EFFECT OF BETWEEN-ROW SPACING ON THE FORAGE PRODUCTION OF MAIZE AND SORGHUM INTERPLANTED WITH SOYBEANS

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ABSTRACT

A one year study was made under irrigated conditions at the Agricultural Research and Education Center of the American University of Beirut in the Beqaa plain, Lebanon, in 1964 to evaluate the effect of between-row spacings on the yield, protein content, and other characteristics of five forage crops. These crops were maize, sorghum, soybeans, maize and soybeans, and sorghum and soybeans. The row spacings were 50 and 75 cm.

None of the characters studied was influenced significantly by the row spacings used. The sorghum hybrid Rs 301F gave the highest amount of forage followed closely by the maize hybrid Ind. 620. Maize produced the greatest total yield of protein and soybeans the least.

Soybeans interplanted with maize and sorghum increased the protein content of the resulting mixture, but delayed the tasseling, silking, and heading stages, decreased the forage yield, yield of total protein, plant height, thickness of stems, and weight per plant of maize. Soybeans, on the other hand, produced taller plants, fewer pods, flowered later and weight per plant was reduced by more than one half when grown with maize.

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INTRODUCTION

Maize and sorghum are considered to be very important forage crops all over the world because of their tremendous yield potentials. Soybeans have been utilized in the United States of America in combination with maize and sorghum to increase the feeding value of the resulting mixtures.

In the Middle East because of the deterioration of the range lands through overgrazing and mismanagement, there is an insufficient supply of feed for the regular and continuous production of livestock. It is therefore desirable to produce and maintain feed reserves by producing hay, silage, and crop by-products.

Approximately one-sixth of the cultivable area of Lebanon is irrigated. Thirty percent of the cultivable area is devoted to the production of cereals and legumes (22). Forage and pastures are few, hence animal production is restricted.

The present investigations were carried out to determine the relative productivity and quality of the following forages: maize, sorghum, soybeans, maize and soybeans, and sorghum and soybeans. The crops were grown during 1964 under irrigated conditions in the north central Beqaa plain, Lebanon.

REVIEW OF LITERATURE

Effect of Spacing on Yield

Numerous studies have been undertaken by various workers to find suitable cultural practices that would produce higher crop yields. Some of the studies related to the effects of spacing on yield and other characteristics of forage crops have been considered in this review of the literature.

Austenson et al. (3) concluded that at constant plant population levels forage-corn spaced 14 by 18 inches outyielded the conventional spacing of six inches between plants in rows 42 inches apart. In addition, the narrow rows produced sturdier plants. Hoff and Mederski (17) reported that, at uniform plant populations, equidistant plantings of 28 by 28 inches between corn plants did not produce more forage than did plantings 42 by 18 inches. Stringfield and Thatcher (40) reviewed an experiment done by Collins and Shedd in Iowa where corn in 21 by 21 inch rows was compared with that in 42 by 42 inch rows. Comparable acre planting rates were used. The results from eight years of research showed that the 21 by 21 inch rows had 14 percent thicker stands and outyielded the 42 by 42 inch rows. In an experiment using sweet corn, Watson and Davis (44) found that a spacing of 24 by 12 inches gave a higher yield of grain and forage than did the other spacings tested. Bryan *et al.* (7) found that row spacings of 21 inches and 42 inches, with the same number of plants per acre, had little effect on yield of corn per acre. Mooers (24) in 1914 and 1915 compared corn grown in rows 3.5 feet apart with rows 7 feet apart. The number of plants per acre was kept the same in both cases. The rows 7 feet apart yielded 75 bushels of grain and 3.42 tons of stover per acre while the rows 3.5 feet apart yielded 88.4 bushels of grain and 4.81 tons of stover. Commer (8) in Texas compared corn in rows three feet apart with corn in rows six feet apart. For all tests, rows three feet apart averaged 21.98 bushels and rows six feet apart 20.1 bushels per acre. Experimenting with dwarf corn, Pendleton and Seif (33) reported that the 30 inch spacing outyielded either of the 20 or the 40 inch spacings. Stickler and Laude (39) studying corn populations of 15,680 and 10,450 plants per acre, planted in rows 40 inches and 20 inches apart, observed that the grain and stover yields were not affected by the plant populations or row spacings.

Stickler and Laude also reported that similar to corn, the silage yields of Atlas sorgo planted at 20 and 40 inch row spacings were not significantly different. Boyd *et al.* (6) concluded that planting 3.4 plants of sorghum per square foot gave a greater yield than did the plantings with 1.8 and 2.6 plants per square foot. Porter *et al.* (34) reported that grain and forage yields from sorghum plants spaced at

40 inches between rows were significantly less than was those spaced at 12 and 20 inches between rows.

