EFFECT OF ROW-WIDTH AND STAND ON YIELD
AND OTHER CHARACTERISTICS OF
GRAIN SORGHUM

by

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ABSTRACT

This study was carried out at the American University Farm to determine the effect of planting three sorghum varieties at within-row spacing of 5, 10 and 15 centimeters in rows 50 and 75 centimeters apart. The plant characters studied were grain yield, number of days to heading, protein percentage, heads per plant, head size, 1000 kernel weight, plant height and stover yield.

The grain yield and protein percentage of sorghum were not influenced by variation in row-width or plant spacing. The heading of sorghum was delayed by half a day when planted in rows 75 centimeters apart.

The number of heads per plant increased by planting in wider row-width or plant spacing. Likewise, heads of bigger size were produced when the row-width was increased or the stand was reduced. The seed weight of sorghum was reduced by thicker planting. Sorghum planted at narrow within-row spacing produced taller plants. A higher stover yield was obtained when sorghum was planted at narrow row-width and thicker stand.

The hybrid, Texas 620, was the best in yield performance in comparison to Early Hegari and Norghum.

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INTRODUCTION

Sorghum (Sorghum vulgare) is one of the important food grain of the world exceeded only by rice and wheat. It is a chief food grain in some parts of Asia and Africa. About 75 percent of the total production (26 million tons) of grains is utilized as a human food (26). The rest is used as feed for poultry, cattle and swine.

Most of the grain sorghum are grown where the summer temperature averages 65°F or higher with a frost free period of 120 days or more. Being a drought resistant crop, it competes with the production of maize. The zone of transition between the predominant acreage of maize and grain sorghum lies approximately along the line of an annual precipitation of 25 inches.

The development of new hybrids, use of fertilizers and more intensive irrigation, make grain sorghum a crop with great potentialities. The production potential can be utilized to the maximum if optimum row spacing and plant population is used.

Lebanon and other Middle East countries import a substantial quantity (44,700 metric tons) of grain sorghum for food and feed purposes (34). These countries can easily become more self sufficient in the production of grain sorghum, by using high yielding varieties, proper fertilization and adopting suitable cultural practices.

This study was undertaken to find out the effect of stand and row-width on yield and other characteristics of grain sorghum under the conditions prevailing in the Beqa'a plain. Three varieties, including a hybrid, were evaluated for their performance at two row-widths and three within-row spacings regarding yield, protein content and other agronomic characteristics.

REVIEW OF LITERATURE

Profitable yields of grain sorghum depend to a large extent upon good cultural practices. One of the most important cultural practices to get the maximum yield of the grain is the optimum spacing of plants. It is the purpose of this section to review the available information pertaining to the effect of row-width and stand on yield and other agronomic characteristics of grain sorghum.

Grain Yield

Karper (12) studied the effect of spacing on two sorghum varieties, Kafir and Milo, for a period of ten years. The two varieties responded differently to the variation in spacing of the plants in the row. The yield of Kafir decreased, while Milo increased when the number of plants within the row was reduced. Maximum production of the Kafir was obtained when the plants were spaced three to nine inches within the row, while the performance of the Milo was best when spaced 18 to 30 inches apart in the row. Martin and Sieglinger (17) also conducted similar experiments under Kansas conditions for ten years. They concluded that the space required for a given variety for maximum yield is determined by two plant characters, viz; the ability to produce more tillers, and the ability to produce larger heads when the space per plant is increased. In these studies the dwarf Milo variety produced almost similar yields at 6, 12, 18 and 24 inch spacings in the row, indicating that it is highly adaptable to variation in plant density . Kafir, a variety which tillers sparsely, produced the highest yield when planted at spacing of six inches within the row. These results were confirmed by Karper, Quinby, Jones and Dickson (13) who obtained similar response from Milo and Kafir to the variation in row spacings.

Vinall, Getty and Cron (35) emphasized that the choice of variety was more important than the row-width and within row spacing. Their results indicated that for grain sorghum production 8 to 12-inch row-width was the best. Nelson (18) compared three varieties of sorghum at the row-width of 24, 30 and 36 inches and within row spacings of 1.2, 1.4, and 2.4 inches. His results showed that the plant spacing within this range, can be varied without materially affecting the yield of the varieties under test. Nelson and Roberts (19) obtained a direct relationship between plant population and yield to a certain extent. They studied the response of eight sorghum varieties to populations ranging from 2.12 to 5.39 plants per square foot in 22-inch spaced rows. The yield increased from 131.1 bushels to 142.2 bushels per acre when the plant population was increased from 92,347 to 150,282 plants per acre. The yield remained at this level for the thicker plant populations i.e. 192,100 and 234788 plants per acre. Pickett and Fredericks (24) conducted row spacing trials with grain sorghum at several locations in Indiana. They found that yields as high as 246 bushels per acre can be obtained when sorghum is planted in rows 7 inches apart with a population of 360,000 plants per acre. The yield decreased with the increase of row-width and plant population.

Ross and Webster (28) observed that grain sorghum planted in 20-inch rows usually produced more grain per acre than that planted in 40-inch rows with the same plant population per acre. Closer spacing of rows and placing seed further apart in rows provided a more uniform feeding around each plant. They recommended that combined with good agronomic practices, the sorghum be planted at 100,000 to 120,000 plants per acre in narrow spaced rows to get the highest yield.

Grimes and Musick (6) conducted experiments from 1952 through 1958 to find the proper spacing of irrigated sorghum. These studies revealed that thickness of stand influences the yield considerably. An area of 50 to 60 square inches per plant was considered most desirable when ample moisture was available. This corresponds to a population of slightly more than 100,000 plants per acre. The sorghum in narrow rows yielded more than in wide rows, when the area per plant remained the same. Ross and Bieberly (27) also emphasized the importance of thick planting to get higher yield under irrigated conditions. The factors responsible for increased yield in narrow rows were listed as i. better plant spacing, ii. increased shading of weeds, iii. more efficient use of water, soil nutrients and light , iv. reduced water evaporation from the soil and from the plant by transpiration, and v. less soil and root disturbance as no cultivation is required. Swinbank (32) on the other hand, obtained higher yield of grain when sorghum was planted at wider spacing and in narrow rows.

