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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 424 APRIL, 1931

DIVISION OF AGRONOMY

Grain Sorghum Date of Planting and Spacing Experiments

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**In cooperation with U. S. Department of Agriculture.
†As of April 1, 1931.

Temperature conditions and the distribution of summer rainfall are important factors that determine the optimum time for planting grain sorghums. Dwarf Yellow milo and feterita generally produced highest yields of grain from June 15 planting at Lubbock, Spur, Big Spring, and Dalhart; from May 15 planting at Chillicothe and Temple; and from April 1 planting at Beeville. Dwarf Blackhul kafir produced highest grain yields from May 15 planting at Lubbock, Chillicothe, Spur, and Temple; from June 15 planting at Dalhart and Big Spring; and from March planting at Beeville. The best grain yields of hegari are usually produced from the later plantings. At Big Spring, hegari planted June 15 yielded 7 bushels, or 40 per cent, more grain than when planted earlier than this date.

Forage yields are ordinarily increased and better quality of forage is produced from the later plantings. At Chillicothe, June 15 plantings returned the highest yield of forage, and at Temple yields were highest from May 15 plantings.

The spacing requirements of grain sorghum varieties depend largely upon their tillering habits. For best yields of grain, varieties that tiller freely require greater plant space than those that tiller but little. The milos are freely-tillering in habit, are grown primarily for grain, and should be spaced 12 to 24 inches. Approximately 20 per cent more grain, or five bushels, was produced from milo spaced 18 to 36 inches in the row at Lubbock than when spaced 3 to 9 inches. The average results at all stations indicate the best spacing of milo to be 12 to 24 inches. Kafir is sparsely-tillering in habit and produced the best yields from a close spacing of around 6 inches, yielding 10 to 20 per cent more grain, or three to four bushels more, than when spaced 12 to 24 inches. Hegari and feterita tiller freely but as they are important forage types they should be spaced so as to allow 6 to 12 inches between plants in the row.

The largest yields and best quality of forage of all varieties were produced from close spacing. Kafir and milo, spaced 3 to 9 inches, produced 11 per cent more forage than when spaced 12 to 18 inches.

Losses in grain yield, due to planting in wide rows instead of normal rows, are too great to withstand unless the use of wide rows fits in with some other farm practice, such as planting wheat following grain sorghum. Forage yields are reduced when planting is done in the wider rows instead of normal rows and over a period of years a reduction of about 25 per cent occurred in forage yields when grain sorghums were planted in wide rows instead of normal rows. Under certain circumstances paired rows can probably be used to advantage, in view of the comparatively small reduction in grain yield resulting from the use of paired rows, particularly with milo. The average decrease in grain yield from paired rows, as compared with that from normal rows, was 1.1 bushels to the acre, and the corresponding decrease when grown in wide rows was 4.6 bushels. The results are fairly consistent in favor of normal rows, but a smaller reduction in yield from using the wider rows occurred at Chillicothe and Spur than at Lubbock, Big Spring, and Dalhart.

Grain yields of kafir were reduced 4.3 bushels; feterita, 6.9 bushels, or about 25 per cent, when cowpeas were planted in alternate rows with these grain sorghums, and forage yields were also decreased about 25 per cent.

The use of the most effective commercial dry-dust seed disinfectants increased germination and emergence of feterita seed 30 to 40 per cent over that of untreated seed. Either Copper Carbonate or Ceresan, applied at the rate of 2 to 3 ounces per bushel of seed, is a convenient and effective dry-dust treatment for sorghum kernel smut.

CONTENTS

BULLETIN NO. 424 APRIL, 1931

GRAIN SORGHUM DATE-OF-PLANTING AND SPACING EXPERIMENTS

R. E. KARPER, J. R. QUINBY, D. L. JONES, AND R. E. DICKSON*

The grain sorghums rank third in total production and money value among the crops grown in Texas, being exceeded only by cotton and corn. The total average annual production is approximately sixty-three million bushels, having a money value of about fifty-one million dollars for the grain alone. The value of the forage incidental to this grain crop is ofttimes underestimated since it is ordinarily consumed on the farm where it is produced but it is the basic roughage and forage in the western part of the State. Texas is the leading state in grain sorghum production, producing, ordinarily, about 47 per cent of the total grown in the United States (Fig. 1). With the exception of Arizona and California, where much of the crop is grown under irrigation, Texas also ranks first in yield per acre, averaging 25.4 bushels. This high acre yield is due to the fact that the sorghums respond favorably to the soil and climatic conditions existing in this State and also to the wide distribution and use of improved and adapted varieties within the State in the past ten to twenty years.

The sorghums are particularly adapted to the western two-thirds of Texas (Fig. 2) and are grown there almost to the exclusion of other feed crops. Following the introduction and improvement of the sorghums, which have provided a basic grain and forage crop for this large and important region, a successful and dependable agriculture has been developed.

Experiments in the management and culture of grain sorghums, looking toward further increases and economy in acre production, have been conducted for a number of years at the various substations. Some of the results have already been published and the object of this Bulletin is to present further experimental results upon some of the important factors in the production of this crop.

SCOPE OF THE BULLETIN

This Bulletin is a report of experiments conducted at Lubbock, Chillicothe, Spur, Big Spring, Dalhart, Temple, and Beeville to determine the best practices in growing grain sorghums in the various parts

*Credit is due H. N. Vinall, Senior Agronomist, and J. C. Stephens, Assistant Agronomist, Office of Forage Crops and Diseases, U. S. D. A.; F. E. Keating, H. J. Clemmer, and B. F. Barnes, Superintendents, Office of Dry-Land Agriculture, U. S. D. A.; and D. T. Killough and R. A. Hall of the Texas Station, for data used from the Chillicothe, Big Spring, Dalhart, Temple, and Beeville Stations.

of the State. The work at the Chillicothe Station has been conducted cooperatively by the Texas Agricultural Experiment Station and the Office of Forage Crops and Diseases, U. S. Department of Agriculture. Inclusion of the results from Big Spring and Dalhart has been made possible through the courtesy of the Office of Dry-Land Agriculture, under whose direction these stations are operated, and the Office of Cereal Crops and Diseases, U. S. Department of Agriculture.

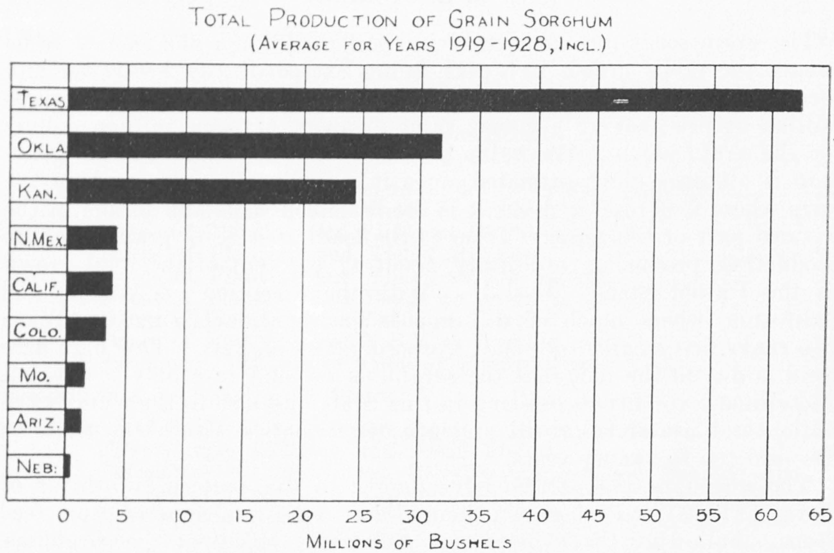

Fig. 1. Total production of grain sorghum, by states, 1919-28, inclusive. Texas produces 47 per cent of the Nation's crop.

Climatic factors, especially rainfall, are recognized as having a most important influence on production. Cultural practices also materially influence production, and these, to some extent at least, are under the control of the grower. Two of the most important factors in obtaining maximum production are planting at the optimum time and the correct spacing of plants. Because of the different climatic conditions existing in the several grain sorghum producing regions in the State and the variability exhibited by different varieties under different climatic conditions and cultural practices, investigations have been conducted at the several state and federal experiment stations to study more fully these various factors in production.

Grain sorghum varieties have been planted at different dates, at different spacings within the row, in normal, paired, and wide rows, and in rows alternated with cowpeas. Yields of grain and forage resulting from such plantings are presented here along with data to show the development of varieties under the environmental conditions existing at the various stations. Data are presented to show the effect of various commercial seed disinfectants upon the germination and emergence of grain sorghum seed in comparison with untreated seed. Information upon rate of planting and stands obtained from seeding 1, 2, 3, 4, and 5 pounds of Dwarf Yellow milo and Blackhul kafir seed to the acre is also presented.

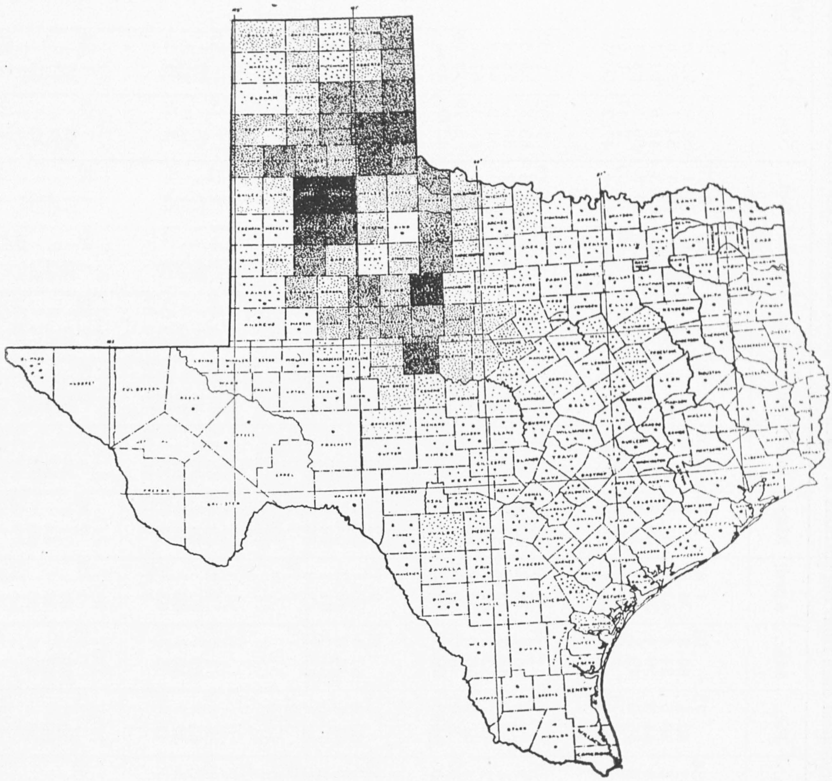

Fig. 2. Distribution of grain sorghums in Texas. One dot represents 100 acres; 1919 census.

LOCATION OF STATIONS, CLIMATIC CONDITIONS, AND SOILS

A brief discussion of the location, soil types, and climatic features existing at the various stations where these experiments were conducted is given here. A summary of meteorological data by months is shown in Table 1. It will be seen that the location of these experiments has been fairly well distributed over the western part of the State where the sorghums are of principal importance. A study of the climatic conditions at the various points will be found helpful to a better understanding of the results of experiments presented later in this Bulletin (Figs. 3 and 4).

Table 1.—Summary of meteorological data from the stations at which these grain sorghum experiments were conducted.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Monthly average	Annual
Lubbock:														
Rainfall, inches, 1911-30	.36	.75	.91	1.62	2.15	2.59	2.18	2.00	2.67	2.70	.60	.70	....	19.23
Mean maximum temperature	53.2	60.1	66.3	74.3	80.6	88.8	92.3	91.1	84.6	74.1	62.9	53.8	73.5	....
Mean minimum temperature	24.6	28.5	34.4	43.5	53.1	61.8	65.0	63.8	57.3	46.4	34.1	25.6	44.8	....
Mean mean temperature	38.9	44.3	50.4	58.9	66.9	75.3	78.7	77.5	71.0	60.3	48.5	39.7	59.2	....
Ave. Rel. humidity, per cent	66.0	56.2	49.3	48.4	54.9	54.8	51.5	55.9	63.0	66.6	65.1	65.4	58.1	....
Evaporation, inches	1.51	2.74	5.00	6.97	7.29	8.20	8.83	7.87	5.83	4.03	2.47	1.67	....	62.41
Wind run, miles	5443	5443	6936	6954	6573	6025	4879	4246	4467	4804	4752	5004	....	65,526
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	207
Chillicothe:														
Rainfall, inches, 1906-30	.51	.72	1.41	2.52	3.33	3.42	2.59	2.55	2.62	3.45	1.32	1.07	....	25.51
Mean maximum temperature	51.8	58.5	66.7	75.2	82.4	92.1	95.8	94.7	87.1	75.3	63.8	53.5	74.7	....
Mean minimum temperature	26.6	30.9	38.3	49.0	58.5	67.5	71.0	69.7	62.4	50.4	38.6	28.6	49.3	....
Mean mean temperature	39.2	44.7	52.5	62.1	70.4	79.8	83.4	82.2	74.7	62.9	51.2	41.0	62.0	....
Ave. Rel. humidity, per cent	69.3	61.2	56.0	54.1	59.4	57.0	53.9	55.7	62.3	65.9	65.3	67.8	60.7	....
Evaporation, inches	2.02	3.01	5.09	6.67	7.91	8.78	9.30	8.67	5.36	4.38	2.79	2.08	....	66.06
Wind run, miles	4740	5180	6621	6412	5983	5195	4126	3629	3816	4030	4209	4655	....	58,596
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	227
Spur:														
Rainfall, inches, 1911-30	.33	.67	.99	2.19	2.88	2.38	1.97	2.70	2.77	2.90	.77	.85	....	21.40
Mean maximum temperature	56.3	60.6	67.4	76.1	83.2	92.2	95.5	94.8	87.1	77.2	66.4	56.2	76.1	....
Mean minimum temperature	26.0	31.1	36.0	46.2	55.0	63.5	67.3	65.9	58.9	48.0	36.0	27.4	46.8	....
Mean mean temperature	41.2	45.5	51.7	61.1	69.1	77.9	81.4	80.4	73.0	62.6	51.2	41.8	61.4	....
Ave. Rel. humidity, per cent	68.6	63.4	61.1	62.9	66.0	63.7	61.4	63.4	68.9	71.5	70.4	67.7	65.8	....
Evaporation, inches	2.50	3.21	5.16	6.12	7.24	8.38	9.03	8.08	5.91	4.96	3.47	2.77	....	66.83
Wind run, miles	4385	4726	5479	5609	5584	4780	4337	3668	3773	4004	4269	4573	....	55,187
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	213
Big Spring:														
Rainfall, inches, 1916–30	.49	.59	1.15	2.25	2.68	2.35	1.25	2.01	2.10	2.27	.78	.51	....	18.43
Mean maximum temperature	55	63	69	77	84	93	95	94	86	76	65	57	76.6	....
Mean minimum temperature	27	32	40	48	58	67	70	69	62	51	38	28	49.2	....
Mean mean temperature	40	47	55	63	71	83	82	82	74	64	51	43	62.9	....
Evaporation, inches	......	......	......	7.77	9.12	10.53	11.16	10.37	7.77	......	......	......	....	52.72
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	217
Dalhart:														
Rainfall, inches, 1906-30	.22	.38	.73	1.89	2.84	3.14	2.56	2.83	1.52	1.75	.58	.51	....	18.95
Mean maximum temperature	48	52	59	69	77	86	91	89	83	71	58	47	69	....
Mean minimum temperature	17	20	27	38	48	57	62	61	52	39	27	17	39	....
Mean mean temperature	32	36	43	53	62	72	76	75	67	55	42	32	54	....
Evaporation, inches	......	......	......	6.98	8.62	9.38	9.77	8.91	7.08	......	......	......	....	50.74
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	177