Hacleman _et_ _al_. (15) in Illinois found that for soybeans, yields were far better from 18 to 32 inch row spacings than they were from 35 to 40 inch spacings. Johnson (19) reported that soybean yields were increased as spacing was decreased from 42 inches to 18 inches. Wiggans (49) studied plant populations obtained by varying the spacings between rows from 8 inches to 32 inches. Three years' results showed that narrower spaces between the rows resulted in higher soybean yields. Weber and Weiss (45) analysed soybean yield data from four states. It was shown that rows spaced 21 inches apart gave slightly higher yields than did those spaced 7, 14, 25 or 42 inches. In experiments in Illinois, involving four soybean varieties, Pendleton _et_ _al_. (32) found that 24 inches between rows gave consistently higher yields than did 40 inch spacings. In another study on plant spacings Wiggans (48) found that the yield of soybeans was affected materially by the distribution of the plants within the rows as well as by the distance between the rows. It was concluded that greater yields will be obtained when the arrangement of plants on a given area approaches a uniform distribution. Other things being constant, smaller distances between rows (thus equalling the space between the plants within the rows) resulted in greater yields. Wiggans also found that, within a wide range, the number of soybean plants per square foot of area has little effect on yield.

In summary it can be stated that there is general agreement in the literature that narrow row spacings are desirable for the highest forage or grain yields.

Corn Interplanted with Soybeans

The influence of soybeans when combined with corn for forage purposes has been studied by various workers. It was found that soybeans interplanted with corn increased the yield of the mixed crop as compared to either crop planted alone.

Nevens and Kendall (27) reported that when corn and sorgo were interplanted with soybeans yields were as follows: Corn and soybeans 6.1 tons of dry matter per acre, corn alone 6.03 tons, sorgo and soybeans 5.06 tons, sorgo alone 5.0 tons, and soybeans alone 2.5 tons. Park *et al.* (31) reported the results of three years of experiments with corn, soybeans, and corn and soybeans mixed. Yields of dry matter were as follows: Corn 3.59 tons per acre, soybeans 2.79 tons, corn and soybeans 4.3 tons. These investigators concluded that under Ohio conditions the corn-soybean combination will produce more feed per acre than will corn alone. Etheridge and Helm (12) found that soybeans interplanted with corn invariably reduced the yield of the corn. This reduction was more pronounced as the proportion of soybeans was increased. Slate and Brown (38) found that a combination of corn and soybeans, yielded approximately one ton of green forage (which contained 500 pounds of dry matter) per acre more than did corn alone. In contrast Witkins and Hughes (51) in Iowa reported that when corn and soybeans were planted together, the yield was composed of 2592.8 pounds of corn and 248 pounds of soybeans per acre. These components were compared with 3018.4 pounds of corn when planted alone. Ahlgren (1) reported that in Kansas corn interplanted with soybeans yielded 13 tons of silage per acre, whereas corn alone produced 17 tons.

Garner and Allard (13) working on soybeans discussed the reduction in total dry weight when artificial shading was practised but did not discuss the effect on percentage dry matter. Welton and Morris (46) concluded that there is a reduction in the percentage of dry matter in the stems of soybeans when they are grown in combination with corn. Wiggans (47) stated that to increase the amount of home grown proteins in New York state soybeans will be of value either as a companion crop to corn for silage or as a hay or silage crop in short term rotations.

It may be concluded from the above that soybeans interplanted with corn increased the yield of dry matter of the resulting mixtures in most cases.

Corn and Sorghum Forage

Quinby and Marion (36) reported that forage sorghums in Texas are more productive of forage than is corn. The varieties Atlas and Honey gave 26 percent and 73 percent more forage, respectively, than did the corn hybrid Texas 34. Owen et al. (29) in Mississippi reported that corn always yielded considerably less than did sorghum. This was true especially during dry summers. Drolsom and Scholl (9) from Wisconsin observed that the variety Rs 301F yielded better than did the other sorghum tested, but that this yield was not significantly different from that of the corn tested at the same time. Lima and Mafra (21) from Brazil concluded that corn hybrids produced from 1000 to 3000 pounds less dry matter per acre than did the sorgo varieties tested. Watkins et al. (43) in Illinois, reported that in silage trials, the hybrid sorghum Rs 301F gave consistently higher yields than did several corn hybrids. The best sorghum yields were almost double those of the best corn hybrids.

In summary it can be stated that there is general agreement in the literature that sorghum hybrids give higher yields of forage than do corn hybrids under dry summer conditions.

Protein Content and Feeding Value in Forage Crops

The quality of a forage crop is usually judged by its protein content. Various workers have studied the feeding value of different forage crops on the basis of protein content.

Morrison (25) stated that corn forage will always have a T.D.N. value superior to that of sorghum because of the higher proportion of grain in the corn. Nevens and Kendall (27) reported that the average daily milk yield per cow was reduced by 2.1 pounds when sorghum silage was substituted for corn silage. However, the milk yield was increased by only 0.8 pounds per cow per day when corn silage was substituted for sorghum silage. Owen et al. (29) observed that in a feeding trial with cows more milk was produced and more weight was gained when corn silage was fed to the cows instead of sorghum silage. The differences were highly significant. These authors reviewed the works of Good, Horlacher and Grimes and of Lamaster and Morrow where it was observed that in milk production and in the fattening of steers sorghum silage was only 72.2 percent as efficient as was corn silage. When the yields of the two crops were considered sorghum was found to be only 92.2 percent as economical as corn.

