EFFECT OF ROW-WIDTH ON YIELD AND OTHER CHARACTERISTICS OF ANNUAL FORAGES

by

Muhammad Anwar Maun

A Thesis Submitted to the Faculty
of Agricultural Sciences in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE IN AGRICULTURE

Major: Agronomy-Plant Pathology
Minor: Soil Science

Approved:

In Charge of Major Work

Chairman, Graduate Committee

American University of Beirut
1963

Cultural Trial in Forages

Maun

ACKNOWLEDGEMENTS

The author wishes to extend his sincere gratitude to Dr. Wallace W. Worzella for his valuable suggestions, constructive criticism and correction of the manuscript.

Special thanks are due to Miss Marie-Louise Davidian of the Mathematics Department for guidance in the statistical analysis of the data.

Muhammad Anwar Maun

ABSTRACT

An experiment was conducted at the American University farm to study several characteristics of four forage crops corn, sorghum, corn+soybeans and soybeans when planted in rows 50 and 75 cms. apart during the year 1962.

The results reveal that the greatest amount of forage and total protein was produced from sorghum since two cuttings were possible under irrigation. Corn alone produced more forage yields than corn-soybean mixture but gave less total protein per dunum. Soybeans grown alone resulted in the lowest yields of total protein.

Interplanting of soybean in the corn rows increased the tasselling and silking period of corn and protein content of the resulting mixture but reduced the height per plant, weight per plant and the circumference of corn stalks. Soybean plants growing in corn had lesser spreading capacity, grew taller, flowered later and produced fewer number of pods per plant than when grown alone. The weight per plant of soybean was also reduced by about one-half.

Planting forage crops in rows 50 and 75 cms. apart did not affect any of the characters studied except the circumference of stalk. Corn and sorghum crops had thicker stems when growing in 50 cm. rows.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Heavy grazing and improper management of range lands in the Middle East have resulted in a critical depletion of the range cover. This has not only led to reduced livestock products of poor quality but also has created soil erosion and water scarcity problems. In consequence, Lebanon spends some 55 million L.L. (14) a year to import animals and animal products which is a heavy drain on the limited resources of the country.

According to Morril (12) the situation can be improved by increasing production and maintaining good feed reserves of high quality forages. This practice is important not only to provide for the nutritional requirements of the animal, but also to avoid overtaxing and overgrazing the ranges in times of low production.

Proteins constitute one of the major items in an animal's feed whether it be supplied from plants or from concentrates. Morrison (13) demonstrated that by increasing the use of high quality forage, the concentrate intake could be cut without reduction in the milk production.

Corn and sorghum are pre-eminently the most important forage crops all over the world with immense potentialities of yielding huge reserves of dry matter. In the United States soybean has been

utilized in combination with corn in an attempt to increase the feeding value of the resulting mixture. By growing soybeans and corn together the protein content has been increased upto 100 percent over that of corn alone. This mixture would narrow the nutritive ratio which would seem sufficient to warrant reducing the amount of concentrates otherwise necessarily supplied from other more expensive sources.

The present investigations were carried out to determine the relative productivity and quality of four forages, namely, corn, soybeans, sorghum and corn-soybean mixture. The crops were grown under irrigated conditions in the north central Beqa'a, Lebanon during 1962.

REVIEW OF LITERATURE

Corn Planted with Soybeans for Forage

Nevens and Kendall (15) concluded that corn interplanted with soybeans gave a maximum yield of 6.1 tons of dry matter per acre followed by corn alone - 6.03 tons, Sorgo + Soybeans - 5.06 tons, Sorgo alone - 5.0 tons and Soybeans alone - 2.5 tons per acre during the year 1943. According to Wiggans (28) the greatest usefulness of soybeans in New York will be either as a companion crop to corn for silage or as a hay or silage crop in short time rotations, to increase the number of legumes and the amount of home grown protein. The same author (27) (29) (30) (31), on the basis of several years of data involving the utilization of soybeans as a forage crop to be combined with corn, obtained the following results:

i. Good soybean varieties when grown alone in cultivated rows, will produce from 65 - 80 per cent as much dry weight, as does corn grown alone in rows the same distance apart.

ii. A combination of any good silage corn, at the optimum rate for silage of one stalk every nine inches in the row, with three times that number of soybean plants in the same row, results, on the average, in a significantly higher yield of total dry matter than does the same corn without the soybeans.

iii. Any combination of the two crops reduces both the total amount

of dry matter of corn plants and the proportion of grain in the cob, as a result of increased competition.

iv. Without exception, the yield of corn was reduced by the addition of soybeans. The loss sustained in the total dry weight of corn may go upto 20 per cent regardless of the variety used.

v. When the two crops are grown together, the losses in soybean production ranged between 59 to 67 per cent according to the variety of corn used.

vi. The depressing effect of soybeans on corn is somewhat in proportion to the size of the corn. The smaller the corn the greater is the percentage reduction in dry matter of corn and the greater is the proportion of soybeans in the mixture.

vii. There seems little doubt that a positive gain occurs by growing corn and soybeans together as compared to corn alone.

Slate and Brown (24) obtained an increased yield of 500 lbs. of dry matter by planting soybean mixed in corn as compared to corn alone. Hughes and Henson (8) reported that a combination of corn and soybeans under average Ohio conditions produced more feed per acre over corn alone and soybean alone.

Welton and Morris (26) concluded that the percentage dry matter of the stems of soybeans is reduced when the soybeans are grown in combination with corn. Garner and Allard (6), working specifically on soybeans, showed the reduction in total dry weight when artificial shading was practiced, but did not show the effect on percentage dry matter.