Herbert and Warren (8) claimed that under dry land conditions in Colorado, the planting of more than two to four pounds of seed per acre was wasteful. They, however, emphasized that although the average yield obtained from 21- and 42-inch rows were similar, there is an advantage of planting sorghum in narrow rows, as it can compete more vigorously with weeds, and the wind erosion hazard is greatly reduced during the winter that follow harvest.

Porter, Jensen and Sletten (25) reported that when soil fertility level was not a limiting factor, significantly higher yields were obtained with sorghum planted in narrow rows of 21-inch width as compared to 42-inch row width. But when the fertility level of soil was low, the wider row spacing produced better yield than the narrow row-width. Painter and Leamer, (21), Paschal and Evans (23) reported similar effect of plant population on yield at high and low fertility levels. They obtained maximum yield when plants were spaced four inches within the row at higher fertility level. At medium soil fertility level no significant difference in yield was observed when the plants were spaced at four or nine inches within the row. Kurtkoti and Diveker (15) recommended that to get maximum yield, the jowar or grain sorghum be drilled at the seed rate of four pounds per acre in rows 24-inch apart, instead of the usual procedure of planting in rows 15-inch apart. An average yield increase of 31 per cent was obtained continuously for three years, when the planting was done according to the recommended method.

Idris (11) concluded from the spacing studies carried out at Tozi, Wad El Huri and Mazmoun in Sudan that the yield differences obtained from 24-inch rows were not significantly different in the early planting. However, with late planting these differences were significantly higher when compared to rows spaced 30-inches apart. The higher density of plants within the row produced greater yield than the low density. Norman and Hsi (20) showed that there was no difference in yield due to variation in row-width when the plant population is kept the same. However, a significant difference in yield was obtained when; in the wide row-width, the plant population was increased and the row-width kept the same. The increase in yield at narrow row -width with the increase in population was non-significant.

Boyd (2) recommended that under Wyoming conditions the crop for grain sorghum should be planted at the rate of four to eight pounds of seed per acre to get the maximum yield. This seeding rate was sufficient to space plants every four to eight inches in rows planted 40-to 42-inches apart. Georgeson, Cottrell and Shelton (4) on the other hand reported that greater yield of grain per acre can be secured by planting sorghum in rows 24 to 30-inches apart with plants spaced at four to eight inches within the row.

According to Kersting (14) the yield increased by 26 per cent when grain sorghum was planted in narrow rows of 20-inch width as compared to 40-inch row-width. The increase in yield was explained to be partly due to the efficient use of nutrients and moisture in the narrower rows. Stickler, Pauli, Laude, Wilkins and Mings (31) obtained a similar increase in yield when the sorghum was planted in narrow rows and individual plants were provided with an area of 60 to 80 square inches. The yield tended to lower with the increase or decrease in the area per plant. Hittle, Pendleton, McKibben and Portz (9) found that in central Illinois the narrow rows of 20 and 30-inch width outyielded the 40-inch rows. In the rate of planting experiments the highest yield was obtained when the plants were spaced 3-inches apart in 40-inch wide rows. The yield progressively decreased with reducing the density of plants within the row. Talbert (33) recommended that for maximum yield production and to get efficient control of weeds by a herbicide without cultivation, the sorghum be planted in 20-inch spaced rows. According to Last (16) spacing and thinning had only minor effects on yields per acre, but altered the yield per plant. Doubling the number of plants by decreasing the spacing between the holes from 50 to 25 centimetres did not effect the yield per acre, but halved the yield per plant. Increasing the spacing from 50 to 100 centimeters again had no effect on yield per acre but doubled the yield per plant.

Greb (5) reported that under the conditions prevailing in Colorado planting in narrow rows of 21-inches resulted in slightly lower population as compared to 42-inch row spacing, when the per acre seeding rates were the same. He obtained higher average yield with wider row-width under various rotations when the water supply was limited.

Protein Percentage

Limited data are available on the effect of row spacing and population on the protein content of the grain. Nelson (18) has reported that row and plant spacing did not alter the protein content of the grain. He also did not obtain any interaction between the varieties and row spacing. Stickler and Pauli (30) on the contrary have reported that protein content was reduced due to the increase in stand and planting in narrow rows.

Heads per Plant

Karper, Quinby, Jones and Dickson (13) reported that for best grain yield, varieties that tiller freely need more space per plant than those which tiller less. They recommend that the variety Milo, which tillers freely, should be spaced 12 to 24 inches in rows, while Kafir, which tillers sparsely should be planted at close spacing of six inches to get the maximum yield. Martin and Sieglinger (17) concluded from ten year studies that the average number of heads per plant increased with the spacing in the case of Milo. This increase in the number of heads was not in proportion to the wider spacing. The Kafir variety produced only slightly more than one head per plant with the thinnest spacing, showing its inability to tiller to any extent. Nelson and Roberts (19) obtained no correlation between the varietal differences in yield and tillering. But the number of tillers per plant decreased as the plant population was increased.

Porter, Jensen and Sletten (25) observed significant differences in number of heads per acre for both the row spacing and planting rates. The number of heads were inversely associated with the number of plants per acre. They cited increased tillering as the factor which equalized the yield of low planting with the high planting rates. Grimes and Musick (6) reported that spacing of plants in row as well as total area per plant appears to influence tillering. High numbers of heads were obtained, when an area of 396 square inches was provided per plant. At 50 to 60 square inches area per plant no tillering occured. The tillering was also reduced when row-width was increased and the plant population held the same.