Thurman et al. (42) pointed out that in a silage trial the coefficient of digestible protein was greater for the sorghum hybrid Rs 301F than it was for the variety Atlas. Reames et al. (37) revealed on the basis of feeding trials with steers, that the sorghum hybrid Rs 301F gave high quality silage very similar to corn silage. Owen and Webster (28) concluded that sorghum hybrids produced less nitrogen free extract and more crude protein than did the open pollinated varieties. Nevens and Kendall (27) concluded that the average protein content of the forage from the corn hybrid U.S. 13 was 7.4 percent against the 6.7 percent of the forage sorgos tested. The same workers also reported that the acre yield of protein of corn hybrid was 587 pounds as compared to an average of 600 pounds for the ten varieties of sorghum tested. Wiggans (50) observed that when a companion crop of soybeans was planted nine inches apart in the rows of corn, the highest yield of crude protein per acre was produced. Slate and Brown (38) reported that corn and soybean mixtures contained 670 pounds of protein per acre when cut for silage. In comparison corn alone produced 550 pounds of protein. Thus inclusion of soybean in the mixture narrowed nutritive ratio from 1:13 to 1:9.8. Thore (41) from Nigeria reported that corn alone contained 358 pounds of total protein per acre while a mixture of corn and cowpeas gave 281 pounds of total protein when cut for silage.

Thus it may be concluded that corn silage, being of high protein content, proved to be superior to sorghum in feeding value. Corn interplanted with soybeans contained more protein per acre than when grown alone. Thore from Nigeria reported a higher yield of protein from corn alone as compared to corn and cowpeas when sown mixed.

Plant Height and Other Characters

Plant height has a great influence on the forage yields. There have been numerous studies on plant heights, base diameters and tillering of plants, all of which are generally understood to have a direct correlation with forage yields.

Dungan et al. (10) reported that in Illinois and Iowa plant populations had little effect on plant height. It was found by Engie (11) that there was no significant difference in plant height as a result of plant spacing. It was reported by Harry and Moss (14) that under extremely high populations the plants were significantly taller, which was attributed to the competition for light. Austenson et al. (3) concluded that plant height in corn was not affected by spacing between rows at constant plant populations. However, the narrower row spacings resulted in sturdier plants with larger ears.

Results of the soybean experiments by Probst (35) showed that of the varieties tested, spacing the plants one to five inches apart had little influence on plant height. However, the plants spaced closer together had a tendency to grow taller than when the plants were spaced five inches apart. Nelson and Roberts (26) reported that shorter plants were observed where greater spacing between the plants existed.

Hittle et al. (16) in Illinois concluded that plants of the sorghum hybrid Rs 301F grew taller than did those of the corn hybrids used. Quinby and Marion (36) reported that the sorghum hybrid Rs 301F attained a height of 67 inches under Texas conditions.

Watson and Davis (44) concluded that by increasing soil area upto 3.95 square feet per plant of sweet corn, the diameter of the lowest internode of the stem increased. Further increases in soil area per hill did not have any effect on the diameter of the stalk. Porter _et al_. (34) studied the effects of different planting rates and of different row spacings at each planting rate, in a sorghum trial. It was observed that the tillering of the plants on the basis of number of heads per acre was not influenced by the between row spacings.

Pendleton and Seif (33) reported that row spacing had no effect on tassel height. It was further stated that plant population had no effect on ear height. Dungan _et al_. (10) suggested that "Retardation of silk emergence may be looked upon as an operation of plant adjustment to high population which, in extremely thick stands, would bring about complete barrenness." It has been observed in many places that increasing the population density delays plant development. Dungan _et al_. (10) in central Illinois studied the dates of half tassel and half silk stages of nine hybrids in rate of planting tests. It was observed in this test that the increase in time between silking and tasseling, resulting from thick planting, was not great. This increase amounted to only a little over one day when the population was increased from 8,000 to 20,000 per acre. Kohnke and Miles (20) reported that silking was delayed by one day for every addition of 3,500 to 4,000 kernels planted per acre. Stringfield and Thatcher (40) reported that the silking period for a stand of five plants per 42 inches of row was roughly two days later than for a stand of three plants in the same space. Bailey (5) working on sweet corn reported that wider spacing between plants hastened silking date. Engie (11) reported the significant effects of spacing on the maturity of three corn hybrids tested. The plants matured earlier when grown with abundant space. However, there was no difference between the effects of 36 inch check rows and 36 by 12 inch drill rows on the maturity. Probst (35) showed that spacing soybean plants two to five inches apart hastened maturity by two to five days when compared with plants only one inch apart.

Ali (2) did not find any significant differences in the number of days from planting to flowering in soybeans attributable to spacing treatments over two seasons of study at the Agricultural Research and Education Center.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research and Education Center of the American University of Beirut, located in the central Beqaa plain. The soil is calcareous, high in clay content, low in organic matter, nitrogen, and phosphorus with a pH of about 8 (52).

