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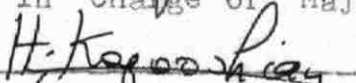
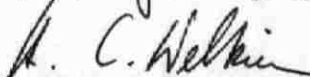
EFFECT OF SUPPLEMENTARY IRRIGATIONS ON YIELD  
AND OTHER CHARACTERISTICS OF  
FORAGE SORGHUM


by  
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Irrigated Forage Sorghum

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## ABSTRACT

An experiment was conducted at the Agricultural Research and Education Centre of the American University of Beirut located in the north central Beqa'a plain, Lebanon, in 1963 to study the effect of supplementary irrigations on the yield and other plant characteristics of forage sorghums. Supplemental irrigation significantly increased the yield, plant height, number of tillers and leaves per plant. The greatest amount of silage and total protein was produced under weekly irrigations. Taller and thinner plants, and more tillers and leaves were also obtained from plots that received weekly irrigations.

Irrigation affected the quality of the forage. The twice-irrigated plants produced the greatest percentage of protein followed by the once-irrigated and non-irrigated plants. The weekly irrigated plants contained the smallest percentage of protein. Percentage dry-matter was decreased with the increased number of irrigations. The irrigated plants were usually of high water content.

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## INTRODUCTION

Sorghum (Sorghum vulgare) is not very exacting in its requirements of soil and moisture and can give good yields of fodder and grain under conditions where most other farm crops fail. Due to a versatile habit of growth and high yielding capacity, sorghums are becoming more popular all over the world.

The development of hybrid forage sorghum varieties with adapted characteristics has influenced world use of this crop. Judicious use of fertilizers, proper seeding rate, carefully arranged time of sowing and staggered dates of harvesting make forage sorghum a crop with great potentialities. Production could be increased if more were known about the irrigation requirements of this crop. Being a drought resistant crop, it will grow under limited moisture conditions but much higher yields can be obtained if irrigation facilities are available.

Supplemental irrigation is needed for the production of forage sorghum under the prevailing conditions of the Beqa'a plain. In this area little or no rainfall is received during the entire growing season of the crop, and the long growing season, high temperatures and low air-humidity accentuate evapo-transpiration. Production of more than one

cutting in a single year from the development of new tillers, depends on the availability of water.

The objective of this experiment was to study the effect of supplementary irrigations on the yield and quality of forage sorghum varieties. In addition, the effects on plant height, number of tillers and leaves per plant, and thickness of stem per plant were studied.



## REVIEW OF LITERATURE

Profitable yields of sorghum depend to a large extent upon good cultural practices. One of the basic cultural practices of paramount importance recognized by agronomists as affecting forage production, is irrigation. The following is a review of the available information pertaining to the effect of irrigation on the yield and other characters of forage sorghum.

### Forage Yield

Prato et al. (34) claimed that production of forage sorghum has been most successful where the crop is grown under irrigation. Worzella et al. (44) at the Agricultural Research and Education Centre of the A.U.B. reported from trials covering a four year period. Ten varieties of forage sorghum were tested under irrigation. The average yields ranged from 1.7 to 3.6 tons per dunum. The varieties Axtel and Rox yielded 3.2 and 2.9 tons per dunum, respectively. According to Karper and Quinby (20), Ross and Webster (39), and Wilson and Mayers (42), although sorghum is drought resistance, it responded very well to irrigation. High yields of fodder and grain were not obtained without irrigation. Higgins and Owens (15), and Wallace and Bressman (41), held the same view regarding corn for silage. Marrio et al. (23) discussed the increasing popularity of

forage sorghum. Average production under Texas conditions is six to ten tons per acre on dry land and up to 30 tons under irrigation. Robert and Manges (37) observed that forage sorghums averaged twelve tons per acre on dry land and 24 tons under irrigation. According to results obtained by Quinby and Marion (35) the use of irrigation increases forage sorghum production per acre in comparison with dry land production. Investigations carried out by Brown and Benedict (5) showed that an increase ranging from 15 to 23 tons of forage per acre was directly a result of the irrigation treatments tested. According to Jones et al.(19) sudan grass gave yields from seven to ten tons per acre under irrigated conditions and two to five tons on dry land. Olson and Kapusta (28) studied the yields of silage maize and other crops grown under dry land and under irrigated conditions. All yielded more than twice as much when irrigated as compared to dry land production. According to Boehle et al.(3), Elken studied the effect of supplemental irrigation on the yields of ten forage crops. Yield increases ranged from 1340 pounds to 1616 pounds per acre. The work of a number of other investigators (1, 8, 12, 14, 24, 27, 30) indicated that high yields of fodder and grain sorghum can be produced with application of irrigation water.

