A STUDY OF THE EFFECTS OF ROW WIDTH AND PLANT POPULATION IN CORN, DWARF GRAIN SORGHUM AND FORAGE SORGHUM

by

FRED CHARLES STICKLER

B. S., Iowa State College, 1953

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1955

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INTRODUCTION

Corn and grain sorghum in their respective areas of production are important as cash and feed crops.

Grain sorghum is the most important row crop throughout the plains area. It can be grown in rotations with wheat to good advantage, especially if the machinery used for wheat production is also used for the production of grain sorghum.

Corn has traditionally been grown in wide rows because of ease of cultivation and harvesting. When dwarf grain sorghums were first introduced the same production methods were used as for corn.

Work at Kansas State College has shown that dwarf grain sorghums can be grown to advantage in narrow rows without mechanical cultivation after planting. The average advantage of the narrow rows was 12.7 bushels per acre, or 26 per cent in 11 years of testing at Manhattan (37).

This thesis reports an investigation made in 1954 of some of the factors responsible for the higher yields of dwarf grain sorghum from narrow rows. Results obtained when corn and sorgo were grown in narrow rows are also reported.

REVIEW OF LITERATURE

As this study dealt with various factors affecting plant growth, the review of literature is divided as such. Previous work is reviewed under the following headings: (a) row width and plant spacing of sorghum, corn, and other crops; (b) transpiration and evaporative power of the air; (c) light; (d) cultural practices and weed control; (e) soil temperature.

Row Width and Plant Spacing of Sorghums, Corn, and Other Crops

Bryan, et al (3), working in Iowa, compared 21 x 21 inch spacings with 42 x 42 inch spacings each with 14,224 plants per acre. In 1938 and 1939 the narrow spacing produced significantly larger yields, but in 1937 no spacing yielded significantly higher than the standard spacing when the plant population was the same. In two out of four years the narrow spacing exceeded the standard spacing by a significant amount. The difference in spacings when four-year averages were used was not significant. Tillering was twice as great in the narrow spacings.

In another study conducted in Iowa by Collins and Shedd (6), it was concluded that higher yields of corn may be expected with close row spacings, the optimum being single-stalk hills evenly spaced with a planting rate suitable for the conditions encountered. Collins and Shedd (6) stated that narrow rows facilitate disposal of crop residues because of better distribution of stalks and roots over the ground.

Another report on these studies (11) stated that when 7 years results were averaged, the advantage of the 21 x 21 inch single hill spacing over the 42 x 42 inch 4 kernel planting was 15 percent.

Dungan (8) found that single plant hills outyielded multiple plant hills of comparable stand in six out of seven years at Urbana, Illinois. This points out the importance of even distribution of the plants.

In Ohio, Stringfield and Thatcher (35) compared row widths from 30 to 80 inches with the same plant population per acre. When soil conditions and season would produce less than 30 bushels of grain per acre, yields decreased as row width increased from 30 inches. As productivity increased, the row width could be wider without yield loss.

Mooers (25), after working with corn in Southern conditions, concluded that best results will probably be obtained with a row width which permits most satisfactory use of tillage implements, but allow the optimum number of plants to be spaced as widely as possible.

Osborn (27) in reporting results obtained in Arkansas with corn grown in rows of 30 and 50 inches with uniform population, stated that wide rows will yield a higher percentage of that of narrow rows under favorable conditions than with unfavorable conditions.

Kiesselbach (13) studied the effect of varied distribution of corn plants on grain yield by varying the numbers of plants in adjacent hills. Little difference in yield was found. It was suggested that corn plants draw upon soil moisture and nutrients for such a distance that considerable irregularity in stand may exist without markedly affecting yields.

Kiesselbach, et al (15) summarized 14 years results of effects of irregularities in stand with constant plant population. These workers concluded that there may be considerable variation in uniformity of stand without materially reducing yields. Open pollinated varieties were used.

Zook and Burr (40) compared the yields of corn planted in 3.5 and 7.0 foot rows at North Platte, Nebraska. The plant population was kept constant. In five out of six years the narrow rows produced the highest yields.

Karper, et al, (12) stated that differences between milo and kafir in response to spacing was accounted for by marked differences in tillering.

Nelson (26) studied the effect of spacing and nitrogen applications on yield of grain sorghum under irrigation. No significant differences between spacings or varieties were found, but highly significant differences between rates of fertilizer application were noted. Plant spacing did not affect the protein content of the grain. A high plant population was necessary to obtain full response from irrigation and fertilizer.

Tingey (36) reported on the yield of rubber and shrub after seeding guayle in various spacings. The number of plants per unit area was the most important factor affecting yield of rubber and shrub. Rows 14 inches in width were compared with 28 inch rows with the same number of plants per acre. Yields of rubber and the percent of rubber in the shrub were higher in the narrow rows, but the tonnage of shrub was lower.

Painter and Leamer (28) demonstrated that close spacing of sorghum plants in the row is necessary for highest yields in New Mexico under irrigation with applications of nitrogen fertilizer.

Sieglinger (33) working at Woodward, Oklahoma with milo and kafir, showed that sorghum varieties which tiller profusely produce similar yields of grain when the distance between plants varies from 6 to 30 inches. Varieties which produce few tillers show progressive reduction in yield for every successive increase in the distance between plants from 6 inches up to 30 inches. Sieglinger (33) states that tillering is influenced by the space per plant, temperature, date of planting, and the stage at which soil is thrown into lister furrows covering the base of the plant.

Martin and Sieglinger (23) found that Dwarf Yellow Milo, kafir and feterita yielded less in widely spaced rows than in narrow rows with the same number of plants per acre, when 80 inch and 40 inch rows were used. These workers stated that stover and fodder yields of all grain sorghums usually are decreased considerably by growing the crop in widely spaced rows.

Wilkins (39), working at Mahhattan, Kansas, found that 60 and 80 square inches per plant gave the highest yields of grain sorghum. The acre yield in 40 inch rows was significantly lower than that of narrower row widths.

Hastings (10) found that close spacing gave higher yields of milo in Texas. Less branching, less tillering, and more uniform maturity was noted. The size of the plant stumps was less. The ripening period was shorter and earlier than with wider spacings.

Transpiration and the Evaporative Power of the Air

Kiesselbach and Montgomery (14) found that evaporation of a freewater surface and transpiration of corn plants fluctuate in near perfect accord. The transpiration for the 12 hours of day was about 13 times that for the night period. Evaporation was only about one-half as great on the ground as 10 feet above the ground. Wind movement at a height of 10 feet was 3.8 times that at four feet in early September in Nebraska.

Martin (20) concluded that transpiration is a function of radiation intensity.

Martin and Clements (21) studied the effect of artificial wind on transpiration in Helianthus annuus. They found with velocities up to two miles per hour, the transpiration rate increases and remains constant as long as the wind acts. For velocities above this there was a high relative initial increase followed by a fall, which in turn is followed by a gradual increase. The initial increase in rate of water loss rises with increases in wind velocity. The effect of wind on the transpiration rate was relatively greater during the night than during the day.

Briggs and Shantz (2) concluded that radiation, wind velocity, air temperature and evaporation are the important factors in transpiration.

Gates (9) studied evaporation at different heights from the ground as measured by Livingston atmometers. An increase in evaporation was uniformly shown. Wind was regarded as an important factor in explaining the larger evaporation rate at the higher level.

Wilkins (39) using Livingston atmometers, measured the evaporative power of the air in plots of dwarf grain sorghum. Water loss was greater in 40 inch than in 20 inch rows. An increase in evaporation was noted with increase in height of the atmometer bulbs. Atmometers placed near the windward end of the plots lost more water than those located further in the plots.

Light

Livingston (17) stated that, in general, light conditions are effective only above the soil.

Shirley (32) studied the influence of light intensity and quality upon the growth of plants. He found that height and leaf area attained maximum development at low intensities. The optimum light intensity for production of dry matter increased with an increase in age. There was a decrease in height and an increase in root growth with an increase in intensity. Leaf thickness was found to increase with an increase in light intensity. The growth rate as measured by increase in dry matter was proportional to light intensity, up to 20 to 30 percent of full sunlight. Time of flowering and fruiting was delayed considerably by low light intensities.

Burkholder (4) summarized the important functions of light as photosynthesis, chlorophyll formation, transpiration, absorption and use of solutes, permeability, protoplasmic movement, photoperiodic stimulation, acidity, stomatal movement, and phototropism.

Popp (29), working with soybeans, found light intensity to be directly proportional to stem thickness in the range of 26 to 4285

f. c. Stem elongation was more rapid with increased light intensity during the initial period of growth.

Cultural Practices and Weed Control

According to Martin and Leonard (24) the fundamental purposes of tillage are (1) to prepare a suitable seedbed, (2) to eliminate competition from weed growth, (3) to improve the physical condition of the soil.

Martin and Sieglinger (23) stated that profitable yields of grain sorghum depend to a large extent upon good cultural practices.

Martin, et al. (22) felt that good seedbed preparation is important in securing stands, and controlling weeds.

Martin claims that "ample tillage prior to planting usually will repay the labor involved".

Laude and Swanson (16) stated that a good seedbed is of primary importance.

Brandon, et al. (1) concluded that sorghums are among the most exacting of the annual field crops in their seedbed requirements. The important aims in seedbed preparation for sorghums, according to Brandon, et al. (1) are to store moisture, destroy weeds, and to warm and mellow the soil. These workers emphasize the importance of encouraging weed seeds to germinate prior to planting the sorghum crop.

It is generally accepted that cultivation after planting is of value mainly in controlling weeds.

Laude and Swanson (16) stated that sorghum should be cultivated principally to control weeds and to keep the soil surface in condition to absorb water.

Salmon (31) found no benefit from clean cultivation beyond that necessary to control weeds. He concluded that cultivation should be directed toward control of weeds and making the soil surface receptive to water.

Cates and Cox (5) concluded that cultivation is not beneficial to corn except in destruction of weeds.

Cox (7) stated that weeds decrease crop yields by depriving crops of moisture, plant food, and sunlight. He emphasized the value of using a drag or spike-tooth harrow both before and after row crops emerge.

Soil Temperature

Weaver and Clements (38) stated that vegetative cover has considerable effect on soil temperature. They concluded that soil is cooler in summer under a vegetative cover because of the interception of radiant energy.