Temple:														
Rainfall, inches, 1913-30	2.42	2.21	2.28	4.68	4.68	2.41	1.47	2.54	3.96	3.73	3.10	2.87	....	36.35
Mean maximum temperature	59.7	64.7	71.2	79.1	84.8	92.3	96.2	96.2	89.8	80.8	70.3	61.3	78.9	....
Mean minimum temperature	35.0	39.3	45.6	54.1	61.9	69.5	71.5	71.4	65.7	54.9	44.9	37.4	54.3	....
Mean mean temperature	47.4	52.0	58.4	66.6	73.3	80.9	83.8	83.8	77.8	67.8	57.6	49.3	66.6	....
Ave. Rel. humidity, per cent	76.7	74.8	69.8	72.6	73.9	71.0	67.5	67.1	72.3	73.3	76.4	77.1	72.7	....
Evaporation, inches	2.21	2.81	4.17	4.91	5.81	7.26	8.35	8.01	5.85	4.64	2.93	2.21	....	59.17
Wind run, miles	4307	4302	5231	4633	3887	3514	3114	2879	2653	2910	3307	3931	....	44,668
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	232
Beeville:														
Rainfall, inches, 1904–30	1.26	1.60	2.27	2.49	4.08	3.13	2.20	2.02	3.72	2.89	2.28	2.37	....	30.31
Mean maximum temperature	67.7	71.3	76.5	82.1	87.2	92.7	95.4	96.9	92.2	84.8	75.5	67.2	82.5	....
Mean minimum temperature	45.5	47.8	54.9	60.7	66.7	71.8	73.2	73.4	69.9	61.3	53.3	46.4	60.3	....
Mean mean temperature	56.6	59.6	65.2	71.4	76.9	82.2	84.3	85.2	81.0	73.1	64.4	56.8	71.4	....
Ave. Rel. humidity, per cent	79.8	78.1	76.8	76.2	78.3	77.6	75.3	73.1	75.8	75.0	76.6	76.3	76.6	....
Evaporation, inches	2.42	2.97	4.38	5.22	6.07	7.22	7.58	7.67	5.78	4.61	3.09	2.41	....	59.42
Wind run, miles	5364	5110	6295	5886	5321	4509	4267	4067	3676	3750	4133	4612	....	56,990
Frost-free period, days	......	......	......	......	......	......	......	......	......	......	......	......	....	286

The Lubbock Station is located three miles east of Lubbock in the High Plains Region of Texas and near the center of what is known as the South Plains. The altitude is 3106 feet above sea level. The average rainfall over a period of 20 years is 19.3 inches, 83 per cent of which falls during the months from April to October, inclusive. The average dates of the last killing frost in the spring and the first killing frost in the fall are April 9 and November 2. The soil is of the Amarillo and Richfield fine sandy loam types, which are typical of a considerable portion of this area.

The Chillicothe Station is located in the eastern part of Hardeman County, five and one-half miles southwest of Chillicothe, about midway between the Red and Pease Rivers. The altitude is 1406 feet above sea level. The average rainfall over a period of 25 years is 25.51 inches, of which about 80 per cent falls during the months from April to October, inclusive. The average dates of the last killing frost in the spring and the first killing frost in the fall are March 24 and November 6. The soils in this section of the State were derived from the weathering of the Permian Red Beds. The soils comprising the station farm are fine sandy loams, loams, and clay loams of the Foard and Vernon series.

This station is operated in cooperation with the Office of Forage Crops and Diseases, U. S. Department of Agriculture.

The Spur Station is located in Dickens County one mile west of Spur. Spur is in the Rolling Plains Region, being 14 miles east of the Cap Rock escarpment, which divides the Low Plains from the High Plains. The elevation is 2274 feet above sea level. The average annual rainfall for a period of 20 years is 21.41 inches, 83 per cent of which falls during the growing period of summer crops. The average dates of the last killing frost in the spring and the first killing frost in the fall are April 4 and November 3. Abilene and Miles clay loams, two typical soils of the southern Red Beds Region, comprise the land on the station.

The Temple Station is located in Bell County and before its removal to a new site in 1927 and during the duration of the experiments reported here was located about four and one-half miles southwest of Temple. The elevation is 740 feet above sea level. The average annual rainfall for the period of 18 years is 36.35 inches, about 61 per cent of which falls from March to September, inclusive. The average dates of the last killing frost in the spring and the first killing frost in the fall are March 24 and November 11. The soils on this old location are dark-brown to black clays of the Simmons and Lewisville series and are not strictly typical of the Blackland Region.

The Beeville Station is located in Bee County in the Interior Black Prairie Region at an altitude of 240 feet above sea level. The average annual rainfall for a period of 27 years is 30.31 inches, of which 66 per cent falls between March and September, inclusive. The average dates of the last killing frost in the spring and the first killing frost in the fall are February 22 and December 5. Victoria and Goliad sandy loams and clay loams are the principal soils comprising the land of the station.

The Big Spring Field Station is located one-half mile north of Big Spring in Howard County in the South Plains Region and at the southern edge of the High Plains. The altitude is 2400 feet above sea level. The average annual rainfall over a period of 15 years is 18.43 inches, 81 per cent of which falls during the months from April through October. The average dates of the last killing frost in the spring and the first killing frost in the fall are March 30 and November 2. The principal soil type is Amarillo fine sandy loam.

The Big Spring Field Station is operated by the Office of Dry-Land Agriculture, U. S. Department of Agriculture.

The Dalhart Field Station is located in Hartley County in the northern Panhandle. The altitude is 3978 feet above sea level. The average rainfall over a period of 25 years is 18.95 inches, 87 per cent of which falls during the period from April to October, inclusive. The average dates of the last killing frost in the spring and the first killing frost in the fall are April 23 and October 16. Amarillo sandy loam soils predominate on this station.

The Dalhart Field Station is operated by the Office of Dry-Land Agriculture, U. S. Department of Agriculture.

EXPERIMENTAL METHODS

The yields reported in this Bulletin were computed to the acre basis from experimental plats. The plat sizes and number of replications have varied on any particular station and from station to station, depending upon the amount of land available. The plats have varied in size from 1/10 to 1/110 of an acre but the most usual plat size has been about 1/20 of an acre, except at Temple, where the plats were always 1/110 of an acre. Single plats were generally used in the work prior to 1925, except at Chillicothe, where duplicate plats were used, but since that time plats have more often been 1/55 of an acre and duplicated or triplicated.

Different row widths are in use at the different stations. The ordinary row width at Lubbock, Spur, Temple, and Beeville is 36 inches; at Chillicothe 40 inches; and at Big Spring and Dalhart 44 inches.

The preparation of the land and the cultivation were always in keeping with good farm practices and as uniform as the nature of the experiments would allow.

Grain yields are presented in bushels of 56 pounds and represent clean, threshed grain.

Forage yields are the total field production of heads and stover and are presented in tons of air-dry matter to the acre.

The measurement and observation of plant characters were made at maturity and are based on the average of ten consecutive plants in the row.

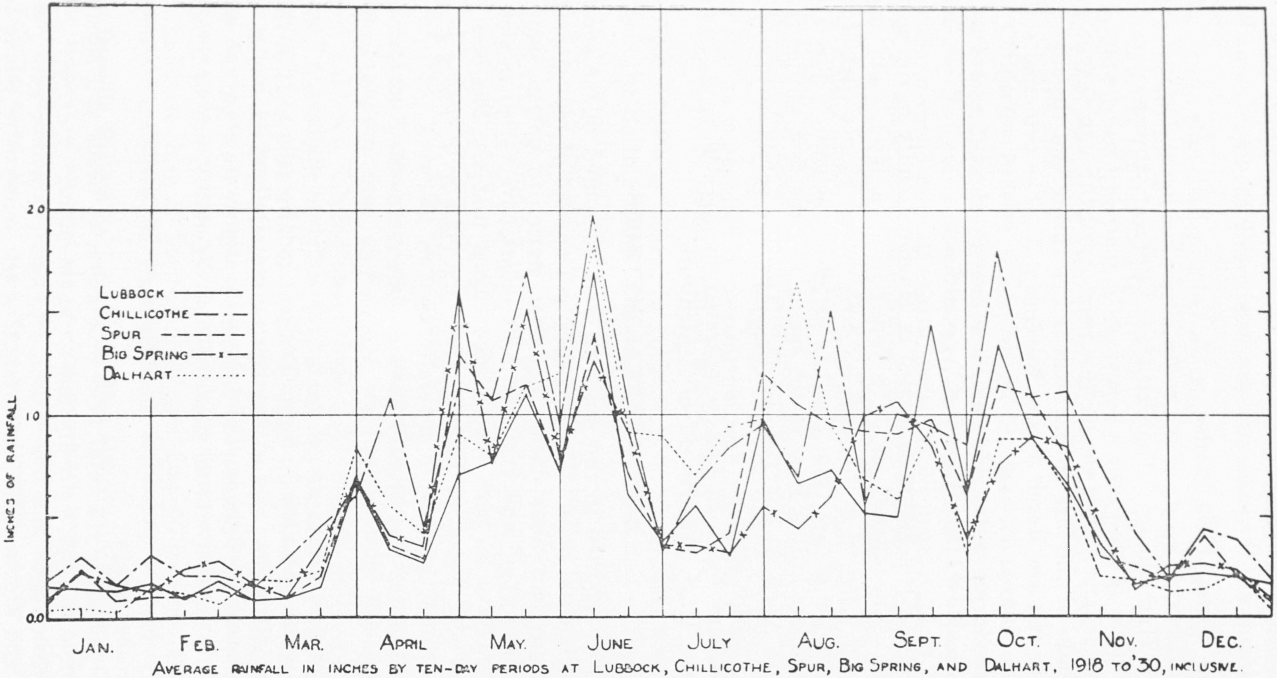

Fig. 3. Average rainfall in inches, by ten-day periods, 1918-30, inclusive, at Lubbock, Chillicothe, Spur, Big Spring, and Dalhart. The distribution is strikingly similar in the various regions but the variation in the peaks and troughs from July to October have a pronounced influence upon the growth of sorghums at the various stations.

Diameter of plant is the average of three measurements, one taken at the butt, one at the middle, and one at the peduncle of the plant.

Number of days from planting to full boot, to full head, and to maturity are, respectively, the actual number of days from planting until 50 per cent of the heads were in full boot, until 50 per cent of the heads were in full head, and until 90 per cent of the heads had mature seed. The period from planting until maturity is called the growth period or crop-growing season.

Per cent of stand is the ratio of actual number of plants obtained to the desired number of plants, expressed as a percentage. All possible care was taken to insure good stands; planting was done at heavy rates, and the poor stands that were obtained were due to inability of the seed to germinate under the unfavorable conditions. Thinning to desired stands was done, ordinarily, about the time the plants were four to six inches high.

The heads were harvested with a pocket knife and cured until dry enough to thresh. The stover was cut by hand or with a row binder. Forage weights were computed by adding the air-dry head weights to the air-dry stover weights.

The figures presented for grain and forage yields are the actual acre yields of grain and forage of the designated plats. A few exceptions are indicated as calculated or interpolated yields. The calculated yield of grain of the 3-inch spacing of kafir at Lubbock, in 1917 (Table 16), is typical of the method used in computing calculated yields. The 6-inch spacing of Blackhul kafir was reliable in each year of the ten-year period, 1916-25, inclusive, but the 3-inch spacing was not reliable in 1917 because a dependable stand was not obtained on that plat. The ratio between the average grain yield of the 6-inch spacing and of the 3-inch spacing was determined for this period of years, excluding 1917. The calculated yield of the 3-inch spacing in 1917 was made to conform to this ratio with respect to the yield of the 6-inch spacing of that year. In this particular case the ratio of average production was found to be 1 to 1 and, therefore, the yield of 7.2 bushels produced by the 6-inch spacing in 1917 was also the calculated yield of the 3-inch spacing that year.

The interpolated yields included in Table 8, the date of planting tests at Chillicothe, are yields taken from a planting of each variety made at about the designated date at some location on the station other than that of the date of planting test.

DATES-OF-PLANTING EXPERIMENTS

Response of Sorghum to Time of Planting

The time of planting sorghums has an important relation to the coincidence of the vegetative and fruiting periods of the plant with an environment favorable or unfavorable to best growth and development. If sorghums are planted too early, before the soil is thoroughly warm, it is difficult to get good stands. Too early planting may prolong the growth period of a variety throughout a longer season and expose the crop to more hazards of unfavorable temperature or moisture. Grain sorghums are generally grown in regions where there is a period or peiods of low summer rainfall and satisfactory yields cannot be obtained when the fruiting period of the crop coincides with such depressions in rainfall. In order to determine how the sorghum plant responds to these different effects when planted at different times, data on various characters were collected from the various varieties of grain sorghums in the date of planting experiments conducted at the Lubbock Station from 1919 to 1926.

Plant Development in Relation to Distribution of Rainfall

The relationship between temperature and the length of growing season limits the season of optimum planting and precludes the possibility of planting on a date early enough to escape periods of drought that are likely to occur in mid-summer. Ordinarily, the total rainfall during July, August, and September is ample to produce profitable yields, provided the distribution is good. However, it frequently happens that a poor distribution is responsible for low yields. Since grain sorghums will not grow rapidly until warm weather prevails, they cannot be planted early and be expected to mature a full crop on moisture stored in the soil from winter and spring rainfall. Even the earliest varieties, such as Spur feterita and Dwarf Yellow milo, when planted on April 15, ordinarily were in boot about July 17 and July 6 and matured on August 14 and August 20. The month of July, and particularly the first 20 days is the driest part of the summer, as will be seen from Fig. 3, and sorghums coming into boot or head at this time will frequently encounter conditions unfavorable to heading and grain production. Early planting, therefore, does not eliminate the possibility of encountering drought conditions during the critical fruiting period when an ample supply of moisture is necessary to produce good yields of grain.