Ross and Webster (28) observed that the growth response of the grain sorghum differed slightly with the thickness of stand. There was little tillering with a thick stand and the heads and stalks became small. This tendency of sorghum is preferred for combine harvesting. Hendry (7) and Hittle, Pendleton, McKibben and Portz (9) reported that when sorghum plants are planted thickly, they stool less, became more slender, produce smaller and more erect heads and by ripening earlier and uniformly become favorable for the efficient use of harvesting machines.

Head Size and Seed Weight

Grimes and Musick (6) concluded from seven year studies with different plant populations and plant spacing relationships that the head size of grain sorghum was related directly to the size of the area provided to each plant. However, the increase in head size is not proportional to the increase in area per plant. Quantity of the grain produced per head increased with the decrease in stand from 7-inch rows with 4 inches spacing between the plants to 28-inch rows with 12 inch spacing within the row. When row-width was increased and the same plant area was maintained by reducing distance between plants within the row, the head size was not changed significantly, indicating that plant area determines the head size.

Porter, Jensen and Sletten (25) reported that average head weight tends to be inversely proportional to the number of plants per acre. However, no significant differences in the head weights were observed due to row spacing. At a higher fertility level the head weights were significantly affected at 20-and 30-inch spacings as compared to 12-or 40-inch spacings. With a higher population and low fertility the head weight was reduced significantly. Increased head weight was the major factor in equalizing the yield of the low planting rates. It was also an important factor in the higher yield of narrow row planting.

Martin and Siegliner (17) concluded from the results obtained from spacing studies conducted over a period of ten years that the weight of grain per plant increased with spacing to a less extent than that necessary to maintain the yields. Consequently, the yields per acre showed a sharp and consistent decrease with the wider spacing. The weight per bushel of grain from the thicker spacing of 6 inches between plants was slightly greater than that from the thinner spacing of 30 inches between the plants. Similar results were reported by Ross and Webster (28) who obtained a reduction in head size when the plant population within the row was increased.

Stickler and Laude (29) reported that seed size was not materially affected by row spacing or plant population. Similar results were obtained under Texas (1) conditions, where the test weight of grains was not affected by either the seeding rate or the row spacing.

Height and Stover Yield

Stickler and Laude (29) reported that the plant height was influenced by the plant population. The plant height was greater in 10-inch rows and decreased with increasing the row-width to 16, 20, 24 and 40 inches. This was attributed to light effects on the internode elongation. Porter, Jensen and Sletten (25) obtained opposite results with the increase in row-width. They reported that the plant height was consistently taller in 40-inch rows as compared to rows spaced at 12 inches width. The planting rate had no effect on the plant height.

Ross and Webster (28) indicated that the plants grow taller when sown thick and the moisture or soil fertility are not limiting. When moisture or fertility level is low, the plants in thicker stands become stunted and shorter in height.

Stickler, Pauli, Laude, Wilkin and Mings (31) concluded that in general the plant height increased as the plant area and row-width decreased. This was attributed to competition for light. Under limited light, elongation of the internode is a common plant response. The plants from the thick planting in 10 and 20-inch rows were taller than in wider rows. Martin and Sieglinger (17) reported similar results of plant population on height. They reported an increase in plant height with the increase in stand.

Last (16) reported that in contrast to the effect of spacing on grain yield, the stover yield was significantly affected when the numbers of plants were quartered by altering the spacing. The stover yield was not quadrupled as was the grain but instead tripled, with consequent significant decrease in yield. Karper, Quinby, Jones and Dickson (13) recommended that varieties that tiller freely but are important forage types be planted at narrow within row spacing to get higher stover yields. Planting in narrow rows increased the yield by 25 per cent as compared to the planting made in wider rows.

Idris (11) attributed the positive relationship between the seeding rate and stover yield to the fact that the seeding rate determines the number of plants per acre. Higher seed rates produced greater numbers of plants per acre and resulted in the highest stover yield. Similarly, Brown and Shrader (3) reported that in general the forage production was increased by increasing the plant population per acre.

Kurtkoti and Divekar (15) observed that the increase of the row space at higher fertility level increased the fodder by 21 per cent, while the grain was increased by 31 per cent. Martin and Siegliner (17) found that the total forage yield was greater at the 18-inch row-width in case of Milo, and the yield of Kafir forage decreased with the increazing of spacings. According to Porter, Jensen and Sletten (25) greater forage was produced when the sorghum was planted in narrow rows of 12-and 20-inch width on the high soil fertility level as compared to 30-and 40-inch row widths.

Greb (5) however, found that the stover yield was high when the sorghum was planted in wider rows of 42-inch width as compared to narrow rows of 21-inch width although the seeding rates per acre were the same.

MATERIALS AND METHODS

The study was carried out for two years, 1962 and 1963, at the American University Farm, situated 80 kilometers east of Beirut, in the Beqa'a plain. This area is characterized by a frost free period extending from April to November with no rains in the summer months. The soil of the plain is well drained and of calcareous clay type. Two varieties Norghum, Early Hegari and hybrid, Texas 620, were evaluated for their performance at three within row spacings and two row-widths as given below:-

Within row spacings	i	5	centimeters
	ii	10	centimeters
	iii	15	centimeters
Row-widths	i	50	centimeters
	ii	75	centimeters

To exploit the yield potential of the varieties, 12 kilograms of nitrogen in the form of ammonium sulphate nitrate and 20 kilograms of P_2O_5 in the form of superphosphate were broadcast on the surface and disked into the soil prior to planting. A supplementary amount of four kilograms of nitrogen was added as a side dressing when the plants were 50 centimeters high. Irrigation was done by sprinkler in the initial stages and later through furrows at weekly intervals throughout the growing season.