The soil was fertilized with an initial application of 12 kg per dunum of nitrogen as ammonium sulphonitrate and 20 kg of P_2O_5 as superphosphate. The fertilizers were broadcast and then disked into the soil prior to planting. Later, an additional four kg of nitrogen were applied as a side dressing to all plots except where soybeans were planted alone.

The experiment was laid out in a split plot design with four replications. The main plots consisted of between row spacings of 50 cm and 75 cm. Superimposed on each of the main plots were the five forages randomized as sub-plots. Each plot consisted of four rows each five meters in length.

Planting was done on April 30, 1964. A V-belt seeder was used for the sorghum and soybeans. The maize was planted with a maize planter in single kernel hills. All the plots were planted thickly and later thinned to give the between plant spacings, and plant populations as shown in Table 1.

Table 1 - Between plant spacing and plant populations used for five forage crops grown in the Beqaa, Lebanon in 1964.

Crop	Spacing in cm		Plant population per dunum*
	Between rows	Within rows	
Maize alone	75	16.5	8,000
	50	25	8,000
Sorghum alone	75	5	26,666
	50	7.5	26,666
Soybeans alone	75	2	66,666
	50	3	66,666
Maize & soybeans			
Maize	75	22.5	6,000
	50	33.5	6,000
Soybeans	75	2.66	50,000
	50	4	50,000
Sorghum & soybeans			
Sorghum	75	7.5	20,000
	50	10	20,000
Soybeans	75	2.66	50,000
	50	4	50,000

* Dunum = 1000 sq. meters.

The varieties used were as follows: Maize - Ind. 620: A high yielding late maturing variety; sorghum - Rs 301F: A tall growing and late maturing variety. In previous research at the Agricultural Research and Education Center, this sorghum has outyielded the above maize hybrid (Ind. 620) (23); soybeans - Clark: A high yielding medium tall, and medium early variety.

The crops were irrigated for the first five weeks by a sprinkler system. Later, furrow irrgation was done at weekly intervals until the crops were mature. Metasystox was sprayed for the control of aphids on August 4.

Data were recorded on forage yield, plant height, weight per plant, thickness of stem, and number of days from planting to tasseling, silking, flowering, and heading.

The flowering date of each of the crops was recorded when 75 percent of the plants in a plot had reached anthesis. The same was done for the date of silking in maize.

In the plots where a mixture of maize and soybeans was grown the maize and soybean plants were harvested separately. The air dry weight of each component of the mixture was divided by the number of plants of each component growing in that row. For comparison the weights per plant, of maize and soybeans growing alone, also were calculated. Four meters from the centre of the two middle rows of each plot were harvested to determine yield data. The date of the first cutting of sorghum was August 31, while the maize and soybeans were harvested on August 20 and September 10, respectively. The second cutting of sorghum was done on October 31. Each crop 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. These stages of development were considered to be heading in sorghum, denting of kernels in maize and filling of green pods of the soybeans.

A ten pound representative sample was taken from each plot for dry matter and protein determination. The same was done from each component of the mixed plots. For protein determination, representative fifteen gram sub-samples were ground in a Wiley mill for analysis made according to the modified Kjeldahl method, as specified in the Association of the Official Agricultural Chemists Official Methods of Analysis (4).

Statistical methods appropriate to the split plot design according to Panse and Sukhatme (30) were used to analyse the data.

RESULTS AND DISCUSSION

A one year study was undertaken to find the effect of between row spacings on yield and other characteristics on five forage crops. The other agronomic data obtained included protein percentage; plant height; number of days to tasseling, silking, and heading; stem thickness; and weight per plant. The data related to each factor studied are reported in Tables 2 to 11. The analyses of the variances and L.S.D. values are given in the Appendix (Tables 12 to 20).

Forage Yields

The yields of the five forages studied are reported in Table 2. The total yield of sorghum alone included the 0.61 tons from the second cutting. This yield was higher than that of the other forage crops although was not significantly different from that of maize alone. Several workers (18, 27, 31, 38) reported greater yields from interplanting maize and soybeans as compared to maize alone. The reason for the poor performance of the maize-soybean mixture in the present investigation may be attributed to a greater need for nitrogen by the mixture than by the maize alone. Inspite of the additional application of four kg of nitrogen per dunum, nitrogen deficiency symptoms were observed in the maize leaves of the maize-soybean mixture during the tasseling and

Table 2 - Yield of five forages (air dry weight) in tons per dunum when grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Sorghum	Maize+	Maize and soybeans	Sorghum and soybeans	Soybeans	Spacing mean
50 cm	2.71	2.56	1.74	2.15	0.86	2.00
75 cm	2.30	2.34	1.92	2.02	0.77	1.87
Forage mean	2.50	2.45	1.83	2.09	0.82**	-

\+ Control
** Significant at 1% level.

silking stages. Moreover, the maize and soybeans did not come to maturity at the same time, the soybeans being earlier in maturity than was the maize. Therefore,it was necessary to harvest the mixture before the maize had reached its maximum stage of development. The same was true for the sorghum-soybean mixture.

