A STUDY OF THE EFFECTS OF ROW SPACING IN DWARF GRAIN SORGHUMS

by

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INTRODUCTION

The production of grain sorghum in the United States has increased steadily since its introduction. Its importance in the grain market has justified the establishment in 1951 of a futures market in the Chicago Board of Trade.

The acreage of grain sorghums has been increased by the acreage of winter wheat that has been abandoned.

Sorghum is a good supplementary crop to be grown with wheat throughout the Plains Area. It can be worked in the rotation program nicely; it adds diversity to the farm business and much of the machinery used for wheat production can be used for the production of sorghum.

Dwarf grain sorghums when first introduced were grown by the same methods as the taller types which were essentially the same as those followed in the production of corn.

It soon became evident that the dwarf plants were not well-suited for planting in the usual 40 or 42 inch rows where weeds were controlled by mechanical cultivation. The plan of planting this crop in rows 20 or 21 inches apart was tried. The average advantage of the narrow rows was 12.4 bushels per acre or 25 percent in 10 years of comparison at Manhattan (29).

This thesis reports a study made in 1953 of some of the factors concerned in the higher yields from the narrow rows.

REVIEW OF LITERATURE

The review of literature in this report pertaining to row spacing of grain sorghum is divided into sections in order to present a clearer picture of the factors influencing the production of grain sorghums. Previous work is reviewed under the following headings: (a) row width and plant spacing of sorghums and other crops, (b) seed bed preparation and weed control, (c) light, and (d) evaporation.

Row Width and Plant Spacing of Sorghums and Other Crops

Profitable yield of grain sorghum, according to Martin, et al (17) depends to a large extent upon cultural practices. He stated that optimum spacing of the plants and seeding at proper dates were two of the more important practices.

Hastings (9) found that by spacing plants close in the rows, higher yields were obtained. He also observed that thick seeding of milo resulted in fewer tillers and side branches which also created more uniform and early-maturing plots than wide spaced plants.

Sieglinger (26) noted that varieties which did not produce an abundance of tillers showed a progressive reduction in yield for every successive increase in distance between plants.

Sorghum grown under irrigation in New Mexico gave higher yields as the space between plants was decreased. Painter and Leamer (21) demonstrated that closer spacing of dwarf grain sorghums would give significantly higher yields.

Spacing sorghum plants closer together under the condition that Nelson (20) used in Washington gave no significant difference in acre yield.

Tingey (28) working with guoyule stated the number of plants per unit area was the most important factor affecting yields of rubber and shrub.

Before any change in planting practices of corn are made, Byron, et al, (4) were of the opinion that the new system should show superiority over the old system to the extent that it would compensate for the cost of the change.

Seed Bed Preparation and Weed Control

Preparation of a good seed bed Martin, et al (16), believed should: (a) secure better stands, (b) help control weeds, (c) conserve moisture, (d) warm the soil. He also stated, "Tillage prior to planting usually will well repay the labor involved." Higher soil temperature helps in rapid germination, early growth, and a more uniform stand. Cowgill (5) was of the opinion that seed bed preparation was the best way to obtain the higher temperature needed.

Yields of sorghum may be increased from 25 to 50 percent by thorough preparation of the seed bed, according to results by Laude and Swanson (12).

Martin, et al, (16) considered sorghum seeds planted in a well-prepared seed bed would emerge only 50 to 70 percent as many plants as seeds were planted. Laude and Swanson (12) agreed that only seed of high laboratory germination should be planted.

Brandon, et al, (2) took the view that sorghum would respond best to a well-prepared seed bed that was warm, mellow, weed-free, and moist.

Primary objective of cultivation is to control weeds, Martin, et al, (16) believed. He stated that weeds injure the crop by using moisture and fertility that the crop needs. Robbins, et al, (23) and Cox (6) went further into the injury caused by weeds. They believed that crop production is a battle with weeds because they compete with crops for all factors of production. From an economic standpoint weeds reduce yield of crops 10 percent, and 8 percent of the value received is used for cultivation made necessary by the weeds.

Three things are necessary, according to Randmacher (24), for the control of weeds by shading: (1) the time at which shading takes place, (2) duration of the shade, and (3) the height of the shade.

Laude and Swanson (12) found that a harrow may be used to destroy many weeds in surface-planted sorghum when approximately three inches high.

Light

In general, light conditions are effective to crop production only to plant parts above the soil level, according to Livingston (14). He concluded that no wholly satisfactory method of measuring light had been brought forward.

Duggar (7) summed up light in its biological effects by, "Transpiration, the osmotic concentration of the plant sap, alkalinity of the sap increases directly with light intensity."

According to the results presented by Shirley (25), i.e., the influence of light intensity on growth, height decreased with increasing light. He observed that leaf structure tended to become more compact with increasing light. Karper, et al, (10) found that the amount of sunlight striking the entire plant influenced the number of tillers. This was shown by the amount of tillers that were produced by plants given equal space in the row but in different widths of row; and that shading appeared to have a marked influence upon the amount of tillering. Sieglinger (26) agreed that tillering is influenced by environmental factors as plant space, temperature, date of planting, and the stage at which soil is thrown into lister furrows covering the base of the plant.

Wiesmann (31) concluded that abundance of light favored the production of tillers in oats.

Evaporation

Two main environmental factors which affect the evaporation of water are the evaporative power of the impinging solar radiation and evaporative power of the air, according to Miller (19). He defined the evaporative power of the air to designate the influence of air temperature, air humidity, and air movement upon evaporation of water.

Kiesselbach (11) working with transpiration in crop plants found that if 22 percent difference occurred in relative humidity, a difference of 38 percent in the amount of water transpired.

Air movement, as considered by Miller (19), Gates (8), and

Briggs and Shantz (3) to be a factor in evaporation, was reported by Martin and Clements (15) with their work on Helianthus annuus to be sound. He found an increase of 138 percent with increased air movement up to 16 miles per hour. They could find no difference in evaporation due to air movement between day and night.

A spherical evaporating surface was the only one that gave proper exposure to both wind and radiation at all times, Livingston (13) believed.

Gates (8), working with the effect of height in the crop upon evaporation, found an increase in evaporation was uniformly shwon even if the atmometer (Livingston atmometers) at the higher level was only 0.2 meter above the lower instrument.

MATERIALS AND METHODS

The 1953 sorghum-spacing experimental work was conducted in field H on the Kansas State Agricultural Experimental Station farm located at Manhattan. The preceding crop was wheat.

Seed bed preparation was started in February, 1953 by plowing. The field was disked three times during the spring, each time destroying a crop of weeds. The third disking was followed by harrowing just prior to the planting.

The data in Table 1 records the temperature, rainfall, and wind movement during the growing period. The rainfall, although below normal, was received in substantial amounts at opportune times. A rain of 3.50 inches fell during the week prior to the planting date. This rain assured a well prepared and moist seed bed for rapid germination leading to an ideal stand.