That vegetative cover is an important factor in affecting soil temperature is substantiated by Lyon and Buckman (19). They stated that vegetative cover markedly influences the amount of insolation received at a given point.

METHODS AND MATERIALS

The experiments reported in this thesis were conducted in field F-3 at the Agronomy Farm of the Kansas Agricultural Experiment Station, Manhattan.

The preceding crop grown was corn.

The field was plowed in November, 1953. Seedbed preparation was begun by disking and harrowing May 14, just prior to planting the corn experiment. The portion of the field planted to grain sorghum was disked and harrowed again June 10, and was given a final disking and harrowing just prior to planting, which began June 18, and was completed June 21. The area planted to Atlas Sorgo was disked and harrowed May 14 and again June 5. The final disking was somewhat ineffective due to a light shower that fell soon after disking was completed. Tables 1 and 2 record the temperatures, precipitation, and wind movement during the growing period. Rainfall was deficient at planting time. Temperatures were unusually high throughout much of the growing season.

The corn was hand planted with the type of planter commonly used to plant yield tests. Two wires, wrapped with adhesive tape at intervals of 10 and 15 inches, respectively, and alternate tape marks painted bright red, were used to mark the plant distances within the 20 and 40-inch rows. Kansas hybrid K-1639 was used.

A randomized block design was used, each treatment being replicated four times. As shown in Table 3, cultivation later altered this basic design. The harvested area in each plot was 70 feet long. A plot of 40-inch rows consisted of four rows, the two interior rows being harvested and the two outer rows serving as guards. In the plots of 20-inch rows, five rows were harvested with two guard rows. Plate I shows corn growing in 20- and 40-inch rows.

Two kernels were planted in each hill. When the plants were about five inches tall, all hills were thinned to one plant. If a

Table 1. Daily maximum and minimum temperatures, precipitation, and wind movement for Manhattan, Kansas, May 1 to June 31, 1954.

Date	May				June			
	Max.	Min.	Prec.	Wind	Max.	Min.	Prec.	Wind
1	52	40	.65	94	71	55	2.05	76
2	46	31	.15	100	70	51	.05	110
3	48	33		49	65	42		52
4	58	39		24	72	55		68
5	68	49	.02	28	76	64	.06	149
6	71	38		41	84	59		153
7	65	36		31	80	56		34
8	67	37		29	80	63		99
9	62	40		23	95	67		108
10	68	48		22	95	73		120
11	72	40		20	96	62	1.23	82
12	74	46		29	81	62	.14	69
13	76	46		45	87	68		101
14	78	55		49	85	64	.33	67
15	84	60	.24	53	70	59	.44	17
16	71	53	.10	38	83	64		76
17	62	49		25	90	70		137
18	75	49		32	91	74		58
19	66	36	.18	44	90	75		83
20	71	51		73	94	73		96
21	85	60		117	97	64		54
22	91	70		126	87	59		33
23	76	57	.31	47	92	73		69
24	64	55	.02	32	100	79		96
25	62	56	T	62	103	79		57
26	76	58	.79	120	100	74		52
27	82	55	.97	48	97	69		63
28	71	48		32	98	73		63
29	72	54	.56	33	99	66		37
30	83	58		146	92	62		48
31	81	48	.93	81				

Table 2. Daily maximum and minimum temperatures, precipitation and wind movement for Manhattan, Kansas, July 1 to August 31, 1954.

Date	July				August			
	Max.	Min.	Prec.	Wind	Max.	Min.	Prec.	Wind
1	96	71	.57	62	81	66	1.6	90
2	101	73		62	92	68		20
3	103	70		50	103	79		81
4	100	68		33	105	78		77
5	102	74		24	97	73	.05	109
6	107	70	.10	54	89	67	.07	53
7	96	64		64	76	63	.06	105
8	93	62		48	85	61		28
9	99	72	.16	112	93	64		23
10	90	71		132	81	68	.03	100
11	112	76		38	80	65	.02	160
12	114	70		24	81	65		85
13	114	75		28	85	66		74
14	110	72		126	98	70		35
15	93	64	.72	96	102	76	T	41
16	87	65	.03	58	107	71	.05	45
17	109	72		27	99	71		62
18	110	77		20	92	66	.99	72
19	108	76		62	83	67		79
20	107	73	.03	40	89	69		77
21	95	73		72	88	70	.59	68
22	87	70	.34	69	95	70	.17	35
23	83	70		27	91	69	.09	50
24	88	71		42	93	72		51
25	91	68		63	98	75		56
26	90	64		42	96	69	.26	89
27	96	75		47	101	72		40
28	100	67		35	104	73		20
29	102	73		45	98	74	.03	47
30	102	78		70	88	64		49
31	96	66	.90	69	85	62		32

Table 3. Design of the corn spacing experiment, 1954*.

Distance between rows - inches	Distance between plants in row - inches	Plant space square inches	Number of plants per acre
40	10	400	15,700
40	15	600	10,500
20	20	400	15,700
20	30	600	10,500

*All the 20 inch rows in replications II and IV were cultivated.

hill was void of plants, two plants were left in the adjacent hill, thus assuring the correct number of plants in the row.

Certified, Midland grain sorghum treated with "Spergon" seed protectant was planted June 18 to June 21. A Planet Jr. vegetable planter mounted on an Allis-Chalmers "G" tractor was used, as the tool bar design of the planter facilitated planting of variable spaced rows. Four randomized blocks of Atlas Sorgo were planted June 7 with a loose-ground lister.

The design of the sorghum experiment is shown in Table 4. A randomized block with each treatment replicated four times was used. The row length was 70 feet. Plates II, III, and IV show dwarf grain sorghum growing in 10-, 20-, and 40-inch rows, respectively.

Even though subsurface moisture and rainfall were plentiful prior to planting, a very poor and uneven initial stand was obtained in both the grain and forage sorghum because the surface had become dry and the planter lacked penetration. No rain fell

EXPLANATION OF PLATE I

Fig. 1. Corn growing in 20 inch rows.

Fig. 2. Corn growing in 40 inch rows.

PLATE I

Fig. 1

Fig. 2

Table 4. Design of sorghum spacing experiment, 1954.

Distance between rows - inches	Distance between plants in row - inches	Plant space square inches	Approximate number of plants per acre (100)
40	1.00	40	160
24	1.66	40	160
20	2.00	40	160
16	2.50	40	160
10	4.00	40	160
40	1.50	60	105
24	2.50	60	105
20	3.00	60	105
16	3.75	60	105
10	6.00	60	105
40	2.00	80	80
24*(3)**	3.33	80	80
20*(2)	4.00	80	80
16*(3)	5.00	80	80
10*(4)	8.00	80	80
40*(7)	3.00	120	52
24*(4)	5.00	120	52
20*(6)	6.00	120	52
16*(5)	7.50	120	52
10*(2)	12.00	120	52
40	4.00	160	40
24	6.66	160	40
20	8.00	160	40
16*(2)	10.00	160	40
10	16.00	160	40

PLATE II

EXPLANATION OF PLATE III

Dwarf grain sorghum growing in 20 inch rows.

PLATE III

EXPLANATION OF PLATE IV

Dwarf grain sorghum growing in 40 inch rows.

PLATE IV

until July 1.

Where the initial stand was adequate and sufficiently uniform, plots were laid out and thinned in an attempt to obtain samples of the different spacing treatments. Table 4 shows the treatments obtained by thinning to an exact stand level in grain sorghum. Other spacings could not be obtained because of the poor stand obtained.

To facilitate accurate thinning to the desired stand, in both grain and forage sorghum, the number of plants in each row was counted. The number of plants to be removed was then determined. Thinning was accomplished by removing the plants so the most uniform stand possible was obtained.

Only the 40 inch sorghum rows received any post-planting cultivation. They were cultivated twice during the season, once approximately 25 days after emergence, and again 50 days after emergence. A Farmall "C" tractor with two-row mounted cultivator was used.

The 40 inch corn and sorgo rows were cultivated with the machine described above. The two replications of corn and sorgo each growing in 20 inch rows that received cultivation were cultivated with a garden tractor.

All the soil temperature data were obtained by inserting centigrade mercury thermometers to a depth of approximately two inches in the center of the space between the rows. Eight readings were taken in each plot at each observation.

The light intensity was measured with a Weston "Sunlight Meter". Readings were taken at noon on cloudless days at the ground level under the plant canopy, as it was desired to measure the amount of diffused light. Data were obtained for the corn July 8, and July 27, approximately a week after tasseling.

Light intensity readings were taken in the grain sorghum plots July 27, when the average plant height was approximately 26 inches, and again August 17, approximately a week after the full heading stage.

With both crops, each time light intensity readings were taken, the plots were scored as to the estimated percent of the ground area shaded by the plant cover at noon. Each one-fifth of each plot was given a score, and then the five scores for the plot were averaged.

The evaporative power of the atmosphere in the plots was measured with Livingston porous, clay-cup atmometer bulbs. The bulbs were mounted on quart glass bottles as described by Weaver and Clements (38), and Loomis and Shull (18).

The atmometers were placed in the center of the rows, the bulbs being approximately 14 inches above the ground. Four atmometers were placed in each of five different plots representing the five different row widths. The plant population was the same in all cases, being 120 square inches per plant. The readings were taken daily at the same hour, weather conditions permitting. The atmometers were filled by siphoning distilled water from a gallon container into a 100 m.l. graduate. The amount required to refill the bottles to the full mark in the neck was recorded, thus giving the daily water-loss from each instrument. The amount of water lost was then multiplied by the correction factor for each particular bulb and then recorded as the corrected water loss.

The atmometer bulbs were cleaned by use of a tooth brush and distilled water at each filling.

Water-loss from the soil surface was measured by taking eight samples per plot in the center of the rows to a depth of approximately one inch and making one composite sample. Moisture determinations were made in duplicate. The moisture percentage was determined by obtaining the wet weight, drying for 24 hours (approximately) at 105 degrees Centigrade, obtaining the dry weight, and the can weight. This procedure is outlined by Lyon and Buckman (19).

Soil moisture depletion was studied by use of a King Tube. In the grain sorghum plots, samples were taken to a depth of five feet, each sampling interval being one foot. In the corn, sampling was to a depth of three feet with intervals of 0-6, 6-12, 12-24, and 24-36 inches. Two cores were taken per plot and composited. Each plot was sampled in the corn experiment, while in the sorghum representative plots of the different treatments were sampled, all samples coming from Block I and Block II. The moisture percentage was determined as outlined above.