Corn and Sorghum for Forage.

Watkins, Hittle, McKibben and Browning (32) observed that hybrid forage sorghums, such as RS301F, consistently outyielded corn hybrids in silage per acre. The best sorghum yields were almost double that of the best corn hybrids and that the advantages of sorghum over corn were more favorable when drought conditions prevailed. Nevens and Kendall (15) reported that the greater yield of forage from sorghum than from corn is often more of an apparent than a real advantage, since under Illinois conditions sorghums are ensiled at an early stage of growth so their dry matter yield may be no more or actually less than that of corn.

Lima and Mafra from Brazil (11) reported that sorgo varieties gave 1000 to 3000 pounds higher yields of dry matter than corn hybrids. The total amount of proteins in pounds per acre was almost double in some varieties of sorgo as compared to corn hybrid. Drolsom and Scholl from Wisconsin (5) revealed that RS301F, gave the highest yield of 6.31 tons of dry matter per acre as compared to other sorghum hybrids and corn. The differences between corn and sorghum hybrid RS301F. were, however, non significant. Hinze and Leonard (9) indicated that the newly released hybrid RS304F was the high producing hybrid compared with the Fremont variety. The hybrid RS301F was also outstanding in yield in the commercial sorgo test. Quinby and Marion (21) found that corn in Texas is less productive of forage than forage sorghums. Atlas and Honey produced 26 and 73 per cent more forage, respectively, than the corn hybrid, Texas 34. According to Owen, Miles, Cowsert, Lusk, Custer and Cardwell (17), the yield of corn was considerably less than

any variety of sorghum especially during the dry summer of 1954.

Spacing and Yield.

Hoff and Mederski (7) found that the number of plants being the same, equidistant plantings of 28 by 28 inches gave somewhat higher yield of corn forage as compared to 42 by 18 5/8 inches. The differences between the two treatments, however, were non-significant. Bryan, Eckhardt and Sprague (3) in Iowa reported the results of a four year test in which plants grown four per hill in 42 by 42 inches spacing were compared with one per hill in 21 by 21 inch spacing. The population was 14,224 plants per acre in both of the cases. The average yield of grain was 80.4 bushels for the 21 inch spacing and 77.3 bushels for the 42 inch spacing. The difference, however, was not statistically significant. Wiggans (29) obtained higher yields by planting soybean within corn rows than by growing two rows of corn alternated with one row of soybeans or two rows of corn alternated with two rows of soybeans. Boyd, Green and Chapman (4) obtained higher yields by planting 3.4 plants of sorghum per square foot as compared to 1.8 and 2.6 plants per square foot.

Austenson, Peabody, Turner and Crandall (1) indicated that at constant plant populations, the conventional spacing of six inches between plants in rows 42 inches apart yields less dry matter (3.96 tons per acre), than a spacing of 14 by 18 inches (4.88 tons) and 28 by 9 inches (4.53 tons). The narrower row spacings resulted in sturdier plants. Stickler and Laude (23) tested corn populations of 15,680 and 10,450 plants per acre in 40 inch and 20 inch rows. They observed that

the grain and stover yields were not influenced by the plant populations or by the row spacings employed. In the forage sorghum trial, the silage yields of Atlas sorgo planted at 20 and 40 inch row spacings also did not show any significant difference.

Protein Content and Feed Quality in Forage Crops

Nevens and Kendall (15) concluded that the average protein content of the forage of sorgos was 6.9 per cent as compared to 7.4 per cent obtained from the corn hybrid US 13. Wiggans (29) showed that the protein content of the forage of corn alone was 4.18 per cent, soybeans alone had 7.16 per cent and the mixture of corn and soybeans ranged from 5 to 6.5 per cent. Interplanting of soybeans in the same row produced higher percentage of proteins as compared to two rows of corn alternated with one row of soybeans or two rows of corn alternated with two rows of soybeans.

Thurman, Stallcup and Reames (25) revealed that the coefficient of digestible protein was the highest for silage from the hybrid RS301F followed by Atlas. Reames, Stallcup and Thurman (22), as a result of feeding trials on steers, concluded that sterile sorghum hybrid RS301F produced high quality silage which was very similar to corn silage in T.D.N. content. It was reported by Owen and Webster (16) that hybrid sorghums are higher in crude protein and lower in nitrogen free extract than the standard varieties.

Morrison (13) pointed out that sorghum forage will not be equal in total digestible nutrients to corn forage if it does not contain similar quantities of grain. Nevens and Kendall (15) observed that

when corn silage feeding was changed to sorghum silage feeding, the average daily milk yield per cow was reduced by 2.1 pounds. On the other hand, the milk yield was increased by 0.8 pounds per day per cow when sorghum silage feeding was changed to corn silage feeding. Owen, Miles, Cowsert, Lusk, Custer and Cardwell (17) found that in the feeding trials with cows, they produced more milk, consumed more silage and gained more weight on the corn silage than on any variety of sorghum. The differences observed were highly significant. They also reviewed the findings of Good, Horlacher and Grimes (1921) and Lamaster and Morrow (1929) who observed that pound for pound sorghum silage was 72.2 per cent as efficient as corn silage for milk productiom and the fattenning of steers; however, when the yields of the two crops were considered, sorghum was 92.2 per cent as economical as corn.

Slate and Brown (24) concluded that corn and soybean mixture cut for silage contained 670 pounds of protein per acre while corn alone provided 550 pounds of protein thus narrowing the nutritive ratio from 1:13 to 1:9.8. According to Nevens and Kendall (15) the mean acre yield of the protein from seven sorgos and three kafirs were approximately 600 lbs. to the acre as compared to 587 lbs. for the corn hybrid. Wiggans (29) reported that the greatest amount of crude protein per acre was obtained when corn was grown nine inches apart in the row with soybeans as a companion crop. All combinations regardless of corn spacing gave greater crude protein production than did corn alone.