The yield of soybeans alone was much less than that of the other forage crops. The mean yield per dunum was no greater than one third that of the other forages.

The narrow row spacing of 50 cm gave slightly higher yields than did the 75 cm row spacings, but the differences were not statistically significant. The trend toward higher yield from the narrow row spacing is in agreement with the results of several workers (3, 7, 17, 33, 34, 40).

Feeding Value of Forage Crops

a. Protein content

One of the most important factors affecting the quality of the forage from any crop is protein content. The protein content of the forage crops studied varied widely, ranging from 5.37 percent for the sorghum alone, to 11.08 percent for the soybeans alone (Tables 3, 4). These differences were statistically significant. Soybeans alone produced a greater percentage of protein than did the other forages. When interplanted with maize and sorghum, the

Table 3 - Effect of between row spacing on the percentage of protein of five forages grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Maize[+]	Sorghum	Maize and soybeans	Sorghum and soybeans	Soybeans	Spacing mean
50 cm	6.02	5.14	6.84	5.79	10.67	6.89
75 cm	6.20	5.61	6.96	6.09	11.50	7.27
Forage mean	6.11	5.37**	6.90**	5.94	11.08**	-

[+] Control

** Significant at 1% level.

Table 4 - Effect of between row spacing on the percentage of protein of five forages grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Maize		Sorghum						Soybeans		
	Alone	In soybeans	Alone			In soybeans			Alone	In maize	In sorghum
			1st cut	2nd cut	Total	1st cut	2nd cut	Total			
50 cm	6.02	6.44	5.54	4.03	5.14	5.87	4.78	5.56	10.67	10.35	10.29
75 cm	6.20	6.69	5.89	4.77	5.61	6.00	4.97	5.63	11.50	11.16	11.05
Mean	6.11	6.56	5.71	4.40	5.37	5.94	4.87	5.59	11.08	10.75	10.67

soybeans increased the protein content of the resulting mixtures. Wiggans (50) reported an increased protein content from maize-soybean mixtures as compared to maize alone. Maize had a significantly higher percentage of protein than did sorghum. The superiority of maize over sorghum silage has been reported by several workers (25, 27, 29, 37).

There was no significant difference in the protein content as a result of spacing treatments, perhaps because only two row spacings were studied in this investigation. In addition, the great soil variability in the plot area made detection of small differences between spacing treatments difficult. The interaction between spacing and forage crops was also not significant.

b. Yield of protein

Data concerning the effect of between row spacing on the yield of protein in kg per dunum are summarised in Table 5. An inspection of the results will show that most of the forage crops studied were significantly different in their production of total protein. Maize alone gave the greatest total yield of protein and soybeans alone the least. The trend toward a higher yield of dry matter observed in the sorghum alone plots was not repeated in the total yield of protein per plot because of the low protein content of the sorghum. The interplanted maize and soybeans and sorghum and soybeans gave a lower yield of total protein than did the maize or sorghum planted alone. These results are in

Table 5 - Effect of between row spacing on the total protein in kg per dunum of forages grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Maize+	Sorghum	Maize and soybeans	Sorghum and soybeans	Soybeans	Spacing mean
50 cm	153.65	139.62	117.96	123.46	98.65	126.67
75 cm	144.86	128.81	130.21	122.89	89.01	123.15
Forage mean	149.25	134.22	124.09*	123.17*	93.83**	-

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

agreement with Thore (41) who obtained a lower yield of digestible crude protein by growing cowpeas mixed in maize than when maize was grown alone. However, the results do not agree with those of Maun (23). Maun reported a greater yield of protein from the maize-soybean mixture than from the maize alone. The reasons for the higher total yield in the mixture may have been because the components had a considerably higher protein content in comparison with the present investigation.

The total yield of crude protein was not affected significantly by the spacing between rows and the interaction between spacing and forage crops was also not significant.

Weight per Plant

It can be seen from Table 6 that the yield per plant of maize was reduced significantly when grown with soybeans. This loss in dry weight is about 12 percent as compared to maize alone.

Soybeans growing in the mixture were subjected to severe competition with the maize. The reduction in yield per soybean plant was more pronounced than was that per maize plant. This difference was not unexpected since 75 percent of the total growth of the mixed crop was maize and 25 percent was soybeans. The soybean plants grown alone were more than twice as heavy as were those grown with maize. The results agree with Wiggans (50) who reported that by growing

Table 6 - Effect of between row spacing on the weight per plant in gms for maize and soybeans grown alone and together in the Beqaa, Lebanon in 1964.

Spacing between rows	Maize		Spacing mean	Soybeans		Spacing mean
	Alone	With soybeans		Alone	With maize	
50 cm	254.00	220.50	237.25	19.38	9.27	14.32
75 cm	244.25	220.00	232.12	21.49	8.65	15.07
Forage mean	249.12	220.25*	-	20.44	8.96*	-

* Significant at 5% level.

the two crops together, the yield of the maize was reduced by 15 percent while the soybeans produced less than one third as much as when grown alone. Similar effects were observed by Maun (23).