In order to determine the relative efficiency in removal of available water by different stand levels, field capacity and the wilting coefficient were determined by the method outlined by Richards (30).

Measurements of plant height in the corn were made July 7, 12, 21, and July 29. Height measurements in the grain sorghum experiment were made August 12, at the time of full head, and

September 23. This note was taken in the corn by having an assistant hold a measuring rod at different points throughout the plot and recording the height of the plants on each area. The sorghum rows were uniform and as a result the height notes were taken by sighting along the tops of the plants to a rod in the middle of the plot and recording the height.

In the sorghum, the date of first head was recorded when approximately 10 percent of the heads were completely out of the boot and 75 percent of the heads were showing. When the heads were in one-half bloom, they were recorded as full head.

Corn with approximately 10 percent of the tassels completely emerged was recorded as first tassel. Full tassel was recorded when the majority of tassels were beginning to flower.

Just prior to harvest the number of plants in the corn rows to be harvested was determined. The ears were removed September 10, counted, and placed in the barn at the Agronomy Farm to dry, as they contained approximately 28 percent moisture. By subtracting the number of ears from the total number of plants and allowing for the plants that developed more than one ear, the percentage of barren plants was determined.

Immediately after the ears were removed the remaining stover was cut and shocked. After drying until air dry the yield from each plot was weighed, using a rack mounted on a set of farm scales.

The corn was shelled October 16 after drying to approximately 15 percent moisture. A portable one-hole sheller was used. The yield of shelled corn and cobs was recorded so that the yield per acre, average ear weight, and shelling percentage, could be determined.

Plot yields for the 40 inch rows were converted to acre-yields as shown below:

$$\frac{43560}{70 \times 6.667} = 93.352 = \text{Factor for converting to a per acre basis.}$$

For plots of 20 inch rows the formula used was:

$$\frac{43560}{70 \times 8.333} = 74.677 = \text{Factor for converting to a per acre basis.}$$

The same system of calculations were used for the grain and forage sorghum plots.

The grain sorghum plots were harvested October 4 by removing the heads with a linoleum knife, counting them, and placing them in previously weighed wire bottom trays supported by four inch clay pots. Placing the trays on the pots facilitated drying by allowing air movement under the trays and keeping them off the ground.

The number of tillers was calculated, assuming the number of plants at thinning time to be correct, by subtracting this value from the total number of heads harvested.

The trays containing the heads were weighed at the time of threshing. A portable thresher commonly known as a "Vogel Thresher" was used. The threshed grain from each plot was placed in sacks, weighed, and stored in the barn at the Agronomy Farm.

Weed growth and development in the grain sorghum was studied by determining the number and species of each weed in the plot areas that were thinned. These counts were made immediately after harvest. Since the size of the plots was so variable, the weed counts are expressed as the average number of weeds per acre by treatments.

The size of kernel of grain sorghum was determined for each plot by counting and weighing two 500 kernel samples from which dockage had been removed with a sieve. The size of kernel is expressed by combining the weight of the two 500 kernel samples into one 1000 kernel sample. The Atlas sorgo was harvested September 30, when the grain was in the hard dough stage. The plants were cut at the base with a corn knife, counted, and weighed immediately, using a rack mounted on a set of scales.

In general, the areas of grain sorghum not used for experimental plots because of poor initial emergence became fairly well populated with plants which emerged after July 1. In these areas the row width was the only variable, and it determined the plant population. The size of these areas was determined by cutting all the rows back to a length of 70 feet and counting the number of rows. These areas were then harvested with a self-propelled combine November 4. All the rows of a given width in each block were harvested as a unit. Yields were then calculated on an acre basis.

EXPERIMENTAL RESULTS

The experimental results reported in this thesis pertaining to spacing of corn, grain sorghum, and forage sorghum plants, are divided into sections by crops in order to present more clearly the influence of row width and area per plant on the growth and development of each of the crops.

Part I. Corn

The experiments with corn deal with the influence of row width and area per plant on: (a) soil temperature, (b) light and shading, (c) evaporative power of the air, (d) temporary wilting and topfiring, (e) height of plants, (f) growth of weeds, (g) removal of soil moisture, (h) number of barren plants, (i) yield of grain, (j) yield of stover, (k) ear weight, and (l) shelling percentage.

Soil Temperature. Soil temperature data for six days are reported in Table 5 and are summarized in Table 6.

In general, at any given time of day the temperature of the surface two inches of soil was lower in 20 inch rows than in 40 inch rows. There were no consistent differences in soil temperature between the two plant populations in either 40 inch rows or 20 inch rows, except for the effect of cultivation mentioned above.

Soil between 40 inch rows tended to warm up earlier in the day than between 20 inch rows.

In general, the temperature of the soil was higher than the temperature of the air at any given time. However, on extremely hot days, such as July 16, when the maximum temperature was 116 degrees Fahrenheit, the temperature of the soil in the corn plots did not reach that of the atmosphere.

The differences in soil temperature observed probably were explained by differences in the degree of shading. It was evident

Table 5. Soil temperatures (degrees Fahrenheit) at different times of day in different plant spacings of corn. (Depth of 2 inches.)

Area per plant	Row width	8 a.m.	10 a.m.	12 n.	2 p.m.	4 p.m.	6 p.m.
				June 30			
400	40	86	89	93	97	93	91
	20	87	93	95	96	93	91
	20 C*	86	87	95	95	92	91
600	40	86	86	95	100	92	91
	20	90	93	94	97	93	92
	20 C	90	94	95	97	94	91
Air temperature		77	82	87	90	92	90
				July 1			
400	40		88	95	99		
	20		87	94	96		
	20 C		87	94	95		
600	40		89	95	97		
	20		87	95	96		
	20 C		87	95	95		
Air temperature		76	86	92	92	86	78
				July 2			
400	40	79	82	89	90	91	87
	20	77	80	86	88	88	86
	20 C	77	80	85	87	88	87
600	40	80	82	89	90	92	86
	20	77	82	86	88	89	86
	20 C	77	81	86	88	88	86
Air temperature		76	82	92	99	101	98
				July 7			
400	40	81	88	95	98	98	96
	20	81	44	89	96	98	96
	20 C	81	88	91	93	93	91

Table 5. (Concl.)

Area per plant	Row width	8 a.m.	10 a.m.	12 n.	2 p.m.	4 p.m.	6 p.m.
600	40	81	89	93	102	100	97
	20	81	88	94	96	96	96
	20 C*	81	89	95	96	96	91
Air temperature		83	88	92	98	97	94
				July 8			
400	40	80	82	91	99	97	95
	20	77	81	88	98	98	93
	20 C	75	79	84	94	92	89
600	40	79	88	89	104	98	94
	20	79	81	92	93	93	89
	20 C	77	81	91	93	95	89
Air temperature		72	78	84	89	93	91
				July 16			
400	40	84	97	104	109	109	104
	20	81	88	94	103	98	98
	20 C	81	89	96	104	100	98
600	40	83	92	98	109	111	104
	20	81	85	98	102	102	98
	20 C	81	84	98	100	102	96
Air temperature		86	100	108	116	115	114

* "C" indicates cultivation.

Table 6. Summary of soil temperature data in corn.

Area per plant	Row width	8 a.m.	10 a.m.	12 n.	2 p.m.	4 p.m.	6 p.m.
		Time of day					
400	40	82	87	94	99	98	95
	20	81	85	92	96	94	93
	20 C*	81	85	92	96	94	93
600	40	82	87	93	100	99	95
	20	81	86	92	95	95	92
	20 C	81	86	92	95	95	91

* "C" indicates cultivation.

that more solar energy reached the surface of the soil in 40 inch rows than in 20 inch rows.

Light and Shading. Shading or reduction in light intensity at the soil surface was considered an important factor in controlling weeds and reducing temperature and evaporation.

If corn is to be grown in narrow rows without post-planting cultivation, the plants must provide sufficient cover early enough to successfully control weeds.

The light intensity at the ground surface in the corn plots July 27 is recorded in Table 7. The data shows essentially no difference in light intensity due to plant population in the 40 inch rows. Within both stand levels, plants growing in 20 inch rows decreased solar energy at the ground surface to a greater extent than did the plants growing in 40 inch rows.

Light intensity in the narrow rows which received cultivation was lower than in narrow rows not cultivated. This increased shading can probably be attributed to the increased height and size

Table 7. Light intensity at the ground surface in corn July 27, 1954.

Plant space square inches	Row width inches	Light intensity - foot candles
400	40	600
	20	411
	20 C*	230
600	40	605
	20	505
	20 C	462

* "C" indicates cultivation.

of the plants which received cultivation, as competition from weeds was markedly reduced.

In most cases, where weeds were growing in the narrow rows, they appeared not to be suffering from lack of light.

Table 8 shows the amount of ground surface shaded by the corn plants July 27. Corn growing in 40 inch rows did not shade more than 32 percent of the area between the rows at mid-day at the time of maximum vegetative development. These plots were cultivated to control weeds. Had they not received cultivation, weeds would have provided serious competition, probably more than in the narrow rows which were not cultivated.

In both the 20- and 40 inch rows, shading was greater where the area per plant was 400 square inches than 600 square inches. These differences were especially evident in the 20 inch rows which received cultivation. There the 400 square inch spacing shaded 48 percent of the ground surface and the 600 square inch spacing shaded only 33 percent of the ground surface.

As discussed later, shading in the narrow rows was not effec-

Table 8. Percentage of the ground surface shaded by corn plants July 27, 1954.

Plant space square inches	Row width inches	Percent shading
400	40	32
	20	40
	20 C*	48
600	40	25
	20	32
	20 C	33

* "C" indicates cultivation.

tive enough to control weeds without post-planting cultivation.

Evaporative Power of the Air. The evaporative power of the air was studied in all the plant spacings except the 20 inch cultivated rows with 600 square inches per plant.

The measurements were made with Livingston atmometer bulbs, which indicate the relative water-loss from the field and not the direct and precise measure of it.

The data presented in Table 9 indicate that in corn there was no material decrease in the evaporative power of the air when the plants were spaced in narrow rows.