Plant Height.

Hittle, McKibben, Browning, Klindworth and Watkins (10) reported that the sorghum hybrid RS301F produced as tall plants as corn hybrids under Illinois conditions. According to Quinby and Marion (21), sorghum hybrid RS301F attained a height of 67 inches under Texas conditions. Probst (20) concluded that varying the distance between the soybean plants had little influence on the height of plants of any variety in his experiment. The tendency, however, was for plants spaced five inches apart to grow slightly shorter than when spaced closer together.

Austenson, Peabody, Turner and Crandall (1) concluded that the plant height of corn was not affected by spacing between rows at constant plant populations but the narrower row spacings resulted in sturdier plants with larger ears. Watson and Davis (33) reported that the diameter of the lowest internode of corn stalks increased with increase of the soil areas upto 3.95 square feet per plant of sweet corn. Further increases in area per hill did not result in increased diameter of stalks. Porter, Jensen and Sletten (19) expressed the tillering of sorghum plants on the basis of number of heads per acre at different planting rates and row spacings. They found that at the same plant populations, the tillering was not affected by varying the distance between rows from 20 to 30 inches.

MATERIALS AND METHODS

The investigations reported in this thesis were carried out at the American University Farm in the Beqa'a plains, under irrigation during 1962. The soil was of a calcareous nature with a pH. of about 8.

Planting was done on April 25, 1962, when the soil had warmed up sufficiently to allow good germination of the seeds. Maximum temperature ranged from about 20°C in April to 34°C in the month of August while the minimum temperature varied between 5°C and 15°C during the same months. No rainfall was received during the growing period. The relative humidity was 99 per cent at the time of planting and tended to decrease with the advance of the growing season. On the whole the seasons were excellent for all of the forage species.

A split plot design with eight replications was employed. The main plots were, the 50 cms. and 75 cms. row-width spacings, and the split plots were represented by the four forages. The forages compared were corn, sorghum, corn + soybeans and soybeans. All plots were over-planted and later thinned to give the following plant populations at each of the two row-width spacings.

Corn	=	8000 plants. per dunum
Sorghum	=	26,666 " per dunum

Corn-soybean	- Corn	= 6,000	plants	per dunum
	- Soybean	= 50,000	"	per dunum
Soybeans		= 66,666	"	per dunum

Seeds of the hybrids Ind. 620 and RS301F were used for the corn and sorghum respectively, while the variety Lincoln was used for soybeans. The plot unit consisted of three rows each five meters in length, both for the 50 cms. and the 75 cms. spacings. One border row of sorghum separated the adjacent plots with different spacing patterns. Corn was planted with a hand-drop corn planter in single kernel per hill. A v-belt hand drill was used for sowing sorghum and soybeans. The soybean seeds were inoculated before sowing with a commercial inoculum called nodogen.

Sprinkler system of irrigation was followed for the first five weeks after planting the crop followed by surface furrow irrigations made at weekly intervals until maturity. Metasystox was sprayed for the control of aphids and corn flea beetles.

Twenty kilograms of P_2O_5 per dunum as superphosphate and 12 kg. of nitrogen per dunum as ammonium sulphate nitrate were broadcast and disked into the soil prior to seeding. Later, an additional 4 kg. of nitrogen was sidedressed when the plants showed nitrogen deficiency symptoms in the lower leaves.

The plots were checked daily during the flowering stages of all the species and the date recorded when 50 per cent of the plants had flowered. The same was done for silking in corn. Data were also recorded for yield, plant height, protein content and flowering time.

The harvesting date of the first cutting of sorghum was the second of August while the rest of the species were cut on the ninth of August. The second cutting of sorghum was done on the eighth of October. Heading in sorghum, denting of the kernels in corn and one half to two third filling of the green pods in soybeans, were regarded as the best dates of harvest.

For obtaining yield data a four meter length of the central row of each plot was harvested. The outer rows and one-half meter at each end served as border rows. A 10 pound representative sample was taken from each plot for chemical analysis, and for dry matter content. Air dry weight of the forage was obtained by storing the samples for 40 days in the seedhouse. To obtain a representative sample the stalks were chopped into smaller pieces with a knife and a representative 15 grams sample ground in a willey mill. Duplicate chemical determinations for nitrogen content were made on each sample by the official A.O.A.C. Methods of Analysis (2). The amount of nitrogen was multiplied by the factor 6.25 and the results expressed as percentage of crude protein.

The forage samples from the second cutting of sorghum were accidentally lost and could not be analyzed for protein content. Therefore, the average protein percentage of the first cutting was used as an estimate in computing total proteins per dunum for sorghum plots.

All of the data were subjected to analysis of variance procedures according to Panse and Sukhatme (18).

RESULTS AND DISCUSSION

In appraising the merits of any forage crop, the yield per unit area is of primary importance. The objective of this investigation, however, was not confined to a comparison of the forage crops on the basis of yield alone. A number of other factors such as height of plants, flowering and silking periods, weight per plant and the feeding value of different forages, were also considered.

The data pertaining to each factor studied, are presented in Tables 1 to 9. The L.S.D. figures for the forage crops, spacing and interaction between spacing and forage crops together with the analysis of variance are also reported in the same Tables.