Weeding was carried out regularly and ceased before the boot stage, when the sorghum plants were able to suppress the weeds by competition.

The crop was sprayed with Metasystox for the control of leaf hoppers and aphids.

The experiment was conducted on a randomised split-split-plot design replicated four times. Within row spacings were assigned the main plots, row-width the sub-plots and varieties the sub-sub-plots. Each variety was seeded in two rows of five meters in length. A border row was planted between the sub-plots for the elimination of the border effect of row-widths on each other.

The planting was done by a V-belt seed drill during the last week of April, when the soil warmed up sufficiently for good germination of the seed. Each plot was seeded thickly and thinned by hand to the required spacings when the plants were four to six centimeters tall.

Data were recorded on grain and stover yield, germination, heading, maturity, plant height, heads per plant, head size, thousand kernel weight and on other characteristics. For grain and stover yield calculation, the central four meters of the row was harvested, leaving one-half meter on each end as border. The plants harvested from each plot were placed into a cloth sack, dried and threshed separately with a nursery thresher. The stover yield was calculated from the dry weight of six representative 10-pounds samples taken from each of the sub-plots and air dried for a period of four weeks.

A representative sample was taken from each treatment for the determination of protein content. The analysis for Nitrogen percentage was done by modified Kjeldahl method as described for maize in the Official Methods of Analysis of the Association of Official Agricultural

Chemists (10). The values thus obtained were multiplied by the factor 6.25 to get the percentage of protein.

To analyse the data, statistical methods appropriate to the design were employed. Analysis of Variance was determined to find the significance of results and "t" test was used for finding the differences between the treatments and their interactions (22).

Because of limited time, the data for grain and stover yield, head size, weight of 1000 kernels and protein content are not reported for the 1963 crop. Data were collected only up to August 15 and these were not available to be incorporated in this thesis.

RESULTS AND DISCUSSION

This experiment was conducted to find the influence of row-width and on grain yield and other agronomic characteristics of three sorghum varieties. The varieties included in this test were Norghum, Early Hegari and Texas 620 being early, medium and late in maturity, respectively. The results of yield and other characteristics are presented in Table 1 to 8. The analysis of variance is given in the appendix (Tables 9 to 16). The varieties Norghum, Early Hegari and Texas 620 are coded V1, V2 and V3, respectively. The row-widths of 50 and 75 centimeters are denoted by R1 and R2, while abreviations S1, S2 and S3 have been used for within-row spacing of 5, 10 and 15 centimeters, respectively.

Grain Yield

The row spacing did not affect the grain yield of the sorghum. That is, planting of sorghum in 50 and 75 centimeters spaced rows gave about the same yield, as is shown in Table 1.

The varieties varied very widely in yield. Texas 620 yielded twice as much as did Norghum. The yield of Early Hegari was somewhat lower than that of Texas 620 but significantly higher than Norghum. The mean yield differences among the varieties were found to be significant at the one percent level. The low yield of Norghum can be attributed to its earliness in maturity.

Table 1. Effect of row-width and stand on yield of grain sorghum in kg. per dunum in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within row	Variety
Norghum (V1)	5 (S1)	529.6	523.5		
	10 (S2)	428.6	469.8	725.3(S1)	467.1
	15 (S3)	442.6	462.8		
Early Hegari (V2)	5 (S1)	800.0	736.2		
	10 (S2)	746.7	716.2	687.4(S2)	772.5
	15 (S3)	810.0	825.9		
Texas 620 (V3)	5 (S1)	859.4	903.3		
	10 (S2)	890.4	973.0	693.3(S3)	857.5
	15 (S3)	769.5	849.3		
Average		693.4	706.7		

	L.S.D (5%)	L.S.D. (1%)
Variety	33.7	45.0
Variety x spacing within row	58.3	78.0

Variety	Texas 620	Early Hegari	Norghum
Mean	857.5	772.5	467.1

Variety x spacing within row

V3S2	V3S1	V2S3	V3S3	V2S1	V2S2	V1S1	V1S3	V1S2
881.7	881.3	817.9	809.4	768.1	731.5	526.6	452.7	449.2 *

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

The spacing of plants within the row did not affect the grain yield of sorghum. The yields obtained were 725.3, 687.4 and 693.3 kg. per dunum when the plants were spaced 5, 10 and 15 centimeters apart in the row, respectively.

The significant interaction between the varieties and spacing within the row shows the differential response of the varieties to the variation in stand. The hybrid Texas 620 produced about the same yield at the medium and narrow spacing. The yield decreased when the space between the plants in the row was increased. The Early Hegari produced comparatively high yield at the wider plant spacing, while Norghum was the most productive at the thicker plant population. These results are in agreement with those reported by Karper (12), Martin and Sieglinger (17), Vinall *et al* (35) and Norman and Hsi (20) who obtained generally no response to row-width or plant spacing within the row. They reported differential response of the varieties to the variation in stand and emphasized that the choice of variety was more important than the row-width or stand.

Number of Days to Heading

The heading of the sorghum was influenced slightly by the plantings made in 50 and 75 centimeter rows as shown in Table 2. Heading of the plants was delayed by half a day when planted in the wider rows.