The total water-loss was less, though, in the narrow rows with 400 square inches per plant that received cultivation, tending possibly to show a small advantage for the narrow rows with cultivation.

It would appear that the optimum space required for corn plants is so large that when grown in narrow rows the plants do not materially reduce the evaporative power of the air more than in 40 inch rows.

Table 9. Effect of row width and plant space on the evaporative power of the air in corn.

Area per plant: square inches	Row width inches	Water loss C.C.			
		July 5-10	July 11-15	July 16-20	Total
400	40	281	390	313	984
	20	261	432	255	948
	20 C	256	294	267	817
600	40	272	379	303	954
	20	240	310	363	913
	20 C	---	---	---	---

Temporary Wilting and Topfiring. In this study, the amount of leaf rolling at the beginning of a period of atmospheric stress was considered a measure of temporary or transient wilting. Observations were taken as explained in methods and materials.

The differences in leaf rolling reported were evident at the beginning of a period of hot dry weather on June 28.

Table 10 records the amount of leaf rolling by row width and plant space. Analysis of variance of these data is shown in Table 11.

Plants growing in 20 inch rows with 400 square inches per plant without cultivation showed the greatest amount of leaf rolling, which was significantly more than in any of the spacings with 600 square inches per plant, except the 20 inch rows not cultivated.

Cultivation of narrow rows in both stand levels reduced the amount of leaf rolling, but not by a significant amount.

In both 20- and 40 inch rows, plants with 400 square inches of

Table 10. Leaf rolling in corn, 1954

Plant space square inches	Row width inches	Leaf rolling - inches
400	40	4.4
	20	8.2
	20 C	3.9
600	40	2.2
	20	4.1
	20 C	1.4

A difference of 5.4 inches is significant for comparing 20 inch rows, 4.7 inches for comparing 20 with 40 inch rows, and 3.8 inches for comparing 40 inch rows.

Table 11. Analysis of variance of leaf rolling in corn, 1954.

	d.f.	SS	Var.	F
Between spacings	5	502.06	100.41	17.10**
Between plots	10	80.5	8.05	1.37
Error	112	657.32	5.87	
Total	127	1239.88		

**Significant at 1 percent level.

space showed twice as much leaf rolling as did plants with 600 square inches per plant, but this difference was not significant.

Leaf rolling was less in the lower stand level probably because there was more available water, at least at the beginning of this period of stress.

The effect of cultivation was to decrease weed competition, thus providing more available soil moisture for the corn plants.

The damage due to topfiring is shown in Table 12. Statistical analysis, shown in Table 13, indicated that topfiring was significantly greater in plants growing in 20 inch rows with 400 square inches per plant without cultivation, than in all other spacing combinations except the narrow rows with 600 square inches per plant not cultivated.

Table 12. Percent of corn plants showing topfiring.

Plant space square inches	Row width inches	Percent of plants showing dead tissue
400	40	1.52
	20	6.01
	20-C	2.79
600	40	.72
	20	4.49
	20-C	2.12

A difference of 2.77 percent is significant for comparing 20 inch rows, 2.32 percent for comparing 20-with 40 inch rows, and 1.96 percent for comparing 40 inch rows.

Table 13. Analysis of variance of topfiring injury in corn.

	d.f.	SS	Var.	F
Between spacings	5	.4886	.0977	6.23**
Error	10	.1545	.0155	
Total	15	.6431		

**Significant at 1 percent level.

The plants that showed the most topfiring, i.e., plants growing in 20 inch rows with 400 square inches per plant without cultivation, also showed the most extensive temporary wilting (leaf rolling). These two phenomena showed a correlation coefficient (r) of +.738, which was not significant with four degrees of freedom.

With both stand levels plants growing in 40 inch rows topfired significantly less than did plants growing in 20 inch rows without cultivation.

Cultivation of 20 inch rows reduced topfiring significantly with 400 square inches per plant. In the 600 square inch spacing, cultivation of 20 inch rows reduced topfiring by one half, but that difference was not statistically significant.

Plants growing in 40 inch rows topfired twice as much in the high plant population as in the low population. This difference, however, was not significant.

The data presented suggest that both plant space and competition from weeds have an important influence upon temporary wilting and topfiring in corn. This influence is no doubt exerted through the amount of available soil moisture and its effect on maintaining turgor in plant cells under conditions of atmospheric drought.

Height of Plants. Plant height was considered important in this study because it is a measure of general vigor and development.

The average height of plants on different days was obtained as described in methods and materials. Table 14 records a summary of the height measurements. Tables 15, 16, 17, and 18 show the analysis of variance of height measurements taken July 7, July 12, July 21, and July 29, respectively.

The data for the different dates could not be combined because of lack of homogeneity of variances, as evidenced by Bartlett's test, as described by Snedecor (34).

Table 14. Summary of height measurements in corn, 1954.*
Figures represent height in inches.

Plant space square inches	Row width	Date			
		July 7	July 12	July 21	July 29
400	40	42.6	55.3	63.4	88.7
	20	39.3	42.9	51.4	72.4
	20-C	41.5	52.8	64.1	85.0
600	40	42.9	55.7	67.5	91.5
	20	39.9	42.3	54.9	75.4
	20-C	45.3	51.3	64.1	72.4
Least significant differences	40	2.0	1.6	3.3	3.9
	20	2.8	2.2	4.4	5.5
	20 and 40	2.5	1.9	4.1	4.8

*Data cannot be compared between dates because of lack of homogeneity of variances.

Table 15. Analysis of variance of height measurement in the corn plots July 7.

	d.f.	SS	Var.	F
Between spacings	5	354.78	70.96	5.05**
Between plots, same treatment	10	194.61	19.46	1.38
Error	96	1348.86	14.05	
Total	111	1898.25		

** Significant at 1 percent level.

Table 16. Analysis of variance of height measurements in the corn plots July 12.

	d.f.	SS	Var.	F
Between spacings	5	2683.6	536.72	62.12**
Between plots, same treatment	10	96.1	9.61	1.11
Error	80	690.8	8.64	
Total	95	3470.5		

**Significant at 1 percent level.

Table 17. Analysis of variance of height measurements in the corn plots July 21, 1954.

	d.f.	SS	Var.	F
Between spacings	5	2326.1	465.22	16.61**
Between plots, same treat.	10	527.5	52.75	1.88
Error	64	1792.39	28.01	
Total	79	4645.99		

**Significant at 1 percent level.

Table 18. Analysis of variance of height measurements in the corn plots, July 29, 1954.

	d.f.	SS	Var.	F
Between spacings	5	3699.15	739.83	19.24**
Between plots, same treat.	10	1276.4	127.64	3.31**
Error	64	2461.2	38.46	
Total	79	7436.75		

** Significant at 1 percent level.

There were no significant differences July 7 in height of plants between stand levels in the 40 inch rows, or in the 20 inch rows not cultivated. Cultivation had a significant effect in increasing plant height in the 20 inch rows with 600 square inches per plant, but had no significant influence on plant height where the plant space was 400 square inches. This suggests that there was possibly enough shading in the narrow rows at that time to subdue weed growth.

In the narrow rows that received cultivation, the plants growing in an area of 600 square inches were significantly taller than those growing in an area of 400 square inches.

The data for July 12 showed no significant differences in height of plants due to stand level. In each stand level plants growing in 40 inch rows were significantly taller than those growing in 20 inch rows not cultivated, or the 20 inch rows that received cultivation.

Cultivation significantly increased plant height in the 20 inch rows.

On July 21, there were no significant differences due to plant population. Within each population, though, there were significant increases in plant height due to cultivation of the 20 inch rows. In each stand level plants in 20 inch rows without cultivation were significantly shorter than in other spacings.

The data taken July 29 showed no significant differences due to stand level in the 40 inch rows, or the 20 inch rows without cultivation. The plants in 20 inch rows with 400 square inches per plant which received cultivation were significantly taller than the

20 inch cultivated rows with 600 square inches per plant. This difference may possibly be explained by lower light intensity in the high plant population.

With an area of 600 square inches per plant, plants growing in 40 inch rows were significantly taller than those in the 20 inch rows not cultivated, and in 20 inch rows that received cultivation. With 400 square inches per plant there was no significant differences between height of plants growing in 40 inch rows and in 20 inch rows with cultivation, but plants growing in 20 inch rows without cultivation were significantly shorter. Cultivation increased plant height significantly in the narrow rows with 400 square inches per plant.

Considering the height data as a whole it is evident that plant height differences in the various spacings became wider as the season progressed. For example, July 7 the difference between the tallest and shortest plants was 5.4 inches, while on July 29 this difference was 19.1 inches. Statistical analysis indicated that the plots became more ununiform throughout the course of the study.

The plants in 40 inch rows were tallest throughout the period probably because of lack of competition from weeds.

Plants growing in 20 inch rows without cultivation were shorter than the other spacings, probably because of severe weed competition.

Growth of Weeds. The percent of the ground surface covered by weeds at harvest time is shown in Table 19. Only five percent of the ground surface was covered by weed growth in the 40 inch

Table 19. Weed growth and development in the corn plots at harvest time, 1951.

Plant space square inches	Row width	Percent of ground surface shaded by weeds
400	40	5
	20	77
	20-C	57
600	40	5
	20	95
	20-C	78

rows in both plant populations. Differences due to plant population in the narrow rows both with and without cultivation were evident, probably because of somewhat more complete shading by the plants in the high stand level.

Cultivation of 20 inch rows was effective in decreasing the amount of weed growth in both stand levels, but this cultivation was rather inadequate, shown by the data in Table 19. Weed growth covered 57 percent and 78 percent of the ground surface in the 400 and 600 square inch spacings, respectively, at harvest time.

These results indicate that corn plants cannot be relied upon to control weeds by shading when grown in narrow rows without post-planting cultivation, as is the case with grain sorghum. The optimum stand level for corn is so low that an insufficient amount of vegetative cover is provided.

Removal of Soil Moisture. The removal of soil moisture to a depth of 36 inches can be ascertained from Table 20. The data show that although significant differences were found between depths, no significant differences were noted between any of the spacings at

Table 20. Soil moisture percentages August 9, 1954 in corn.