Yield of Forage

The yield of the four forages tested as is evident from Table 1, showed highly significant differences. Sorghum hybrid, RS301F, gave an average of 3.00 tons of air dry forage per dunum which constituted 2.10 tons from the first cutting and 0.90 ton from the second cutting. This yield was higher than the other forage crops studied and was about one and one half times that of corn alone. Watkins, Hittle, McKibben and Browning (32) got double the yield from sorghum hybrids as compared to corn alone. Similar results have also been reported by Drolsom and Scholl (5) Quinby and Marion (21) and Owen, Miles, Cowsert, Lusk, Custer and Cardwell (17).

Table 1. Yield of four forages (air dry weight) in tons per dunum when grown in Beqa'a, Lebanon in 1962.

Spacing between rows	Sorghum	Corn	Corn + soybean	Soybean	Average
50 cms.	3.11	2.04	1.68	0.92	1.94
75 cms.	2.89	1.94	1.66	1.01	1.87
Average	3.00	1.99	1.67	0.96	--

L. S. D.

	At 5 per cent	At 1 per cent
Forage crops	0.48	0.56
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.
Replications	7	0.085
Spacing	1	0.060
Error (a)	6*	0.128
Forage crops	3	11.490**
Forages x spacings	3	0.076
Error (b)	42	0.461

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

Corn alone yielded slightly higher than the corn-soybean combination. The results do not agree with Nevens and Kendall (15), Wiggans (27) (29), Slate and Brown (24), and Hughes and Henson (8), who consistently obtained higher yields by growing corn and soybeans together as compared to corn alone. One of the reasons may be the need of more nitrogen fertilizer for the corn-soybean mixture than corn alone, because inspite of the supplementary addition of four kilograms of nitrogen per dunum, the corn leaves continued to show nitrogen deficient, symptoms at the tasselling and silking stages. Moreover, the corn hybrid Ind. 620 and Lincoln soybeans did not reach the optimum maturity at the same time. The corn hybrid used was later in maturity than the soybeans so this mixture had to be harvested before the corn reached its optimum growth.

The yield of soybean alone was much lower than that of the other forage crops. The mean yield per dunum was 0.96 tons of air dry forage, which is rather low to be of great importance to a grower.

For the spacing between rows, the convenience of the cultivator has been largely responsible for fixing the customary distance between rows. The yields have to be sometimes sacrificed in order to fit in the implements, to facilitate the cultivation and harvesting operations.

The narrow row spacing of 50 cms. between rows resulted in very slightly higher yields of air dry forage than the 75 cms. spacing, at constant plant populations. The differences, however, were not statistically significant. These results are in conformity with Hoff and Mederski (7), Bryan, Eckhardt and Sprague (3), Austensen, Peabody, Turner and Crandall (1), Stickler and Laude (23) and Boyd, Green and

Chapman (4), who obtained higher yields from narrower row spacings at uniform plant populations. Austenson, Peabody, Turner and Crandall (1), were of the view that narrower row spacings will allow corn roots to permeate practically all of the surface soil and take up all available moisture and nutrients. The wider row spacings on the other hand will result in intense root competition within the row with very poor root distribution in the wide spaces between the rows. Similarly, the leaf distributions will affect light availability. In the present investigations, the spacings tried were not widely different hence no significant differences in yield could be noted.

Feeding Value of Forage Crops

Forage yields alone are not an adequate measure of the feeding value of a crop. The usefulness of the four forages was studied by determining their protein content and the yield of total protein per dunum.

a. Protein Content. The protein content of the forage crops differed widely falling within the range of 5.34 per cent for sorghum to 10.83 per cent protein for soybeans alone (Table 2). The differences obtained in the protein percentage due to the forage crops were highly significant. Soybean, being a leguminous crop, is rich in proteins and resulted in a significantly higher percentage of proteins than that in the other forages. When soybean was grown in combination with corn, it increased the protein content of the resulting mixture by about 30 per cent. Wiggans (29) got an increased protein content of 37.5 per cent in corn - soybean mixture over corn alone and reported that it was possible to increase the protein content up to 100 per cent by increasing the amount of soybeans in the mixture.

Table 2. Percentage protein content of forage crops at maturity when grown in Beqa'a, Lebanon in 1962.

Spacing between rows	Sorghum	Corn	Corn + soybean	Soybean	Average
50 cms.	5.15	5.01	7.08	10.30	6.88
75 cms.	5.54	5.85	7.11	11.37	7.46
Average	5.34	5.43	7.09	10.83	--

L. S. D.

	At 5 per cent	At 1 per cent
Forage crops	0.66	0.89
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.
Replications	7	0.257
Spacing	1	5.480
Error (a)	6*	1.445
Forage crops	3	105.603**
Forages x spacings	3	0.853
(Error (b)	42	0.867

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

Corn gave slightly higher percentage of proteins than sorghum RS301F but the differences were non significant. The results are in agreement with Nevens and Kendall (15), who reported 0.5 per cent higher protein content from corn forage as compared to sorgo forage. The superiority of corn over sorgo silage has also been shown by Morrison (13), Reames, Stallcup and Thurman (22), and several others.

No differences in protein content were found due to spacing treatments and the interaction between spacing and forage crops (Table 2).

b. Yield of Protein. In the absence of feeding trials it is of interest to make comparisons in terms of the total kilograms of proteins per dunum of forage from corn alone, sorghum alone, soybean alone and from the combination of corn and soybean. Table 3 reports the data for this character.

It is evident that sorghum, although it was very low in the percentage of protein content, gave significantly higher yield of total crude proteins in kg. per dunum, than that from the other forage crops. This was due to its high tonnage of forage per dunum. These results are in agreement with Nevens and Kendall (15), who obtained 600 pounds of crude protein per acre from sorgos against 587 pounds from corn.