Table 1. Daily maximum and minimum temperatures, precipitation, and wind movement (miles per day) for Manhattan, Kansas, June 1 to August 31, 1953.

Date	June				July				August			
	Max.	Min.	Prec.	Wind	Max.	Min.	Prec.	Wind	Max.	Min.	Prec.	Wind
1	87	65		65	90	72		110	102	78		79
2	83	60		59	102	76		77	103	76		83
3	87	67		119	93	65	0.60	93	101	67	1.72	65
4	95	72		110	84	66	0.43	84	90	70		31
5	91	62	0.15	73	101	71		74	88	70		36
6	66	56	0.13	76	102	66	0.15	68	90	61	1.24	79
7	74	58		66	79	60		48	90	62	0.02	31
8	89	59		127	89	65		49	80	54	0.03	28
9	93	72		64	79	57	0.07	46	81	56		28
10	101	77	0.10	105	82	58		42	89	66		44
11	100	75		72	85	63		62	91	71		82
12	105	68		15	83	59		34	85	55		22
13	99	74		33	82	55		28	66	55		31
14	106	70		36	84	61		29	92	59		27
15	93	70	0.35	88	87	62	0.01	26	97	85		53
16	97	62		43	64	59	0.33	39	67	64	0.16	88
17	85	62	0.01	30	87	58		44	75	61		64
18	98	72		115	89	63		17	81	58		58
19	105	80		114	93	66		18	83	51		42
20	102	75		139	94	69	0.08	43	85	56		22
21	93	65		56	89	69	0.04	39	84	63		39
22	98	62	0.15	110	93	68		48	85	56		52
23	95	64	0.11	65	91	55		53	89	56		33
24	94	71		88	94	61		25	91	66	0.03	46
25	101	58		161	95	70		93	91	64		73
26	82	56		60	98	73		102	93	66		79
27	93	68	0.36	163	98	71		57	95	67		81
28	99	62	0.12	108	97	72		46	94	67		80
29	85	67	0.12	31	101	70		69	95	72		100
30	94	72		94	101	72		51	97	74		87
31					100	72		50	95	71		78

On June 3 the variety Midland was planted in field plots. A randomized block experiment replicated four times was used. Each block was 70 x 170 feet, the rows extending across the block. The block included 20 plots each guarded by rows of like-spacing to reduce competition effects. Table 2 shows the row widths to be 40, 30, 20, and 10 inches. The spacing within the row was planned to give an area per plant of 40, 60, 80, 120, and 160 square inches. The number of plants varied from 40,000 to 160,000 per acre.

Width of row was obtained by the use of a variable space six-row "Planet Junior" planter. Spacing within the row was obtained by planting all plots thick and thinning by hand to the desired stand. Thinning of the plots was started at about the time the food supply of the kernel was exhausted and before the secondary roots were well established. A board 1 by 2 inches, 6 feet long was marked to show the desired space between plants. The board marker was placed beside the row to be thinned and excess plants were removed by hand. Any lack of plants per board length was carried to the next length and there satisfied, thus giving the desired number of plants per 70 feet of row.

The only plots which received cultivation were the 40 inch row widths. They were cultivated twice during the season, once approximately 30 days after emergence and again 50 days after emergence. A standard two-row mounted cultivator was used.

The light intensity was measured with a Weston "Sunlight Meter." Light intensities were taken at noon at ground level as clear skies would permit, beginning 30 days after planting and

Table 2. Plan of experiment on spacing dwarf grain sorghum.

Distance between rows inches	Approximate rate of planting lbs/acre	Average space between plants sq. inches	Average area per plant sq. inches	No. plants per acre (000)
40	20	1	40	160
30	20	1.33	40	160
20	20	2	40	160
10	20	4	40	160
40	13	1.50	60	105
30	13	2	60	105
20	13	3	60	105
10	13	6	60	105
40	10	2	80	80
30	10	2.66	80	80
20	10	4	80	80
10	10	8	80	80
40	8	3	120	52
30	8	4	120	52
20	8	6	120	52
10	8	12	120	52
40	5	4	160	40
30	5	5.33	160	40
20	5	8	160	40
10	5	16	160	40

continuing until after maturity.

To obtain an average light intensity for a plot, six readings were taken, three in the north half of the plot and three in the south half. In rows where the leaves did not provide enough shade to protect the instrument from the direct rays of the sun, a small card was held approximately six feet above the instrument to shield it from the direct sun rays.

A series of readings was taken in (1) like plant spaces in all row widths, (2) all plant spaces in one row width, (3) all plots in one block, and (4) all plots in all blocks.

The approximate plant height, percent of area shaded, and light intensity above the plants were recorded each time a set of readings was taken.

The evaporative power of the air was measured through the use of Livingston atmometer bulbs. These porous clay-cup atmometers were mounted on quart glass bottles; the mountings used were those described by Weaver and Clements (30). The atmometers were placed equidistant between the rows as shown by Fig. 1.

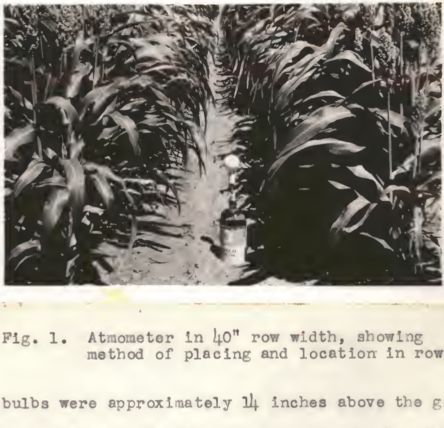

Fig. 1. Atmometer in 40" row width, showing method of placing and location in row.

The bulbs were approximately 14 inches above the ground. The instruments were protected from tipping over by placing them in quart oil cans from which the ends had been removed. The cans were forced into the soil a short distance before placing the instrument in the can.

Duplicate readings were taken in each area and each area was replicated. Each series was run for five consecutive 24-hour periods. The readings were taken in the morning at the same hour each day. The distilled water was siphoned from a gallon container into a 100 ml. cylinder. The amount required to refill the atmometer bottles back to the zero mark was recorded, thus giving the daily evaporation from each instrument.

Fig. 2. Method and equipment used to fill atmometers.

The atmometers were cleaned after each series, as shown by Fig. 3. A tooth brush was used to scrub the bulbs to remove dust and insect excretion from the bulbs.

Sets of instruments were maintained for five days in the 80 square inch per plant area of both 40 and 20 inch row widths.

One set of data was recorded to check the influence of air movement on evaporation. The method used was to place four instruments equidistant, beginning 15 feet from the south end of

Fig. 3. Method and equipment used to clean atmometers between series.

the plots at 15-foot intervals. The height of the instrument above the ground was 14 inches. A 25-foot road ran along the south end of the plots. Dwarf grain sorghum was south of this road.