The varieties differed in the number of days from planting to heading. Texas 620 headed in 97.2 days, Early Hegari in 88.3

Table 2. Effect of row-width and stand on number of days to heading of sorghum in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within Row	Variety
Norghum (V1)	5 (S1)	74.5	74.0	85.9(S1)	74.7
	10 (S2)	75.2	74.7		
	15 (S3)	74.5	74.5		
Early Hegari (V2)	5 (S1)	87.0	86.0		
	10 (S2)	89.2	89.2	87.2(S2)	88.3
	15 (S3)	89.5	88.7		
Texas 620 (V3)	5 (S1)	97.0	97.0		
	10 (S2)	97.6	97.2	87.0(S3)	97.2
	15 (S3)	97.2	97.5		
Average		86.9	86.5		

	L.S.D. (5%)	L.S.D. (1%)
Row-width	0.3	—
Variety	0.4	0.6
Variety x spacing within row	0.7	1.0

Row-width	50 cms.	75 cms.
Mean	86.9	86.5

Variety	Texas 620	Early Hegari	Norghum
Mean	97.2	88.3	74.7

Variety x spacing within row

V3S3	V3S2	V3S1	V2S2	V2S3	V2S1	V1S2	V1S3	V1S1
97.4	97.4	97.0	89.2	89.1	86.5	75.0	74.7	74.2 *

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

and Norghum in 74.7 days. This effect of heading had a direct association with the yield of the grain. The variety Norghum which matured earlier produced the lowest yield, while Texas 620 which matured later produced the highest grain yield.

The significant interaction of varieties x spacing within-row showed that the varieties generally headed earlier when planted at 5 centimeters spacing as compared to 10 or 15 centimeters. This effect of closer planting on the number of days to heading was much more evident in case of Early Hegari.

Protein Percentage

The protein percentage results are presented in Table 3. It is evident from the data that the spacing between the row and within the row did not affect the protein content. These results are in conformity with those of Nelson (18), who did not obtain any affect of plant or row spacing on protein.

The varieties varied significantly in the protein content. The protein percentage was 8.58, 7.59 and 6.28 for Norghum, Texas 620 and Early Hegari, respectively. It is interesting that the variety which gave the lowest grain yield was high in protein.

Heads per Plant

The data regarding heads per plant as affected by row-width and stand are given in Table 4. The number of heads per plant of sorghum were increased when the row-width was increased or the stand

Table 3. Effect of row-width and stand on protein percentage of sorghum in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within Row	Average Variety
Norghum (V1)	5 (S1)	8.56	8.54		
	10 (S2)	8.54	8.83	7.52(S1)	8.58
	15 (S3)	8.58	8.45		
Early Hegari (V2)	5 (S1)	6.47	6.51		
	10 (S2)	6.06	6.30	7.52(S2)	6.28
	15 (S3)	5.98	6.36		
Texas 620 (V3)	5 (S1)	7.71	7.33		
	10 (S2)	7.59	7.81	7.41(S3)	7.59
	15 (S3)	7.43	7.67		
Average		7.43	7.53		

	L.S.D. (5%)	L.S.D. (1%)
Variety	0.19	0.26

Variety	Norghum	Texas 620	Early Hegari
Mean	8.58	7.59	6.28

within the rows decreased. This ability or tendency to produce more than one head is of practical importance in enabling the plant to take advantage of the surplus space and plant food available in the soil.

A significant interaction was obtained between spacing within-row and row-width. The highest number of heads per plant were produced when each was provided with 1125 square centimeters of area, or by spacing plants 15 centimeters apart in 75 centimeter rows. The area per plant being the same, the number of heads per plant was not affected by altering the row-width or spacing within-row. There was no difference in the tillering when the planting was done in 50 centimeter rows at a spacing of 5 or 10 centimeters within the row. Similar results were obtained by Porter, Jensen and Sletten (25) and Grimes and Musick (6). They got an increase in the number of heads when the sorghum was planted in wider rows or wider plant spacings within the row.

The varietal differences in producing more than one head per plant were highly significant. The variety Norghum Produced 50 per cent more heads as compared to 40 and 20 per cent in the case of Early Hegari and Texas 620. The hybrid Texas 620 produced the lowest number of heads per plant showing its comparative inability to tiller as much as the other varieties.

Generally, all of the three varieties produced more heads per plant when the row-width was increased or the stand in the row decreased, as is evident from the significant interaction of varieties with the row-width and the spacing within the row. The variety Nor-

Table 4. Effect of row-width and stand on heads per plant of sorghum in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within Row	Average Variety
Norghum (V1)	5 (S1)	1.05	1.14		
	10 (S2)	1.13	1.66	1.03(S1)	1.55
	15 (S3)	1.63	2.72		
Early Hegari (V2)	5 (S1)	0.96	0.99		
	10 (S2)	1.14	1.43	1.27(S2)	1.40
	15 (S3)	1.53	2.37		
Texas 620 (V3)	5 (S1)	1.01	1.01		
	10 (S2)	1.01	1.24	1.88(S3)	1.21
	15 (S3)	1.24	1.77		
Average		1.19	1.59		

	L.S.D. (5%)	L.S.D. (1%)
Spacing within row	0.17	0.26
Row-width	0.05	0.07
Spacing within row x row-width	0.09	0.13
Variety	0.07	0.10
Variety x spacing within row	0.13	0.18
Variety x row-width	0.11	0.15

Spacing within row	15 cms.	10 cms.	5 cms.
Mean	1.88	1.27	1.03

Row-width	75 cms.	50 cms.
Mean	1.59	1.19

Variety	Norghum	Early Hegari	Texas 620
Mean	1.55	1.40	1.21

ghum produced about double the number of heads at 75 centimeter row-width or when the plants were spaced 15 centimeter apart within the row. The hybrid Texas 620 produced fewer heads per plant at 75 centimeter row-width and 15 centimeter plant spacing in comparison to Norghum and Early Hegari.

Head Size

The summary of the results of sorghum head size as affected by variation in row and plant spacing is given in Table 5. The head size was increased when the stand within the row was reduced. The increase in head size, however, was not significant in case of the medium and wider plant spacings. The head size also increased due to the increase in row-width. A 16 per cent increase in head size was obtained when the sorghum was planted in rows 75 centimeters apart as compared to rows 50 centimeters apart.