Corn - soybean mixture, inspite of being low in yielding ability, produced 10 kg. more proteins per dunum than corn alone. Slate and Brown (24) also obtained more yield of crude protein by growing soybean mixed in corn as compared to corn alone. The same behaviour led Wiggans (29) to support the growing of the two crops together, where production of the most nutritious silage, with the greatest economy, is desired.

Table 3. Yield of crude protein in kilograms per dunum of forage crops when grown in Beqa'a, Lebanon in 1962.

Spacing between rows	Sorghum	Corn	Corn + soybean	Soybean	Average
50 cms.	159.87	102.84	117.26	94.80	118.69
75 cms.	160.09	113.26	118.89	115.60	126.96
Average	159.98	108.05	118.07	105.20	--

L. S. D.

	At 5 per cent	At 1 per cent
Forage crops	12.8	17.2
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.
Replications	7	733.08
Spacing	1	1093.13
Error (a)	6*	603.69
Forage crops	3	10302.93**
Forages x spacings	3	361.07
Error (b)	42	319.89

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

Soybean alone has also given as good yield of protein as corn alone but its relative low yield of air dry forage does not justify its cultivation as a forage crop by the farmers.

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

Plant Height

The plant height is said to have a direct correlation with the yield of forage crops. The average height, obtained by measuring five plants from each plot, was recorded at the time of maturity. The data are presented in Table 4.

The analysis of variance data reveal that the forage crops showed significant differences in plant height. The sorghum, hybrid RS301F, produced the tallest plants followed closely by corn. The differences between these two, however, were non-significant. Hittle, McKibben, Browning, Klindworth and Watkins (10), also pointed out that hybrid sorghum RS301F grows as tall as corn hybrids.

The plant height of corn was significantly reduced by the inter-planting of soybeans as compared to corn alone. Since soybeans compete with corn both for food and moisture, the nitrogen deficiency experienced in these plots during tasselling no doubt contributed towards a reduction in the height of the corn plant.

It is interesting to note that soybean grown in combination with corn produced slightly taller plants than soybean alone. This increase in height may be probably due to the shading effect of corn plants on

Table 4. Height per plant of forage crops in cms. at two spacings, when grown in Beqa'a, Lebanon in 1962.

Spacing between rows	Sorghum	Corn	Corn in soybeans	Soybean in corn	Soybean	Average
50 cms.	246.9	232.2	213.9	179.0	171.4	208.6
75 cms.	236.5	235.2	218.1	173.0	167.9	206.1
Average	241.7	233.7	216.0	176.0	169.6	--

L. S. D.

	At 5 per cent	At 1 per cent
Forage crops	10.32	13.74
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.
Replications	7	139.62
Spacing	1	130.05
Error (a)	6*	299.29
Forage crops	4	17443.01**
Forage x spacings	4	151.95
Error (b)	56	211.82

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

soybeans. Garner and Allard (6) also recorded similar increase in plant height from artificially shaded soybean plants.

The spacing treatments and the interaction between spacing x forage crops did not significantly affect the height of plants.

Days from Planting to Flowering

An indicator of the relative maturity of forage crops is the number of days from planting to blooming. To determine the relative maturity of the forage crops studied, records were taken for the average date of tasselling in corn, flowering in soybeans and the first appearance of heads from the boot in sorghum.

It is evident from the data in Table 5 that hybrid sorghum RS301F required 98.4 days to reach the heading stage under Beqa'a plain conditions. Corn growing alone tasselled significantly earlier than corn grown in combination with soybeans. A similar behaviour was noted in case of soybeans. The plants growing alone on the average flowered 7.1 days earlier than those grown together with corn. It can be concluded that the relative maturity of both corn and soybeans was delayed by planting them together in comparison with planting each alone.

Spacing between rows did not significantly affect the number of days taken to flowering in soybeans, tasselling in corn and heading in the case of sorghum.

Weight per Plant

The best method suggested by Wiggans (29) for combining corn and soybeans for the purpose of producing a high protein silage, is to

Table 5. Number of days from planting to flowering in soybeans, tasselling in corn and appearance of heads in sorghum, when grown in Beqa'a, Lebanon in 1962.

Spacing between rows	Sorghum	Corn	Corn in soybeans	Soybean in corn	Soybean	Average
50 cms.	97.9	76.2	81.4	58.2	49.5	72.6
75 cms.	98.9	77.0	82.1	59.0	53.5	74.1
Average	98.4	76.6	81.7	58.6	51.5	--

L. S. D.

	At 5 per cent	At 1 per cent
Forage crops	1.65	2.20
Spacing	N.S.	N.S.
Interaction	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.
Replications	7	16.67
Spacing	1	41.65
Error (a)	6*	6.89
Forage crops	4	5607.12**
Forage x spacings	4	8.42
Error (b)	56	5.42

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

grow the two crops together in the same row. The two crops grow nicely as companions but do compete for light and nutrients.

In order to see the effect of each on the weight per plant of the other, corn and soybean plants were harvested separately from a four meter row in the mixed plots. The air dry weight of each was divided by the number of corn and soybean plants growing in that row. Similarly the weight per plant of corn and soybean growing alone was calculated for comparison. The data are presented in Table 6.

It is clear that without exception, the yield per plant of corn was reduced significantly by the addition of soybeans. The loss sustained was 13 per cent in the air dry weight of a single corn plant as compared to corn alone.

The behaviour of the soybeans under these conditions also is of considerable interest. The value of this method of silage production depends on the performance of soybeans under the severe competition of growth with corn. The weight per plant of soybean alone and in combination with corn is shown in columns five and six of Table 6.