The evaporation was measured also at different heights in the crop when it was in full head. The area checked was the 60-square-inch area per plant from the 20-inch rows. Ten instruments were placed in the plot checking the evaporation at ten different heights as shown by Fig. 4.

The interval between heights was six inches beginning at 2 inches above the ground for nine positions; the 10th position was 72 inches above the ground. Beginning at the atmometer two inches above the ground, the first three instruments were below the

Fig. 4. Atmometers in the layering series showing the arrangement of the instruments.

leaf canopy; the fourth and fifth were within the leaf canopy, the sixth just above the canopy, the seventh and eighth were in the head region, with nine and ten above the crop.

The plant height was taken 80 days after planting at the time the plants were in full head. The average height was obtained by measuring at random 12 plants from each plot in each block. The average of each plot and an average of all plots of like space and row width was calculated.

The date of first head was recorded as the time when ten percent of the heads were completely out of the boot and 75 percent of the heads were showing. The full head data were taken when heads were in one-third bloom.

The number of heads per plot was obtained by counting the heads in all plots except the 10-inch row widths prior to harvesting. The heads in the 10-inch row width were counted after harvest and just before threshing.

The number of tillers was calculated, assuming the plants per plot to be correct, by subtracting from the total number of heads per plot the assumed number of plants per plot.

Plots 1 to 40 were harvested September 11 and 12; plots 41 to 80 were harvested September 19, 20, and 21. The moisture content of the grain at time of harvest was approximately 14.5 percent. The heads were cut with a linoleum knife and placed in weighed wire-bottom trays at the end of each plot. The trays were supported by 6-inch clay pots to provide circulation of air through the trays.

The area harvested in the 10, 20, and 30 inch rows was 5 by 70 feet or six, three, and two rows, respectively. The area harvested in the 40 inch row width was 6 2/3 by 70 feet or two rows.

The trays containing the heads were weighed at the time of threshing. The threshing was accomplished by the use of a portable threshing machine. The grain from each plot was placed in sacks with a tag stating the plot number, weight of tray, and weight of tray plus heads. The sacks were stored in the barn at the agronomy farm for further processing.

The weed count was made just prior to harvest. The area in which the count was made was the same as that harvested. A careful count of all species was made and recorded for each plot.

The yield per plot was calculated for the 40 inch row by the formula:

$$\frac{43560}{70 \times 6.67 \times 56} = 1.666 \text{ x wt. grain per plot equals bushels per acre.}$$

The formula used for plots with 10, 20, and 30 inch rows was:

$$\frac{43560}{70 \times 5 \times 56} = 2.222 \text{ x wt. grain per plot equals bushels per acre.}$$

The test weight per bushel was determined by the method and use of the Fairbanks scale as described in the U. S. D. A. bulletin No. 1065, May 18, 1922.

The size of kernel was recorded as weight in grams of 1000 kernels. Samples were obtained by first removing the dockage with a hand sieve having round holes 2½/64 inches in diameter. From this dockage-free sample two 500-kernel samples were hand counted and weighed.

The size of head was calculated by using the total weight of grain per plot in pounds divided by the number of heads harvested from each plot. The size of head was recorded as pounds per 1000 heads.

EXPERIMENTAL RESULTS

The experimental results in this paper pertaining to spacing of grain sorghum plants were divided into sections in order to present more clearly the influence of difference between rows and between plants in the row on the production of dwarf grain sorghums. The subdivisions deal with: (a) light and shading, (b) growth of weeds, (c) tillering, (d) height of plants, (e) evaporative power of the air, (f) acre yield, (g) size of kernel, and (h) weight per bushel.

Effect of Distance Between Rows and Between Plants on Light and Shading

The shading or reduction of light intensity at the soil surface was considered a possible means of controlling weeds and reducing evaporation.

Fig. 5. Sorghum in rows 40 inches apart at full head.

The amount of cover provided by the plants and the length of time needed to provide this cover are probably important points in the successful production of dwarf grain sorghum in narrow rows without post-planting cultivation.

Early shading was most effective in controlling growth of weeds and reducing evaporation from the soil.

Sorghum in the 40 inch rows did not shade more than 60 percent of the area between the rows at noon at the time of full head. The plots were cultivated to control the weeds; had they not received cultivation, weeds would have provided serious competition. Fig. 5 shows that the leaves at their maximum development did not extent to the center of the row, so adequate shading was not possible.

Fig. 6. Sorghum in rows 30 inches apart at the time of full head.

Sorghum in the 30 inch rows shaded 85 percent of the area between the rows at noon when the plants were in full head. The percent of shading decreased as the area per plant increased.

The shading in the plots of sorghum in rows spaced 30 inches apart did not give adequate shading enough to control weeds, as shown by Fig. 6, page 17.

Figs. 7 and 8 are of sorghum plants grown in rows 20 and 10 inches apart.

In 20 inch rows the sorghum provided very good shading since approximately 95 percent of the area was shaded at noon 40 days after planting. This shading was effective in controllong weed growth.

Fig. 7. Sorghum in rows 20 inches apart at the time of full head.

The cover provided in 10 inch rows was very complete with 100 percent of the soil shaded at noon less than 40 days after planting where the space per plant was 40 square inches. This was not true, however, in the 160 square inch areas. The larger area did not provide adequate shading to prevent the early growth

Fig. 8. Sorghum in rows 10 inches apart at the time of full head.

of weeds.

Figs 9 and 10 illustrate the type of shading obtained by sorghum grown in 20 inch rows. In Fig. 9 note how the leaves of one row overlap and nearly reach the adjoining row. The effectiveness of this shading may be seen in Fig. 10.

Light intensity, as used in this paper, refers to the amount of light striking the soil at noon equidistant between the sorghum rows.

Comparison of light intensities between dates was not possible because of the many factors that affect light intensities; i.e., clouds, haze, dust, movement of the leaves by the wind, and growth of the crop. These uncontrollable factors would make

Fig. 9. Top view of sorghum grown in rows 20 inches apart.

Fig. 10. End view of sorghum grown in rows 20 inches apart.

comparison impracticable.

Table 3 is presented to illustrate the reduction of light as

Table 3. *Amount of light striking the soil on different dates, listed by areas and row widths. Figures are the percent of light striking the soil at noon in rows 40" apart.

Row Width inches	Days after planting				
	49(7-22)	43(7-16)	36(7-9)	50(7-23)	83(8-25)
	Plant space-square inches				
	40	60	80	120	160
40	100	100	100	100	100
30	60	73	76	53	55
20	26	56	49	26	36
10	11	16	30	20	46

* The data recorded in this table are not comparable between dates, as growth, wind, and total light intensities were different on these dates.

influenced by row widths on given dates. A definite reduction was noted on each date with a reduction of row width except between the 10 and 20 inch rows in the 160 square inch area. In this case, the difference probably can be accounted for by the shape of the areas.

Table 4 presents the data in foot candles striking the soil on August 25, 1953, between the hours of 11:30 a.m. and 1:15 p.m. Average light intensity above the crop was 10,500 foot candles. The plants at this time were near maturity, so nearly all growth had ceased.