Plant space square inches	Row width inches	Depth in inches 0-6	6-12	12-24	24-36
400	40	18.4	20.3	16.5	15.8
	20	20.4	18.9	15.8	15.6
	20-C	18.7	21.1	18.5	15.8
600	40	15.7	18.7	17.9	16.5
	20	16.9	17.0	15.6	15.5
	20-C	19.4	20.5	17.1	16.3
Field capacity		21.0*		26.3	29.0
Wilting coefficient		10.0*		12.9	15.5

*Determination for 0-1 foot.

A difference of 4.2 percent is significant for comparing 20 inch rows, 3.6 percent for comparing 20- with 40 inch rows, and 2.9 percent for comparing 40 inch rows.

Table 21. Analysis of variance of soil moisture determinations in the corn experiment, 1954.

	d.f.	SS	Var.	F
Between spacings	5	.3650	.0730	1.69
Between depths	3	.7758	.2586	6.98**
Between plots	40	1.7162	.0429	1.15
Interactions				
Depths x spacing	15	.5550	.0370	
Total	63	3.4120		

**Significant at 1 percent level.

a given depth. This data compared with the wilting coefficient recorded in Table 20 suggest that plants in both row widths and rates of planting withdrew practically all available soil moisture.

It would appear from examining the yield of grain and stover that the thicker planting better utilized the available moisture.

Number of Barren Plants. Table 22 records the number of barren plants as a percentage of the total number of plants. In both row widths the percentage of barren plants was higher in the 400 square inch plant space than with an area of 600 square inches per plant, but not significantly higher.

Table 22. Percentage of barren plants in corn, 1954.

Plant space square inches	Row width inches	Percent of barren plants
400	40	44.5
	20	66.0
	20-C	57.0
600	40	23.7
	20	43.5
	20-C	35.0

A difference of 28.2 percent is significant for comparing 20 inch rows, 24.4 percent for comparing 20 inch with 40 inch rows, and 19.9 percent for comparing 40 inch rows.

Table 23. Analysis of variance of percentage of barren plants in the corn experiment, 1954.

	d.f.	SS	Var	F
Between spacings	5	30.58	611.6	3.82*
Error	10	16.01	160.1	
Total	15	46.59		

*Significant at 5 percent level.

The inadequate cultivation given the 20 inch rows reduced the number of barren plants, but not by a significant amount.

The percentage of barren plants was significantly higher in the 20 inch rows in the high stand level without cultivation than in the 40 inch rows in the low stand level, and in the 20 inch cultivated rows in the low stand level.

The extreme barreness in the 20 inch rows in the high plant population without cultivation is due probably to the combined effects of a large plant population and severe weed competition. Had there been more available moisture, probably all spacings would have had less barren plants.

In both stand levels there was an approximate 10 percent advantage due to cultivation of the narrow rows.

Yield of Grain. The acre yield of grain is shown in Table 24. Statistical analysis, shown in Table 25, revealed no significant differences among the different plant spacings.

Table 24. Acre yields of corn grain, 1954.

Plant space square inches	Row width inches	Bushels per acre (15.5 percent moisture)
400	40	39.7
	20	17.4
	20-C	28.4
600	40	34.7
	20	23.7
	20-C	32.6

Table 25. Analysis of variance of corn grain yields, 1954.

	d.f.	SS	Var.	F
Between spacings	5	850.65	170.13	1.68
Error	10	1014.45	101.45	
Total	15	1865.1		

In 20 inch rows, the highest yields were obtained in the low stand level. However, in the 40 inch rows, the highest yields were obtained with the high plant population, i.e., 400 square inches per plant. This difference may possibly be explained by the influence of severe competition from weeds in the narrow rows, which was not a factor in the 40 inch clean cultivated rows.

In the narrow rows in both populations an average of 10 bushels increase in yield was attributed to cultivation, even though the cultivation was quite inadequate as shown by the weed growth at harvest time.

Yield of Stover. The stover was harvested and managed without loss of leaves as explained in methods and materials. Table 26 records the acre yield of corn stover from the various spacings. Analysis of variance (Table 27) revealed highly significant differences in yield.

The highest stover yields were in the high plant population. These yields were significantly higher than that of the corresponding row width in the low population, with the exception of the 20 inch rows that were cultivated.

With 400 square inches per plant, i.e., the high stand level, there were no significant differences between any of the spacings. In the low stand level of 600 square inches per plant, the 40 inch rows and the 20 inch cultivated rows yielded significantly higher than did the 20 inch rows without cultivation.

That there was a significant effect due to cultivation in the narrow rows at the low stand level but not at the high stand level may possibly be explained by the somewhat more effective shading and weed control in the high population. This same phenomenon was noted with grain yield.

Table 26. Yield of corn stover.

Plant space square inches	Row width inches	Yield air dry stover tons per acre
400	40	4.10
	20	3.77
	20-C	4.35
600	40	3.30
	20	2.45
	20-C	3.60

A difference of .92 tons is significant for comparing 20 inch rows, .80 tons for comparing 20 and 40 inch rows, and .65 tons for comparing 40 inch rows.

Table 27. Analysis of variance of stover yields in corn, 1954.

	d.f.	SS	Var.	F
Between spacings	5	5.96	1.192	7.012**
Error	10	1.71	.17	
Total	15	7.67		

**Significant at 1 percent level.

Weight of Ears. The weight per ear as recorded by row width and plant space is shown in Table 28. Ear weight was greater in the 600 square inch spacings than with 400 square inches per plant. The differences were not significant, however.

Cultivation of the narrow rows had no significant influence on ear weight, although significance was approached at the high level of planting.

In both stand levels, plants in 40 inch rows produced ears weighing significantly more than those produced in the uncultivated 20 inch rows.

Table 28. Ear weight of corn, 1954.

Plant space square inches	Row width inches	Weight per ear in pounds (15.5 percent moisture)
400	40	.34
	20	.22
	20-C	.30
600	40	.36
	20	.29
	20-C	.34

A difference of .09 pounds is significant in comparing 20 inch rows, .08 pounds for comparing 20 with 40 inch rows, and .06 pounds for comparing 40 inch rows.

Table 29. Analysis of variance for ear weight in corn, 1954.

	d.f.	SS	Var.	F
Between spacings	5	3.329	.666	3.88*
Error	10	1.715	.172	
Total	15	5.044		

*Significant at 5 percent level.

Shelling Percentage. The shelling percentage was determined as outlined in methods and materials.

The average shelling percentage of ears from the different plant spacings is shown in Table 30. Analysis of variance (Table 31) revealed no significant differences present.

Shelling percentage was higher in the low stand level than in the high stand level, especially in the 20 inch rows without cultivation.

The shelling percentage of the ears produced in 20 inch uncultivated rows at the high stand level, i.e., 400 square inches per plant, was materially lower than that of ears produced in the other spacings.

Table 30. Shelling percentage of corn, 1954.

Plant space square inches	Row width inches	Shelling percentage
400	40	77.4
	20	67.6
	20-C	77.3
600	40	80.6
	20	78.2
	20-C	78.2

Table 31. Analysis of variance of shelling percentage data for corn, 1954.

	d.f.	SS	Var.	F
Between spacings	5	2.36	.4727	1.324
Error	10	3.57	.3571	
Total	15	5.93		

Part II. Dwarf Grain Sorghum

The experimental results pertaining to spacing dwarf grain sorghum plants concerned the following subdivisions: (a) soil temperature, (b) light intensity and shading, (c) evaporative power of the air, (d) water loss from the soil surface, (e) removal of soil moisture, (f) growth of weeds, (g) height of plants, (h) tillering, (i) acre yield, (j) size of head, (k) size of kernel, and (1) yield of areas not used for experimental plots.

The Effect of Row Width on Soil Temperature. Soil temperature data for five bright days in July and August are recorded in Table 32. These data were obtained as explained in materials and methods.

In general, at any given time of day, the soil at depths of 2 inches was warmer in the 40 inch rows than in the narrower row widths. This was explained by lack of shading by the plants in the wide rows. When the row width decreased from 40 inches to 10 inches, the soil temperature likewise decreased.

The data suggest that the narrow rows are effective in preventing solar energy from reaching the soil surface.

The data reveal that the temperature of the soil at a depth of two inches on very warm days approaches but does not equal the air temperature. On cooler days, such as August 6 and August 7, the soil temperature was greater than that of the air. These same results were obtained in corn.

The data show the importance of solar radiation in influencing soil temperature.

Evaporative Power of the Air. In conducting this spacing study it was felt that the evaporative power of the air in the various row widths should be determined. The evaporative power of the air was measured by use of Livingston atmometer bulbs, which give only an indication of the amount of water loss from the field, and not a precise, direct measure of it. Table 33 records these data.

A comparison of the evaporative power of the air was made in the 120 square inch plant space in 10-, 16-, 20-, 24-, and 40 inch

Table 32. Temperature of the soil at a depth of 2 inches at different times of day at various days in dwarf grain sorghum. (Plant space = 120 square inches.)

Row width	Time of day 8	10	12	2	4	6
			July 28			
10		77	81	84		
16		79	82	86		
20		80	86	91		
24		80	86	93		
40		86	91	99		
Air temperature	82	91	94	99	100	100
			July 29			
10	75	81	86	91	95	91
16	77	81	88	91	97	93
20	77	82	91	93	100	93
24	77	82	93	95	100	93
40	80	86	99	99	107	95
Air temperature	76	86	94	100	102	97
			August 4			
10		75	77	81	84	
16		75	79	82	86	
20		77	81	84	86	
24		79	81	88	88	
40		82	88	93	97	
Air temperature	88	90	102	104	104	100
			August 6			
10			79	82		
16			81	84		
20			83	88		
24			84	89		
40			91	100		
Air temperature	78	80	83	89	84	78
			August 7			
10				79		
16				79		
20				81		
24				81		
40				88		
Air temperature	72	76	76	76	74	72

Table 33. Effect of row width on the evaporative power of the air in grain sorghum. (Plant space, 120 square inches).

Row width inches	Water loss c.c. from atmometer bulbs				
	July 26-31	Aug. 1-6	Aug. 7-12	Aug. 13-18	Total
10	84	151	50	85	370
16	103	163	53	86	405
20	135	201	66	117	519
24	141	218	71	125	555
40	170	277	96	166	709
Average temperatures					
Maximum	97	95	83	97	
Minimum	72	72	64	70	
Wind Movement	51	73	83	55	
Precipitation	.9	.12	.11	1.04	
Evaporation free water surface	2.869	2.445	1.839	2.412	

rows. This comparison was carried out over four six-day periods.