It is evident from the data that the reduction per plant of soybean was much higher than that found for corn. This may be expected since about 75 per cent of the total growth of the combined crop was corn and 25 per cent was soybeans. The air dry weight per plant of soybean growing alone was 14.98 gms. as compared to 7.36 gms. when growing in combination with corn. Therefore, soybean plants grown alone were twice as heavy as those grown together with corn. The results agree with Wiggans (29), who observed that by growing the two

Table 6. Comparison of weight per plant in gms. of corn and soybeans when grown alone and in combination in Beqa'a, Lebanon in 1962.

Spacing between rows	Corn			Soybean		
	Alone	With soybean	Average	Alone	With corn	Average
50 cms.	255.8	216.2	236.0	13.79	7.53	10.66
75 cms.	242.0	217.9	229.9	15.18	7.19	11.18
Average	248.9	217.0	--	14.48	7.36	--

L. S. D.

	Corn		Soybean	
	At 5%	At 1%	At 5%	At 1%
Forage crops	18.2	25.3	1.21	1.68
Spacing	N.S.	N.S.	N.S.	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.	
		Corn	Soybean
Replications	7	2799.76	2.75
Spacing	1	290.29	2.24
Error (a)	6*	912.98	3.66
Forage crops	1	8105.83**	405.84**
Crops x spacings	1	478.17	5.90
Error (b)	14	580.17	2.58

* D. F. reduced by one due to confounding.

** Significant at the one per cent level.

crops together, corn was reduced by 15 per cent while soybeans produced not more than one third as much as when grown alone. He went further to say that:

"There seems to be no question that any combination of soybean with corn in the same row decreases the total yield of corn, a fact repeatedly established by all experimental work on this problem. The same is true for soybeans as well."

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

Other Characters.

1. Corn.

a. Planting to Silking Time. The date of silking occurs at a critical time in the development of corn plants and has been used widely as a criterion of the relative maturity of a variety. It also has been used as marking the transition from the vegetative to the fruiting stage. This period is very important from the standpoint of yield because it is the time of ear shoot development and fertilization both of which greatly influence the amount of seed set. The mean date of appearance of first silks from five plants in each plot was used as an estimate of the silking period. The average number of days from planting to silking for corn growing alone and in combination with soybeans are recorded in Table 7.

It is evident from the data that silking occurred 4.3 days earlier in the corn-alone plots as compared to corn growing in mixture with soybeans. The differences were highly significant. Soybeans,

Table 7. Number of days taken to silking and the circumference of stalk in cms. of corn grown alone and in combination with soybeans in Beqa'a, Lebanon, in 1962.

Spacing between rows	Days taken to silking			Circumference of stalk		
	Corn alone	Corn with soybeans	Average	Corn alone	Corn with soybeans	Average
50 cms.	87.0	91.5	89.25	8.56	7.74	8.15
75 cms.	86.0	90.1	88.05	8.17	7.40	7.78
Average	86.5	90.8	--	8.36	7.57	

L. S. D.

	Days taken to silking		Circumference of stem	
	At 5%	At 1%	At 5%	At 1%
Forage crops	1.88	2.61	0.17	0.23
Spacing	N.S.	N.S.	0.28	N.S.
Interaction	N.S.	N.S.	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.	
		Days taken to silking	Circumference of stem
Replications	7	19.63	0.07
Spacing	1	11.28	1.07*
Error (a)	6***	2.16	0.11
Forage crops	1	148.78**	5.00**
Crops x spacing	1	0.28	0.01
Error (b)	14	6.17	0.05

*** D. F. reduced by one due to confounding.
* Significant at the five per cent level.
** Significant at the one per cent level.

therefore, delay the appearance of silks in the case of corn-soybean mixture.

The differences in silking time due to spacing and interaction between spacing and forage crops did not reach the level of significance.

b. Circumference of Stalk. Stout and sturdy corn plants are very desirable for high forage productivity. To measure the effect of soybeans on the thickness of corn plants, the average circumference from five plants in each plot was recorded. The data together with the analysis of variance are reported in Table 7.

Corn growing alone had significantly higher circumference of stalk as compared to corn growing in combination with soybeans.

It will be noted that the two row spacimgs used in this trial influenced the size of resulting corn stalks. Corn growing in 50 cm. rows resulted in plants with significantly larger stalk circumference as compared to those planted 75 cms. apart. This observation is in conformity with Austenson, Peabody, Turner and Crandall (1) who reported sturdier plants from narrower spacings. The interaction between forage crops and spacing between rows did not produce any significant differences.

2. Soybeans

a. Number of Pods per Plant. The number of pods per plant, reported in Table 8, were obtained by averaging the number of pods from five plants in each plot. The data show that the number of pods per plant were higher when the soybeans were grown alone in comparison to those growing in combination with corn. Soybean grown alone produced

Table 8. Number of pods and number of branches per plant of soybean when grown alone and with corn in Beqa'a, Lebanon, in 1962.

Spacing between rows	Pods per plant			Number of branches		
	Soybean alone	Soybean with corn	Average	Soybean alone	Soybean with corn	Average
50 cms.	31.6	17.3	24.4	1.87	1.00	1.43
75 cms.	24.2	15.6	19.9	1.25	0.75	1.00
Average	27.9	16.4	--	1.56	0.87	

L. S. D.

	Pods per plant		Number of branches	
	At 5%	At 1%	At 5%	At 1%
Forage crops	4.92	6.88	0.51	N.S.
Spacing	N.S.	N.S.	N.S.	N.S.
Interactiom	N.S.	N.S.	N.S.	N.S.