According to many authors (2, 10, 21, 39, 43) the maximum yield of sorghum can be obtained with two to four irrigations. This is dependent on climatic conditions,

supply of water and texture of soil. According to Roe (38), Singleton made similar observations on corn grown for silage. Owens and Ensign (29) were able to grow a satisfactory silage crop of corn with only two irrigations, providing soil moisture at planting time was good. Moustafa et al. (26) studied the effect of time of irrigation on the yield of maize. It was concluded that yield increased according to the increase in the number of irrigations.

Gonzales et al. (11) found a significant relation between different weekly irrigation rates and their respective yields. Brown and Shrader (6) proved that increasing plant populations at various moisture levels resulted in increased forage production of Martin grain sorghum.

Houk (17) reviewed the work of McDowell and of Marr. McDowell showed an optimum irrigation application of about three feet of water for sorghum under eastern Texas conditions, where the annual rainfall was 15.82 inches. Marr in Arizona, where the annual rainfall was seven inches, got maximum yields of grain sorghum with about one and half feet of irrigation water. It seems evident that evapo-transpiration is higher in eastern Texas than it is in Arizona. Pitman and Stewart (32) concluded that corn yields increased with increased amounts of irrigation water up to a level of 20 inches of water applied. The yields changed little as the water was increased from 20 to 30 inches, above which there was a decrease in yield.

In a lysimeter experiment (4), sorghum was grown on sandy soils where the water table was maintained at different depths. It was found that plants grown with the water table at 24 inches yielded best. With the water table at twelve inches, the yield was only ten percent of that produced with the water table at 24 inches. With the water table at 36 inches, yields were 96 percent as much as when the water table was at 24 inches.

Raney (36) estimated that usually less than two acre inches of water was required to produce an extra ton of dry forage of sudan grass, sorghum and corn for silage. According to Moustafa et al. (26), King indicated a requirement of approximately three acre inches of water per ton of dry matter for dent corn and two for flint corn. According to Houk (17), Power and Lewis determined that there is a water requirement of about one inch per ton of corn silage.

#### Protein Percentage

Limited data are available on the effect of irrigation treatments on the protein content of forage and grain sorghum. Quinby and Marion (35) discovered that percentage of protein was lowest under irrigated conditions and highest on dry land. It was observed that high forage yields were accompanied by high yield of protein per acre. Ross and Webster (39) mentioned that grain sorghum grown in dry areas and in dry years, invariably is significantly higher in protein content

than the same varieties grown in humid areas or under irrigation. Patel and Shah (31) on the contrary reported that sorghum grown on irrigated plots contained a greater percentage of protein as compared to non-irrigated ones.

Roe (38) stated that percentage of protein markedly decreased with increased use of water. The total yields of protein tended to increase with fewer irrigations. According to Carleton (7), Widtsoe and Stewart reported that the percentage of protein in all parts of cereal crops increased as irrigation was decreased.

According to Boyd et al. (4), Stephens et al. found that when sorghum was grown with the water table at 36 inches, the protein content was approximately eight percent. With the water table at 24 inches, the protein content was six percent and when the water table was maintained at twelve inches the protein content was only three percent.

#### Plant Height

Studies in Kansas (25) with sudan grass and sorghum varieties indicated that when the moisture was maintained at constant levels, plants reached maximum heights. Howe and Rhoades (18) and MacGillivray (22) observed that maximum height of corn was obtained where soil moisture was maintained at optimum levels during the growing season of the crop. According to Carleton (7), Welch gave average results of four years' work at Gooding, Idaho, on the water

requirements of barley. It was found that the plants which received the most water were three inches taller than those which received the least.

Denmead and Shah (9) demonstrated that when moisture stress was applied during the growth of the plants, stalk height was reduced considerably as compared to check where no moisture stress was imposed at any stage of growth.

In general, the existing literature on the effect of irrigation on the yield and quality of forage sorghums indicated that the yield was increased, but percent protein decreased with increased use of irrigation water. It has also been observed that taller plants resulted where irrigation was practiced.