There appears to be a correlation between high yield and the date of booting (Table 2). Highest yields of the milos resulted from the June 15 plantings, which booted about August 15. Highest yields of Dwarf Blackhul kafir resulted from the May 15 and the June 15 plantings, which booted on August 1 and August 23, respectively. Standard feterita made best yields from the June 15 planting, which booted on August 12. All of the plantings of the late kafirs booted after August 1, the earliest of which was on August 3 and the latest on September 5. On the whole, booting early in July resulted in decreased yields. It seems apparent that planting should be done on a date that will allow heading in late July, August, or early September (Fig. 5). At Lubbock, June 20 to July 20 and August 20 to September 10 constitute periods characterized by the lowest rainfall of the growing season and sorghums coming into head during these periods are apt to suffer a loss in yield. On the other hand, peaks in the distribution of rainfall occur, on the average, between July 20 and August 20 and between September 10 and 20 (Fig. 3) and if the sorghums are heading during these periods

Table 2.—Average dates of full boot, of full head, and of maturity from date of planting grain sorghum varieties at Lubbock, 1919-26, incl.

	Date of full boot when planted on			Date of full head when planted on			Date of maturity when planted on		
	April 15	May 15	June 15	April 15	May 15	June 15	April 15	May 15	June 15
Dwarf Yellow milo	July 6	July 22	Aug. 15	July 15	July 31	Aug. 23	Aug. 14	Aug. 23	Sept. 19
Standard Yellow milo	July 8	July 23	Aug. 17	July 15	July 31	Aug. 25	Aug. 15	Aug. 21	Sept. 18
Dwarf White milo	July 9	July 29	Aug. 16	July 16	Aug. 5	Aug. 23	Aug. 14	Aug. 24	Sept. 15
Standard White milo	July 13	July 24	Aug. 16	July 20	Aug. 1	Aug. 24	Aug. 15	Aug. 23	Sept. 17
Dwarf Blackhul kafir	July 17	Aug. 1	Aug. 23	July 26	Aug. 8	Sept. 1	Aug. 28	Sept. 4	Oct. 3
Standard Blackhul kafir	Aug. 8	Aug. 8	Sept. 4	Aug. 19	Aug. 19	Sept. 13	Sept. 10	Sept. 15	Oct. 16
Red kafir	Aug. 3	Aug. 15	Sept. 3	Aug. 14	Aug. 22	Sept. 12	Sept. 9	Sept. 16	Oct. 16
Pink kafir	Aug. 16	Aug. 13	Sept. 5	Aug. 17	Aug. 24	Sept. 14	Sept. 15	Sept. 20	Oct. 17
Standard feterita	Aug. 12	July 18	Aug. 12	July 19	July 26	Aug. 20	Aug. 17	Aug. 19	Sept. 12
Spur feterita	July 17	July 21	Aug. 17	July 24	July 29	Aug. 21	Aug. 20	Aug. 20	Sept. 15
Dwarf feterita	July 16	July 16	Aug. 10	July 23	July 22	Aug. 16	Aug. 17	Aug. 12	Sept. 10
Texas Blackhul kafir	July 18	Aug. 4	Aug. 21	July 24	Aug. 9	Aug. 28	Aug. 23	Sept. 2	Sept. 27
Chiltex	July 10	July 20	Aug. 6	July 15	Aug. 4	Aug. 13	Aug. 8	Aug. 17	Sept. 10

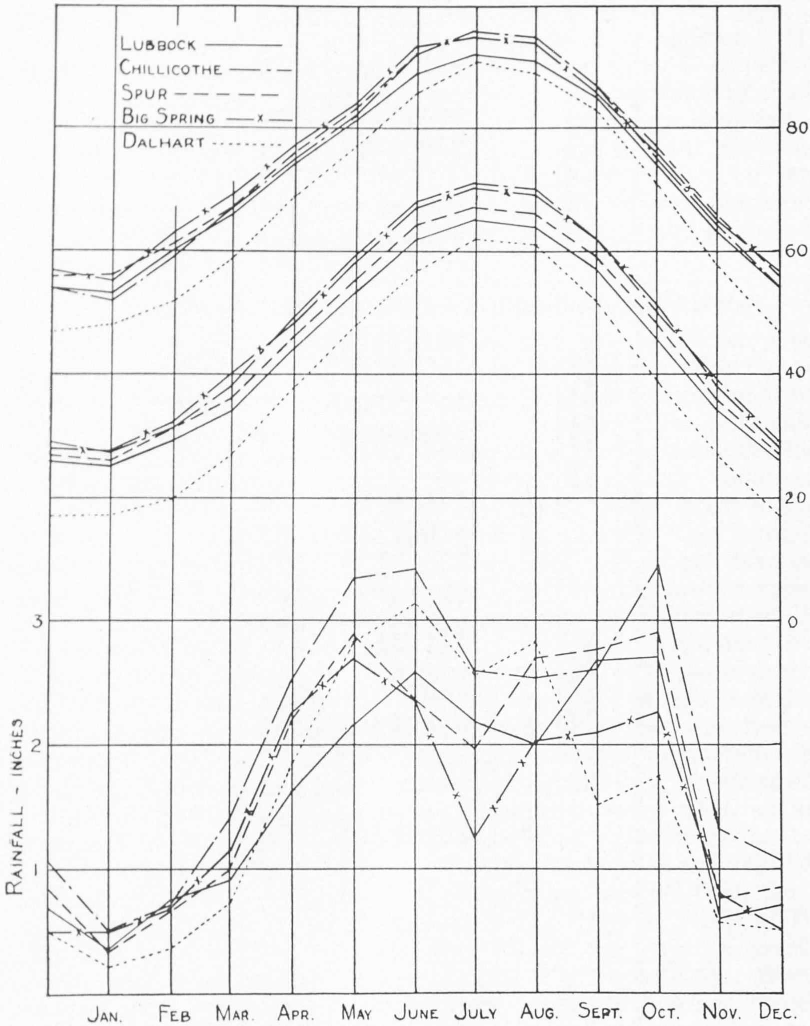

Fig. 4. Mean monthly rainfall (below) and mean maximum and mean minimum temperatures (above) at the Lubbock, Chillicothe, Spur, Big Spring, and Dalhart stations.

higher yields will be produced. Early-maturing varieties should be planted somewhat later than late-maturing varieties.

Time of Planting in Relation to Growth Period

Sorghums planted April 15 do not mature 30 days ahead of the same variety planted on May 15. Maturity dates of two such plantings are more likely to be less than 15 days apart (Table 2). Over a period of years there is considerable variation in the length of the season from planting to maturity (Table 3) but, in general, the later plantings made on June 15 mature in the shortest length of time. Grain sorghum plants grow slowly until the soil is warm and relatively high temperatures prevail. Early planting results in retarded early growth with consequent lengthening of the growth period (Table 4). Dwarf Yellow milo planted on April 15, May 15, and June 15 matured, on the average, in 121, 101, and 96 days, respectively. Corresponding growing seasons of Dwarf Blackhul kafir were 135, 112, and 109 days; and of Spur feterita were 127, 98, and 92 days. Maturity is also retarded by lowered temperatures in the late fall months. May 15 plantings of the milos, which ordinarily head about August 1, have a shorter period from heading to maturity than do June 15 plantings, which head about August 25. The difference is more marked in the late kafirs. May 15 plantings of Standard Blackhul kafir headed about August 19 and matured in 28 days from heading. June 15 plantings of the same variety headed about September 13 and matured in 33 days from heading. These results indicate that conditions in the fall tending to prolong the growing season exist as early as the middle of September at least.

The length of the crop-growing season is not determined solely by the prevailing temperatures. Sorghums have the ability to withstand severe droughts before the crop boots and then to make an excellent crop of grain if good rains come. It is this characteristic of the sorghums that makes them particularly well adapted to the Great Plains region. When severe drought prevails prior to heading, the plants practically cease growth and the retardation of growth results in a longer growing season. The reaction of plants to drought conditions causes the extreme differences in length of growth period for any one date of planting of any one variety, as shown in Table 3. Also, varieties differ in reaction to extreme drought conditions. It is characteristic of milos and feteritas to continue growth and to mature, whether rains come or not. Kafirs, on the other hand, are more likely to cease growth almost entirely and not head until rain comes. In either case the growth period is lengthened but this characteristic difference in growth habit between varieties accounts for the greater differences between the shortest and longest growth periods exhibited by the kafir varieties.

Effect of Time of Planting Upon Stands

Good stands were more difficult to obtain on April 15 than on May 15 or June 15 planting dates. On account of the soft, starchy nature of sorghum seed they are liable to attack from fungi, which rot the seed and prevent germination. The seed germinate slowly and may rot when planted before the soil is thoroughly warm. Germination of feterita seed is particularly low and stands of feteritas, particularly when planted early, are harder to obtain than stands of other varieties. The percentages of stand of the varieties planted at the various dates are shown

Table 3.—Dates of planting grain sorghum varieties and lengths of growth periods at Lubbock, 1919-26, incl.

Date of planting	Length of growth periods, days										
	1919	1920	1921	1922	1923	1924	1925	1926	Average	Extremes	
										Short	Long
Dwarf Yellow milo:											
April 15	127	132	110	117	132	121	108	122	121.1	108	132
May 15	109	....	104	97	102	104	101	87	100.6	87	109
June 15	100	....	89	94	101	102	97	87	95.7	87	102
Standard Yellow milo:											
April 15	127	137	112	117	128	123	113	122	122.4	112	137
May 15	105	....	108	95	100	102	101	82	99.0	82	108
June 15	103	....	92	90	94	102	97	87	95.0	87	103
Dwarf White milo:											
April 15	121	135	112	114	131	122	113	122	121.3	112	135
May 15	111	....	104	99	104	103	103	87	101.6	87	111
June 15	100	....	90	92	92	87	97	87	92.1	87	100
Standard White milo:											
April 15	124	137	112	117	128	122	113	122	121.9	112	137
May 15	109	....	110	102	100	102	98	87	101.1	87	110
June 15	100	....	92	97	94	87	97	89	93.7	87	100
Dwarf Blackhul kafir:											
April 15	139	145	124	129	135	153	125	129	134.9	124	153
May 15	116	....	113	112	104	112	123	107	112.4	104	123
June 15	104	....	103	100	119	131	102	105	109.1	100	131
Standard Blackhul kafir:											
April 15	142	150	140	143	153	172	139	143	147.8	139	172
May 15	123	....	124	128	126	123	123	124	124.4	123	128
June 15	*	....	108	104	145	131	113	138	123.2	104	145
Red kafir:											
April 15	145	150	140	143	153	168	136	142	147.1	140	168
May 15	126	....	124	130	124	128	118	124	124.9	118	128
June 15	*	....	108	104	145	131	113	138	123.2	104	145
Pink kafir:											
April 15	148	145	140	156	158	172	169	145	153.0	140	172
May 15	123	....	130	128	130	128	137	128	129.1	123	137
June 15	*	....	115	104	142	131	113	137	123.7	104	142

*Did not mature.

Standard feterita:											
April 15	133	134	118	119	129	126	113	122	124.3	113	134
May 15	113	....	108	105	62	103	97	89	96.7	62	113
June 15	94	....	89	85	92	89	87	89	89.3	85	94
Spur feterita:											
April 15	140	139	118	127	132	126	111	122	126.9	111	140
May 15	110	....	108	105	68	103	97	92	97.6	68	110
June 15	94	....	91	87	97	89	92	92	91.7	87	94
Dwarf feterita:											
April 15	....	....	....	132	138	127	105	119	124.2	105	138
May 15	....	....	....	105	68	97	92	89	90.2	68	105
June 15	....	....	....	80	97	83	85	88	86.6	80	97
Texas Blackhul kafir:											
April 15	....	....	....	....	....	....	134	125	129.5	125	134
May 15	....	....	....	....	....	....	113	106	109.5	106	113
June 15	....	....	....	....	....	....	102	105	103.5	102	105
Chiltex:											
April 15	....	....	....	....	....	....	108	122	115.0	108	122
May 15	....	....	....	....	....	....	97	92	94.5	92	97
June 15	....	....	....	....	....	....	87	87	87.0	87	87

in Table 5. Poor stands, no doubt, have some influence upon yield; nevertheless poor stands do not account wholly for the lower yields of April 15 plantings. The average per cent of stand of the April 15 planting of Dwarf Yellow milo was 84 per cent; the May 15 planting, 85 per cent. The yields, however, differ by 6.3 bushels in favor of May 15 planting. Likewise, the average per cents of stand of Red kafir were 91 and 99 for the two dates, respectively; yet the earlier date has the higher average yield by 1.3 bushels.

Influence of Time of Planting Upon Plant Characters

Plant height and diameter of stalk are influenced more by soil-moisture conditions than by temperature conditions. In general, however, shorter and more slender plants result from April 15 than from May 15 and June 15 plantings, although the average height at maturity and the diameter of stalk differ but little (Table 6). Also, there is very little difference in the amount of suckering but here, also, the later plantings, on the average, have the higher number of stalks to plants. No doubt, the poorer stands that frequently occurred in the early planting would tend to make the plants larger and to produce more suckers, and the poor stands may tend to cover up differences in plant size and amount of suckering that actually exist when stands are absolutely comparable. In general, the better plant growth obtained in the later plantings indicates that better growing conditions for sorghum exist in the summer and fall than in the spring and early summer.

Time of Planting in Relation to Yield in Various Regions

From the preceding discussion it has been shown how the sorghum plant responds to various factors when planted at different dates. The general effects of these factors upon the behavior of the plant and their indirect influence upon production are important but the relation of time of planting to yield of grain and forage is the principal consideration. Experiments have been conducted at the various stations to determine the relative yields that can be expected in the different regions when the principal grain sorghum varieties are planted at different dates throughout the possible planting period.

The growing season, as ordinarily considered, is the period between the last killing frost in the spring and the first killing frost in the fall. Spring temperatures optimum for growth of sorghums do not exist until sometime after the last killing frost in the spring (Table 1 and Fig. 4) and the growing season of grain sorghums, therefore, does not coincide with the frost-free period. The soil is warm enough and mean temperatures are high enough to allow planting by February 15 in the southern part and by April 1 in the northern part of the State. Since favorable growing conditions for grain sorghum usually exist right up to the date of killing frost in the fall, and since the latest of the grain sorghums grown will mature, ordinarily, in 120 to 130 days, the possible range of planting date covers a period of at least 90 days, even in the northern

Table 5.—Average and extreme per cents of stand obtained, and average yield of grain from dates of planting grain sorghum varieties at Lubbock, 1919-26, inclusive.