The spacing between rows did not affect the weight per plant of the maize or soybeans.

Plant Height

The yield of forage is considered to have a close association with plant height. Five plants from each plot were selected at random to be measured at harvesting time and the average heights are given in Table 7.

It can be seen from the analysis of variance (Table 16) that the forage crops differed significantly in height. Sorghum gave the tallest plants followed by maize. This difference was significant. Hittle et al. (16) also reported that this particular sorghum hybrid Rs 301F grew taller than the maize hybrid which was used in a similar forage trial. In the present investigation maize and sorghum did not grow as tall when interplanted with soybeans, as when grown alone. The soybeans were in competition with the maize and sorghum for both moisture and nutrients. Therefore, it is suggested that the nitrogen deficiency symptom observed in the plots was an important factor causing shorter plants. Soybeans, on the other hand when interplanted with maize or sorghum grew

Table 7 - Effect of between row spacing on the height in cm of forage crops grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Sorghum	Maize+	Maize in soybeans	Soybeans	Sorghum in soybeans	Soybeans in maize	Soybeans in sorghum	Spacing mean
50 cm	253.50	240.88	231.64	156.00	233.10	165.31	167.79	206.89
75 cm	241.90	236.75	215.25	150.27	226.45	157.50	160.75	198.41
Forage mean	247.70	238.81*	223.45**	153.14**	229.77*	161.40**	164.27**	-

\+ Control.
* Significant at 5% level.
** Significant at 1% level.

slightly taller than when grown alone. This increase in height is perhaps a result of shading by the maize and sorghum. Garner and Allard (13) also noted similar increases in height from artificially shaded soybean plants.

The between row spacings did not have any effect on the plant height of all the crops. The interaction between spacing and forage crops was also not significant.

Days from Planting to Flowering

The dates of the following growth stages: Tasseling in maize, appearance of heads in sorghum, and flowering in soybeans, were noted to determine the maturity dates of the forage crops studied. The data are reported in Table 8.

It may be seen from the results that all crops reached the flowering stage significantly earlier than when grown in the mixture. Similar results were reported by Maun (23). It can be concluded that by planting the forage crops in the mixture the relative maturity of maize, sorghum and soybeans was delayed.

Spacing between rows did not significantly affect the number of days taken to flowering in soybeans, tasseling in maize, or heading in sorghum.

Table 8 - Effect of between row spacing on the number of days from planting to flowering in soybeans, tasseling in maize and appearance of heads in sorghum grown in the Beqaa, Lebanon in 1964.

Spacing between rows	Sorghum	Maize+	Maize in soybeans	Soybeans	Sorghum in soybeans	Soybeans in maize	Soybeans in sorghum	Spacing mean
50 cm	98.25	77.50	80.0	76.50	100.50	81.25	81.25	85.03
75 cm	99.25	78.50	81.0	78.00	101.50	81.75	82.75	86.03
Forage mean	98.75**	78.00	80.50**	77.25	101.00**	81.50**	82.00**	-

\+ Control.
** Significant at 1% level.

Other Characters

a. Maize

Number of days from planting to silking: The appearance of the silks on five plants from each plot was recorded as the silking date for that plot. The number of days from planting to silking for maize growing alone and when interplanted with soybeans are presented in Table 9.

It may be seen from the data that silking occurred significantly earlier in the plots when maize was growing alone. In other words the appearance of silks in the maize-soybean mixture was delayed by the presence of the soybeans.

The difference in silking time due to spacing between rows and the interaction between spacing and forage crops were not significant.

Circumference of stem: The average circumference of five maize plants per plot grown alone and interplanted with soybeans was measured and the data are reported in Table 9. An inspection of the data will show that the stems of maize were significantly thicker, when the plants were growing alone, than they were when interplanted with soybeans.

There was a trend toward thicker stems in the plants from the 50 cm rows, but the difference was not significant. These results do not agree with Maun (23) where it was observed that a significantly greater circumference in maize stem occurred in the 50 cm rows. For stem circumference, the

Table 9 - Effect of between row spacing on the number of days to silking and on the circumference in cm of stalks, of maize grown alone and in combination with soybeans in the Beqaa, Lebanon in 1964.

Spacing between rows	Days taken to silking			Circumference of stalks		
	Maize alone	Maize in soybeans	Spacing mean	Maize alone	Maize in soybeans	Spacing mean
50 cm	83.50	86.00	84.75	8.52	7.70	8.11
75 cm	83.00	85.50	84.25	8.20	7.40	7.80
Forage mean	83.25	85.75**	-	8.36	7.55**	-

** Significant at 1% level.

interaction between spacing and forage crops was not significant.

b. Soybeans

Number of pods per plant: The number of pods from five plants per plot was recorded and the data are reported in Table 10.