A significant spacing within row x row-width interaction was found in this test. This was caused by the tendency for head size to increase with the reduction in stand or the increase in row-width. The increase in head size may have been the major contributing factor in equalizing the yield of various populations obtained by the variation in row-width and stand. These results are in agreement with those reported by Grimes and Musick (6). They obtained a direct relationship of head size to the area provided to each plant.

The three varieties differed widely in the production of head size. Texas 620 had the heaviest heads of 41.8 grams, it was

Table 5. Effect of row-width and stand on head size of sorghum in grams in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within-row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within row	Average Variety
Norghum (V1)	5 (S1)	12.6	17.2		
	10 (S2)	19.1	21.3	22.1(S1)	18.3
	15 (S3)	20.4	19.3		
Early Hegari (V2)	5 (S1)	20.8	27.8		
	10 (S2)	32.4	37.3	34.5(S2)	32.8
	15 (S3)	39.5	39.3		
Texas 620 (V3)	5 (S1)	21.1	33.4		
	10 (S2)	44.0	52.7	36.4(S3)	41.9
	15 (S3)	46.4	53.7		
Average		28.5	23.5		

	L.S.D. (5%)	L.S.D. (1%)
Spacing within row	2.5	3.7
Row-width	1.1	1.5
Spacing within row x row-width	1.8	2.6
Variety	1.1	1.5
Variety x spacing within row	2.0	2.6
Variety x row-width	1.6	2.2
Variety x spacing within row x row-width	2.8	3.7

Spacing within row	15 cms.	10 cms.	5 cms.
Mean	36.4	34.5 *	22.1

Row-width	75 cms.	50 cms.
Mean	33.5	28.5

Variety	Texas 620	Early Hegari	Norghum
Mean	41.9	32.8	18.3

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

more than twice the head size of Norghum, which weighed 18.3 grams. The variation in the head size was the important factor which resulted in the big difference in yields of the varieties.

The interaction of varieties x spacing within the row and varieties x row-width both were found to be significant. The head size of all the three varieties increased with the reduction of stand. Texas 620 and Norghum produced heavier heads at medium and wider plant spacing in the row, while Early Hegari produced heavier heads at the wider plant spacing. Similarly, a direct relationship of head size was obtained with the row-width spacings. The increase in head size ranged from 11 to 20 per cent. The head size of Norghum and Early Hegari increased by 11 and 13 per cent, while that of Texas 620 by 20 per cent. As both the within-row and row-width spacings affected the head size of the varieties, the interaction of varieties x spacing within row x row-width was also significant.

<u>1000 Kernel Weight</u>

The weight of 1000 kernels was significantly affected by the variation in plant spacing of sorghum within the row (Table 6). The seed weight increased with the decrease in stand within the row. The seed weights obtained from plants spaced at 5, 10 and 15 centimeters apart were 22.9, 23.4 and 23.8 grams, respectively. The weight differences between the seeds produced by plants at the narrow and medium planting, and medium and wide planting were not

Table 6. Effect of row-width and stand on weight of 1000-kernels of sorghum in grams in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	Row-width in cms. 75(R2)	Average Spacing Within row	Average Variety
Norghum (V1)	5 (S1)	22.5	23.6		
	10 (S2)	23.0	23.5	22.9(S1)	23.4
	15 (S3)	23.7	23.9		
Early Hegari (V2)	5 (S1)	19.3	19.9		
	10 (S2)	18.7	19.2	23.4(S2)	19.3
	15 (S3)	19.4	19.5		
Texas 620 (V3)	5 (S1)	25.8	26.6		
	10 (S2)	27.9	28.2	23.8(S3)	27.4
	15 (S3)	27.8	28.4		
Average		23.1	23.6		

	L.S.D. (5%)	L.S.D. (1%)
Spacing within row	0.5	—
Variety	0.4	0.5
Variety x spacing within row	0.7	0.9

Spacing within row	15 cms	10 cms	5 cms
Mean	23.8	23.4	22.9 *

Variety	Texas 620	Norghum	Early Hegari
Mean	27.4	23.4	19.3

Variety x spacing within row

V3S3	V3S2	V3S1	V1S3	V1S2	V1S1	V2S1	V2S3	V2S2
28.1	28.0	26.2	23.8	23.2	23.0	19.6	19.4	18.9 *

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

sufficient to be statistically significant. The increase in the seed weight with wider plant spacing can be attributed to more sunlight and nutrient availability per plant.

The seed weight of the varieties ranged from 19.3 to 27.5 grams per 1000 kernels. The seed weights were 27.5, 23.4 and 19.3 grams for Texas 620, Norghum and Early Hegari, respectively.

The significant interaction of varieties x spacing within-row indicated a differential response of the varieties to the variation in stand. The seed weights of Norghum and Texas 620 were inversely related to plant population within the row. It increased when the stand in row was decreased. The difference in seed weight due to variation in plant spacing in the case of Early Hegari were not significant.

Plant Height

The data regarding the effect of row-width and stand on plant height at maturity are presented in Table 7. The plant height increased significantly when sorghum was planted at a spacing of 5 centimeters within the row. The plant height did not differ when the sorghum plants were spaced 10 or 15 centimeters apart in the row.

The varieties differed significantly in plant height. Early Hegari had the tallest plants, Texas 620 was medium in height and Norghum produced the shortest plants. The plant heights were 162.6 159.4 and 149.7 centimeters for Early Hegari, Texas 620 and Norghum, respectively.