Variety	Per cent of stand										Grain yield in bushels to the acre			
	April 15			May 15			June 15			Aver.	April 15	May 15	June 15	Aver.
	Aver.	Extremes Low	Extremes High	Aver.	Extremes Low	Extremes High	Aver.	Extremes Low	Extremes High					
Dwarf Yellow milo	84	56	100	85	31	100	100	98	100	90	21.1	27.4	27.5	25.3
Standard Yellow milo	68	34	100	79	27	100	93	73	100	80	16.9	25.3	23.5	21.9
Dwarf White milo	63	42	100	85	41	100	97	93	100	82	16.3	24.1	27.4	22.6
Standard White milo	78	58	100	85	66	100	88	63	100	84	19.1	22.0	23.8	21.6
Average	73	......	......	84	......	......	95	......	......	84	18.4	24.7	25.6	22.9
Dwarf Blackhul kafir	74	45	100	91	69	100	100	100	100	88	18.1	21.0	20.3	19.8
Standard Blackhul kafir	97	93	100	95	89	100	99	95	100	97	22.0	21.6	20.8	21.5
Red kafir	91	66	100	99	96	100	96	85	100	95	21.7	20.4	17.4	19.8
Pink kafir	94	66	100	91	70	100	94	86	100	93	24.8	23.5	22.7	23.7
Average	89	......	......	94	......	......	97	......	......	93	21.7	21.6	20.3	21.2
Standard feterita	67	38	100	70	16	100	96	78	100	78	19.0	20.4	21.2	20.2
Spur feterita	48	15	92	66	36	100	91	66	100	68	20.4	25.0	23.7	23.0
Average	58	......	......	68	......	......	94	......	......	73	19.7	22.7	22.5	21.6
Dwarf feterita	25	10	45	64	29	100	63	21	90	51	8.9	15.7	16.7	13.8
Texas Blackhul kafir	92	83	100	100	100	100	100	99	100	97	27.8	18.1	29.0	25.0
Chiltex	36	18	54	81	67	95	100	100	100	72	11.1	17.2	26.1	18.1

Table 4.—Growth periods of grain sorghum varieties as influenced by date of planting. Average number of days from planting to full head, from full boot to full head, from full head to maturity, and from planting to maturity at Lubbock, 1919-26, incl.

Variety	Days, planting to full head				Days from full boot to full head				Days, full head to maturity				Days, planting to maturity			
	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.
Dwarf Yellow milo......	91	76	69	79	9	9	8	9	30	25	27	27	121	101	96	106
Standard Yellow milo....	91	76	71	79	7	8	8	8	31	23	24	26	122	99	95	105
Dwarf White milo......	92	81	69	81	7	8	7	7	29	21	23	24	121	102	92	105
Standard White milo.....	96	77	70	81	7	8	8	8	26	24	24	25	122	101	94	106
Dwarf Blackhul kafir....	102	84	77	88	9	7	9	8	33	28	32	31	135	112	109	119
Standard Blackhul kafir..	126	96	90	104	11	11	9	10	22	28	33	28	148	124	123	132
Red kafir..............	121	99	89	103	11	7	9	9	26	26	34	29	147	125	123	132
Pink kafir..............	124	101	91	105	11	11	9	10	29	28	33	30	153	129	124	135
Standard feterita........	95	72	66	78	7	8	8	8	29	25	23	26	124	97	89	103
Spur feterita............	100	75	70	82	7	8	7	7	27	23	22	24	127	98	92	106
Dwarf feterita*.........	99	68	62	76	7	6	6	6	25	22	25	24	124	90	87	100
Texas Blackhul kafir**...	100	86	74	87	6	5	7	6	30	24	30	28	130	110	104	115
Chiltex**..............	91	80	69	80	5	15	7	9	24	15	26	22	115	95	87	99
Average..........	102	82	74	......	8	9	8	......	28	24	27	......	130	106	101	......

*5-year average. **2-year average.

Table 6.—Plant characters of grain sorghum varieties as influenced by date of planting. Averages of height, diameter, stalks to plant, plants having suckers, and pendent heads at Lubbock, 1919-26, inclusive

Variety	Height at maturity, inches				Diameter of plant, centimeters				Number of stalks to plant				Per cent of plants having suckers				Per cent of pendent heads			
	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.	April 15	May 15	June 15	Aver.
Dwarf Yellow milo.........	39	41	41	40	1.45	1.44	1.50	1.46	2.0	2.0	2.1	2.0	60	62	62	61	10	12	7	10
Standard Yellow milo.......	57	60	59	59	1.28	1.38	1.52	1.39	1.7	1.5	1.7	1.6	25	60	57	47	6	12	15	11
Dwarf White milo..........	43	41	41	42	1.40	1.45	1.46	1.44	1.7	1.6	1.7	1.7	50	48	43	47	5	2	0	2
Standard White milo.......	58	61	58	59	1.27	1.46	1.50	1.41	1.5	1.6	1.8	1.6	27	52	62	47	5	17	7	10
Dwarf Blackhul kafir.......	43	43	42	43	1.59	1.60	1.66	1.62	1.1	1.2	1.3	1.2	12	20	25	19	......	......	......	......
Standard Blackhul kafir.....	46	49	49	48	1.77	1.85	2.03	1.88	1.1	1.2	1.1	1.1	5	12	8	8	......	......	......	......
Red kafir................	51	50	51	51	2.00	1.84	1.90	1.91	1.1	1.1	1.1	1.1	5	10	7	7	......	......	......	......
Pink kafir................	51	52	55	53	1.73	1.90	1.95	1.86	1.1	1.2	1.1	1.1	5	13	10	9	......	......	......	......
Standard feterita..........	59	60	59	59	1.43	1.49	1.34	1.42	1.4	1.9	2.3	1.9	25	48	65	46	......	......	......	......
Spur feterita..............	53	52	54	53	1.66	1.68	1.66	1.67	1.6	1.7	2.0	1.8	37	48	60	48	......	......	......	......
Dwarf feterita*...........	43	39	40	41	1.56	1.57	1.59	1.57	1.3	1.4	1.9	1.5	22	34	62	39	......	......	......	......
Texas Blackhul kafir**......	46	43	48	46	1.39	1.44	1.63	1.49	1.0	1.1	1.0	1.0	0	5	5	3	......	......	......	......
Chiltex**.................	35	34	47	39	1.60	1.28	1.49	1.46	1.0	1.7	1.5	1.4	0	35	25	20	......	......	......	......
Average............	48	48	50	......	1.55	1.57	1.63	......	1.4	1.5	1.6	......	21	34	38	......	7	11	7	......

*5-year average. **2-year average.

part of the State. In the southern and eastern region, where the sorghum midge is a limiting factor in production, grain sorghums must be planted early enough to allow heading and flowering before the midge becomes numerous. Even here, however, there is a possible range of planting date of some 90 days.

Dates of Planting and Yields at Lubbock

Ten of the principal varieties of grain sorghum were planted over a period of eight years at Lubbock on three dates: April 15, May 15, and June 15. Three additional varieties were grown for shorter periods.

Plantings prior to April 1 are not feasible because of the difficulty of getting stands. Plantings made after July 1 are frequently caught by frost and stands are sometimes hard to obtain because of deficient soil moisture. These three dates are representative of the possible range of planting in this region.

In the following discussion, varieties grown for only two years will be disregarded. The grain yields resulting from April 15 plantings are generally lower than from May 15 and June 15 plantings (Table 7). Dwarf Yellow milo produced 27.4 and 27.5 bushels on the May 15 and June 15 plantings, and 21.1 bushels on the April 15 planting. Dwarf Blackhul kafir produced 21.0 and 20.3 bushels on the May 15 and June 15 plantings, and 18.1 bushels on the April 15 planting. Spur feterita produced 25.0 and 23.7 bushels on the May 15 and June 15 plantings, and 20.4 bushels on the April 15 planting. Yields of the late-maturing varieties, Standard Blackhul kafir, Red kafir, and Pink kafir are not in line with the results from the earlier varieties. The differences in production of these late varieties, when planted on April 15 and May 15, are probably not significant but are in favor of the earlier date. The reduction in yield of these later varieties in the June 15 planting is due largely to their being caught by an early frost in 1919, and with that year excluded, the yields of June 15 compare favorably with those of April 15 and May 15 plantings. Apparently these late varieties of kafir may be planted earlier than milo and feterita. This condition is brought about by the fact that the long growing season and habits of growth of these varieties, when planted on April 15, causes them to mature about the same time that earlier varieties mature when planted 30 or 40 days later.

Dates of Planting and Yields at Chillicothe

Three varieties, Dwarf Yellow milo, Dwarf Blackhul kafir, and feterita were planted on different dates each year at Chillicothe from 1913 to 1928, excluding 1918. Whenever soil and climatic conditions would permit, plantings were made from April 1 to June 1, at 15-day intervals. In early years plantings were made up to July 1 but beginning in 1919 the last planting was made on June 1, and an early planting on March 15 was added. June 1 does not represent the latest possible planting date at Chillicothe, and unfortunately the yields for the early years are not representative because of a series of unfavorable seasons. The yields

Table 7.—Dates of planting grain sorghum varieties and the yields of grain at Lubbock, 1919-26, inclusive

Date of planting	Grain yield, bushels to the acre								
	1919	1920	1921	1922	1923	1924	1925	1926	Average
Dwarf Yellow milo:									
April 15	33.7	21.7	19.0	15.4	20.8	17.2	17.4	23.4	21.1
May 15	45.4	31.8	35.9	21.0	26.4	22.7	18.3	17.7	27.4
June 15	26.4	27.4	30.8	19.3	25.6	26.8	23.0	40.5	27.5
Standard Yellow milo:									
April 15	33.6	12.8	12.0	16.6	16.5	9.2	10.1	24.1	16.9
May 15	34.2	10.6	41.7	22.1	23.8	23.4	22.1	24.1	25.3
June 15	24.2	21.5	30.3	21.5	21.1	23.4	13.1	32.7	23.5
Dwarf White milo:									
April 15	33.4	13.3	12.7	15.8	10.0	11.1	9.6	24.4	16.3
May 15	35.6	24.9	29.0	23.8	22.6	22.4	16.4	17.7	24.1
June 15	37.5	24.3	32.5	23.8	22.0	26.6	16.8	35.6	27.4
Standard White milo:									
April 15	35.4	16.5	15.7	13.7	20.2	9.6	12.3	29.4	19.1
May 15	30.1	19.7	30.3	18.1	25.1	19.9	14.3	18.4	22.0
June 15	26.7	21.2	27.2	20.7	20.0	24.1	13.8	36.3	23.8
Dwarf Blackhul kafir:									
April 15	19.1	22.3	24.1	14.9	10.1	15.7	14.5	24.4	18.1
May 15	30.2	26.4	19.3	20.0	18.1	20.0	21.0	13.1	21.0
June 15	26.1	25.2	30.7	11.9	19.5	4.4	21.3	23.0	20.3
Standard Blackhul kafir:									
April 15	40.2	35.9	26.6	8.5	12.2	8.2	15.3	28.7	22.0
May 15	35.6	40.3	25.3	13.6	19.4	18.9	14.9	4.4	21.6
June 15	12.0	31.4	33.9	12.9	21.9	19.5	16.8	18.0	20.8
Red kafir:									
April 15	41.1	34.1	26.5	11.8	13.6	7.5	16.7	22.0	21.7
May 15	31.7	40.7	26.8	12.6	19.2	13.4	13.2	5.5	20.4
June 15	17.3	29.1	29.9	9.4	17.8	9.2	13.1	13.6	17.4
Pink kafir:									
April 15	45.2	42.0	30.3	9.6	12.7	7.5	20.4	30.4	24.8
May 15	39.1	41.8	29.2	16.3	20.8	19.8	14.5	6.1	23.5
June 15	16.1	36.8	38.9	13.1	16.8	18.3	21.9	19.5	22.7

Standard feterita:											
April 15		34.6	17.6	27.0	15.1	10.0	12.8	8.4	26.4	19.0
May 15		30.3	16.7	38.8	16.8	18.4	17.0	9.6	15.8	20.4
June 15		24.4	23.2	21.9	17.8	17.1	19.6	16.0	29.7	21.2
Spur feterita:											
April 15		41.2	7.9	27.1	14.3	12.3	12.8	11.2	36.4	20.4
May 15		42.6	14.9	43.7	19.8	22.4	16.1	19.6	20.5	25.0
June 15		25.3	23.4	25.0	22.7	21.0	23.0	18.9	30.0	23.7
Dwarf feterita:											
April 15					5.5	3.1	14.8	2.9	18.0	8.9
May 15					15.2	16.9	18.3	14.0	14.0	15.7
June 15					15.7	14.8	19.9	17.9	15.1	16.7
Texas Blackhul kafir:											
April 15								22.3	33.2	27.8
May 15								22.2	13.9	18.1
June 15								25.7	32.3	29.0
Chiltex:											
April 15								10.0	12.1	11.1
May 15								14.5	19.9	17.2
June 15								25.9	26.3	26.1

to be obtained by a planting date later than about June 15 can, therefore, only be surmised.

The range of optimum planting date is wider at Chillicothe than at Lubbock, and Dalhart on account of lower altitude and higher mean temperatures (Fig. 4). The differences in grain yield from the different dates of planting are not as great at Chillicothe as at Lubbock, Big Spring, and Dalhart and there is less tendency for any particular planting date consistently to return the highest yield, due probably to difference in altitude, greater variability of growing conditions from year to year, and the heavier type of soil at Chillicothe.

The highest grain yields of 21.0 bushels of Dwarf Blackhul kafir, 22.2 bushels of feterita, and 20.8 bushels of Dwarf Yellow milo were all made on the May 15 date. The lowest yield for each variety was made on the April 1 date (Table 8). The differences in yield of any of the varieties from the dates of April 15, May 1, May 15, and June 1 are not great, but they do increase consistently as the date of planting advances toward the later date. No average yields are given for plantings after June 1 but the results of the early years and a knowledge of the length of growing season indicate no marked reduction in yield from planting as late as July 1.