## MATERIALS AND METHODS

An irrigation experiment on forage sorghum was conducted during the year 1963, at the Agricultural Research and Education Centre of the American University of Beirut located in the north central Beqa'a plain, Lebanon. This area is characterized by 375 to 400 mm of winter rain and rainless summer months. In general, the soil is high in clay content, low in organic matter, nitrogen and phosphorous, high in potassium content and is well-drained with a pH of about 8.0 (44). A good seed bed was prepared and the land was levelled to facilitate more uniform and even distribution of irrigation water to the plots. Two similar varieties, Axtel and Rox, were evaluated for their performance under four irrigation treatments. These varieties were known to be well adapted to the production of fodder under irrigation, in the Beqa'a plain (44).

Twelve kilograms of nitrogen in the form of ammonium sulphonitrate and twenty kilograms of  $P_2O_5$  in the form of superphosphate per dunum were broadcast and worked into the soil by disking prior to planting. On May 8, 1963, planting, using a V-belt seeder, was begun. On this date the soil temperature was about  $18^{\circ}C$ , a temperature suited to germination of sorghum seed. When 1.5 mm. of rain fell

in the afternoon of May 8, it was not possible to complete planting of all the plots. All of replication one was completed on May 8, and the remaining three replications were seeded on May 11, 1963, when the soil had dried sufficiently to permit the resumption of seeding. The planting was made thickly using 65 seeds per five meter row. When the plants were 10 to 15 centimeters tall they were thinned so there was a space of approximately 10 centimeters between plants within the rows. This spacing gave a population of about thirteen thousand plants per dunum. Where there was poor germination replanting was done by hand to maintain a between plant spacing of 10 cms.

To ensure uniform stand establishment all the plots were irrigated on May 14, by sprinklers as a pre-emergence irrigation. The following irrigation treatments (frequencies) were used:

1. Check (One pre-emergence irrigation with sprinklers).  
This treatment, will be referred to as the no irrigation treatment throughout the text of this thesis, because it received no post-emergence irrigations.
2. Irrigated once, two weeks after seeding of the crop.  
(One pre-emergence sprinkler irrigation applied to ensure uniform germination).
3. Irrigated twice, two weeks after seeding, and again three weeks after seeding of the crop using the sprinkler method for both irrigations. (One pre-emergence sprinkler



irrigation applied to ensure uniform germination).

4. Irrigated at weekly intervals throughout the growing season of the crop. The first two irrigations were applied by sprinkler method, later irrigations were by the furrow method. (One pre-emergence sprinkler irrigation applied to ensure uniform germination).

The first two irrigations were applied with sprinklers because the seedlings were too small to permit the opening of furrows for furrow irrigation. Subsequently the furrow method with a gated pipe was used for irrigation of the plots during this experiment.

At each irrigation, sufficient water was applied to return the moisture content to field capacity. The field capacity was determined by taking soil samples 24 hours after irrigation. It was found that this soil has a field capacity of about 32 percent moisture. The amount of water applied per irrigation with the sprinkler system was 1.6 inches at a pressure of 40 pounds per square inch. The amount of water applied per irrigation by the furrow method was also measured. Collection of the water in buckets as it was released from the gated pipe, enabled an estimation of the amount of water applied per irrigation. When the amount of water applied to the furrow was sufficient to bring the soil to field capacity, the application of water to the furrow was stopped. Repeated collections were averaged to determine an estimate of approximately two inches of water

applied per irrigation with the furrow method. The total amount of water applied to the various treatments prior to first cutting were, therefore, 1.6, 3.2, 4.8 and 26.8 inches for the treatments numbered 1, 2, 3, and 4, respectively. These totals include the 1.6 inches applied as a pre-emergence irrigation.

The experiment was laid out in a split-plot design with four replications. The main plots consisted of the irrigation treatments. Superimposed on each of the main plots were the two varieties randomized as sub-plots. Each variety plot consisted of six rows, spaced 75 cms. apart and five meters long.

Hand weeding was performed regularly until the boot stage when sorghum plants were able to compete with the weeds.

Data were recorded on forage yield, plant height, number of tillers and leaves per plant, and thickness of stems.