The total corrected water-loss from the atmometers was 1.36 times as much in the 40 inch rows as in the 20 inch rows, and nearly twice that of the 10 inch rows.

The water loss from the atmometer units decreased with a decrease in row width from 40 inches to 10 inches.

These results suggest that when sorghum is grown in narrow rows, with proper plant space, an increase in humidity within the crop will result, possibly because the influence of wind, and temperature are reduced. This in turn could possibly mean an actual decrease in transpiration from the plants.

In an attempt to explain the differences in water-loss between six-day periods, temperature, wind movement, precipitation, and evaporation data are included in Table 33.

It appeared that water loss from the atmometer bulbs was somewhat associated with evaporation from an open surface and with temperature. Wind movement was seemingly associated with water loss from the atmometers in the period August 1 to 6 compared with July 26 to 31.

The extremely low water loss during the period of August 7 to August 12 was due probably to the combined effects of low temperature and several intermittent, light showers, resulting in a period of high relative humidity.

Loss of Moisture from the Soil Surface. This experiment was carried out in an attempt to demonstrate the relative rates of water-loss from the soil surface after a rain. From visual observation it was evident that the surface soil in more exposed 40 inch rows dried more rapidly than did the surface soil in the narrow rows.

Samples were taken and determinations made as mentioned in methods and materials August 4 after 1.6 inches of precipitation on August 1, and September 11 after 1.18 inches of precipitation fell on September 8.

As shown in Table 34, it was evident that moisture was lost from the surface inch by evaporation more rapidly in the 40 inch rows than in the narrower row widths.

The surface soil dried very slowly in the 10- and 16 inch rows.

These differences in rate of drying in the different row widths are due to the extent of plant cover and its influence on shading and soil temperature and possible restriction of wind movement.

Table 34. Moisture percentage in the surface one inch of soil at different dates in grain sorghum (plant space = 120 square inches).

Row width	August 4	September 11
10	19.8	27.1
16	16.5	26.8
20	9.7	24.2
24	7.3	20.3
40	5.5	10.2

Removal of Soil Moisture. It was considered important to determine the degree of exhaustion of available soil moisture under different row widths and stand levels.

Table 35 records the amount of soil moisture at different depths by plant area and row width.

Table 35. Percent moisture in soil at different depths in grain sorghum, September 21, 1954.

Plant space square inches	Row width inches	Depth in feet				
		0-1	1-2	2-3	3-4	4-5
80	10	10.4	14.3	16.4	16.5	18.6
	16	10.5	13.1	15.2	15.3	18.1
	20	10.9	13.2	15.6	15.6	18.4
	24	13.5	13.4	17.2	15.7	19.0
120	10	10.7	13.1	17.3	17.5	18.4
	16	11.5	13.0	16.4	15.3	18.6
	20	10.2	13.2	15.8	15.9	16.3
	24	13.1	14.2	15.7	16.8	20.1
	40	10.7	14.3	16.5	15.4	19.7
160	16	11.2	14.1	16.9	16.5	18.3
Field Capacity (.33 atm.)		21.0	26.3	29.0	27.7	28.1
Wilting Coefficient (15 atm.)		10.0	13.0	15.6	15.2	15.2

The data indicate there were no marked differences in the uptake of soil moisture by plants in the different row widths or stand levels. Water was withdrawn nearly to the wilting point to a depth of four feet in all row widths and stand levels at maturity.

Where plants were growing in 16 inch rows with 160 square inches per plant, soil moisture was practically the same as where plants had 80 square inches. The crop in the 80 square inch spacing produced 18 bushels of grain per acre more than in the 160 square inch spacing, which was a significant amount.

This suggests that growing grain sorghum with 80 square inches per plant provided for better utilization of available soil moisture than where the area per plant was 160 square inches.

Light Intensity and Shading. The reduction of light intensity or shading at the soil surface was considered important as a possible means of controlling weeds, and reducing the loss of water from the plants and soil surface.

The ability of plant cover to intercept solar energy early in the season and rather completely is probably an important factor in the successful production of dwarf grain sorghum in narrow rows without post-planting cultivation.

As shown in Table 36, sorghum in 40 inch rows with 120 square inches per plant did not shade more than approximately 50 percent of the area between the rows at noon at the time of maximum vegetative development. Had the 40 inch rows not been cultivated, weeds would have provided serious competition.

Sorghum growing in 24 inch rows with 80 square inches per plant shaded 75 percent of the soil surface at noon.

Table 36. Amount of the ground surface shaded at noon by grain sorghum in different spacings.

Row width inches	July 27		August 17	
	Plant area - square inches			
	80	120	80	120
10	74	60	92	79
16	68	52	83	76
20	53	46	81	67
24	45	37	75	63
40	--	28	--	48

Table 37 shows that on both dates the percent shading decreased as the area per plant increased and the row width increased.

Table 37. Light intensity in foot candles at the soil surface at different dates in grain sorghum, 1954.

Row width inches	July 27		August 17	
	Plant area - square inches			
	80	120	80	120
10	138	178	60	98
16	189	235	77	120
20	284	340	140	170
24	334	428	186	205
40	--	525	--	310

The shading in the 24 inch rows was not adequate to control weeds. In these rows weed growth was subdued, but not completely controlled.

Even though just slightly more shading was provided by the 20 inch rows, than by the 24 inch rows, shading was effective in controlling weeds in the 20 inch rows.

The cover provided by the 10- and 16 inch rows was very complete and very effective in controlling weeds.

These data suggest that when sorghum is grown in narrow rows without post-planting cultivation, the row width should not be more than 20 inches.

As shown in Table 37, a definite reduction in light intensity was noted on each date in both stand levels with a decrease in row width and area per plant. The plants on August 17 had completed heading, so nearly all growth had ceased.

When the data pertaining to shading and that pertaining to light intensity were compared, it was evident that high light intensity was associated with low relative shading, and spacings that were low in light intensity had considerable shading. This shows that where the diffused light under the leaf canopy was of low intensity, as in the narrow rows, the amount of shaded ground surface was also great. Both of these factors are important in weed control without post-planting cultivation.

<u>Growth of Weeds</u>. It was felt that information should be obtained regarding the ability of grain sorghum to control weeds when grown in narrow rows without post-planting cultivation. If weeds could be controlled by shading the cost of post-planting cultivation would be eliminated.

Table 38 records the number and species of weeds found in the different spacings. Water hemp (<u>Acnida altissima</u>) and rough pigweed (<u>Amaranthus retroflexus</u>) were the most common broad leaf weeds found. The predominating weedy members of the grass family were crabgrass (<u>Digitaria sanguinalis</u>) and fall panicum (<u>Panicum dichotomiflorum</u>).

The number of weeds found increased with an increase in row

Table 38. Average number of weeds per acre found in harvested areas in grain sorghum in cultivated rows.

Common name of weed	Plant space (square inches)		
	80	120	160
		10 inch rows	
Crabgrass[1]	281	0	
Fall panicum[2]	160	103	
Groundcherry[3]	0	240	
Rough pigweed[4]		0	
Water hemp[5]	191	309	
Shoo-fly[6]	0	0	
Total	632	652	
		16 inch rows	
Crabgrass	0	582	0
Fall panicum	243	0	489
Groundcherry	133	0	278
Rough pigweed	0	228	0
Water hemp	284	514	567
Shoo-fly	0	0	0
Total	660	1324	1334
		20 inch rows	
Crabgrass	0	0	
Fall panicum	0	519	
Groundcherry	0	0	
Rough pigweed	378	486	
Water hemp	620	551	
Shoo-fly	0	173	
Total	998	1210	
		24 inch rows	
Crabgrass	427	210	
Fall panicum	0	182	
Groundcherry	80	80	
Rough pigweed	369	1050	
Water hemp	306	750	
Total	1182	2272	

[1]*Digitaria sanguinalis*
[2]*Panicum dichotomiflorum*
[3]*Physalis virginiana*
[4]*Amaranthus retroflexus*
[5]*Acnida altissima*
[6]*Hibiscus trionum*

width and area per plant. It would appear from Table 38 that row width is probably the most important factor governing the growth of weeds.

The weed plants in the 10-, 16-, and 20 inch rows were small, spindly, and definitely showed the effects of having developed in low light intensity. Many failed to produce seed.

In the 24 inch rows many of the pigweed (Amaranthus spp.) and water hemp (Acnida spp.) plants grew taller than did the sorghum plants as shown in Plate V.

It appeared that shading by sorghum plants growing in 24 inch rows was not adequate to control weeds. In the 10-, 16-, and 20 inch rows virtually none of the weeds grew above the sorghum leaves.

It was observed that not only the number of weeds, but likewise the vigor and size of the weeds growing in rows narrower than 24 inches was less than in the 24 inch rows.

In general, plant population affected both the amount and vigor of weed growth.

Row width appeared to be important in influencing the vigor and growth habit of the weeds in addition to the number present. For example, in the 20 inch rows with 120 square inches per plant and 24 inch rows with an area of 80 square inches per plant, the number of weeds found was approximately the same, but the weeds in the 20 inch rows were less vigorous than those in the 24 inch rows.

It appeared that the width of row should be no wider than 20 inches in order to insure weed control without post-planting cultivation.

EXPLANATION OF PLATE V

Pigweeds (*Amaranthus spp.*) growing in 24 inch sorghum rows.

PLATE V

<u>Height</u> <u>of</u> <u>Plants</u>. An attempt was made to record the effects of row width and plant population on the height of the sorghum plants. The average height was obtained as described in methods and materials. These data are presented in Table 39. Analysis of variance (Table 41) showed highly significant differences.

Table 39. Height in inches of grain sorghum at maturity.

Row width inches	Plant space square inches		
	80	120	160
10	50.3 (4)*	46.0 (2)	
16	48.7 (3)	45.4 (5)	43.0 (2)
20	46.0 (2)	45.0 (6)	
24	48.3 (3)	44.8 (4)	
40		46.4 (7)	

* Figures in parenthesis indicate the number of plots.

Table 40. Least significant differences for comparison of means of height measurements derived from different numbers of plots.