The average yields of Dwarf Yellow milo are not typical of the results secured in recent years. Chinch bugs, with perhaps an associated plant disease, have reduced yields of milo, particularly in May and early June plantings. The extent of the damage varies from year to year, but in certain instances, complete failure may result. Plants are attacked usually in June when only a few inches high. The bud frequently rots and suckers develop, which are attacked in turn, and a very poor crop results. The reduced yields of May and June plantings in 1927 and 1928 are the result of this damage. No figures other than these are available but observations indicate that early plantings made in April, or late plantings made after about June 10, escape this damage almost entirely. Damage also seems to be more severe on clay loam or heavier types of soil and negligible on sandy types of soils. As long as the loss from this cause exists, milo should not be planted on heavy soils during the period from May 10 to June 10 in this section of the State if chinch bugs are prevalent.

Forage yields increase with late planting (Table 9). Average yields of 2.42 tons of Dwarf Yellow milo, 2.72 tons of Dwarf Blackhul kafir, and 1.89 tons of feterita were produced on the June 1 planting while the average yield of forage of these varieties planted April 1 was about 20 per cent less. In addition, a better quality of forage is produced on the later plantings since the later plantings retain their leaves in a green condition to a much greater extent than do the early plantings.

Dates of Planting and Yields at Spur

Date of planting experiments have been conducted at Spur over a considerable period of years but plantings were so often prevented on

Table 8.—Dates of planting grain sorghum varieties and the yields of grain, per cent of stand, growth period, and height of plant at Chillicothe, 1913-28.

Date	Grain yield in bushels to the acre																Per cent stand	Growth period, days	Height of plant, inches
	1913	1914	1915	1916	1917	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	Aver.			
Dwarf Yellow milo:																			
March 15	.....	.....	.....	.....	.....	23.3	33.8	0	18.7	14.6	.....	.....	0	22.1	13.9	.....	67	148	47
April 1	10.9	28.2	17.1	16.5	1.8	21.7	28.0	8.2	14.0	13.4	32.2	.....	0	28.1	9.8	16.4	69	129	46
April 15	11.6	17.7	19.8	12.7	2.8	16.5	36.7	16.3	14.0	5.8	24.6	25.5	36.3	31.1	3.4	18.3	85	119	44
May 1	8.4	35.7	19.8	11.6	.8	18.7	32.6	16.3	28.1	4.7	28.7	30.8	38.7	21.8	4.1	20.1	80	120	44
May 15	1.6	*37.7	28.4	7.6	6.6	28.7	24.8	14.0	18.7	4.7	50.8	41.3	36.3	10.5	.8	20.8	100	113	45
June 1	0	*29.3	39.3	0	6.7	7.3	.....	25.7	0	15.8	46.3	61.5	16.7	21.4	2.6	19.5	98	107	45
June 15	0	47.0	0	0	3.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	109	45
July 1	0	55.0	0	0	7.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	99	53
Dwarf Blackhul kafir:																			
March 15	.....	.....	.....	.....	.....	12.0	25.6	0	16.4	38.6	.....	.....	0	23.3	27.8	.....	60	149	55
April 1	0	16.1	32.1	6.3	8.7	18.7	32.6	21.0	16.4	13.4	21.1	.....	0	36.0	15.0	17.0	50	136	56
April 15	0	14.8	38.0	3.4	6.2	10.8	16.3	18.7	30.4	5.3	27.2	16.5	30.4	42.4	16.9	18.5	86	128	54
May 1	0	47.1	25.9	0	4.5	17.5	17.1	16.3	30.4	3.5	25.2	20.3	29.8	39.4	16.1	19.5	95	130	54
May 15	0	*47.0	39.8	0	.9	19.5	23.9	15.2	4.7	31.0	22.6	30.8	33.3	34.5	11.6	21.0	94	123	52
June 1	0	*56.8	*37.2	0	8.4	12.8	.....	12.8	4.7	16.4	19.6	26.3	34.5	39.0	22.1	20.8	87	113	52
June 15	0	55.5	0	0	4.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	122	57
July 1	0	47.9	0	0	7.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	112	66
Feterita:																			
March 15	.....	.....	.....	.....	.....	16.5	5.8	0	9.4	36.3	.....	.....	0	15.4	17.6	.....	47	147	60
April 1	14.8	35.9	11.4	13.5	10.2	23.5	15.4	9.3	23.4	18.7	29.7	.....	0	26.3	14.6	17.6	39	128	60
April 15	12.7	44.8	14.3	17.3	3.2	25.2	20.1	23.3	16.4	12.0	32.2	4.5	20.8	25.1	13.5	19.0	69	118	57
May 1	13.6	20.0	29.3	18.8	7.4	19.8	23.3	15.2	32.7	18.1	26.7	6.8	26.2	40.5	16.5	21.0	70	103	55
May 15	3.9	*33.3	33.6	15.2	7.9	17.2	44.9	9.3	35.1	0	28.2	13.5	41.1	39.0	10.5	22.2	86	97	56
June 1	0	*33.3	30.4	22.3	8.3	19.8	.....	5.8	18.7	4.1	35.2	19.5	23.8	32.3	3.0	18.3	82	99	52
June 15	0	26.6	37.0	19.5	12.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	99	57
July 1	0	48.4	0	0	11.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	92	64

*Interpolated.

the desired dates that the results are not complete for each year and only a summary is presented (Table 10).

The climatic conditions at Spur are quite similar to those at Chillicothe except for slightly lower rainfall.

Highest yields of milo and feterita resulted from June plantings and highest yields of kafir from May plantings. Probably there is no significant difference in the yields of milo between May plantings and June plantings but April plantings are undoubtedly too early, as they encounter more troublesome weed growth, making cultivation more expensive, and yields are reduced about 10 bushels to the acre. July plantings are too late and it is ofttimes easier to get a good stand from May plantings than it is from June plantings.

Table 9.—Dates of planting grain sorghum varieties and yields of forage at Chillicothe, 1913-23.

Date	Forage yield, tons to the acre										
	1913	1914	1915	1916	1917	1919	1920	1921	1922	1923	Aver.
Dwarf Yellow milo:											
March 15	......	......	......	......	......	2.29	2.94	0	.97	2.78	......
April 1	.93	4.18	1.18	1.14	.40	2.16	2.42	1.40	1.03	2.52	1.74
April 15	1.22	3.53	1.45	.98	.59	2.45	2.16	1.50	.41	2.18	1.65
May 1	1.00	5.45	2.33	1.24	.51	2.61	2.74	1.18	.87	2.93	2.09
May 15	1.05	*5.59	3.65	1.12	1.03	3.14	3.14	2.22	1.77	3.11	2.58
June 1	1.02	*6.00	3.88	1.34	1.44	1.83	......	1.89	1.84	2.56	2.42
June 15	1.55	5.45	5.23	1.09	1.41	......	......	......	......	......	2.95
July 1	*1.23	5.55	3.58	0	1.61	......	......	......	......	......	......
Blackhul kafir:											
March 15	......	......	......	......	......	1.41	2.29	0	.81	5.72	......
April 1	1.66	4.63	2.70	1.61	1.71	2.03	2.87	2.35	.88	4.05	2.45
April 15	1.88	3.30	3.23	1.65	1.74	1.41	1.83	1.44	1.17	5.26	2.29
May 1	1.89	5.28	2.38	1.79	1.56	1.63	1.57	2.16	1.25	2.97	2.25
May 15	1.90	5.26	4.28	1.95	1.31	1.93	2.74	1.92	1.27	3.98	2.65
June 1	2.16	5.45	*3.99	2.28	2.27	1.44	......	1.60	1.69	3.63	2.72
June 15	2.57	5.33	4.83	2.48	1.06	......	......	......	......	......	3.25
July 1	*2.10	6.07	4.83	0	1.89	......	......	......	......	......	......
Feterita:											
March 15	......	......	......	......	......	1.47	.52	0	.42	3.00	......
April 1	1.08	3.73	1.23	.97	1.18	1.93	1.76	1.37	1.13	3.14	1.75
April 15	1.09	5.09	1.68	1.23	.57	2.06	1.70	1.31	.60	2.34	1.77
May 1	1.27	5.03	2.28	1.38	.82	1.86	1.76	1.54	1.03	2.33	1.93
May 15	1.28	*5.11	3.30	1.18	.72	1.50	2.35	1.70	.96	.80	1.89
June 1	1.24	*5.48	3.28	1.65	.90	1.57	......	1.14	.92	.86	1.89
June 15	1.64	3.65	4.44	1.46	1.44	......	......	......	......	......	2.53
July 1	*1.06	4.30	3.00	0	1.63	......	......	......	......	......	......

*Interpolated.

Table 10.—Summary of the effects of different dates of planting grain sorghum varieties and average yield of grain at Spur.

Variety	Grain yield, bushels to the acre			
	April 15	May 15	June 15	July 15
Milo	19.5	28.8	30.2	22.7
Kafir	22.0	32.3	25.6	19.3
Feterita	20.3	34.2	35.7	30.6
Average	20.6	31.8	30.5	24.2

The lower yields of kafir in the June and July plantings are caused by the fact that such plantings encounter unfavorable growing conditions late in the season due to the long growing season of that variety.

The April plantings of feterita, like those of kafir and milo, produced lower grain yields. There is probably no significant difference in yield between the May plantings and the June plantings. Feterita, however, usually responds better to late planting than the other varieties.

Dates of Planting and Yields at Big Spring

Dwarf Yellow milo, Dawn kafir, Standard feterita, and hegari have been planted on different dates at Big Spring in certain years during the period 1919 to 1930. Plantings were made at 15-day intervals from April 15 through July 1.

In general, highest yields have resulted from June 1 and June 15 plantings (Table 11). Larger differences result from different dates of planting than at Lubbock, Dalhart, Chillicothe, or Spur. The yields from the April 15, May 1, and May 15 plantings of each variety are lower than those from the June 1, June 15, and July 1 plantings, with one exception: the yields of Dawn kafir on the May 1 and May 15 plantings are higher than the July 1 planting.

The yields of milo, 28.1 and 27.8 bushels on June 1 and June 15, and yields of 18.7, 18.8, and 21.0 bushels, respectively, on May 1, May 15, and July 1 show the advisability of planting milo during late May and the first half of June. Quite similar results were obtained from other varieties except hegari, which apparently responds better to late planting than other varieties. Dawn kafir produced 20.8 and 18.0 bushels of grain from June 1 and June 15 plantings and less than 15 bushels when planted either earlier or later than these dates. Standard feterita produced 19.5 and 18.5 bushels of grain from June 1 and June 15 plantings, and 15.0 bushels or less on each earlier or later planting. The highest grain yield of hegari, 24.8 bushels, was produced from June 15 planting and the next two highest yields, 20.3 and 19.4 bushels, were from July 1 and June 1 plantings. A yield of 18.9 bushels was made from May 1 plantings and during this period of four years in which hegari was grown, that variety has made good yields in individual years from each date of planting. Hegari is notoriously erratic in its response to climatic and soil condition and it is difficult to predict its behavor. However, it seems that with this variety late planting will return the most consistent yields of grain. Hegari also is an excellent forage variety and produces a high quality of forage, especially when planted late.

There seems to be a more restricted period of optimum planting of sorghums at Big Spring than at some other western stations. The period of low rainfall during July and August extends over a rather long period (Fig. 3). Sorghums planted in June reach the heading period in late August and September, when rainfall conditions are more favorable, and this undoubtedly accounts for the better yields obtained from planting in June rather than April or May.

Table 11.—Dates of planting grain sorghum varieties and the yields of grain at Big Spring, 1919-30, inclusive.

Date of planting	Grain yield, bushels to the acre												
	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	Aver.
Dward Yellow milo:													
April 15	65.6	0	22.2	0	13.4	7.9	0	10.4	7.4	13.6	7.9	0	12.4
May 1	48.6	0	0	39.8	36.6	9.6	4.1	23.7	13.3	18.7	8.2	21.2	18.7
May 15	62.9	0	0	27.3	28.2	18.7	11.8	28.8	0	21.2	10.0	17.2	18.8
June 1	48.3	52.8	29.8	32.3	38.5	14.1	14.5	30.1	15.0	33.0	13.9	15.3	28.1
June 15	44.6	50.1	25.2	27.6	38.4	0	17.8	35.3	14.3	39.3	20.5	20.2	27.8
July 1	34.0	44.3	19.7	6.2	17.7	0	19.5	26.4	16.1	23.2	28.1	16.8	21.0
Dawn kafir:													
April 15	42.3	0	11.0	0	15.0	1.8	0	9.4	13.4	20.6	......	0	10.3
May 1	38.9	0	0	21.6	23.4	2.7	12.3	16.3	12.5	23.9	......	10.8	14.8
May 15	45.3	0	0	16.9	15.9	5.0	15.3	19.6	0	27.5	......	10.7	14.2
June 1	33.0	34.8	20.9	21.6	15.3	9.6	14.8	23.8	12.1	29.1	......	13.6	20.8
June 15	30.3	22.3	9.4	14.3	21.6	0	14.1	24.9	14.5	33.8	......	13.1	18.0
July 1	22.0	32.5	4.0	2.4	17.7	0	20.4	17.7	13.1	18.5	......	0	13.5
Standard feterita:													
April 15	......	......	......	0	16.1	1.3	0	12.1	13.4	7.9	11.3	0	6.9
May 1	......	......	......	20.4	21.6	.9	7.9	16.8	15.2	8.9	15.3	9.8	13.0
May 15	......	......	......	17.7	13.3	2.7	12.6	17.5	0	10.0	19.3	13.3	11.8
June 1	......	......	......	33.8	9.8	17.4	11.3	17.8	17.7	30.3	22.0	15.3	19.5
June 15	......	......	......	23.2	24.1	0	11.3	20.7	17.0	29.4	20.2	21.0	18.5
July 1	......	......	......	13.6	14.3	0	14.5	24.2	16.1	22.0	16.8	13.4	15.0
Hegari:													
April 15	......	......	......	......	......	......	......	......	7.3	33.7	17.7	0	14.7
May 1	......	......	......	......	......	......	......	......	9.4	39.1	17.5	9.5	18.9
May 15	......	......	......	......	......	......	......	......	0	0	20.4	10.0	7.6
June 1	......	......	......	......	......	......	......	......	10.9	46.9	16.1	3.6	19.4
June 15	......	......	......	......	......	......	......	......	17.9	45.5	22.5	13.4	24.8
July 1	......	......	......	......	......	......	......	......	17.7	22.5	28.1	13.0	20.3

Dates of Planting and Yields at Dalhart

Dwarf Yellow milo and Dawn kafir have been grown in date of planting experiments for a period of 12 years, 1919 through 1930. Feterita was grown from 1921 and hegari from 1927 through 1930. During the period from 1919 to 1921, inclusive, plantings were made on four different dates at 15-day intervals, beginning May 1. From 1922 to 1926 an additional planting was made on July 1. From 1927 to 1930, inclusive, plantings were made on only three dates: May 15, June 1, and June 15. The results are recorded in Table 12.