Analysis of Variance

Source	D. F.	M. S.	
		Pods per plant	Number of branches
Replications	7	169.60	0.81
Spacing	1	166.53	1.53
Error (a)	6***	45.03	0.62
Forage crops	1	1046.53**	3.78*
Crops x spacing	1	63.29	0.28
Error (b)	14	42.12	0.46

*** D. F. reduced by one due to confounding.
* Significant at the five per cent level.
** Significant at the one per cent level.

27.9 pods per plant as compared to 16.4 in case of soybean interplanted in corn. Differences for spacing between rows and for the interaction between spacing x forage crops were not significant.

b. Number of Branches per Plant. The yield of crop plants in soybeans for forage can be resolved to its two basic components, height of plants and number of branches per plant. The latter factor was studied by recording the average number of branches from five plants in each plot. The results together with the L.S.D. and the analysis of variance are reported in Table 8.

It is evident from the data that the number of branches per plant were higher when soybean was growing alone. The differences were significant at the five per cent level. Soybean interplanted in corn had a tendency to grow upright producing fewer branches probably due to the shading effect of corn on soybeans. Row spacings did not influence branching in soybean.

3. Sorghum

Data on the effect of spacing between rows on the circumference of second basal internode of sorghum and the number of tillers per plant are given in Table 9. The differences were compared on the basis of "t" test. The observed "t" and the D. F. are also reported in the same Table.

a. Circumference of Stem. The data reveal that plants growing in rows 50 cms. apart had significantly greater stalk circumference as compared to those in 75 cm. rows. A similar observation was also made

Table 9. Effect of spacing between rows on the circumference of stem and number of tillers per plant of sorghum when grown in Beqa'a, Lebanon, in 1962.

Spacing between rows	Circumference of stem cms.	Number of tillers per plant
50 cms.	5.55	1.61
75 cms.	4.78	1.44
Observed "t"	3.08	0.49
D. F.	14	14

in corn plants which leads to the conclusion that at constant plant populations narrow between-row spacing increases the thickness of sorghum stems.

b. Number of Tillers per Plant. The number of tillers per plant of sorghum, as reported in Table 9 were not affected by the between row spacings of 50 cms. and 75 cms. The results agree with those of Porter, Jensen and Sletten (19) who expressed tillering of sorghum plants on the basis of number of heads per acre at different planting rates and row spacings. They noted that at the same plant populations, the tillering was not affected by varying the distance between rows from 20 inches to 30 inches.

Economic Aspect.

In the preceding discussion it was shown that sorghum was outstanding in yield over corn and other forages. This increased yield

was primarily due to the two cuttings possible from sorghum and only one cutting from the other crops. The second cutting which remained in the field for two months after the first harvest, gave 0.9 tons of air dry forage per dunum. It is important, therefore, to study the comparative economic value of the four forage crops under study.

After deducting all of the extra expenses for labour, irrigation and fertilizer, a farmer will obtain a net income of approximately 100 L.L. per dunum by allowing sorghum to continue in the field for an additional period of two months. In contrast the corn plots were lying fallow for two months and the land could easily be plowed and prepared for winter wheat. If the farmer wants to make use of this land just after the removal of corn by sowing a short duration crop like turnips, he may also get a net income of 100 L.L. in two months. In turnips, of course, he will have to incur four times more initial expenditure for preparing the land and for labour, seed and other expenses while for sorghum he does not need to run into such extra expenses.

It is, therefore, reasonable to conclude that getting a second cutting of sorghum from a hybrid such as RS301F, is desirable under the Beqa'a valley conditions.

SUMMARY AND CONCLUSIONS

Four forage crops corn, sorghum, corn + soybeans and soybean were seeded in rows 50 and 75 cms. apart at the American University farm in the Beqa'a plain, Lebanon, during 1962. They were evaluated for yielding ability, quality, plant height, flowering time, weight per plant and other individual plant characters.

The forage sorghum hybrid, RS301F, produced the highest tonnage of air dry forage as compared to corn alone, corn-soybean mixture and soybean alone. The corn-soybean mixture produced lower yields than corn alone while the soybean yielded the least.

Soybean forage contained the highest percentage of proteins of the four crops tested. When soybean was grown in combination with corn, it increased the protein content of the resulting mixture by about 30 per cent. Slight differences in protein percentage were noted in the corn and the sorghum forage.

Sorghum, because of its high tonnage of forage, produced the greatest amount of total protein per dunum. The corn-soybean mixture although lower in air dry weight than corn, produced slightly more total protein per dunum than corn alone.

The weight per plant of corn was reduced by the addition of soybeans. Corn grown with soybeans resulted in plants weighing about 13 per cent less than when grown alone. The weight per plant of the interplanted soybeans was likewise reduced by about one half.

Interplanting of soybean in corn rows reduced the height of corn plants, delayed the tasselling and silking period and reduced the thickness of corn stalk as compared to corn alone.

Soybean plants growing in mixture with corn grew taller and thinner, were later in flowering, had lower branching ability and produced significantly lower number of pods per plant than when grown alone.

Sorghum hybrid RS301F, proved to be a tall growing hybrid and required 98.4 days for heading. Ratooning of sorghum to get one more cutting proved successful under the prevailing Beqa'a plain conditions.

The spacing between rows did not affect any of the characters studied except the circumference of stalk. The size of the stalks in corn and sorghum were larger in the plants growing in the 50 cm. rows than those in the 75 cm. rows.

It may, therefore, be recommended to the farmers in Beqa'a valley that the sorghum variety RS301F, is a high yielding hybrid producing higher tonnage of forage as compared to corn alone, corn-soybean mixture and soybean alone. On the basis of one year data row spacings of 50 cms. and 75 cms. had little effect on the resulting yields.