Table 7. Effect of row-width and stand on plant height of sorghum in centimeters in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	Row-width in cms. 75(R2)	Average Spacing Within Row	Average Variety
Norghum (V1)	5 (S1)	149.6	150.6		
	10 (S2)	147.9	150.0	158.3(S1)	149.7
	15 (S3)	149.2	151.0		
Early Hegari (V2)	5 (S1)	165.7	162.1		
	10 (S2)	162.4	160.5	156.5(S2)	162.6
	15 (S3)	162.1	162.8		
Texas 620 (V3)	5 (S1)	160.7	161.1		
	10 (S2)	159.2	159.1	156.9(S3)	159.4
	15 (S3)	159.0	157.5		
Average		157.3	157.2		

	L.S.D. (5%)	L.S.D. (1%)
Spacing within row	0.9	1.3
Variety	0.5	1.1
Variety x row-width	1.2	-
Variety x spacing within row x row-width	2.0	2.7

Spacing within row	5 cms	15 cms	10 cms
Mean	158.3	156.9	156.5 *

Variety	Early Hegari	Texas 620	Norghum
Mean	162.6	159.4	149.7

Variety x row-width

V2R1	V2R2	V3R1	V3R2	V1R2	V1R1
163.4	161.8	159.6	159.2 *	150.5	148.9

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

The interaction of varieties x row-width was found to be significant. The varieties responded differently to the row-width plantings. Early Hegari produced taller plants at narrow row-width. The late maturing hybrid was not affected by changes in row-width, probably due to its longer maturity period. The early maturing Norghum produced the taller plants when the row-width was increased.

Due to the accumulative effect of varieties, row-width and stand, the interaction of varieties x spacing within row x row-width became significant.

Stover Yield

The results of stover yield as affected by variation in populations of sorghum plants are summarized in Table 8. The stover yield of sorghum was high when planted at narrow spacing within the row, but not significantly different from sorghum grown in wider spacing. This may be due to more tillering at the wider plant spacings. Sorghum planted in the narrow rows of 50 centimeters produced more stover yield than that in rows of 75 centimeters. These results are in agreement with those obtained by Karper, Quinby, Jones and Dickson (13), Idris (11) and Brown and Shrader (3).

The hybrid, Texas 620, produced three times more stover than Norghum as shown in Table 8. The stover yield corresponded with the grain yield. The high yielding variety produced the higher stover yields, while the low yielding one also gave the lower stover yield.

The significant interaction of varieties with spacing within-

Table 8. Effect of row-width and stand on stover yield of sorghum in kg. per dunum in 1962 in Beqa'a, Lebanon.

Variety	Spacing Within row in cms.	Row-width in cms. 50(R1)	75(R2)	Average Spacing Within Row	Average Variety
Norghum (V1)	5 (S1)	531	497		
	10 (S2)	424	456	1106(S1)	475
	15 (S3)	465	475		
Early Hegari (V2)	5 (S1)	1302	1014		
	10 (S2)	1060	975	960(S2)	1105
	15 (S3)	1177	1100		
Texas 620 (V3)	5 (S1)	1746	1549		
	10 (S2)	1146	1384	1001(S3)	1489
	15 (S3)	1370	1422		
Average		1060	986		

	L.S.D.(5%)	L.S.D.(1%)
Spacing within row	112	-
Row-width	63	-
Variety	38	51
Variety x spacing within row	66	88
Variety x row-width	54	72
Variety x spacing within row x row-width	93	125

Spacing within row	5 cms.	15 cms.	10 cms.
Mean	1106	1001	960 *

Row-width	50 cms.	75 cms.
Mean	1060	986

Variety	Texas 620	Early Hegari	Norghum
Mean	1489	1105	475

* Treatment means underlined by the same line do not differ significantly from each other at 5% level.

row showed that the varieties interacted with the narrow plant spacing to produce higher stover yield. The reaction of varieties to variation in row-width was, however, different. Texas 620 and Early Hegari produced significantly higher stover yield at narrow row-width. There was, however, no difference in stover yield due to variation in row-width in case of Norghum. This may be due to its high tillering capacity when planted in the wider rows.

The interaction of varieties x spacing within row x row-width was found to be significant due to their additive effect on stover yield of sorghum.

SUMMARY AND CONCLUSIONS

This study was conducted at the American University Farm in the Beqa'a plain in 1962 to find the influence of row-width and stand thickness on yield and other characteristics of grain sorghums. Three varieties Texas 620, Early Hegari and Norghum were evaluated for their performance when grown in rows 50 and 75 centimeters apart and at three plant spacing of 5, 10 and 15 centimeters.

The grain yield of sorghum was not influenced by row-width or the plant spacing employed. The varieties, however, differed in grain production. The hybrid, Texas 620, produced the highest yield, whereas Norghum produced the lowest grain yield. The response of the individual varieties to plant spacing was significant. The high yielding varieties produced maximum yield when planted 10 to 15 centimeters apart in the row, while the low yielding variety performed best at the 5 centimeter spacing.

The date of heading of the sorghum was delayed by half a day when the row-width was increased from 50 to 75 centimeters. The Norghum variety headed about three weeks earlier than the late maturing Texas 620, which required 97 days from planting to heading. The heading of all the three varieties was delayed by the thinner stands.

The protein percentage in sorghum was not affected by either the plant spacings or row-width. The varieties varied in protein content from 8.58 to 6.28 per cent. The low yielding Norghum had the highest protein content, while Early Hegari contained the least.

An increase in the number of heads per plant was obtained with the increase of row-width or the reuction of stand of sorghum within the row. The varieties differed in the production of more than one head per plant. Norghum produced 50 per cent more heads as compared to 40 per cent for Early Hegari and 20 per cent for Texas 620. I n all the three varieties usually the number of heads per plant increased with the increase in row spacing and decrease in stand. The head size of sorghum was affected by variation in row-width and stand. It increased progressively with the reduction in stand within the row and decreased when the row-width was reduced. The head size was directly related to the grain yield. The varieties which produced bigger heads also produced higher grain yields.