It can be seen from the data that the number of pods per plant growing alone was significantly greater than when growing in combination with maize or sorghum. Differences between spacing and the interaction between spacing and forage crops were not significant.

Circumference of stem: To measure the effect of maize and sorghum on the thickness of soybean plants, the circumference of the plants growing alone and in combination with maize and with sorghum were determined, and the data are reported in Table 10.

It is evident from the data that soybeans growing alone had significantly thicker stems as compared to when grown with maize or sorghum. Similar results were obtained by Maun (23).

Differences between spacings and the interaction between spacing and forage crops were not significant.

c. Sorghum

The effect of between row spacings on the circumference of sorghum and the number of tillers per plant is presented in Table 11. It can be seen from the data that the

Table 10 - Effect of between row spacing on the number of pods per plant and circumference in cm of stalks of soybeans grown alone and in combination with maize and sorghum in the Beqaa, Lebanon in 1964.

Spacing between rows	No. of pods per plant				Circumference of stalks			
	Soybean+	Soybean in maize	Soybean in sorghum	Spacing mean	Soybean+	Soybean in maize	Soybean in sorghum	Spacing mean
50 cm	27.00	12.80	13.20	17.66	3.15	2.02	1.96	2.38
75 cm	26.80	11.75	11.20	16.58	3.06	1.96	1.86	2.29
Forage mean	26.90	12.27**	12.20**	-	3.10	1.99**	1.91**	-

\+ Control.

** Significant at 1% level.

Table 11 - Effect of between row spacing on the circumference of stem, and number of tillers per plant, of sorghum when grown alone and in combination with soybeans in the Beqaa, Lebanon, 1964.

Spacing between rows	Circumference of stem in centimeters			No. of tillers per plant		
	Sorghum	Sorghum in soybeans	Spacing mean	Sorghum	Sorghum in soybeans	Spacing mean
50 cm	5.35	4.62	4.98	1.79	1.65	1.72
75 cm	4.78	4.44	4.61	1.70	1.52	1.61
Forage mean	5.06	4.53**	-	1.75	1.58*	-

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

sorghum plants growing alone had thicker stems as compared to those grown with soybeans. The two spacings used in this trial did not have any effect on the circumference of the stems, although there was a trend toward thicker stems from the 50 cm spacing. Maun (23) reported that significantly thicker stems were found in rows 50 cm apart. This lack of agreement with Maun may be explained by the greater sensitivity of Maun's experimental design. Maun used eight replications whereas only four were used in the present investigation. The number of tillers per plant of sorghum was significantly reduced by the soybeans in the mixture. The number of tillers was not affected by spacing between rows. The results agree with Porter *et al.* (34) where it was reported that tillering was not affected by varying the distance between rows from 20 to 30 inches at the same plant population.

SUMMARY AND CONCLUSIONS

The experiment reported in this thesis was conducted to determine the effect of between row spacings on the relative productivity and quality of five forage crops. In addition, the influence on plant height, number of days from planting to flowering, weight per plant, and the thickness of stems, was also studied. The spacing treatments were 50 cm and 75 cm between rows.

The following conclusions can be made from this study:

When grown under irrigation conditions, sorghum alone (two cuttings of which the second was only 0.61 tons) produced 2.50 tons per dunum of forage containing 5.37 percent protein. Maize produced only 2.45 tons of forage, but with a protein percentage of 6.11. The maize-soybean and sorghum-soybean mixtures yielded 1.83 and 2.09 tons of forage containing 6.90 and 5.94 percent protein respectively.

The total protein yield produced by sorghum, maize, soybeans and the maize-soybean and sorghum-soybean mixtures was 134.22, 149.25, 93.83, 124.09, and 123.17 kg per dunum, respectively.

Plant heights were not affected by the spacing used in this trial. However, there was a trend toward taller plants in the 50 cm row spacing.

Soybeans interplanted with maize and sorghum delayed the tasseling, silking and heading stages. The presence of soybeans in the mixture resulted in less yield per plant of maize as compared to maize grown alone. The yield per plant of soybeans was also reduced by more than one half when grown with maize.

The circumference of the forage crops also was not affected by the spacing treatments. There was trend toward thicker stems in the 50 cm row spacings. The circumference of the maize and sorghum stems was significantly reduced by the inclusion of soybeans.

On the basis of the yield data, the sorghum hybrid Rs 301F appears to have the best potential for high forage production under the irrigated conditions in the central Beqaa plain, Lebanon. Higher yields would be possible from the second cutting of sorghum by the application of nitrogen fertilizer.

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A P P E N D I X

Table 12 - Analysis of variance of forage yields of five forages grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	M.S.	F
Replication	3	0.11	N.S.
Spacing	1	0.18	N.S.
Error (a)	2+	0.38	-
Forage crops	4	3.73	71.73**
Forage x spacing	4	0.09	N.S.
Error (b)	24	0.052	-

\+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L.S.D. At 5 percent	L.S.D. At 1 percent
Forage crops	0.74	1.01
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Table 13 - Analysis of variance of protein percentage of five forage crops grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	M.S.	F
Replication	3	.07	N.S.
Spacing	1	1.06	N.S.
Error (a)	2+	.065	-
Forage crops	4	44.28	340.61**
Forage x spacing	4	0.21	N.S.
Error (b)	24	0.13	-

\+ 1 d.f. has been removed because between row spacings were not randomised because of irrigation method used.
** Significant at 1% level.