LITERATURE CITED

1. Austenson, H.M., Peabody, Dwight V., Jr., Turner, D.O., and Crandall, P.C. Silage corn research in Western Washington. Wash. Agr. Expt. Sta. circular 404:1-11. 1962.

2. Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis. 9th. Ed. 1960.

3. Bryan, A.A., Eckhardt, R.C., and Sprague, G.F. Spacing experiments with corn. J. Am. Soc. Agron. 32:707-714. 1940.

4. Boyd, F.T., Green V.E., Jr., Chapman, H.L., Jr. Production of sorghum forage and grain in South Florida. Univ. Florida Agr. Expt. Sta. Bull. 628:1-28. 1961.

5. Drolsom, P.N., and Scholl, J.M. Sudan grass and forage sorghum yields. (Madison) Wisconsin, Sorghum Newsletter 6:69-71. 1963.

6. Garner, W.W., and Allard, H.A. Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. J. Agr. Res. 18:553-606. 1920.

7. Hoff, D.J., and Mederski, H.J. Effect of equidistant corn spacing on yield. Agron. J. 52:295-297. 1960.

8. Hughes, D. Harold., and Henson, R. Edwin. Crop Production. Principles and Practices. The Mac. Co. N. Y: 377. 1960.

9. Hinze Greg., and Leonard, W.H. Forage and grain sorghum yield tests. Colorado Agr. Expt. Sta. Progress Report 34. 1962.

10. Hittle, C.N., McKibben, G.E., Browning, D.R., Klindworth, L.E., and Watkins, P.W. Grain and forage sorghums. 1960 performance in Illinois. Univ. Illinois Agr. Expt. Sta. Bull. 673. 1960.

11. Lima Mario Coelho de A., and Mafra Rivaldo. Comments on sorghum in Northeast Brazil. Sorghum Newsletter 6:5-6. 1963.

12. Morril, Glenn J. Importance of reserve forage. Regional Range Management Training Course Tehran, Iran: 53-56. 1955.

13. Morrison, F.B. Feeds and Feeding. 22nd Ed. Morrison Publishing Co., Ithaca. N.Y. 1956.

14. Middle East, The. 9th. Ed.:248. 1962. Europa Publications LTD. 18, Bedford, Sq. London W.C.I.

15. Nevens, W.B., and Kendall, K.A. Sorghums and soybeans as silage crops for milk production. Univ. Illinois Agr. Expt. Sta. Bull. 578: 1-62. 1954.

16. Owen, F.G. and Webster, O.J. Effect of sorghum maturity at harvest and variety on certain chemical constituents in sorghum silages. Agron. J. 5: 167-169. 1963.

17. Owen, J.R., Miles, J.T., Cowsert, W.C., Lusk, J.W., Custer, E.W., and Cardwell, J.T. Feeding value of corn and sorghum silage for milk production. J. Dairy Sci. 40: 1554-1558. 1957.

18. Panse, V.G. and Sukhatme, P.V. Statistical Methods for Agricultural Workers. Indian Council Agr. Res. New Delhi. 1957.

19. Porter, K.B., Jensen, M.E., and Sletten, W.H. The effect of row spacing, fertilizer and planting rate on the yield and water use of irrigated grain sorghum. Agron. J. 52: 431-434. 1960.

20. Probst, A.H. Influence of spacing on yield and other characters in soybeans. J. Am. Soc. Agron. 37: 549-554. 1945.

21. Quinby, J.R., and Marion, P.T. Production and feeding of forage sorghum in Texas. Texas Agr. Expt. Sta. Bull. 965: 1-16. 1960.

22. Reames, C.E., Stallcup, O.T., and Thurman, R.L. A comparison of the digestibility of Atlas sorgo silages with corn silage. J. Dairy Sci. 44: 693-698. 1961.

23. Stickler, F.C., and Laude, H.H. Effect of row spacing and plant populations on performance of corn, grain sorghum and forage sorghum. Agron. J. 52: 275-277. 1960.

24. Slate, W.L., and Brown, B.A. Corn and soybeans as a combination crop for silage. (Connecticut) Storrs Agr. Expt. Sta. Bull. 133. 1925.

25. Thurman, R.L., Stallcup, O.T., and Reames, C.E. Quality factors of sorgo as a silage crop. Univ. Arkansas, Fayetteville. Agr. Expt. Sta. Bull. 632: 1-24. 1960.

26. Welton, F.A. and Morris, V.H. The lodging of soybeans. J. Am. Soc. Agron. 22: 897-902. 1930.

27. Wiggans, R.G. Combinations of corn and soybeans for silage. Cornell Univ. Agr. Expt. Sta. Bull. 634: 1-34. 1935.

28. Wiggans, R.G. Soybeans in the northeast. J. Am. Soc. Agron. 29: 227-235. 1937.

29. _____. Corn and soybean for silage. Cornell Univ. Agr. Expt. Sta. Bull. 548: 1-36. 1932.

30. _____. The influence of space and arrangement on the production of soybean plants. J. Am. Soc. Agron. 31: 314-321. 1939.

31. _____. The effect of growing corn and soybeans in combination on the percentage of dry matter in the two crops. J. Am. Soc. Agron. 26: 59-65. 1934.

32. Watkins, P.W., Hittle, C.N., McKibben, G.E., and Browning, D.R. Grain and forage sorghums. 1959, Performance in Illinois. Univ. Illinois Agr. Expt. Sta. Bull. 659. 1959.

33. Watson, Alfred N., and Davis, R.L. The statistical analysis of a spacing experiment with sweet corn. J. Am. Soc. Agron. 30: 10-17. 1938.