Number of plots	2	3	4	5	6	7
2	3.0	2.8	2.7	2.6	2.5	2.5
3		2.5	2.4	2.3	2.2	2.3
4			2.1	2.0	1.9	1.9
5					1.8	1.8
6						1.7

Table 41. Analysis of variance of height measurements taken in grain sorghum, 1954.

	df	ss	var	F
Between spacings	9	137.3	15.26	6.69**
Error	28	63.8	2.28	
Total	37	201.1		

** Significant at one percent level.

Table 40 records the least significant differences at the five percent level. They are presented in this manner in order to facilitate comparing any two treatment means derived from different numbers of plots.

Plants growing in an area of 80 square inches were significantly taller than those in the corresponding row width with 120 square inches per plant, with the exception of the 20 inch rows.

There were no significant differences in height due to row width when the area per plant was 120 square inches.

With 80 square inches per plant, plants in the 10 inch rows were significantly taller than those growing in other row widths.

Competition for light seemed to be the predominating factor influencing plant height. These findings are in agreement with those of Karper, et al (12) and Wilkins (39).

Tillering. The ability of the sorghum plant to utilize a given space has long been recognized. In this experiment tillering was determined by actual plant counts as described in methods and materials.

Table 42 records the number of tillers produced by 100 plants growing in the different row widths and stand levels.

In general, tillering was greater in the 120 square inch spacings than where the area per plant was 80 square inches. As shown in Table 43 these differences were not significant. Within each stand level there were no significant differences in tillering.

The tillers originated from the crown, which definitely distinguished them from axillary branches, which were very rarely found.

Table 42. The effect of row width and plant space on tillering in grain sorghum, 1954. Figures represent the number of tillers per 100 plants.

Row width - inches	Plant space - square inches		
	80	120	160
10	4 (4)*	6 (2)	
16	8 (3)	11 (5)	17 (2)
20	7 (2)	11 (6)	
24	17 (3)	18 (4)	
40		12 (7)	

*Figures in parenthesis indicate number of plots.

Table 43. Analysis of variance of tillering in the grain sorghum, 1954.

	d.f.	SS	Var.	F
Between spacings	9	660.57	73.39	1.583
Error	28	1297.75	46.35	
Total	37	1958.32		

Yield of Grain. The results presented in this section are those from experimental plots where the plants were thinned to the desired stand.

Table 44 records the yield of grain sorghum by row width and plant population. Least significant differences for comparison of the yield means derived from different numbers of plots are presented in Table 45.

Row width had no significant influence on yield in the 120 square inch spacings. When the area per plant was 80 square inches, sorghum growing in 16 inch rows yielded significantly more than did

Table 44. Acre yield of grain sorghum in bushels as recorded by plant space and row width.

Row width inches	Plant space - square inches		
	80	120	160
10	86.9 (4)*	71.4 (2)	
16	89.0 (3)	75.8 (5)	71.3 (2)
20	82.1 (2)	74.8 (6)	
24	79.5 (3)	73.7 (4)	
40		75.7 (7)	

*Figures in parentheses indicate the number of plots.

Table 45. Least significant differences for comparison of means of grain yield derived from different numbers of plots.

Number of plots	2	3	4	5	6	7
2	11.1	10.0	9.6	9.2	9.0	8.9
3		9.0	8.5	8.1	7.8	7.6
4			7.8	7.4	7.2	6.9
5					6.7	6.5
6						6.2

Table 46. Analysis of variance of grain sorghum yields.

	d.f.	SS	Var.	F
Between spacings	9	1313.4	145.93	5.04**
Error	28	810.5	28.97	
Total	37	223.9		

**Significant at 1 percent level.

plants growing in 24 inch rows. Yields of the other row widths did not differ significantly.

Yields were higher in the 80 square inch areas than where the plant space was 120 square inches in all row widths. However, the difference was significant only in the 10- and 16 inch rows.

The lowest yield was obtained with plants growing in an area of 160 square inches in the 16 inch rows. This was not significantly different from that of any of the row widths with 120 square inches per plant, but was significantly less than the yields of plants grown with 80 square inches per plant in all row widths.

The data suggest that the area given each plant is relatively more important than the row width in influencing final yield. Table 44 points out the importance of obtaining a sufficient stand to fully utilize the factors of production.

In this study it appeared that sorghum growing with 120 square inches and 160 square inches per plant did not fully utilize the space provided.

Size of Heads. The number of plants per acre and the size of heads together determine the final yield of grain. Weight of 100 heads was regarded as a measure of head size.

Table 47 shows the size of heads as influenced by row width and area per plant. Sorghum plants with 80 square inches per plant produced significantly smaller heads than did plants growing in areas of 120 or 160 square inches. However, in general this decrease in head size was more than compensated for by the larger number of plants per acre, resulting in higher yields in the smaller area.

Row width had no significant influence on head size when the plant space was 80 square inches. With 120 square inches per plant heads produced in 40 inch rows were significantly larger than those produced by plants growing in 24 and 20 inch rows.

Table 47. Size of head as expressed by weight of grain from 100 heads in pounds.

Row width inches	Plant space - square inches		
	80	120	160
10	6.06 (4)*	7.23 (2)*	
16	5.91 (3)	7.45 (5)	8.75 (2)
20	5.62 (2)	7.24 (6)	
24	5.38 (3)	6.78 (4)	
40		7.87 (7)	

Table 48. Least significant differences in pounds for comparison of means of head size derived from different numbers of plots.

Number of plots	2	3	4	5	6	7
2	.93	.85	.81	.78	.76	.75
3		.76	.71	.68	.66	.64
4			.66	.62	.60	.59
5					.57	.55
6						.53

Table 49. Analysis of variance of head size data.

	d.f.	SS	Var.	F
Between spacings	9	34.73	3.86	18.59**
Error	28	7.89	.208	
Total	37	42.62		

**Significant at 1 percent level.

Plants grown in 16 inch rows with 160 square inches per plant produced larger heads than any other spacing combination.

Heads produced on tillers were smaller than those produced on plants without tillers.

<u>Size of Kernels</u>. It was considered desirable to obtain information pertaining to the influence of row width and area per plant upon the size of kernels.

Table 50 records the weight of 1000 kernels by row width and area per plant. Least significant differences are shown in Table 51.

Table 50. Weight in grams of 1000 kernels recorded by row width and area per plant.

Row width inches	Plant space - square inches		
	80	120	160
10	22.89 (4)*	22.98 (2)	
16	22.79 (3)	22.59 (5)	22.93 (2)
20	22.58 (2)	22.98 (6)	
24	22.91 (3)	22.61 (4)	
40		23.86 (7)	

*Figures in parentheses indicate the number of plots.

Table 51. Least significant differences for comparison of means of kernel size derived from different numbers of plots.

Number of plots	2	3	4	5	6	7
2	.66	.61	.57	.55	.53	.48
3		.54	.50	.49	.47	.46
4			.47	.44	.43	.41
5					.39	.38
6						.37

No significant differences were found between plant populations where comparisons could be made.

No significant differences due to row width were found in the 80 square inch spacings. With 120 square inches per plant, plants growing in 40 inch rows produced significantly larger kernels than

Table 52. Analysis of variance of kernel size, 1954.

	d.f.	SS	Var.	F
Between spacings	9	6.71	.746	7.13**
Error	28	2.93	.1046	
Total	37	9.64		

did plants grown in 10-, 16-, 20-, or 24 inch rows.

Plants grown in 40 inch rows with 120 square inches per plant produced significantly larger kernels than any other spacing combination.

The data presented suggest that row width is an important factor influencing kernel size. These findings are in accord with those of Wilkins (39).

Yield of Grain from Areas not Used for Experimental Plots. The results presented in this section pertain to yields obtained by harvesting the areas of the field where no thinning was done to make experimental plots. The only variable was the width of row. The row width, however, determined the number of plants per acre, as for example, there were four times as many plants per acre, theoretically, in the 10 inch rows as in the 40 inch rows. Stand counts were considered unmeaningful, because of the tremendous variation in stand throughout the field. Stands were poor in all row widths.

As shown in Table 53, yield increased with a decrease in row width, except that the yield in 24 inch rows was slightly higher than in the 20 inch rows. This difference, however, was not considered meaningful.

Table 53. Yields of grain from areas not used for experimental plots in the grain sorghum experiment, 1954.

Row width	Number of rows	Yield (bushels per acre)
10	169	82.6
16	79	72.9
20	156	61.6
24	82	62.2
40	108	43.9

As there were more plants per acre with a decrease in row width it appeared that the high yields of the narrow rows was due to the stand level and not directly to row width. This conclusion was based upon the findings reported earlier in this paper with experimental plots where the differences in yield were due mainly to differences in plant population, and not row width.

It was felt that these data pointed out the possible results that would be obtained in farm situations with sorghum planted in narrow rows without post-planting cultivation.

These results show an advantage of 17.7 bushels per acre for 20 inch rows compared with 40 inch rows, and even greater advantages for 16- and 10 inch rows.

It appeared that partial, uneven stands may more nearly approach the yield of a full stand in narrow rows than in the 40 inch rows.

Part III. Forage Sorghum

The subdivisions of the experimental results dealing with forage sorghum are: (a) tillering, and (b) acre yield of silage.

Tillering. As shown in Table 54 tillering was significantly greater in the 40 inch rows than in any of the 20 inch rows. There were no significant differences in any of the 20 inch row plantings, but the plants growing with 250 square inches per plant with cultivation tillered more than did plants growing in other 20 inch row spacings.

Table 54. Tillering in Atlas Sorgo expressed by number of tillers per 100 plants.

Plant space square inches	Number of plants per acre	Row width inches	Tillers per 100 plants
250	25,000	40	76
		20	6
		20*	18
125	50,000	20	12
		20*	14

* Cultivated

A difference of 28 tillers is significant in comparing 20 inch rows, 24 tillers when comparing 20- and 40- inch rows.

Table 55. Analysis of variance of tillering in Atlas Sorgo.

	d.f.	SS	Var.	F
Between spacings	4	11959.22	2989.7	21.61**
Error	7	969.46	138.4	
Total	11	12928.68		

**Significant at 1 percent level.

Tillering was considered a means by which the sorghum plant could adjust to the available space.

The large amount of tillering in the 40 inch rows was possibly due to the poor initial stand. Karper, et al. (12) concluded that "crowding and shading have a marked influence on tillering".