A significant difference was found between row widths in each case except one; viz., between the 10 and 20 inch rows with plant space of 160 square inches. There was a significant difference in 75 percent of the cases between areas per plant. Light intensity was about twice as high in the 160 as in the 40 square inch area. The higher light intensity at ground level

Table 4. Light intensity at the soil surface on August 25, 1953, as measured in foot candles in all plots.

Row Width	Plant space-square inches				
	40	60	80	120	160
40	349	405	417	482	609
30	165	245	229	313	337
20	105	128	160	220	221
10	69	84	122	198	284

A difference of 16.5 foot candles is significant.

Table 5. Analysis of variance of light intensity on August 25.

	df	ss	var.	F
Between blocks	3	773	257.6	1.81
Between areas	4	366887	91721.7	645.92**
Between row widths	3	1163886	38796.0	1077.60**
Interactions:				
Area x widths	12	41053	3421.0	24.00**
Area x blocks	12	1456	121.3	
Width x blocks	9	1187	131.8	
Area x width x block	36	5113	142.0	
Total	79	1580355		

** Significant at one percent level.

in the 160 square inch area per plant appeared to influence the plant height and number of tillers per plant.

Row width and plant space independently and in combination affected the amount of light reaching the soil at a given time. The row width, as shown by tables 4 and 5, appeared responsible for the greater influence on the amount of light at the soil level.

Effect of Distance Between Rows and Between Plants on Growth of Weeds

The possibility of controlling weeds by shading, thereby eliminating the cost of post-planting cultivation and conserving moisture was one point investigated in this experiment. Smooth and rough pigweed (*Amaranthus spp.*) were the most common broad leaf weeds in this field. The grass-like weeds were those of the *Digitaria spp.* and *S$\overset{e}{\text{o}}$taria spp.* Fig. 11 indicates the lack of sufficient shade provided by the sorghum in 30 inch rows to provide good control over the smooth pigweeds.

The weeds in the 20 and 10 inch sorghum rows were forced into a different habit of growth than those in the 30 inch row

Fig. 11. Smooth pigweed (*Amaranthus spp.*) in the 30 inch row width

widths. The broad leaf weeds developed a single stem with side branches originating only after the sorghum had matured and the weeds had grown above the crop. The grass-like weeds were very spindly and many of those plants died before they produced seed. Table 6 for the 20 and 10 inch rows do not show a great reduction in the number of weeds over the 30 inch row width, the big difference being in the competition provided by the weeds.

The area per plant appeared to be the greatest factor in the control of grass-like and broad leaf weeds. The data in Table 6 show a definite increase in the number of weeds as the area increased above 80 square inches per plant, regardless of row width. The amount of shade provided by the closer-spaced plants was assumed to be responsible for the decrease in weed numbers rather than competition for water and nutrients.

Fig. 12. Crab grass in sorghum in 30 inch rows

Crab grass (Digitaria spp.) was partially controlled by sorghum in 30 inch rows, i.e., it was changed from a prostrate to a more upright type of plant and the extent of growth was limited. In Fig. 12, the crab grass plant is upright in growth in search of more light.

Table 6 is a record of the number of weeds counted in the areas harvested in the 30 inch rows.

Table 6. Number of weeds found in harvested areas.

Weed by Common Name	Plant space (square inches)				
	40	60	80	120	160
			30 inch rows		
Rough pigweed[1]	1	1	0	0	0
Smooth pigweed[2]	12	23	15	30	31
Crabgrass[3]	29	35	31	58	131
Foxtail[4]	4	14	8	12	6
Stinkgrass[5]	0	0	0	3	0
Barnyard grass[6]	0	0	0	0	0
Browneyed susan[7]	1	0	0	0	0
Mat spurge[8]	2	2	1	6	13
Groundcherry[9]	7	0	7	2	0
Nutgrass[10]	0	0	25	17	64
Ticklegrass[11]	0	0	0	0	0
Hedge Bindweed[12]	0	0	2	1	0
			20 inch rows		
Rough pigweed	0	0	0	0	0
Smooth pigweed	15	25	21	34	30
Crabgrass	39	42	91	142	195
Foxtail	5	15	4	13	11
Stinkgrass	0	1	1	0	1
Barnyard grass	0	0	0	0	0
Browneyed susan	0	0	0	0	0
Mat spurge	0	0	0	0	0
Groundcherry	3	8	13	0	0
Nutgrass	0	0	0	10	2
Ticklegrass	0	0	0	0	0
Hedge Bindweed	0	0	0	0	0

Table 6 (concl.).

Weed by Common Name	Plant space (square inches)				
	40	60	80	120	160
	10 inch rows				
Rough pigweed	0	2	1	0	3
Smooth pigweed	7	14	12	23	23
Crabgrass	0	12	25	58	124
Foxtail	0	0	0	5	10
Stinkgrass	0	0	0	0	0
Barnyard grass	0	0	0	0	0
Browneyed susan	0	0	0	0	1
Mat spurge	0	0	0	1	0
Groundcherry	0	0	1	0	0
Nutgrass	0	0	0	0	0
Ticklegrass	0	0	0	0	0
Hedge Bindweed	0	0	0	0	4

Scientific names:

1. *Amaranthus retrofleurus*
2. *Amaranthus hybridus*
3. *Digitaria sanguinalis*
4. *Setaria lutescents*
5. *Eragrostis cilianensis*
6. *Echinochloa crusgalli*
7. *Higiscuc trionum*
8. *Euphorbia gylptosperma*
9. *Physalis virginiana*
10. *Cyperus esculentus*
11. *Agrostis hyemalis*
12. *Convolvulus sepium*

The number of weeds tended to increase with increase in space per plant. The number of broad leaf and grass-like weeds was highest in the 120 and 160 square inch area per plant. Sorghum in 30 inch rows did not give satisfactory control of weeds. Although weeds were not abundant enough to influence the yield, they did produce seed to contaminate the field.

Effect of Distance Between Rows and Between Plants on Tillering

The ability of the sorghum plant to utilize a given space has long been recognized. In this experiment, data were taken on the number of tillers in each row width, and by areas, as shown in Table 7.

In each row width there was an increase in the number of tillers as the area per plant increased. The shape of the area provided appeared to influence the number of tillers. The larger number of heads was produced on tillers in the 120 and 160 square inch areas. The largest number of heads was found in the 160 square inch area of the 10 inch rows. The 10 inch rows also produced the greatest number of tillers, followed by the 20 inch rows. This seems to indicate the shape of the area is a factor in the amount of tillering. The 40 and 30 inch rows provided a rectangular area while the 10 and 20 inch rows provided an area which approached a square, thus allowing a greater light intensity at the base of the plants.

Table 7. Average number of tillers per plot by row widths and area per plant.