Harvesting was done with hand sickles, cutting the sorghum plants four inches from the ground so that they would recover and tiller readily. Four meters from the two middle rows of each plot were harvested for forage yield. Each treatment was harvested when it was thought that the plants had reached a stage of development when maximum quantity and quality of forage could be obtained. This stage of development was when the plants had attained

full growth, but before leaf loss, as a result of advanced maturity, had occurred. The dates of harvesting of the four irrigation treatments were as follows:

Irrigation treatment	Date of harvesting	
	1st cutting	2nd cutting
1. No irrigation	August 9	October 12
2. One irrigation	August 16	October 12
3. Two irrigations	August 24	November 5
4. Weekly irrigations	August 16	November 5

Immediately after a plot was harvested it was irrigated to stimulate regrowth. The check plot was also given this one irrigation, but no subsequent irrigations. It was intended that plots receiving treatments 2, 3, and 4, be again subjected to the appropriate irrigation frequencies following the one post harvesting irrigation. However, a misunderstanding led to one extra irrigation being applied the second week after the second harvest to treatments 2, and 3. During the second irrigation period (that following first cutting) the four treatments received 2, 6, 8 and 22 inches of water, respectively.

Green weights were recorded and the yield data were based on the total production i.e., first cutting plus second cutting. For calculation of the air-dry yield of fodder all the material from the plots of treatments 1 and 2 was placed in separate cloth bags and dried in the sun for about four weeks. Representative 10 pound samples were taken from each of the plots of treatments, 3 and 4 and

air-dried for about one month. The air-dry forage was weighed and chopped into half inch lengths. For the determination of percent dry-matter, representative samples of the chopped material were taken in duplicate and dried in an oven at 110°C for 48 hours. Calculation of air-dry fodder and percent dry-matter from the second cutting was done in the same manner as described above for the first harvested material.

Plant color and vigor at each harvest date were observed. It was found that plants of treatments 1 and 2 appeared dry and growth was retarded. These plants did not attain nearly the stature of those of treatments 3 and 4. The plants of treatment 3 were of normal color, but growth was somewhat reduced as compared to treatment 4. The plants of treatment 4 showed vigorous growth with a healthy deep green color. Prior to second cutting the plants of treatments 3 and 4 were slightly yellowish in appearance suggesting nitrogen deficiency symptoms. The plants subjected to the remaining treatments had normal growth and green color.

For protein determination, a representative sample of each plot was ground in a Wiley mill using 20 mesh seive and the ground material was collected and stored in screw top bottles prior to chemical analysis.

Nitrogen was determined by a modified Kjeldahl method, as detailed in the Official Methods of Analysis of the Association of Official Agricultural Chemists (16).

The nitrogen values obtained were multiplied by the factor 6.25 to convert to crude protein percentage (13).

Statistical analyses of the data were done by a method appropriate to the design as described by Snedecor (40).

## RESULTS AND DISCUSSION

This experiment was designed to determine the effect of supplementary irrigations on the yield and other characteristics of forage sorghums. Data concerning forage yield, percent of dry-matter, plant height, number of tillers and leaves per plant, thickness of stems, percent protein and total protein for two forage sorghum varieties are reported in Tables 1 to 8.

### Forage Yield

The data for forage yield produced under four different irrigation treatments are summarized in Table 1. It is evident that irrigation resulted in increased forage yields. The increase in yield resulting from only one irrigation was not significant when compared to the check or no irrigation treatment. The highest forage yield which amounted to 3.45 tons of air-dry fodder per dunum was achieved under weekly irrigations. The lowest forage yield of 0.86 tons of air-dry fodder was secured from the non-irrigated or check plots. There was a direct relationship between forage yields and the amount of irrigation water applied. The weekly irrigations quadrupled the forage yield from plots which had received no irrigation, trebled the

Table 1. Effect of supplementary irrigations on the average forage yield in tons per dunum of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Forage yield in tons per dunum					
	Variety				Average for irrigation treatment	
	Axtel		Rox			
	Green	Air-dry	Green	Air-dry	Green	Air-dry
No irrigation	3.37	0.82	3.03	0.91	3.20	0.86
One irrigation	3.84	0.94	3.89	0.95	3.86	0.94
Two irrigations	6.17	1.72	6.11	1.66	6.14	1.69
Weekly irrigations	13.12	3.58	12.58	3.33	12.85	3.45
Variety average	6.62	1.76	6.40	1.71		
Difference required for significance between average air-dry forage yield for irrigation treatments at the one percent level of probability:					0.25 tons per dunum	
Difference between varieties: not significant						
Interaction between irrigation and variety: not significant						

yield over that from one irrigation and doubled the yield over that from two irrigations. These results are in close agreement with the well known fact that production is closely associated with water availability. The high yields of forage under weekly irrigations may be attributed to the maximum plant growth and development which resulted. These results emphasize that supplementary irrigations will greatly increase forage production per unit area.