Yield of Silage. The yield of Atlas sorgo silage recorded by row width and plant space is presented in Table 56. Analysis of variance revealed no significant differences, as shown in Table 57.

Table 56. Acre yield of Atlas Sorgo Silage.

Plant space square inches	Number of plants per acre	Row width inches	Yield per acre tons
250	25,000	40	22.0
		20	18.5
		20*	20.8
125	50,000	20	18.6
		20*	20.9

*Cultivated.

Table 57. Analysis of variance of Atlas sorgo yields.

	d.f.	SS	Var.	F
Between spacings	4	24.2	6.05	1.70
Error	7	24.9	3.50	
Total	11	49.11		

These preliminary results with a small number of plots indicate that forage sorghum may be grown in narrow rows without materially decreasing the yield of forage. Grain yields were not determined.

Weeds were effectively controlled in the 20 inch rows where a simple cultivation was given. Weed growth was subdued in the 20 inch rows not cultivated, but weeds were not completely controlled. All the weeds growing in the plots acquired the characteristics of plants grown in low light intensity. They were small, spindly, restricted in branching, and many failed to produce seed.

The predominating species were rough pigweed (Amaranthus retroflexus) and crabgrass (Digitaria sanguinalis).

SUMMARY

In 1954 a spacing experiment with corn, dwarf grain sorghum, and forage sorghum was conducted on the agronomy farm of the Kansas Agricultural Experiment Station, at Manhattan.

Randomized block experiments of corn, dwarf grain sorghum, and forage sorghum were planted in rows extending across the block. Hand thinning was used to obtain the desired stands. Poor stands were obtained in the grain sorghum and forage sorghum experiments, making it impossible to obtain all the desired spacings.

Previous work at Manhattan has shown that dwarf grain sorghum grown in 20 inch rows yielded 25 percent more than sorghum grown in 40 inch rows.

This thesis presents the results of one year's study of the influence of row width and plant population in corn, grain sorghum, and forage sorghum on the various agronomic factors affecting production of these crops.

CONCLUSIONS

Conclusions from this study as supported by the findings with the different crops are presented below.

Part I. Corn

Differences in row width, area per plant, and cultivation of narrow rows, influenced soil temperature, shading, light intensity, plant height, grain and stover yields, temporary wilting and topfiring, the number of barren plants, removal of soil moisture and weed growth.

Soil temperature was higher in the 40 inch rows than in 20 inch rows.

Light intensity and shading were influenced by row width, plant space and cultivation of 20 inch rows. Shading was greater and light intensity less with 400 square inches per plant than with 600 square inches per plant. Shading in narrow rows was not effective in controlling weeds, indicating that corn is best grown in 40 inch rows with clean cultivation.

Row width or stand level did not materially affect the evaporative power of the air, due probably to the low optimum stand level.

Temporary wilting and topfiring were greater with 400 square inches than with 600 square inches per plant. Cultivation of 20 inch rows reduced topfiring.

Plant height was greater in 40 inch rows. Cultivation of 20 inch rows increased plant height. Height differences between spacings became more pronounced as the season progressed.

Cultivation of 20 inch rows materially decreased weed growth in those rows in both stand levels.

No significant differences were found between plant spacings in the different row widths and stand levels in removal of soil moisture.

The percentage of barren plants was greater in the high stand level than in the low stand l vel. In 20 inch rows, cultivation reduced the number of barren plants.

Yields of grain were highest in the 40 inch rows. Cultivation of narrow rows increased the yield of grain from these rows.

Yield of stover was greater where the area per plant was 400 square inches. Highest yields were obtained from 40 inch rows and from 20 inch rows that received cultivation.

The size or weight of ear was greater with 600 square inches per plant than at the higher plant population. The largest ears were produced in 40 inch rows.

There were no significant differences in shelling percentage in any of the spacing combinations, but the shelling percentage of ears produced in 20 inch rows without cultivation at the high stand level was somewhat low.

Part II. Dwarf Grain Sorghum

Differences in width of row and/or differences in space per plant influenced soil temperature, light intensity and shading, weed growth, the evaporative power of the air, water loss from the soil surface, plant height, tillering, acre yield, and head and kernel size.

Soil temperature was higher in 40 inch than in narrower rows. Increase in row width from 10- to 40 inches was associated with increase in soil temperature at a depth of two inches.

The evaporative power of the air was greater among plants in 40 inch rows than in 20 inch rows. The amount of water lost from Livingston atmometer bulbs 14 inches above the ground during a 24 day period in 40 inch rows was 1.37 times that lost in 20 inch rows, and nearly two times that lost in 10 inch rows.

Shading was an effective means of controlling weeds in 10-, 16-, and 20 inch rows.

Shading was not sufficient in 24 inch rows to effectively control weeds.

The amount and vigor of weed growth decreased with a decrease in area per plant and row width.

Light intensity was less in 80 square inch spacings and in narrow rows than with 120 square inches per plant and wider rows.

Loss of moisture from the soil surface through evaporation was greater in 40 inch than in 20 inch rows. The surface soil dried very slowly after a rain in 10 inch and 16 inch rows.

There were no marked differences in removal of soil moisture in plots of different row widths and plant spacings. In all cases practically all the available moisture was removed.

Plant height was greater in the 80 square inch area in the 10 and 16 inch rows, and decreased with an increase in row width and area per plant. The shortest plants were found in 40 inch rows with 120 square inches per plant.

Yield of grain from experimental plots where thinning was used to determine stand was greater in the 80 square inch spacings than in the lower stand levels. No significant differences were found due to row width where the number of plants per acre was the same.

The largest heads were produced in the 120- and 160 square inch plant areas. Sorghum plants growing with 80 square inches per plant produced significantly smaller heads than did plants growing with more space. Decrease in head size was more than compensated for by a larger number of heads per acre, which resulted in higher yields with the 80 inch spacing.

Size of kernel did not differ significantly between spacings in either of the two plant populations. The largest kernels were produced in 40 inch rows, and a decrease in size of kernel was noted with a decrease in row width.

Yield of grain from areas not used for experimental plots and where no thinning was done was highest in 10 inch rows, and decreased with an increase in row width. Yield of 20 inch rows was 17.7 bushels per acre higher than that from 40 inch rows. /It appeared that the number of plants per acre is very important in determining final yield. It was felt that these data pointed out the possible results in farm situations.

Plants grown in an area of 80 square inches appeared to better utilize the factors of production than did plants grown with 120 or 160 square inches of space.

It appeared that partial, uneven stands may more nearly approach the yield of a full stand in the narrower rows than in 40 inch rows.

The results suggest that sorghum may be grown successfully in 20 inch rows without post planting cultivation without reduction in yield.

Part III. Forage Sorghum

Atlas sorgo plants grown in 40 inch rows tillered significantly more than did those grown in 20 inch rows.

No significant differences in yield of silage were obtained due to differences in plant population or row width.

Weed control by shading was not completely effective in 20 inch rows.

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ACKNOWLEDGMENTS

The author is grateful to Dr. H. H. Laude, major instructor, and to Mr. A. W. Pauli for advice, criticism, and helpful suggestions in planning and conducting the experiment and for criticising the manuscript.

Appreciation is expressed to Dr. L. A. Tatum for his suggestions and help with the experimental work with corn.

Thanks are due Dr. F. W. Smith for the use of the planter and tractor, and to Dr. R. J. Hanks for advice concerning the soil moisture study, and for making the field capacity and wilting coefficient analysis.

To Dr. J. A. Hobbs thanks are expressed for use of the scales and rack.

Credit is due Dr. E. D. Hansing for advice on seed treatment and to Dr. John C. Frazier for advice and the use of the Weston "Sunlight Meter".

Appreciation is expressed to the agronomy farm staff for providing equipment assistance and to others in the Department of Agronomy for their help and suggestions.

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A STUDY OF THE EFFECTS OF ROW WIDTH AND PLANT POPULATION IN CORN, DWARF GRAIN SORGHUM AND FORAGE SORGHUM

by

FRED CHARLES STICKLER

B. S., Iowa State College, 1953

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1955

The importance of corn and the sorghums in their respective areas of production is generally recognized.

It has been shown that dwarf grain sorghum can be grown successfully in narrow rows without postplanting cultivation.

The purpose of this study was to determine the factors responsible for the advantages of growing sorghum in narrow rows, and to ascertain whether corn and forage sorghum also may be grown in narrow rows satisfactorily.

Corn, grain sorghum, and forage sorghum were planted in randomized block experiments at the Agronomy Farm. Corn and forage sorghum were grown in 20 and 40 inch rows at two plant populations. Grain sorghum was grown in 10, 16, 20, 24, and 40 inch rows at two stand levels.

Day time soil temperatures were lower in 20 than in 40 inch rows in corn and grain sorghum.

Light intensity was lower and shading greater in narrow than in 40 inch rows in corn and grain sorghum. Shading was not effective in controlling weeds in narrow rows in corn, but was very effective in controlling weeds in sorghum grown in 20 inch or narrower rows.

In corn, no material differences were noted in the evaporative power of the air in the different spacings. In grain sorghum the evaporative power of the air in 40 inch rows was 1.37 times that in 20 inch rows and about twice that of 10 inch rows.

In both corn and grain sorghum available soil moisture was approximately the same in all spacings at the end of the season.

In grain sorghum plants were taller in narrow rows at the high stand level than in wide rows with lower plant population. In corn, plant height was greater in 40 than in 20 inch rows. Cultivation of narrow rows increased plant height.

In corn, temporary wilting, topfiring and the number of barren plants were greater in the high plant population than in the low plant population and were reduced by cultivation in narrow rows.

Yield of corn stover was greater in the high stand level than low stand level. Yield of grain was somewhat higher in 40 than in 20 inch rows, but the differences were not significant.

Experimental plot yields of grain sorghum were higher in 80 square inch spacings than in other spacings. No differences were noted due to row width. Smaller heads were produced in 80 square inch spacings than with 120 or 160 square inches per plant. Kernel size was greater in 40 inch than in narrower rows.

Yield of grain sorghum from areas not used for experimental plots was greatest in 10 inch rows, and lowest in 40 inch rows. The yield of 20 inch rows was 17.7 bushels greater than 40 inch rows. It was believed that these results approximated those expected with farm situations.

Tillering in forage sorghum was significantly greater in 40 than in 20 inch rows. No significant differences in yield of silage were found.

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