Row Width	Plant space (square inches)				
	40	60	80	120	160
40	0	0	0	18	62
30	0	0	22	30	80
20	0	0	8	99	105
10	0	12	52	184	190

Wiessmann (31) stated, "The abundance of light favors the production of tillers." Karper, et al, (10) found that the amount of tillering increased with increased space within the row.

The tillers in the 10 inch rows began appearing approximately 20 days after planting, but ceased as the plants provided more shade.

Fig. 13. Tillering of a sorghum plant in a 10 x 16 inch area.

Fig. 13 shows the tillering of a sorghum plant that was grown in an area of 160 square inches in a 10 inch row.

The growth and development of the tillering plant (center Fig. 14) was normal in that the main stalk was first to head and mature, but was shorter than the tillers.

The height of the tillers was in reverse to the date of their appearance; the last to appear was tallest and latest to mature.

The tillers originated from crown buds which definitely distinguished them from axillary branches, as is shown in Fig. 15.

Fig. 14. Sorghum plant at maturity showing height of tillers and main stem.

Fig. 15. Roots and stalk of sorghum plant showing origin of tillers.

Effect of Distance Between Rows and Between Plants on Height of Plants

An attempt was made to record the effects of row width and plant population on the height of the sorghum in this experiment.

The average height was obtained by the method described in methods and materials. Table 8 records these data.

Table 8. Average plant height in inches for each area in each row width.

Row Width inches	Plant space in square inches					
	40	60	80	120	160	Average
40	44.1	45.3	44.0	43.0	40.4	43.3
30	46.0	45.4	45.3	43.7	40.4	44.1
20	45.0	45.2	43.5	42.2	39.9	43.1
10	48.3	46.5	44.9	41.4	40.7	44.3
Average	45.8	45.6	44.4	42.5	40.3	

A difference of 1.7 inches is significant.

Table 9. Analysis of variance of height measurements taken in the sorghum plots, 1953.

	df	ss	var.	F
Between blocks	3	8.13	2.71	1.73
Between areas	4	362.33	90.58	58.06**
Between row widths	3	19.87	6.62	4.24*
Interactions:				
Areas x widths	12	44.24	3.68	2.35*
Areas x blocks	12	18.92	1.57	
Widths x blocks	9	24.40	2.71	
Areas x widths x blocks	36	56.16	1.56	
Total	79	534.05		

* Significant at 5 percent level.
** Significant at 1 percent level.

In the statistical analysis the formulae as outlined by Paterson (22) were used.

The 40 square inch area per plant, Table 8, appeared to influence the height as the row width was decreased. Plants in the 10 inch row width were significantly taller than plants of any other row width as is indicated by Fig. 19. These results seem to agree with the findings of Martin, et al (17).

An area of 60 square inches per plant resulted in more uniform plant height than any other area per plant, regardless of row width.

Plants in the 80 square inch area were very similar to the plants in the 60 square inch area; however, there was a significant decrease in height in the 20 and 10 inch rows.

Plants in the 120 and 160 square inch areas continued to decrease in height as the area per plant increased. The decrease in height in each row width was significant, with the exception of the 10 inch rows, as shown in Figs. 16 to 19.

Row width and area per plant independently and in combination affected the height of the plants as shown by Tables 8 and 9.

Competition for light seemed to be the greatest factor influencing plant height.

An increase in height was associated with decrease in area per plant. The shape of the area also appeared to influence the height to some extent. There was a general increase in height as the width of the row decreased, which indicates that the wider row widths increase the amount of light striking the entire plant, thereby satisfying its desire for light.

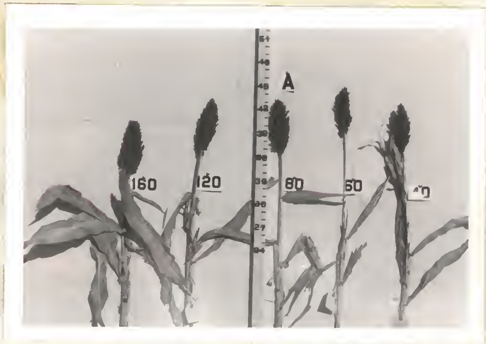

Fig. 16. Plants from A or 40" rows, all areas included. 160 sq. in. area on the left to 40 sq. in. area on the right.

Fig. 17. Plants from B or 30" rows, all areas included. 160 sq. in. area on the left, to 40 sq. in. on the right.

Fig. 18. Plants from C or 20" rows, all areas included. 160 sq. in area on the left to 40 sq. in. area on the right.

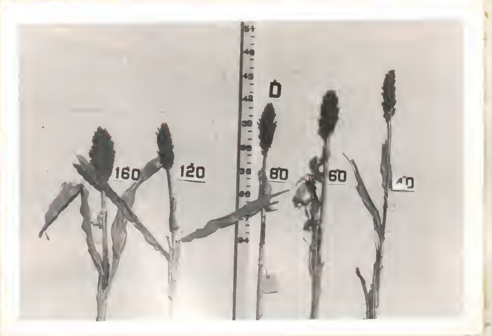

Fig. 19. Plants from D or 10" rows, all areas included. 160 sq. in. on the left to 40 sq. in. area on the right.

Plant height was greatest in the 40 square inch areas and shortest in the area of 160 square inches per plant.

Effect of Distance Between Rows and Between Plants on Evaporative Power of Air

A study was made of the evaporative power of the air in several different situations; including plots of different row widths, different areas per plant, and within a plot at several distances from the end and at different heights in the crop.

The evaporative power of the air was measured by Livingston atmometer bulbs which give only an indication of the amount of evaporation from the field and not a direct measure of it.

Row width and plant space, when properly adjusted, will give a cover which will result in an increase in humidity within the crop, probably by reducing the influence of both temperature and wind.

A comparison of the evaporative power of the air was made between the 80 square inch area per plant in the 40 and 20 inch rows. This comparison was made for five, five-day periods. The total amount evaporated from the atmometers was 1.46 times as much in the 40 inch rows as in the 20 inch rows.

Table 10 is a record of the amount evaporated from the 40 and 20 inch rows with a plant space of 80 square inches per plant.

Evaporative power of the air was measured at different heights in the 20 inch rows where the space per plant was 60 square inches. The method used is described on page 12 of "Materials and Methods."

Table 10. Effect of row width on evaporation (plant space = 80 square inches)

	Row width	
	40	20
	cc	cc
July 24 to 28	425	265
July 29 to Aug. 2	606	390
August 6 to 10	130	94
August 25 to 29	498	343
August 30 to Sept. 4	568	424

Table 11 shows the average amount evaporated in five days at the different heights in plots of 20 inch rows. Fig. 4, page 13, pictures the arrangement of the atmometers in the row.

Table 11. Average daily evaporation at different heights of sorghum grown in 20 inch rows (plant space = 60 square inches).