There were no significant differences between forage yields of the two varieties. In the absence of interaction between irrigation treatments and varieties, it can be concluded that both varieties responded similarly to the irrigation treatments. The results obtained under the conditions of this experiment are in agreement with the findings of several other investigators (5,34,35,44).

#### Percent Dry-matter

The percentage dry-matter in the forage harvested is presented in Table 2. It is evident that there was a reduction in dry-matter percentage as the amount of irrigation water was increased. This is probably a result of larger yields under irrigation. This is in agreement with the known fact that forages produced under dry land conditions usually contain a higher percent of dry-matter than do those grown under irrigated conditions.

There was a significant interaction between



irrigation and variety. This shows that the variety Axtel gave a greater response to irrigation treatments than did Rox. The variety Axtel contained a higher percentage of dry-matter than did Rox. On the basis of the yield and percent of dry-matter, the variety Axtel appears to be better for forage production under irrigated conditions in the north central Beqa'a plain, Lebanon.

#### Plant Height

Plant height is known to have a close association with the yield of forage crops. Five plants per plot were selected at random to be measured at harvesting time and the average heights are given in Table 3. It was observed that the irrigated plants were taller than the non-irrigated ones. The greatest height was attained under weekly irrigations. The lowest height was recorded from the non-irrigated plants.

The analysis of the data revealed that the increase in height resulting from one or two irrigations was not significant when compared with the check or no irrigation treatment. A highly significant interaction indicated that the varieties did not react similarly to the different irrigation treatments. This demonstrates that the variety Axtel responded with taller plants where irrigation was more frequent than did Rox. It is interesting that the variety which produced the taller plants, gave higher

Table 2. Effect of supplementary irrigations on percentage of dry-matter of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Percent dry-matter		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	22.82	21.19	22.00
One irrigation	21.49	20.94	21.21
Two irrigations	21.52	19.46	20.49
Weekly irrigations	20.21	19.36	19.78
Variety average	21.51	20.23	
Difference required for significance between averages for irrigations at the one percent level of probability:			1.01
Difference required for significance between averages for varieties at the one percent level of probability:			0.18
Difference required for significance of interaction between irrigation and variety at the one percent level of probability:			0.35

forage yields. This is in agreement with Poehlman (33) who stated that plant height is one of the vital components of forage yields of sorghum.

#### Number of Tillers per Plant

An increase in number of tillers per plant is often accompanied by better quality and yield of fodder. The number of tillers per plant counted at harvesting time is recorded in Table 4.

It is obvious that a greater number of tillers were produced by those plants irrigated only twice, and by those irrigated weekly. Fewer tillers were produced by the less frequently irrigated plants, namely, those irrigated only once, and those not irrigated at all. It is noteworthy that tillering appeared to be a contributing factor towards increased forage yield. It should also be noted that a direct relationship appears to exist between number of tillers and the number of leaves per plant. This capacity to produce more tillers per plant is of practical importance in enabling the plants to take full advantage of the space, nutrients and moisture available in the soil.

There was no significant difference in the tillering ability of the two varieties under study. The results obtained under the conditions of this trial indicate that although tillering is genetic character it was modified by the irrigation treatments employed.

Table 3. Effect of supplementary irrigations on plant height of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Plant height in centimeters		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	119.00	106.31	112.65
One irrigation	120.66	111.94	116.30
Two irrigations	129.12	118.12	123.62
Weekly irrigations	226.81	213.94	220.37
Variety average	148.89	137.57	
Difference required for significance between averages for irrigations at the one percent level of probability:			13.65 cms.
Difference required for significance between averages for varieties at the one percent level of probability:			2.78 cms.
Difference required for significance of interaction between irrigation and variety at the one percent level of probability:			5.74 cms.