	L. S. D.	
	At 5 percent	At 1 percent
Forage crops	0.37	0.50
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Table 14 - Analysis of variance of total protein of five forages grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	M.S.	F
Replication	3	293.75	N.S.
Spacing	1	122.30	N.S.
Error (a)	2+	1304.95	-
Forage crops	4	3298.82	11.03**
Forage x spacing	4	187.91	N.S.
Error (b)	24	299.21	

+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L. S. D.	
	At 5 percent	At 1 percent
Forage crops	23.32	32.13
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Table 15 - Analysis of variance of weight per plant of maize and soybeans grown in the Beqaa, Lebanon, 1964.

Sources		Maize		Soybeans	
	D.F.	M.S.	F	M.S.	F
Replication	3	1470.00	N.S.	2.49	N.S.
Spacing	1	105.00	N.S.	2.27	N.S.
Error (a)	2+	1024.00	-	37.17	
Forage crops	1	3335.00	7.00*	526.28	7.04*
Forage x spacing	1	86.00		7.54	N.S.
Error (b)	6	476.00		73.47	

\+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

* Significant at 5% level.

	L.S.D.			
	Maize		Soybeans	
	At 5 percent	At 1 percent	At 5 percent	At 1 percent
Forage crops	26.67	N.S.	10.27	N.S.
Spacing	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.

Table 16 - Analysis of variance of height plant of forage crops grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	M.S.	F
Replication	3	355.76	N.S.
Spacing	1	1008.52	N.S.
Error (a)	2+	105.06	
Forage crops	6	13519.48	190.25**
Forage x spacing	6	26.71	N.S.
Error (b)	36	68.96	

+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L. S. D. At 5 percent	L. S. D. At 1 percent
Forage crops	8.42	11.32
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Table 17 - Analysis of variance of planting to flowering of forage crops grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	M.S.	F
Replication	3	10.90	N.S.
Spacing	1	16.07	N.S.
Error (a)	2+	4.32	
Forage crops	6	789.70	669.24**
Forage x spacing	6	0.24	N.S.
Error (b)	36	1.18	-

+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L. S. D.	
	At 5 percent	At 1 percent
Forage crops	1.07	1.43
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Table 18 - Analysis of variance of plant to silking and circumference of stems of maize grown in the Beqaa, Lebanon, 1964.

Sources		Days taken to silking		Circumference of stem	
	D.F.	M.S.	F	M.S.	F
Replication	3	4.50	N.S.	.03	N.S.
Spacing	1	1.0	N.S.	.39	N.S.
Error (a)	2+	2.75		.04	
Forage crops	1	25	30.17**	2.62	43.66**
Forage x spacing	1	1.0	N.S.	0	N.S.
Error (b)	6	0.83		.06	-

\+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L. S. D.			
	Days taken to silking		Circumference of stem	
	At 5 percent	At 1 percent	At 5 percent	At 1 percent
Forage crops	0.98	1.48	0.29	0.44
Spacing	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.

Table 19 - Analysis of variance of pods per plant and circumference of stems of soybeans grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	No. of pods per plant M.S.	No. of pods per plant F	Circumference of stalk M.S.	Circumference of stalk F
Replication	3	13.29	N.S.	.06	
Spacing	1	6.93	N.S.	.03	
Error (a)	2+	8.49		.085	
Forage crops	2	574.23	128.75**	3.45	115**
Forage x spacing	2	1.68	N.S.	0	
Error (b)	12	4.46		.030	

\+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.

** Significant at 1% level.

	L. S. D.			
	No. of pods per plant		Circumference of stalk	
	At 5 percent	At 1 percent	At 5 percent	At 1 percent
Forage crops	2.28	3.21	0.19	0.27
Spacing	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.

Table 20 - Analysis of variance of circumference of stem and number of tillers per plant of sorghum grown in the Beqaa, Lebanon, 1964.

Sources	D.F.	Circumference of stem M.S.	Circumference of stem F	No. of tillers M.S.	No. of tillers F
Replication	3	0.14	N.S.	.04	N.S.
Spacing	1	0.55	N.S.	0.10	N.S.
Error (a)	2+	0.15		.04	
Forage crops	1	1.14	19.0**	.05	6.25*
Forage x spacing	1	0.15	N.S.	0	N.S.
Error (b)	6	.06		.008	

\+ 1 d.f. has been removed because between row spacings were not randomised because of the irrigation method used.
* Significant at 5% level.
** Significant at 1% level.

	L. S. D.			
	Circumference of stem		No. of tillers per plant	
	At 5 percent	At 1 percent	At 5 percent	At 1 percent
Forage crops	0.24	0.31	0.11	N.S.
Spacing	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.