Bulb height inches	Evaporation c.c.	Bulb height inches	Evaporation c.c.
2	10	32	27
8	13	38	33
14	15	42	35
20	16	48	39
26	19	72	45

The instruments located from 2 to 26 inches high were below the leaf area, i.e., below the height of the top leaf and measured the evaporative power of the air among the leaves. The amount evaporated above the leaf canopy but below the top of the heads is shown by the instruments located 32, 38, and 42 inches high. Considering only those atmometers within the crop, 43 percent of the total amount evaporated from the instruments was within or below the leaf canopy; 57 percent was evaporated above the the leaf canopy. This evidence would indicate the value of a good cover to reduce the loss of water from the soil and help to reduce the amount lost from the plants.

One series of readings was concerned with measuring the evaporative power of the air at different points in the rows. The method used was described previously.

Table 12 shows the amount evaporated from the instruments in c. c. as well as a percent of the total. The amount evaporated decreased from south to north; this decrease amounted to 62 c.c. or 5 percent of the total amount evaporated from the instruments placed between rows that were 40 inches apart. The decrease from south to north in the 20 inch rows was 82 c.c. or 10 percent of the total amount lost from the instruments. This greater decrease in the 20 inch rows over the 40 inch rows indicates the effectiveness of narrower rows in reducing evaporation presumably due to checking the rate of air movement.

Table 12. Evaporation from atmometers located at different distances from the windward (south) end of the plots.

Row width inches	Distance (ft.) from south end			
	15	30	45	60
	Evaporation during 5-day period, c.c.			
40	315	287	263	253
20	236	213	189	154
	Proportion evaporated in percent.			
40	28	26	24	23
20	30	27	24	20

Effect of Distance Between Rows and Between Plants on Acre Yield

The acre yield of sorghum grown in rows 40 inches apart was as low or lower than in rows 10, 20, or 30 inches apart, as shown by Table 13. Acre yields by areas are given in Table 15. The acre yields by row widths are shown in Table 16.

Table 13. Acre yields of sorghum spacing, 1953, recorded by row width and plant space.

Row Width inches	Plant space square inches				
	40	60	80	120	160
40	84	88	87	86	79
30	90	91	94	90	84
20	86	96	87	87	85
10	88	90	93	86	91

A difference of 5.5 bushels is significant.

Table 14. Analysis of variance of acre yields of sorghum spacing experiment, 1953.

	df	ss	var.	F
Between blocks	3	4764.0	1121.6	70.14**
Between areas	4	412.9	103.2	6.45**
Between row widths	3	263.3	87.7	5.48**
Interactions:				
Areas x widths	12	433.4	36.1	2.25*
Areas x blocks	12	276.6	23.0	
Widths x blocks	9	185.0	20.5	
Areas x widths x blocks	36	565.1	15.9	
Total	79	6900.6		

* Significant at 5 percent level.
** Significant at 1 percent level.

The F-ratio, as shown in Table 14, indicated a significance between blocks, between areas, and between row widths at the one percent level.

Acre yields by areas of all row widths are shown in Table 15.

Table 15. Acre yields by area per plant.

	Plant space square inches				
	40	60	80	120	160
Bushels	87	91	90	87	85

A difference of 2.7 bushels is significant.

Average yield of sorghum was significantly higher in the 60 and 80 square inch areas per plant than in either the thicker or thinner rates. The lowest yield was in the 160 square inch area per plant. It would appear that the plants in this area could not fully utilize the space provided.

Acre yield by row width for all areas is shown in Table 16.

Table 16. Acre yields by row widths.

	Distance between rows, inches			
	40	30	20	10
Bushels	85.0	90.0	88.3	89.4

A difference of 2.5 bushels is significant.

The average yield of sorghum in the 40 inch rows was significantly lower than that of any other row width. The yields in the other three row-widths did not differ significantly.

A comparison of acre yields between 40 and 20 inch rows in bushels of Midland grown at Manhattan (29) for a 10-year period is shown in Table 17. The average advantage for the narrower row was 12.4 bushels per acre, or 25 percent.

Table 17. Acre yield (bu.) comparing the 40 and 20 inch row widths.

Year	Row width 40	Row width 20	Advantage of narrow rows
1944	44	59	15
1945	33	65	32
1946	28	27	-1
1947	21	26	5
1948	52	68	16
1949	73	86	13
1950	80	92	12
1951	64	81	17
1952	17	29	12
1953	85	88	3
Average	49.7	62.1	12.4

The data presented in Table 17 seem to indicate that the wider rows fail to use properly the factors of production.

Area per plant and row width independently and in combination affected the acre yield of sorghum as shown in Tables 13 and 14.

Effect of Distance Between Rows and Between Plants on Size of Heads

The size of head best indicates the influence of area per plant on the development of the plants; even though the size of head was greatly reduced in the smaller areas, the acre yield was not influenced. The larger population of plants in the smaller areas supports the yield.

Table 18. Average size of head in pounds per 1000 heads recorded by row width and area per plant.

Row Width	Plant space square inches				
	40	60	80	120	160
40	34.7	49.3	69.2	90.0	98.6
30	35.0	54.0	59.6	89.3	95.6
20	36.9	55.1	61.7	75.7	91.1
10	32.2	47.7	61.1	64.2	81.6

A difference of 4.8 pounds is significant.

There was a significant increase in the size of head as the area per plant increased in each width of row, with one exception; viz., between the areas of 80 and 120 square inches per plant of the 10 inch row width. Perhaps this exception can be explained by the larger number of heads produced on tillers in the 10 inch row width.

Table 19. Analysis of variance of sorghum head size.

	df	ss	var.	F
Between blocks	3	1923.66	641.22	53.5**
Between areas	4	32535.95	8133.98	679.0**
Between row widths	3	1418.25	472.75	39.4**
Interactions:				
Areas x widths	12	1491.88	124.32	10.3**
Areas x blocks	12	975.84	81.32	6.7**
Widths x blocks	9	331.48	36.83	3.1*
Areas x widths x blocks	36	431.22	11.97	
Total	79	39108.31		

*Significant at 5 percent level.
**Significant at 1 percent level.

Table 19 shows a highly significant interaction of area per plant by row width. Equal areas per plant reacted differently in different row widths. This difference increased as the size of the area increased.

The effect of row width was less in the 40, 60, and 80 square inch areas per plant than in the 120 and 160 square inch areas. The difference in head size of the 120 and 160 square inch area is, perhaps, the effect of shape of area rather than a direct effect of row width.

Table 7 lists the number of tillers per plot. The size of heads produced on the tillers were smaller than those produced by plants without tillers. The number of tillers was greater in the areas that approach a square in shape; i.e., the 10 and 20 inch rows. It would appear that the number of tillers in these row widths influenced the size of the head.

Area per plant had the greatest effect on head size; row width also had a significant influence on size of head in the 80 square inch area and larger areas.

The plants with an area of 160 square inches produced the largest heads. Comparing the heads produced in 160 square inch areas with those produced in the 40 square inch areas, the heads in the 160 square inch areas were twice, and most cases nearly three times larger.