Table 4. Effect of supplementary irrigations on the number of tillers per plant of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Number of tillers per plant		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	4.0	4.0	4.0
One irrigation	4.5	4.2	4.3
Two irrigations	4.7	4.7	4.7
Weekly irrigations	4.7	4.7	4.7
Variety average	4.5	4.4	
Difference required for significance between averages for irrigations at the one percent level of probability:			0.5
Difference between varieties:		Not significant	
Interaction between irrigation and variety:		Not significant	

### Number of Leaves per Plant

More leaves per plant increase the palatability and nutritive value of the forage. In addition, this substantially increases the total carbohydrate manufacturing area of the plant, playing a vital role in determining the ultimate size of the mature plants.

Five plants per plot were selected at random, and the number of leaves per plant were counted at harvesting time. The data presented in Table 5 clearly indicate that all the irrigated plants produced more leaves than did the non-irrigated ones. It is also shown that as more frequent irrigations were applied, a greater number of leaves were formed. Since the leaf is the seat of manufacture of carbohydrates, an increase in the number of leaves may in turn mean a greater degree of performance by the plants. This could possibly create a further problem of fertilizer requirements, in that soil nutrients may become factors limiting both yield and quality of forage when plentiful moisture supplies are available to the plants. Therefore, for maximum yields, irrigation and fertilization must be in proper balance.

There was no significant difference in leaf production between the two varieties included in this trial.

### Thickness of Stalk

Thinner and taller plants of sorghum are very

Table 5. Effect of supplementary irrigations on the number of leaves per plant of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Number of leaves per plant		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	6.2	6.9	6.5
One irrigation	8.1	7.8	7.9
Two irrigations	8.4	8.1	8.2
Weekly irrigations	11.5	11.5	11.5
Variety average	8.5	8.5	
Difference required for significance between averages for irrigations at the one percent level of probability:			0.6
Difference between varieties: Not significant			
Interaction between irrigation and variety: Not significant			



desirable both for the quality and quantity of forage production. To determine the effect of supplemental moisture on the thickness of stalks, ten plants per plot were selected at random and their thickness was recorded at harvesting time. These data are recorded in Table 6.

An inspection of the data reveals that there was a decrease in the thickness of stem with increased number of irrigations. The thinnest stems were produced under weekly irrigations and the thickest stems were obtained under no irrigation. The plants grew taller under weekly irrigations than they did under no irrigation and so were thinner. The variety Axtel produced plants with significantly thinner stems. It is interesting that the variety which produced the thinner plants, gave the greatest amount of dry-matter per dunnage under the conditions of this experiment. This may be accounted for by the greater number of stems produced by Axtel. In addition, these stems were taller even though thinner.

### Protein Content

#### a. Percent Protein

One of the most important factors affecting the quality of the forage from any crop is protein content. The protein percentage results from this study are summarized in Table 7, where it is seen that protein content was markedly affected by the irrigation treatments. The



Table 6. Effect of supplementary irrigations on thickness of stalk of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Thickness of stalk in inches		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	1.26	1.34	1.30
One irrigation	1.24	1.29	1.26
Two irrigations	1.12	1.23	1.17
Weekly irrigations	1.13	1.17	1.15
Variety average	1.18	1.25	
Difference required for significance between averages for irrigations at the five percent level of probability:			0.11
Difference between varieties: Not significant			
Interaction between irrigation and variety: Not significant			

greatest percentage of protein was recorded from the plants that received two irrigations. The smallest percentage of protein was recorded from the plants that received weekly irrigations. This may be because the nitrogen present in the soil was utilized by the plants which were thus stimulated to grow rapidly and extensively, but then the supply of nitrogen was insufficient for later requirements of the vigorously growing well-established plants.

The varieties were significantly different in protein content. The variety Rox produced a greater protein percentage than did Axtel. This probably is a result of larger fodder yields of Axtel.

The significant interaction of the varieties with the irrigation treatments showed that the varieties did not respond in a linear manner to the irrigation treatments used in this study. Both varieties produced plants with a higher percentage of protein when two irrigations only were applied. This indicates that the application of two irrigations resulted in the maximum absorption of nitrogen by the individual plants without any dilution effect.