Each of the three varieties grown over a sufficient period to render the results reliable has produced the highest yield from the June 1 or the June 15 planting. The earliest and the latest dates, May 1 and July 1, produced the lowest yields in all varieties. Average yields from the May 15, the June 1, and the June 15 plantings of Dwarf Yellow milo, for the entire 12-year period, were 30.8, 34.7, and 34.0 bushels to the acre, respectively. The corresponding yields of Dawn kafir were 30.0, 30.4, and 30.4 bushels to the acre. It seems to be typical of kafir varieties to have a longer range of optimum planting date but it is true with kafir, as with milo, that yields of May 1 plantings were below those of later plantings on May 15, June 1, and June 15.

Yields of Standard feterita from the different dates of planting indicate a rather definite optimum planting date. The best yields, 29.9 and 28.4 bushels, were produced on the June 15 and the June 1 plantings. Standard feterita, on account of its early maturity, will stand late planting better than kafir or milo, but even with feterita there was a reduction in yield when planting was done as late as July 1.

The results with hegari are too fragmentary to allow conclusions to be drawn but the indications, which are supported by the behavior of the crop elsewhere, are that hegari will produce the heaviest yields when planted comparatively late. June is probably the optimum time for planting hegari.

The summer rainfall depression is not nearly so pronounced at Dalhart as at other stations and the low trough is followed more closely by a favorable rainfall peak during the first ten days in August (Fig. 3). Sorghums have produced exceptionally good yields rather consistently over a long period of years at this station, and this favorable distribution of rainfall is largely responsible for these consistent yields. There is a rather definite optimum planting time for grain sorghums at Dalhart, around the first part of June, due partially to the fact that the heading period of sorghums planted at this time coincides with a favorable rainfall period, and further to the fact that earlier plantings encounter less favorable temperature conditions due to the higher altitude of this region. For instance, the mean temperature for June at Dalhart is 72 degrees and is quite similar to the mean temperature at Chillicothe for May, 70.4 degrees (Fig. 4).

Table 12.—Dates of planting grain sorghum varieties and the yields of grain at Dalhart, 1919-1930, inclusive.

Date of planting	Grain yield, bushels to the acre												
	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	Aver.
Dwarf Yellow milo:													
May 1	42.7	34.1	39.5	25.9	15.0	22.0	20.2	25.5	......	......	......	......	28.1
May 15	45.9	39.5	32.0	17.5	8.8	20.5	23.6	26.8	35.4	47.7	40.2	32.1	30.8
June 1	57.1	25.7	35.4	*19.8	27.5	22.9	25.5	28.8	28.2	47.9	51.4	45.8	34.7
June 15	46.3	42.7	37.3	9.5	40.5	23.8	21.4	34.1	23.2	43.0	48.2	38.0	34.0
July 1	......	......	......	11.4	26.3	8.6	25.0	27.1	......	......	......	......	19.7
Dawn kafir:													
May 1	5.7	26.3	39.5	22.1	29.1	21.6	35.0	27.9	......	......	......	......	25.9
May 15	4.6	27.9	34.5	12.9	31.6	21.8	41.3	25.2	42.3	46.4	44.0	27.5	30.0
June 1	13.9	21.8	40.7	*13.0	31.8	31.8	30.4	20.7	30.7	42.9	49.1	37.7	30.4
June 15	26.4	32.1	25.7	8.9	37.0	36.4	20.0	29.8	24.8	33.8	54.3	36.0	30.4
July 1	......	......	......	0	22.1	14.3	10.5	20.0	......	......	......	......	13.4
Standard feterita:													
May 1	......	......	32.7	30.7	20.7	22.3	18.9	24.8	......	......	......	......	25.0
May 15	......	......	27.5	24.6	20.5	20.7	32.3	20.2	17.1	35.0	30.6	10.5	23.9
June 1	......	......	51.6	*29.3	26.8	21.4	32.3	21.8	15.5	26.3	40.9	18.3	28.4
June 15	......	......	27.9	18.2	36.8	25.4	29.3	18.4	26.3	35.2	51.2	30.6	29.9
July 1	......	......	......	18.2	29.8	20.4	21.6	22.7	......	......	......	......	22.5
Hegari:													
May 1	......	......	......	......	......	......	......	......	......	......	......	......	......
May 15	......	......	......	......	......	......	......	......	......	33.0	26.4	13.2	......
June 1	......	......	......	......	......	......	......	......	......	......	48.2	22.8	......
June 15	......	......	......	......	......	......	......	......	26.1	40.9	60.6	37.5	......
July 1	......	......	......	......	......	......	......	......	......	......	......	......	......

*Calculated.

Dates of Planting and Yields at Temple

The results at Temple extend over four years, 1919 to 1922. Plantings of four varieties were made at 15-day intervals, beginning with March 1 and ending with August 1. The yields are lower than are ordinarily to be expected in Central Texas due to the fact that crowded conditions on the station made it necessary to put this test on some relatively poor land. The yields resulting from the various dates of planting should be comparable, however.

Mean temperatures at Temple during March and April are only slightly higher than those at Chillicothe and Lubbock, but enough higher to allow stands to be obtained by March 1. For this 4-year period the highest yields of both grain and forage were obtained from the May 15 planting (Table 13). The yields of grain, however, vary within a narrow range of about two to three bushels to the acre from all plantings from March 1 through June 1. All of these plantings matured sometime during the month of August, the earliest plantings early in the month and the later planting close to the end of the month. Plantings made between June 15 and July 15 matured in September, and August 1 plantings of milo and feterita matured in October. Kafir, planted on August 1, failed to mature before frost. The length of growing season for plantings made after June 1 are much shorter than those of earlier plantings. Plantings made after June 15 spend their entire growing period during the months of low summer rainfall. The maturity is hastened by the high temperatures and plants and heads are small.

The month of May appears to be the optimum planting period for grain sorghums at Temple but not much reduction in grain yield will result from earlier planting. During the four years this experiment was conducted at Temple there was no appreciable damage from sorghum midge. Temple is, however, in the territory where the midge does occasional damage.

Forage yields of more than four tons to the acre were obtained from May and June plantings. Yields of less than two tons were made only from the March 1 and the August 1 plantings.

The fact that fairly good yields of grain result from planting over a long period, and that forage yields are comparatively good over the whole range, from March 1 to August 1, makes grain sorghums an important crop to supplement corn as a feed crop in Central Texas. Unlike corn, which has a rather limited range of optimum planting, grain sorghums may be planted with good results any time from March through June. The acreage devoted annually to grain sorghums varies to a considerable degree, depending upon crop prospects for corn and cotton, but the adaptability of grain sorghums to a wide range of planting dates makes them of importance to Central Texas.

Table 13.—Average yield of grain and forage from dates of planting grain sorghum varieties at Temple, 1919-22, inclusive.

Variety	Mar. 1	Mar. 15	April 1	April 15	May 1	May 15	June 1	June 15	July 1	July 15	Aug. 1	Aver.
	Grain yield, bushels to the acre											
Dwarf Yellow milo	10.9	10.8	11.0	12.6	10.7	13.5	10.6	9.0	8.2	5.1	2.2	9.5
Dwarf Blackhul kafir	9.6	9.8	8.7	9.6	8.8	10.4	8.9	7.3	6.8	3.2	.0	7.6
Standard Blackhul kafir	10.1	9.6	10.5	10.5	10.0	11.0	9.5	7.8	6.5	3.1	.0	8.1
Standard feterita	12.7	14.1	12.7	14.1	14.0	15.2	13.5	11.2	10.5	5.7	1.9	11.4
Average	10.8	11.1	10.7	11.7	10.9	12.5	10.6	8.8	8.0	4.3	1.0	....
	Forage yield, tons to the acre											
Dwarf Yellow milo	1.76	2.59	3.28	3.85	4.40	4.51	5.19	4.06	3.43	2.53	1.72	3.39
Dwarf Blackhul kafir	1.75	2.29	2.23	3.04	3.50	3.91	3.27	3.35	2.82	2.02	1.29	2.68
Standard Blackhul kafir	2.03	3.05	3.02	4.00	3.90	4.05	3.78	4.19	3.21	2.09	1.45	3.16
Standard feterita	2.20	3.71	4.57	4.55	5.43	5.03	4.72	4.56	4.12	3.23	1.91	4.00
Average	1.94	2.91	3.28	3.86	4.31	4.38	4.24	4.04	3.40	2.47	1.59	....

Date of Planting and Yields at Beeville

Temperature conditions at Beeville allow a longer range of planting date of grain sorghums than that at any other station from which results are reported here. However, damage from the sorghum midge is likely to be severe on any planting that heads in late June and July and the range of planting date is automatically shortened.

Six varieties of grain sorghums were planted on four dates during the years 1925 to 1929 (Table 14). Dwarf Yellow milo produced its highest grain yield of 13.5 bushels on the April 1 planting, but the yield of 6.7 bushels on the March 10 date is partially due to excessive bird damage to the plats that would not be encountered in large fields. Very low yields of 1.1 bushels were made from the late April and May plantings.

The response of Texas Blackhul kafir and Shallu to the different dates of planting are quite similar. Highest yields of 20.2 and 20.0 bushels were made by kafir and Shallu on the March 10 date of planting while yields for the April 1 date were 16.9 and 16.3 bushels to the acre. Late April and May plantings produced much lower grain yields.

Table 14.—Average yields of grain and forage from dates of planting grain sorghum varieties at Beeville, 1925-29, inclusive.

Variety	Grain yield, bushels to the acre			
	Mar. 10	April 1	April 20	May 19
Dwarf Yellow milo	6.7	13.5	1.1	1.1
Texas Blackhul kafir	20.2	16.9	6.9	1.0
Spur feterita	10.8	11.8	6.5	.4
Hegari	5.5	14.4	11.7	7.4
Shallu	20.0	16.3	9.8	5.4
Darso	21.2	20.6	7.3	2.7
Average	14.1	15.6	7.2	3.0
	Forage yield, tons to the acre			
Dwarf Yellow milo	1.57	2.24	1.46	2.61
Texas Blackhul kafir	3.34	3.31	2.83	2.85
Spur feterita	2.26	3.04	3.48	3.03
Hegari	2.20	3.65	2.76	4.00
Shallu	2.31	2.88	2.71	2.17
Darso	3.62	3.74	2.38	2.33
Average	2.55	3.14	2.60	2.83

Spur feterita is subject to excessive damage by birds and the grain yields are lower with respect to the other varieties than they should be. Like Texas Blackhul kafir and Shallu, the highest grain yields resulted from the March and early April plantings.

Grain yields of Darso were higher in the March and early April plantings, being 21.2 and 20.6 bushels to the acre, while the late April and May plantings yielded 7.3 and 2.7 bushels to the acre.

Hegari responds to late planting better than other varieties, the best yields of 14.4 and 11.7 bushels to the acre being produced from plantings on April 1st and 20th. The low yield of the March plantings, 5.5 bushels, is due partially to damage from birds. Hegari has become very popular throughout this section because it produces good yields of grain and forage over a wide range of planting dates. It is often planted in August after the fall rains begin and when planted late or used as a catch crop produces good yields of grain and forage.

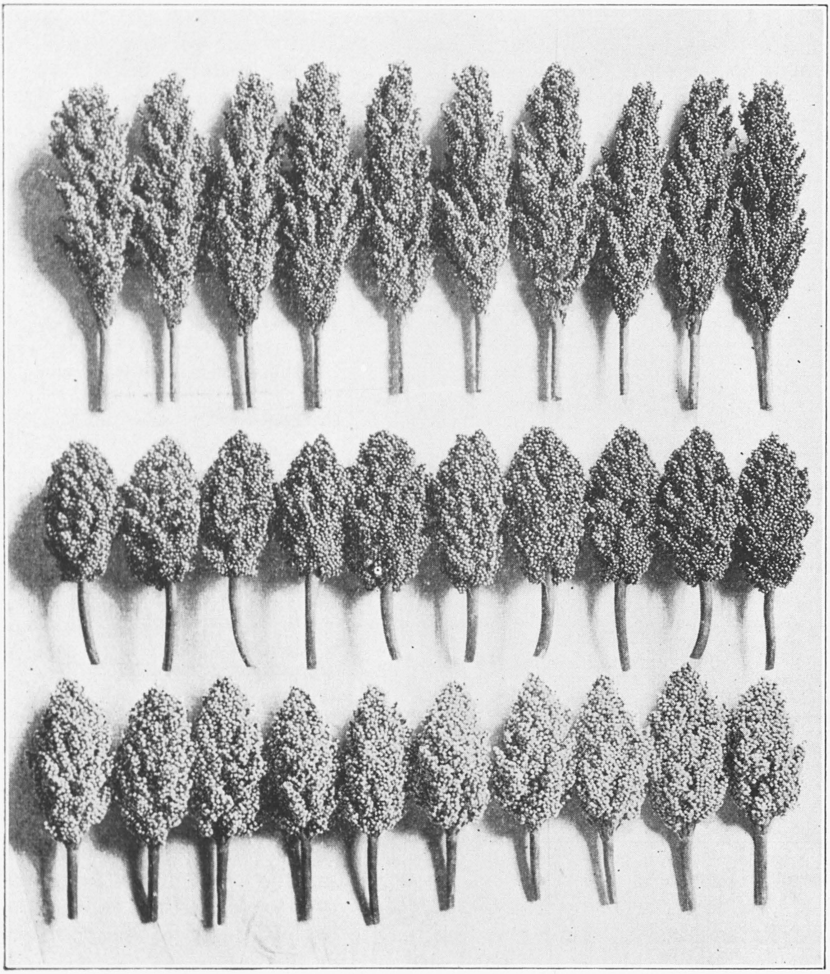

Fig. 5. Typical heads of Dwarf Blackhul kafir, Dwarf Yellow milo, and Spur feterita from late planting at the Lubbock station. Three of the best varieties of grain sorghum for Texas.

There is no consistent increase in forage yield with later planting because plantings made about April 1 or earlier will frequently produce two crops when later plantings do not. The average for all varieties shows April 1 to be the best planting date. The forage yield for all varieties shows April 1 to be the best planting date. The forage yield for all varieties, when planted March 10, April 1, April 20, and May 19 average 2.55, 3.14, 2.60, and 2.83 tons to the acre, respectively. The results at Beeville show a greater difference in response of varieties to date of planting than at any other station and the indications are that all varieties should be planted before April 10, but that hegari can stand plantings up to May 1 better than other varieties.