The seed weight of sorghum was directly associated with the increase in plant spacing in the row. An increase of 3.7 per cent in the weight of 1000 kernels was obtained when the plant spacing within the row was increased from 5 to 15 centimeters. There was a general increase in the seed weight of the varieties when the plant spacing was increased. The high yielding variety produced the heavier seeds.

Sorghum planted 5 centimeters apart in the row produced the taller plants. Early Hegari, Texas 620 and Norghum Produced plants of tall, medium and short stature, respectively. The Early Hegari and Texas 620 produced taller plants when planted in 75 centimeter rows, but Norghum produced the taller plants when planted in 50 centimeter rows.

Stover yield of sorghum increased with the thickness of stand. There was a direct relationship of stover and grain yield. The hybrid Texas 620, which produced the highest grain yield, also produced the highest stover yield.

This study conducted in 1962 indicates that varieties which have high yield potential should be planted at a spacing of 10 to 15 centimeters within the row, while the low yielding variety should be planted at 5 centimeters to get the maximum yield. The experiment should be conducted for a number of years to arrive at more definite conclusions.

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APPENDIX

Table 9. Analysis of variance
for yield of grain sorghum.

Source	D.F.	M.S.
Block	3	1347.5
Spacing within row	2	9971.2
Error "a"	6	14722.6
Row-width	1	1537.6
Spacing within row x Row-width	2	3943.1
Error "b"	8+	5883.4
Variety	2	961835.4**
Variety x Spacing within row	4	17118.7**
Variety x Row-width	2	6076.2
Variety x Spacing within row x Row-width	4	4580.9
Error "c"	36	3329.8

** denote F values significant at the 1% level.
+ reduced by one degree due to confounding.

Table 10. Analysis of variance for number of days to heading of grain sorghum.

Source	D.F	M.S
Blocks	3	0.6
Spacing within row	2	11.3*
Error "a"	6	2.8
Row-width	1	1.7
Spacing within row x Row-width	2	0.2
Error "b"	8+	0.3
Variety	2	3082.6**
Variety x Spacing within row	4	4.7**
Variety x Row-width	2	1.0
Variety x Spacing within row x Row-width	4	0.3
Error "c"	36	0.5

* denote F values significant at the 5% level.
** denote F values significant at the 1% level.
\+ reduced by one degree due to confounding.

Table 11. Analysis of variance for percentage of protein of grain sorghum.

Source	D.F	M.S
Blocks	3	0.29
Spacing within row	2	0.09
Error "a"	6	0.11
Row-width	1	0.18
Spacing within row x Row-width	2	0.22
Error "b"	8+	0.19
Variety	2	31.97**
Variety x Spacing within row	4	0.15
Variety x Row-width	2	0.07
Variety x Spacing within row x Row-width	4	0.17
Error "c"	36	0.11

** denote F values significant at the 1% level.
+ reduced by one degree due to confounding.

Table 12. Analysis of variance for number of heads per plant of grain sorghum.

Source	D.F	M.S
Blocks	3	0.06
Spacing within row	2	4.58**
Error "a"	6	0.06
Row-width	1	2.94**
Spacing within row x Row-width	2	0.93**
Error "b"	8+	0.01
Variety	2	0.70**
Variety x Spacing within row	4	0.20**
Variety x Row-width	2	0.15**
Variety x Spacing within row x Row-width	4	0.50**
Error "c"	36	0.02

** denote F values significant at the 1% level.
+ reduced by one degree due to confounding.

Table 13. Analysis of variance for size of head of grain sorghum.

Source	D.F	M.S
Blocks	3	20.02
Spacing within row	2	1422.18**
Error "a"	6	12.36
Row-width	1	462.74**
Spacing within row x Row-width	2	53.57**
Error "b"	8+	3.71
Variety	2	3388.06**
Variety x Spacing within row	4	200.62**
Variety x Row-width	2	91.79**
Variety x Spacing within row x Row-width	4	28.42**
Error "c"	36	3.83

** denote F values significant at the 1% level.
+ reduced by one degree due to confounding.

Table 14. Analysis of variance for 1000 kernel weight of grain sorghum.

Source	D.F	M.S
Blocks	3	1.65
Spacing within row	2	4.25*
Error "a"	6	0.53
Row-width	1	4.91
Spacing within row x Row-width	2	0.48
Error "b"	8+	1.04
Variety	2	397.14**
Variety x Spacing within row	4	3.66**
Variety x Row-width	2	0.20
Variety x Spacing within row x Row-width	4	0.34
Error "c"	36	0.49

* denote F values significant at the 5% level.
** denote F values significant at the 1% level.
\+ reduced by one degree due to confounding.

Table 15. Analysis of variance for plant height of grain sorghum.

Source	D.F	M.S
Blocks	3	7.27
Spacing within row	2	20.75**
Error "a"	6	1.52
Row-width	1	0.20
Spacing within row x Row-width	2	1.80
Error "b"	8+	4.49
Variety	2	1084.95**
Variety x Spacing within row	4	4.45
Variety x Row-width	2	16.50
Variety x Spacing within row x Row-width	4	5.97*
Error "c"	36	1.99

* denote F values significant at the 5% level.
** denote F values significant at the 1% level.
\+ reduced by one degree due to confounding.

Table 16. Analysis of variance for stover yield of grain sorghum.

Source	D.F	M.S
Blocks	3	32346.36
Spacing within row	2	136385.26*
Error "a"	6	25159.70
Row-width	1	98368.30*
Spacing within row x Row-width	2	46406.12
Error "b"	8+	13482.80
Variety	2	6291334.24**
Variety x Spacing within row	4	36761.27**
Variety x Row-width	2	34664.74**
Variety x Spacing within row x Row-width	4	30960.05**
Error "c"	36	4265.05

* denote F values significant at the 5% level.
** denote F values significant at the 1% level.
\+ reduced by one degree due to confounding.