#### b. Yield of Protein

Data for the effect of irrigation on the yields of protein in kilograms per dunum are summarized in Table 8. From the results shown in Table 8 it is evident that the total protein per dunum increased according to the increase

Table 7. Effect of supplementary irrigations on protein percentage of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Protein percent, determined on dry-matter basis.		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	7.28	8.14	7.71
One irrigation	7.81	8.34	8.07
Two irrigations	8.47	9.64	9.05
Weekly irrigations	6.59	7.26	6.92
Variety average	7.53	8.34	
Difference required for significance between averages for irrigations at the one percent level of probability:			0.26
Difference required for significance between averages for varieties at the one percent level of probability:			0.12
Difference required for significance of interaction between irrigation and variety at the five percent level of probability:			0.19

in the number of irrigations. Protein yields were significantly higher on the irrigated plots when compared to the check or non-irrigated plots. A careful examination of the Tables 1, 7 and 8 indicates that high forage yields were accompanied by high yields of protein per dunum, even though percent protein decreased with an increase in the number of irrigations. .

The varieties grown responded uniformly to the irrigation treatments and were not significantly different in their protein yields.

Table 8. Effect of supplementary irrigations on the yield of protein in kilograms per dunum of two forage sorghum varieties grown in the Beqa'a plain, Lebanon in 1963.

Irrigation treatment	Protein yields in kilograms per dunum		
	Variety		Average for irrigation treatment
	Axtel	Rox	
No irrigation	55.98	52.26	54.12
One irrigation	64.43	67.92	66.18
Two irrigations	112.48	115.68	114.08
Weekly irrigations	174.64	177.14	175.89
Variety average	101.88	103.25	
Difference required for significance between averages for irrigations at the one percent level of probability:			4.59 kgs.
Difference between varieties: Not significant			
Interaction between irrigation and variety: Not significant			

## SUMMARY AND CONCLUSIONS

The study reported in this thesis was undertaken to better understand the effect of various irrigation treatments on the yield and quality of two forage sorghum varieties. The influence of these irrigation treatments on plant height, thickness of stems, and on the number of tillers, and leaves per plant was observed.

The four irrigation treatments were:

1. Check, or no irrigation.
2. Irrigated once, two weeks after seeding of the crop.
3. Irrigated twice, two weeks after seeding and again three weeks after seeding of the crop.
4. Irrigated at weekly intervals throughout the growing season of the plants.

The following conclusions can be made from this trial.

### Forage Yield

All the irrigation treatments resulted in increased forage yields when compared to the check, or non-irrigated treatment. Weekly irrigations gave a yield of forage four times that from no irrigation, three times that from one irrigation, and twice that from two irrigations.



### Plant Height

Plant height was markedly affected by the irrigation treatments. The tallest plants were produced by weekly irrigations and the shortest plants were obtained from the non-irrigated, or the check plots.

### Thickness of Stem

Irrigation resulted in thinner stems. The non-irrigated plots contained plants with the thickest stems, whereas the weekly irrigated plots contained the finest stemmed plants.

### Number of Tillers

Irrigation increased the number of tillers per plant. The greatest number of tillers were secured from plants that received watering twice and at weekly intervals throughout their growing season.

### Number of Leaves

More leaves were produced by irrigated plants than by non-irrigated ones. The greatest number of leaves per plant were formed under weekly irrigations.

### Percentage of Dry-matter and Protein

Percentage of dry-matter and of protein of the forage was greatly affected by the different irrigation treatments. The weekly irrigated plants contained a smaller percentage of dry-matter and protein and had a higher

moisture content. Those plots receiving irrigation less frequently had a considerably greater percentage of dry-matter and protein.

#### Yield of Protein

The total yield of crude protein was increased according to the increase in the number of irrigations.

#### Varietal Response

Both varieties performed well under irrigated treatments. On the basis of yield and the other characters studied, the variety Axtel appeared better for forage production under irrigation in the north central Beqa'a plain, Lebanon.

This study conducted in 1963 indicates that satisfactory yields of high quality fodder can be obtained with two or more than two irrigations applied during the growing season of the crop.

It would be of interest to pursue this study in more detail, with a view toward elucidating the results indicated in this experiment. It is suggested that irrigation should be restricted in the early stages of growth because moisture should be more readily available in the soil at that time. The first irrigation after seeding should be delayed until the plants are about one month old and have established themselves in the soil. Subsequent irrigations may be given at different intervals to find out



more detailed information about the irrigation requirements of this crop.

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