Summary: Effects of Time of Planting Upon Yield

Grain sorghums are not greatly restricted in their date of planting requirements. The crop responds well to the climatic conditions of Texas during the entire growing season, except in the very early spring. This wide adaptability in time of planting grain sorghums increases their usefulness and allows for an organization of farm work so that planting, cultivation, and harvesting of the feed crop will not materially interfere with other farm enterprises. In those sections of the state where sorghums are grown as a feed crop to supplement corn, the wide range of possible planting time and the consistent yields of grain and forage over the wide range makes sorghums particularly valuable for use when prospects for corn production are poor.

Although sorghums produce well when planted over a wide range, they have a rather definite optimum time of planting in the different sorghum-producing regions in the State (Table 15). The principal limiting factors governing time of planting are temperature conditions and the distribution of summer rainfall. The additional factor of midge damage exists in the sorghum midge area.

Dwarf Yellow milo has produced highest yields of grain from June 15 planting at Lubbock, Spur, Big Spring, and Dalhart; from May 15 planting at Chillicothe and Temple; and from April 1 planting at Beeville. Dwarf Blackhul kafir has produced highest grain yields from May 15 planting at Lubbock, Chillicothe, Spur, and Temple; from June 15 planting at Big Spring and Dalhart; and from March planting at Beeville. Feterita has produced highest yields of grain from May 15 planting at Chillicothe and Temple; from June 15 planting at Lubbock, Spur, Big Spring, and Dalhart; and from April 1 planting at Beeville. Hegari, while not grown at all stations for periods long enough to give comparable results, produces well from reasonably late planting. Highest grain yields of hegari were produced from June 15 plantings at Big Spring.

In West Texas, forage yields are increased and better quality of forage is produced from the later plantings. At Chillicothe, June 15 plantings returned the highest yield. At Temple, forage yields were highest from May 15 plantings. At Beeville, the forage yields were not in favor of any particular date because two crops were frequently made from early plantings.

Table 15.—Summary: Effects of different dates of planting on yield of grain sorghum varieties at Lubbock, Chillicothe, Spur, Big Spring, Dalhart, Temple, and Beeville.

	Grain yield, bushels to the acre					
	Mar. 15	April 1	April 15	May 15	June 15	July 1
Lubbock:						
Dwarf Yellow milo	....	....	21.1	27.4	27.5	....
Dwarf Blackhul kafir	....	....	18.1	21.0	20.3	....
Spur feterita	....	....	20.4	25.0	23.7	....
Average	....	....	19.9	24.5	23.8	....
Chillicothe:*						
Dwarf Yellow milo	....	16.4	18.3	20.8	19.5	....
Dwarf Blackhul kafir	....	17.0	18.5	21.0	20.8	....
Feterita	....	17.6	19.0	22.2	18.3	....
Average	....	17.0	18.6	21.3	19.5	....
Spur:*						
Dwarf Yellow milo	....	....	19.5	28.8	30.2	22.7
Blackhul kafir	....	....	22.0	32.3	25.6	19.3
Feterita	....	....	20.3	34.2	35.7	30.6
Average	....	....	20.6	31.8	30.5	24.2
Big Spring:						
Dwarf Yellow milo	....	....	12.4	18.8	27.8	21.0
Dawn kafir	....	....	10.3	14.2	18.0	13.5
Standard feterita	....	....	6.9	11.8	18.5	15.0
Hegari	....	....	14.2	7.4	24.1	19.8
Average	....	....	11.0	13.1	22.1	17.3
Dalhart:						
Dwarf Yellow milo	....	....	....	30.8	34.0	19.7
Dawn kafir	....	....	....	30.0	30.4	13.4
Standard feterita	....	....	....	23.9	29.9	22.5
Average	....	....	....	28.2	31.4	18.5
Temple:						
Dwarf Yellow milo	10.8	11.0	12.6	13.5	9.0	8.2
Dwarf Blackhul kafir	9.8	8.7	9.6	10.4	7.3	6.8
Standard feterita	14.1	12.7	14.1	15.2	11.2	10.5
Average	11.6	10.8	12.1	13.0	9.2	8.5
Beeville:						
Dwarf Yellow milo	6.7	13.5	1.1	1.1	....	....
Texas Blackhul kafir	20.2	16.9	6.9	1.0	....	....
Spur feterita	10.8	11.8	6.5	.4	....	....
Hegari	5.5	14.4	11.7	7.4	....	....
Average	10.8	14.2	6.6	2.5	....	....

*Yields shown June 15 are from June 1 planting at Chillicothe; at Spur yields shown under July 1 are average of July plantings.

Unfavorable temperature conditions for growth and development of grain sorghums in the early spring in West Texas prevent maturity before about the middle of August, even when planted at the earliest possible date. The distribution of summer rainfall is such that the period of least rainfall of the summer months occurs at most stations from June 20 until July 20. The yields from all western stations indicate that poor yields are likely to be produced if heading takes place during early July. Planting should be done, insofar as possible, so the crop can bridge over this depression, when the plants are young and not in a critical stage of development, and have the heading period coincide with the more favorable rainfall periods in August and September.

EXPERIMENTS ON SPACING OF PLANTS

Effects of Spacing on Different Types of Grain Sorghum

Grain sorghums are grown primarily for the grain produced, and while the stover may be of secondary importance, nevertheless it is of considerable value. The life of a grain sorghum plant may be considered as consisting of two periods: the vegetative period, the time prior to flowering; and the fruiting period, the time from pollination to maturity of the seed. The yield of forage is generally much less variable from year to year than the yield of grain because the vegetative, or forage-producing period of the crop occurs when soil-moisture is almost invariably ample, whereas the fruiting, or grain-producing, period coincides with that period of summer when the distribution of rainfall is the most uncertain.

If the production of grain is entirely dependent upon rain falling just prior to heading or about the time of flowering, and upon good soil-moisture conditions during the fruiting period, obviously grain production is more uncertain than forage production. Such a condition will exist whenever the supply of available soil-moisture is completely consumed in vegetative growth. Grain sorghum, if it is to give consistent and profitable yields of grain, therefore, must enter the fruiting period with a supply of available soil-moisture sufficient to produce good heads, or a timely rain must intervene about heading time. Close spacing of plants results in early depletion of the available soil-moisture and a fair yield of stover may be produced at the expense of grain production. Too wide a spacing, on the other hand, makes it impossible for the plants to use all of the available soil-moisture in seasons when late summer rainfall is ample, and consequently, lower grain yields are obtained than from thicker spacing. Varieties differ in their growth habits with regard to the number of suckers produced, and consequently, the number of stalks per unit of land and not the number of plants per unit of land is the important factor in grain production. Varieties, therefore, differ in their plant-spacing requirements, depending on their tillering habits. The important grain sorghum varieties may be grouped according to their tillering habits. The milos and hegari sucker freely; feterita somewhat less, but depending upon the variety; and the kafirs but little (Fig. 6).

In sections where the sorghum midge is prevalent, the highest yields result from close spacing, which suppresses suckering and causes the most uniform heading and flowering. The western half of Texas, which

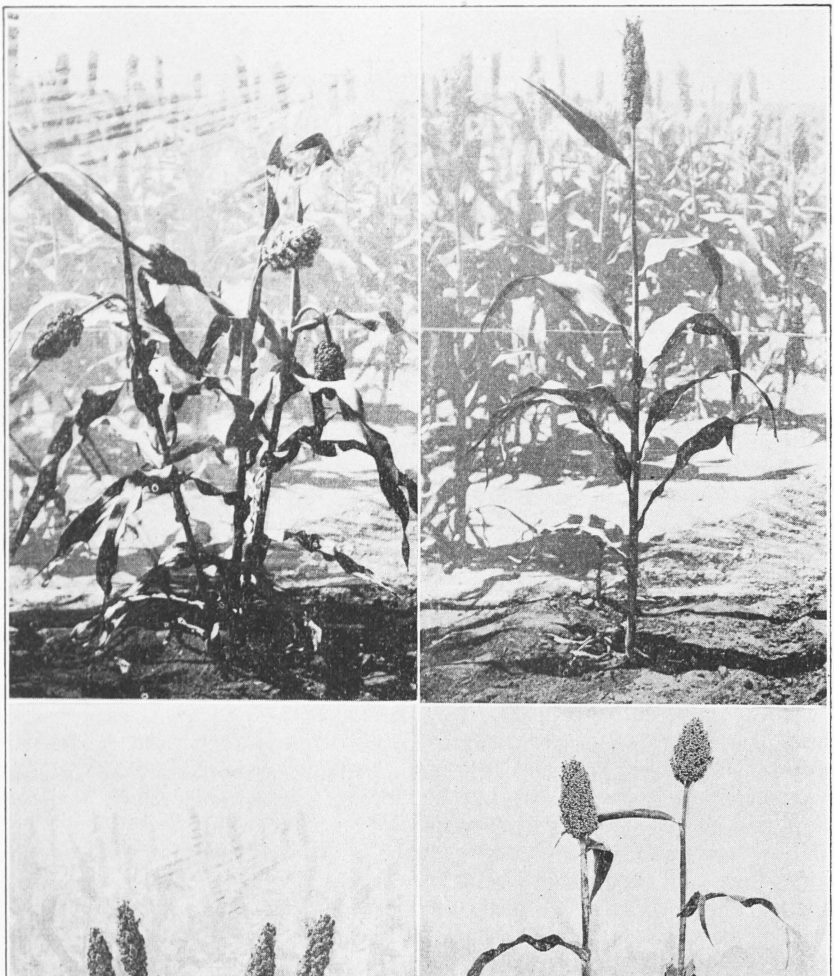

Fig. 6. Plants of Dwarf milo and Texas Blackhul kafir (above) and hegari and Spur feterita (below) grown at the Chillicothe station, 1927, showing tillering habits of the varieties.

comprises the major grain sorghum area, is free from the sorghum midge, and in the central part of the State midge damage is usually inconsequential. However, in the southern and eastern parts of the State spacing of plants of grain sorghums should be considered in connection with evasion of midge damage.

In order to determine the general effects of spacing on tillering habits, grain yields, forage yields, size of heads, amount of recurving, shelling percentage, and other characteristics, an experiment, including the two most important varieties of grain sorghum, kafir and milo, was conducted at Lubbock from 1916 to 1925. The experiment was planned to include, by 3-inch intervals, each variation lying between a minimum of 3 inches and a maximum of 36 inches in the row. Data on the average yield of Dwarf Yellow milo and Dwarf Blackhul kafir for each of the 12 rates of planting involved are shown for the 10-year period (Table 16). During this time the records were continuous and unbroken, except for three seasons in milo and one in kafir when a poor stand was obtained on the plats having a 3-inch spacing between plants. Average per cent of stand obtained for the various spacings are shown in Table 19. When calculated on a percentage basis, stands have averaged 98 per cent perfect for milo and 99 per cent for kafir.

Table 16.—Spacing of milo and kafir plants in the row and the annual and the average yields of grain at Lubbock, 1916-25, inclusive.

Distance between plants	Grain yield, bushels to the acre										
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Aver.
Dwarf Yellow milo:											
3	21.8	*7.2	.4	30.4	36.6	35.8	*23.3	19.2	11.0	*16.8	20.3
6	24.0	7.5	.9	30.9	39.9	34.6	24.6	17.1	12.4	17.3	20.9
9	24.1	8.7	.7	21.8	44.6	33.5	24.3	25.1	15.7	17.8	21.6
12	25.4	9.0	1.0	25.2	46.8	36.8	28.5	24.0	17.5	19.3	23.4
15	28.1	11.7	3.5	29.6	39.3	32.6	25.5	25.4	17.3	18.8	23.2
18	32.2	11.4	2.6	40.4	42.8	40.2	28.8	29.8	19.6	17.0	26.5
21	27.7	11.6	4.8	40.2	42.8	38.1	27.9	29.3	22.2	18.4	26.3
24	30.2	12.0	3.7	31.3	46.2	38.3	30.7	29.8	21.8	18.9	26.3
27	33.9	11.1	5.0	31.1	49.7	39.4	29.1	26.6	21.6	17.1	26.5
30	27.5	11.9	4.5	27.8	48.7	39.3	30.2	31.1	19.3	19.0	25.9
33	24.9	12.4	6.8	31.9	52.1	41.3	31.0	27.3	17.3	18.1	26.3
36	23.8	10.9	10.1	26.0	52.6	35.6	28.3	28.3	19.8	21.2	25.7
Average	27.0	10.5	3.7	30.6	45.2	37.1	27.7	26.1	18.0	18.3	24.4
Dwarf Blackhul kafir:											
3	15.3	*7.2	14.3	39.3	57.8	45.3	16.0	21.5	7.5	31.3	25.6
6	24.9	7.2	13.3	41.3	49.9	46.5	19.6	24.5	8.1	20.0	25.5
9	20.8	7.0	13.1	40.7	47.9	38.0	19.6	26.1	10.4	17.6	24.1
12	20.9	7.4	16.1	37.0	45.8	38.0	17.8	19.7	9.5	19.3	23.2
15	18.7	9.7	14.3	32.6	41.0	37.6	20.1	22.8	12.8	17.6	22.7
18	19.5	9.6	12.8	33.5	40.9	43.2	19.8	21.2	12.6	17.1	23.0
21	18.9	11.8	12.5	32.0	35.4	34.8	19.6	23.2	12.0	16.8	21.7
24	18.5	11.7	10.9	31.7	33.8	35.4	19.8	20.2	13.2	17.3	21.3
27	15.6	11.7	11.2	33.4	31.4	36.2	18.3	20.8	12.0	16.3	20.7
30	16.9	13.8	10.5	38.3	32.0	37.9	19.6	22.6	13.4	19.2	22.4
33	16.1	14.9	11.3	35.2	33.4	33.2	17.5	27.6	13.9	16.4	22.0
36	15.7	14.7	11.3	38.0	32.6	31.0	20.0	16.6	14.1	19.6	21.4
Average	18.5	10.6	12.6	36.1	40.2	38.1	19.0	22.2	11.6	19.0	22.8

*Calculated.

Effects on Tillering and Grain Yield

The spacing treatments varied by 3-inch intervals, with close spacing of 3 inches between plants and a wide spacing of 36 inches as the two extremes. During most seasons these two limits were sufficiently wide to include the optimum somewhere between the extremes. However, in very dry years, such as 1917 and 1924, the maximum yields were made by the plats having the widest spacing and perhaps higher yields would have followed still wider spacing. Poor stands in the plats with 3-inch spacings rendered the yields unreliable for kafir in 1917 and for milo in 1917, 1922, and 1925; so these actual yields were discarded and calculated yields substituted.

