Division, Faculty of Agricultural Sciences. American University of Beirut.

Table 11. Estimated net returns (LL) less the cost of nitrogen and other expenses for each irrigation and nitrogen combination of treatments, based on a unit of irrigation.

Nitrogen levels	Irrigation frequencies			
	I_1	I_2	I_3	I_4
N_1	168.0	276.0	273.0	224.0
N_2	192.5	285.0	253.5	206.0
N_3	194.0	274.0	216.0	148.0

2. From each of the returns listed under I_2 where one unit of irrigation can be used to irrigate twice as much land, twice the fixed costs estimate must be deducted. Thus LL 100, 103, and 106 must be subtracted from the I_2N_1, I_2N_2 and I_2N_3 returns, respectively.

3. From each of the returns listed under I_3 where one unit of irrigation can be used to irrigate three times as much land, three times the fixed costs estimate must be deducted. Thus LL 150, 154.50, and 159 must be subtracted from the I_3N_1, I_3N_2, and I_3N_3 returns, respectively.

4. From each of the returns listed under the I_4 the fixed costs were multiplied by four, ie. LL 200, 206, and 212 must be subtracted, respectively. It can be seen from Table 11 that the greatest net income was obtained from the I_2N_2 combination of treatments.

In addition the low quality of the fodder produced by the I_3 and I_4 treatments further emphasizes that such lengthy irrigation intervals are not practical.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This experiment was conducted during the year 1966 at the Agricultural Research and Education Center, of the American University of Beirut, located in the Beqa'a plain of Lebanon. The objectives were to determine the effect of four irrigation frequencies and three nitrogen levels on total dry matter yields, protein content, protein yield, and other agronomic characteristics of a variety of forage sorghum called Beefbuilder. The design of the experiment was a split plot. The irrigation frequencies and nitrogen levels studied were as follows:

<u>Irrigation frequencies</u>

I_1 - Irrigation at one week intervals.

I_2 - Irrigation at two week intervals.

I_3 - Irrigation at three week intervals.

I_4 - Irrigation at four week intervals.

<u>Nitrogen levels</u>

N_1 - 12 kg of nitrogen per dunum applied prior to planting time.

N_2 - 24 kg of nitrogen per dunum, in two equal portions, 12 kg prior to planting and an increment of 12 kg as a side dressing.

N_3 - 36 kg of nitrogen per dunum, in three equal portions, 12 kg prior to planting and two side dressings at the rate of 12 kg each.

The plots were harvested twice. The greatest total yield of dry matter was obtained from the I_1 plots. The differences in yield between the I_1 and the other treatments were highly significant statistically.

Nitrogen rates also had a direct influence on total yields of dry matter. The differences in yield between N_1 and the other nitrogen treatments studied were also highly significant statistically. The interaction between irrigation intervals and nitrogen rates was significant, and the largest amount of dry matter was produced by the I_1N_3 combination of treatments.

The protein percentage of the plants at the time of the first harvest was affected by both nitrogen rates and irrigation frequencies. The weekly irrigated plots produced plants with a lower percentage of protein than did the other irrigation frequencies. However, in spite of their lower protein percentage, the I_1 plants produced more protein per dunum because of their greater production of dry matter. The percentage of protein in the sorghum plants of the second cut followed the same pattern.

The percentage of leaf plus head and the thickness of the stems were affected significantly by irrigation frequencies. The highest percentage of leaf plus head and thinnest stems were produced under the I_1 irrigation treatment. These characters were not affected significantly by the nitrogen levels studied.

The heights of the plants at the time of the first harvest were significantly different as affected by the different irrigation frequencies. The tallest plants were produced under the I_1 and the shortest under the I_4 irrigation frequencies. The same results were obtained for these plants at the time of the second harvest, except that the difference between the heights of the I_1 and the I_2 plants was not significant. Nitrogen rates had a direct influence on plant heights, the tallest plants being produced under the N_3 treatment.

The daily growth rates of the plants prior to the first harvest were influenced by irrigation frequencies. The weekly irrigation curve showed a constant increase in height. The growth curve of plants irrigated bi-weekly showed a sharp increase in growth rate which started one day after irrigation. This was followed by a gradual decrease in rate until eventually, near the end of the second week no further increase in height was observed. The growth rate curve of the plants getting water at three or four week intervals was markedly non-linear. In these two irrigation treatments the plants were wilted severely and, as the tips of the leaves were dried and broken, the plants decreased in height toward the end of each irrigation interval. The weekly growth rate curves, determined for the same plants again, prior to the second harvest were more linear.

According to this experiment the following conclusions can be made:

1. The total dry matter and protein yields per dunum from the two harvests were greatest under the weekly irrigation treatment. This treatment also produced the tallest plants with the thinnest stems and with a higher percentage of leaves plus heads.

2. The rate of 36 kg of nitrogen per dunum resulted in the greatest total dry matter and protein yield per dunum. The plants receiving this high rate were taller than were those receiving lesser amounts of nitrogen. The first increment of nitrogen resulted in a greater increase in yield of dry matter than did the second increment. The thickness of stem and the percentage of leaves plus heads were only slightly affected by nitrogen rates.

3. The protein percentage of the plants increased significantly as the irrigation interval was extended from one to two, three, and four weeks.

4. Increasing the nitrogen level increased the percentage of protein. The highest percentage of protein was obtained from the I_4 and N_3 combination of treatments. The protein percentage in the second harvest was much higher than that of the first harvest. This was especially

so for the I_3 and I_4 irrigation treatments.

5. The growth rate of the plants was affected by the irrigation intervals. When the interval between irrigations was increased to more than two weeks very limited growth resulted. When irrigation intervals were extended beyond one week a period of one or two days was required after each irrigation, before the plants were able to recover and resume a normal growth rate.

On the basis of this experiment the following recommendations can be made:

1. Where irrigation water is not a limiting factor but land is, the best combination of treatments for higher net profit is I_1N_2.

2. Where irrigation water is limited but where there is more land available than can be irrigated weekly, more fodder of comparable quality could be obtained by applying the I_2N_2 combination of treatments. That is , twice as much land, irrigated half as often will produce economically the greatest return.

3. Experiments in more detail,that is using smaller increments of nitrogen applied more frequently at earlier stages of growth must be conducted to find the best combination of irrigation and nitrogen treatments.

4. Since the experimental area is a good corn producing area and corn forage is known to be more valuable than sorghum forage, this experiment should be expanded

to include both of these crops.

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