Area per plant and row width affected head size independently and in combination. The difference between blocks, as shown by Table 19, perhaps influenced the interaction of areas x blocks and widths x blocks, making those interactions significant.

Size of head, as represented by Figs. 24, 25, 26, 27, and 28, show the same trend; i.e., a marked increase in size as the area increased up to 120 square inches per plant.

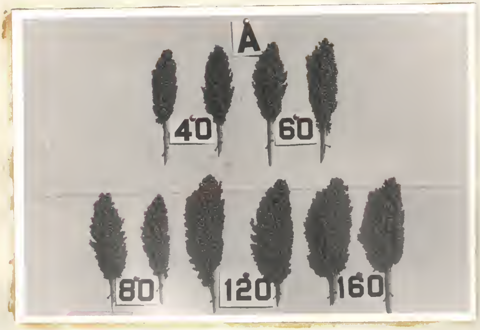

Fig. 20. Plants from A or 40" rows, all areas included, 40 sq. in. upper left to 160 sq. in. lower right.

Fig. 21. Plants from B or 30" rows, all areas included, 40 sq. in. upper left to 160 sq. in. lower right.

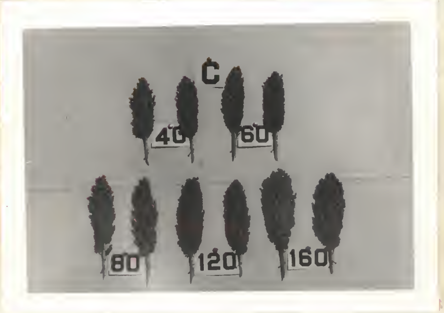

Fig. 22. Plants from C or 20" rows, all areas included, 40 sq. in. upper left to 160 sq. in. lower right.

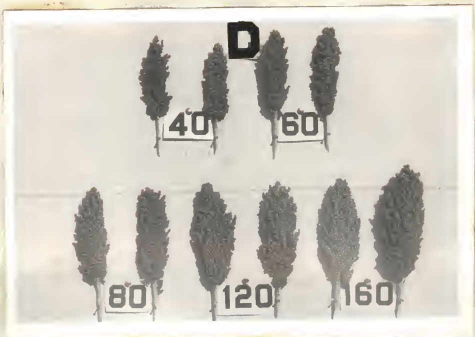

Fig. 23. Plants from D or 10" rows, all areas included, 40 sq. in. upper left to 160 sq. in. lower right.

Fig. 24. Plants from 40 sq in. area per plant of all row widths, A - 40" row, B - 30", C - 20", and D - 10" row.

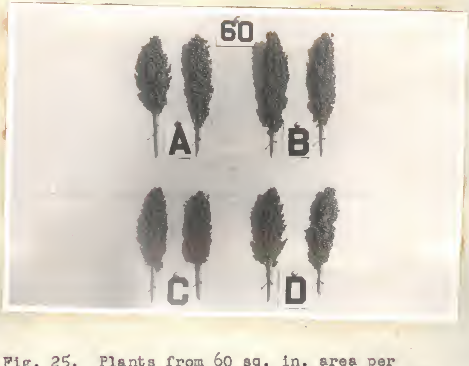

Fig. 25. Plants from 60 sq. in. area per plant from all row widths. A = 40", B = 30", C = 20", D = 10" row.

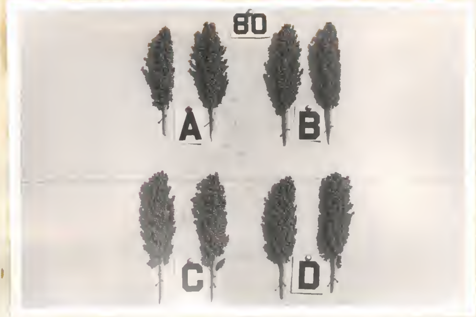

Fig. 26. Plants from 80 sq. in. area per plant from all row widths. A = 40", B = 30", C = 20", D = 10".

Fig. 27. Plants from 120 sq. in. area per plant from all row widths. A = 40", B = 30", C = 20", D = 10" row.

Fig. 28. Plants from 120 sq. in. area per plant from all row widths. A = 40", B = 30", C = 20", D = 10" row.

Effect of Distance Between Rows and Between Plants on Size of Kernel

The size of kernel was influenced by row width and plant space, the greater influence being that of row width. The largest kernels were produced in the 40 inch rows while the smallest were produced by the 10 inch rows. The data recorded in Table 20 show that a significant difference existed between the 10 and 40, 20 and 40, and 30 and 40 inch rows. The kernels produced by the 80 square inch and greater area per plant, in most cases, were significantly larger than those produced by the 40 and 60 square inch areas in the rows 40 inches apart. The kernels produced by the plants in the 160 square inch area of the 30, 20, and 10 inch rows in nearly all cases were sig-

Table 20. Kernel size by weight in grams of 1000 kernels recorded by row width and area per plant.

Row Width inches	Plant space square inches				
	40	60	80	120	160
40	24.8	24.6	25.4	25.1	25.0
30	23.0	22.9	23.5	23.6	24.0
20	21.9	22.0	22.0	22.2	23.7
10	22.4	22.0	21.8	22.3	23.0

A difference of 0.58 gram is significant.

icantly larger than those produced in the smaller areas.

Table 21 shows that area per plant and row width were significant in influencing the size of the kernels. These factors in combination affected the size of kernel.

Table 21. Analysis of variance of size of sorghum kernels in the 1953 plots.

	df	ss	var.	F
Between blocks	3	0.9456	0.3152	1.78
Between areas	4	10.2360	2.5590	14.45**
Between row widths	3	96.8446	32.2815	18.28**
Interactions:				
Areas x widths	12	6.7830	0.5652	3.19*
Areas x blocks	12	1.1674	0.0972	
Widths x blocks	9	2.2783	0.2531	
Areas x widths x blocks	36	6.3724	0.1770	
Total	79	124.6273		

* Significant at 5 percent level.
** Significant at 1 percent level.

Effect of Distance Between Rows and Between Plants on Weight per Bushel

The test weight of sorghum in the 1953 spacing experiment was above the standard 56 pounds per bushel in all areas and row widths.

Table 22. Average test weight of sorghum in pounds per bushel.

Row Width inches	Plant space-square inches					
	40	60	80	120	160	Average
40	59.9	59.9	59.9	60.0	60.0	59.9
30	59.9	59.6	59.7	59.7	59.5	59.6
20	59.3	59.5	59.5	59.5	59.6	59.4
10	59.2	59.5	59.8	59.4	59.6	59.5
Average	59.5	59.6	59.7	59.6	59.6	

A difference of 0.24 pounds is significant.

Table 23. Analysis of variance of weight per bushel of sorghum spacing experiment, 1953.

	df	ss	var.	F
Between blocks	3	2.18	0.72	6.00**
Between areas	4	0.38	0.09	0.75
Between row widths	3	3.06	1.02	8.50**
Interactions:				
Areas x widths	12	1.18	0.09	0.75
Areas x blocks	12	0.70	0.05	0.41
Widths x blocks	9	1.29	0.14	1.16
Areas x widths x blocks	36	4.53	0.12	
Total	79	13.32		

** Significant at 1 percent level.

The data presented in Table 22 shows that row width had a greater effect on weight per bushel than area per plant. Sorghum grain produced in rows 40 inches apart was significantly higher than grain produced in any other row width. The difference in average bushel weight between areas was not significant.

SUMMARY

The 1953 sorghum-spacing experiment was conducted on the Kansas Agricultural Experiment Station farm located at Manhattan.

On June 3 Midland sorghum was planted in a randomized block design replicated four times. Each block was 70 by 170 feet with rows extending across the block. The plots were planned to give the same area per plant regardless of row width. The areas used were 40, 60, 80, 120, and 160 square inches per plant.

Previous work at Manhattan has shown that dwarf grain sorghum grown in narrow 20 inch rows had an advantage of 25 percent in acre yield over that planted in rows 40 inches apart.

This paper records the results of one years' study of the influence of row width and spacing of plants on the character of growth and acre yield and on shading and humidity as possible factors for higher yields in the narrow rows.

CONCLUSIONS

Conclusions from this experiment supported by the material presented in this paper are:

1. Differences in widths of row and differences in space (square inches) per plant influenced shading, light intensity, tillering, plant height, evaporation, size of head and kernel, and acre yield.

2. Shading was an effective means of controlling weeds, and was most efficient in the 10 and 20 inch rows where the space per plant did not exceed 120 square inches.

3. Shading was not sufficient in the 30 inch rows to be effective in the control of weeds.

4. The higher light intensity at ground level resulted in shorter plants and greater tendency to produce tillers.

5. Evaporation was less in 20 inch than in 40 inch rows. The amount evaporated from atmometer bulbs placed 14 inches above the ground, during a 25-day period, was 1.46 times as much in 40 inch rows than in 20 inch rows.

6. There was a greater evaporation loss in 40 than in 20 inch rows due to the effect of prevailing winds. A reduction in evaporation of 10 percent was found in favor of the 20 inch rows.

7. The amount of water evaporated from atmometer bulbs placed at different heights in the crop in 20 inch rows was 57 percent above the leaf canopy; while 43 percent was lost within and below the leaf canopy.

8. Plant height was greatest in the 40 or 60 square inch areas and decreased with increase in area per plant, being shortest in the area of 160 square inches per plant. The plant height was greatest in the 10 and shortest in the 40 inch rows.

9. The largest number of heads was produced on tillers in the 120 and 160 square inch areas. The number decreased with increase in row width and with decrease in distance between plants within the row.

10. There appeared to be no consistent relation between

size of head and acre yield of grain. The largest heads were produced in areas of 160 square inches.

11. Size of kernel was greater in the 160 than in the 40 square inch area. The size of kernel was decreased with each decrease in row width.

12. Row width appeared to have a greater influence on weight per bushel than area per plant.

13. Average acre yield of sorghum was significantly higher in the 60 and 80 square inch areas per plant than in either smaller or larger areas. The yield in the 160 square inch area gave the lowest yield.

14. Acre yield in the 40 inch rows was significantly lower than that of any other row width.

15. It appears that plants in the 40 inch rows did not utilize the factors of production as well as in the other row widths.

16. Plants in the 160 square inch areas were not able to utilize properly the area provided.

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A STUDY OF THE EFFECTS OF ROW SPACING IN DWARF GRAIN SORGHUMS

by

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INTRODUCTION

The production of grain sorghum in the United States has increased steadily since its introduction. Sorghum is a good crop to grow throughout the central and southern Plains area, whether it is to be used as a crop in a rotation or to replace abandoned acreage of wheat.

The dwarf type of grain sorghum appears not to be as well adapted to production in the usual 40 or 42 inch row as the taller types. A system of growing the dwarf type in 20 or 21 inch rows was tried with considerable success. It was the purpose of this study to investigate the reasons for the advantages of growing sorghum in the narrower rows.

MATERIALS AND METHODS

Midland sorghum was planted June 3, 1953 in field plots in a randomized block design with four replications. Each block was 70 by 170 feet with rows extending across the block. Each block included 20 plots. The row widths used were 40, 30, 20, and 10 inches. In each row width the plants were spaced 40, 60, 80, 120, and 160 square inches per plant. These spacings were obtained by hand thinning.

The plots consisting of 40 inch rows were the only ones that received post-planting cultivation.

Light intensity was measured with a Weston "Sunlight Meter". Readings were taken from 30 days after planting until after maturity.

The evaporative power of the air was measured by Livingston atmometer bulbs in plots having various combinations of row width and plant space, and at different heights in the crop.

Crop data were taken on plant height, date of first head, date of full head, amount of tillering, size of head, size of kernel, test weight, and acre yield.

RESULTS

Differences in width of row and differences in space (square inches) per plant influenced shading, light intensity, tillering, plant height, evaporation, size of head, size of kernel, and acre yield.

Shade provided an effective means of controlling weeds in the 10 and 20 inch rows where the space per plant did not exceed 120 square inches; however, the shade provided by plants in 30 inch rows was not sufficient to adequately control weeds.

A tendency for plants to be shorter and produce more tillers appeared to be associated with a higher light intensity at ground level. The largest number of tillers was produced by plants in the 10 and 20 inch rows in areas of 120 and 160 square inches.

Plants in the 40 square inch areas were the tallest while those in the 160 square inch areas were shortest. The difference is assumed to be associated with difference in light intensity, which was found to decrease with decrease in area per plant.

Evaporation was less in the 20 inch than the 40 inch rows. The amount evaporated from atmometer bulbs 14 inches above the ground during a 25-day period was 1.46 times as much in 40 inch rows as in 20 inch rows.

Results obtained from atmometers placed in 40 and 20 inch rows to record the difference in evaporation attributed to air movement show a decrease of 5 percent from south to north in the 40 inch rows and a 10 percent decrease from south to north in the 20 inch rows.

Data were recorded for atmometers placed at different heights within the crop in 20 inch rows. The results indicated that 57 percent of the total amount evaporated was lost above the leaf canopy; 43 percent was lost within and below the leaf canopy.

There appeared to be no consistent relation between size of head and acre yield of grain. There was an increase in head size as the area per plant was increased.

The size of kernel was greatest in the plant space of 160 square inches and smallest in the 40 square inch area. A decrease in kernel size was noted with each decrease in row width.

Average acre yield was significantly higher in the 60 and 80 square inch areas per plant. The lowest yield was recorded for the 160 square inch area per plant. The acre yield in the 40 inch rows was significantly lower than that of any other row width.

It appeared that sorghum grown in 40 inch rows did not utilize the factors of production as well as in the other row widths.