Kafir and milo have directly opposite reactions to wide spacing and narrow spacing of plants in the row, as may be seen by referring to Table 17 and the accompanying graphs. The yield of kafir decreases and that of milo increases as the space between plants increases. Lowest yields of kafir, on the average, occur around the 27-inch spacing. Above this point there are slight increases in yield, due to the influence of the two years, 1917 and 1924. These two years were extremely dry, the total annual rainfall in each being below 10 inches, and as would be expected, the yields increased directly as the distance between plants increased. Favorable moisture conditions in 1919 and 1925 enabled the extremely wide spacings to compensate their lower yields through tillering, which helps to accentuate the tendency for the widest spacings in kafir to advance slightly in yield.

Yields of milo decrease rapidly, on the average, when plants in the row are spaced closer than 18 inches. Above this point, however, there is little variation, indicating that milo is not so restricted in its optimum space requirements as kafirs. Distances between 18 and 33 inches seem to be almost equally favorable and within this range the milo plant is able to make its own adjustments through tillering.

The differences between kafir and milo in response to variations in spacing may be assigned largely to their inherently different stooling habits. The milo plant approaches a determinate habit of growth when moisture is not plentiful but stools freely when fertility and moisture conditions are favorable, while kafir is indeterminate in its growth and normally not inclined to sucker freely. Milo, if planted thin enough, can, by tillering, thus adjust its own spacing distance to a remarkable degree. Apparently little advantage would be gained by striving for a definite spacing of 24 to 30 inches, for instance, but a loss in yield would have followed spacing closer than 18 inches. Viewed from this angle, stooling is an asset to the milo plant. Its range of optimum row space, 18 to 30 inches, is twice as great as the optimum range, 3 to 9 inches, for kafir. Maximum yields of milo seem less dependent upon exactness in rate of seeding than is the case with kafir and other sparsely-tillering varieties, which depend pretty largely upon a thick seeding rate for optimum yield.

Milo has yielded, as an average for 10 years, approximately 20 per

Table 17.—Comparison of linear and curvilinear relationships in kafir and milo spacing experiments at Lubbock, 1916-25.

Year	Kafir						Milo					
	Correlation coefficient, r	Sy from straight line	Correlation index, Rho	Sy from curve	Optimum		Correlation coefficient, r	Sy from straight line	Correlation index, Rho	Sy from curve	Optimum	
					Space, inches	Yield, bushels					Space, inches	Yield, bushels
1916......	—0.58 ±.13	2.21	0.64 ±.12	2.09	9	20.1	0.34 ±.17	3.31	0.83 ±.06	1.96	21	30.1
1917......	0.98 ±.01	0.62	0.98 ±.01	0.62	36	16.1	0.76 ±.09	1.52	0.93 ±.03	0.54	27	12.0
1918......	—0.78 ±.08	1.02	0.78 ±.08	1.01	3	14.5	0.92 ±.03	1.07	0.94 ±.02	0.92	36	8.6
1919......	—0.39 ±.16	3.03	0.81 ±.07	1.95	3	42.2	0.09 ±.19	5.19	0.42 ±.16	4.72	21	33.0
1920......	—0.93 ±.02	2.91	0.99 ±.01	1.30	3	56.9	0.73 ±.09	3.33	0.87 ±.05	2.41	36	52.8
1921......	—0.81 ±.07	2.67	0.81 ±.07	2.64	3	44.6	0.58 ±.13	2.14	0.61 ±.12	2.08	33	38.7
1922......	0.25 ±.18	1.21	0.50 ±.15	1.08	21	19.6	0.77 ±.08	1.44	0.84 ±.06	1.20	30	29.8
1923......	—0.22 ±.19	2.75	0.21 ±.19	2.76	3	23.4	0.76 ±.08	2.67	0.90 ±.04	1.80	27	29.4
1924......	0.90 ±.04	0.95	0.95 ±.02	0.70	36	13.8	0.72 ±.09	2.38	0.94 ±.02	1.15	24	20.9
1925......	—0.51 ±.14	3.35	0.82 ±.06	2.23	3	26.6	0.45 ±.16	1.04	0.53 ±.15	0.98	36	19.8
10 years..	—0.85 ±.06	0.83	0.92 ±.03	0.57	3	25.5	0.84 ±.06	1.15	0.90 ±.04	0.83	30	26.2

cent, or 5 bushels, more grain to the acre, when planted 18 to 36 inches in the row than when planted 3 to 9 inches.

Kafir, for the same period, has yielded 15 per cent, or approximately 4 bushels, more grain when planted 3 to 9 inches in the row than when planted over 18 inches.

Kafir at its optimum spacing of 6 inches averaged slightly under 1 bushel less per acre than milo at its optimum of an 18-inch space. There are undoubtedly genetic differences between these two varieties which give milo an advantage in adjustment commensurate with available moisture. Its ability to tiller and to compensate the spacing over a relatively wide range probably accounts for the popularity of milo in the sorghum area of the Southern Great Plains, where there is a quite variable distribution of rainfall.

Statistical Nature of the Relationship Between Spacing and Grain Yield

A clearer picture of the average trend and grouping of the yields over the range of spacing included in this experiment is shown by the graph in Fig. 7. The curve used to describe the relationship of row space per plant to yield is a second degree parabola fitted by the method of least squares. The equation to this curve is $y = a + bx + cx^2$. Actual yields are also plotted on the graph. The non-linear regression between rate of seeding and yield in kafir and milo can more readily be shown by mathematically fitting this type of curve to the data. In choosing this treatment arbitrarily and applying it to each year's data, one cannot expect, of course, that a good fit will result in all cases, but on the whole it describes the relationship better than when a linear regression is assumed. Assuming that the optimum spacing for kafir and milo lies somewhere between the limits of spacing used here, the important consideration is to determine the point at which grain yields begin to fall off with increase or decrease of distance between plants.

It is seen in Fig. 7 that kafir and milo react in an exactly opposite manner under conditions of close and wide spacing of plants in the row. The yields of milo increase steadily as the space allotted increases, but when the distance between plants has reached 30 inches, a decrease in yield follows. Yields of kafir decrease as the space increases from 6 to 27 inches, after which there is again an advance in yield. At this point the plants are apparently so thin on the ground that an appreciably greater number of tillers develop and tend to offset the decline in yield. With milo, the increase in the size of the heads, together with the increase in the number of suckers, tends to increase gradually the yield over the whole range, but the maximum effectiveness of these two forces is reached at 30 inches. In 1919, for instance, spacings of 6, 12, 18, 24, 30, and 36 inches increased progressively in the number of suckers developed, the suckers constituting 10, 21, 37, 60, 63, and 67 per cent of the total stalks, respectively.

In the majority of seasons, a straight line fits the kafir data almost as well as the parabolic curve. Just how much more closely the parabola

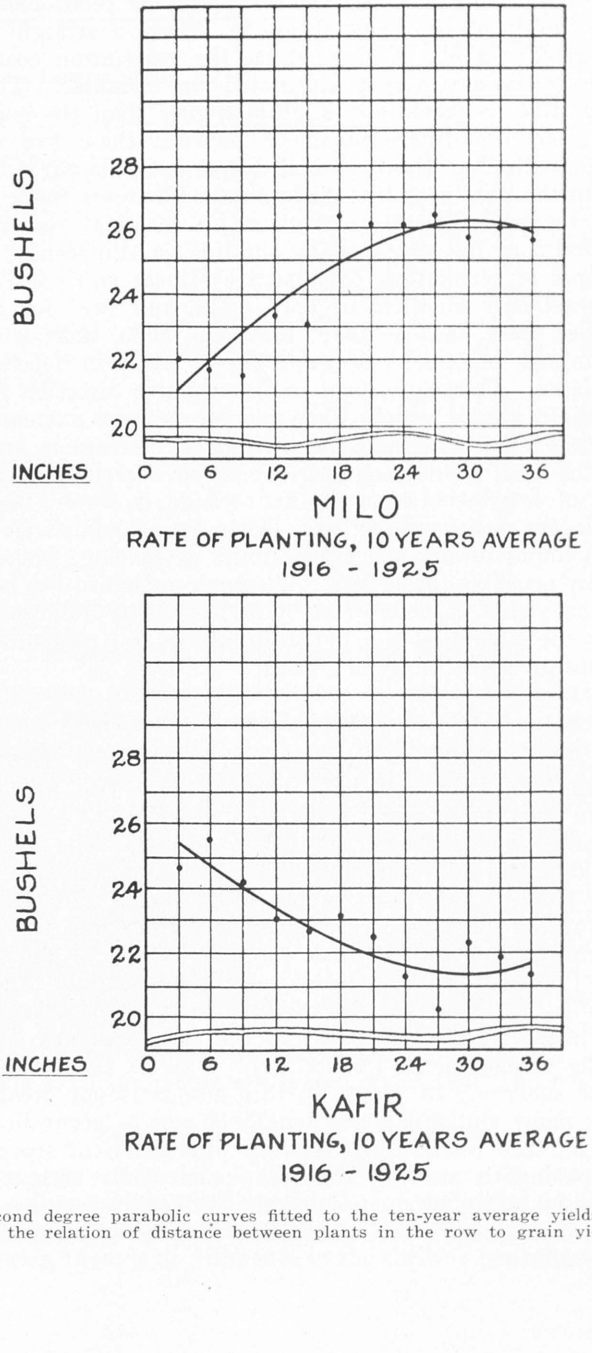

Fig. 7. Second degree parabolic curves fitted to the ten-year average yields of milo and kafir to show the relation of distance between plants in the row to grain yield.

fits each year's results than does the straight line can be seen by comparing the coefficients of linear and of curvilinear relationships in Table 17. As a result of the calculations in fitting a straight line and a second degree parabola to these data, the correlation coefficients and correlation index are readily calculated by formulae. The index of correlation, Rho, is essentially slightly higher than the correlation coefficient r, but the difference shown between these two constants is mainly due to the fact that a second degree parabola curve constitutes a better fit to the data than a straight line. Wherever there is a marked difference between the two coefficients, a material reduction in the standard error, or the scatter about the line, is also seen.

Coefficients of correlation, calculated by linear and curvilinear methods, are practically identical in 1917, 1918, and 1921 for kafir, but in certain other years, such as 1919, 1922, and 1925, there is clearly non-linearity in the placement or grouping of yield in relation to space between plants. Correlation was in the negative direction in all except three years, in two of which, when the rainfall was extremely low, the yields increased almost directly with a given increase in space between plants. The milo yields each year are better described by the parabola and index of correlation than the kafir yields; however, the correlation is always in the positive direction. Optimum calculated yields for milo are always found toward the upper limits of spacing, whereas, in kafir they usually occur at the lowest. Whenever moisture has been very restricted, the yields of both crops have practically followed a straight line and in the same direction, but in seasons of fair or abundant rainfall the relationship is distinctly non-linear.

Effects of Spacing Upon Forage Yields

Greater forage yields are invariably to be expected from the thicker stands with both kafir and milo (Table 18). The first three years reported in this table were poor crop years and, consequently, the average forage yields shown are below normal. The average forage yields for kafir and milo were 1.99 and 1.70 tons to the acre. The average forage yield of kafir for spacings of 12 inches and closer was 2.33 tons and for the spacings of 27 inches and wider was 1.76 tons to the acre. Corresponding forage yields for milo were 1.73 and 1.57 tons to the acre. Plants grown with wider spacing are slightly taller and have thicker stalks but the larger size of plant in the wide spacings does not offset the larger number of stalks in the close spacings sufficiently to equalize the forage yields (Table 19). This is true even with milo because the suckering of plants in thin stands is not great enough to produce as many stalks per unit length of row as occur in the thicker stands. The true relationship between production of stover from the different spacings is partially obscured, particularly with milo, because of the unequal grain production of the different spacings. From the standpoint of roughage alone, the thicker spacings of all grain sorghums are to be preferred.

Table 18.—Spacing of milo and kafir plants in the row and the annual and average yields of forage at Lubbock, 1916-19, inclusive.

Distance between plants	Forage yields, tons to the acre				
	1916	1917	1918	1919	Average
Dwarf Yellow milo:					
3	1.68	*1.19	.82	3.50	1.80
6	2.00	1.17	.90	2.99	1.76
9	2.06	1.14	.78	3.03	1.75
12	1.95	1.16	.88	2.47	1.62
15	2.29	1.13	.86	2.48	1.69
18	2.22	1.02	.70	3.58	1.88
21	2.34	.99	.72	3.59	1.91
24	2.22	1.01	.63	2.85	1.68
27	2.44	.86	.75	2.50	1.64
30	2.04	.88	.68	2.40	1.50
33	2.01	.94	.99	2.53	1.62
36	1.76	.90	1.15	2.27	1.52
Dwarf Blackhull kafir:					
3	2.52	.93	1.80	4.28	2.38
6	1.19	.94	3.59	4.00	2.43
9	2.61	.53	2.72	3.61	2.37
12	2.35	1.02	1.96	3.25	2.15
15	2.29	1.00	1.94	2.71	1.99
18	2.39	.97	1.68	2.87	1.98
21	2.22	.97	1.49	2.57	1.81
24	2.06	1.08	1.44	2.63	1.73
27	1.83	.99	1.35	2.60	1.69
30	1.86	1.03	1.10	3.16	1.79
33	2.00	1.14	1.18	2.82	1.79
36	1.79	1.01	1.21	3.04	1.76

*Calculated.

Effects Upon Size of Head and Recurving

There is another relationship that has an important bearing on the desired spacing. Where the crop, no matter of what variety, is to be headed by hand it is desirable, the yields being equal, to have the heads as large as possible. Wider spacing results in large heads in all varieties and the effect of plant space upon the size of the head is shown in Fig. 8. With milo, wider spacing also results in more recurved heads, due to the mechanics of recurving, but recurved heads are more difficult to harvest, either by machinery or by hand. A large head of milo breaks out through the leaf sheath as it is coming out of the boot and the weight of the head on the unsupported soft and growing peduncle causes a recurved peduncle, or "gooseneck" as it is commonly termed. The per cent of erect, inclined, and pendent heads resulting from the different spacings with milo is shown in Table 19. The data show that there is no appreciable difference in the percentage of either the inclined or pendent heads until the plants are spaced wider than 12 inches apart.

Effects Upon Shelling Percentages

The shelling percentage data in Table 19 represents the average of each of the 12 spacings for both kafir and milo for the entire 10-year period. While the size of the head increases almost directly as the space between plants increases, there is no difference in the shelling per cent of the heads

Table 19.—Spacing of milo and kafir plants in the row and its influence on height and diameter of plant, shelling percentage, recurving, and yields of grain and forage at Lubbock, 1916-25, inclusive.

Distance between plants, inches	Height at maturity, inches	Diameter of stalk, centimeters	Shelling per cent	Per cent stand	Average acre yields		Per cent of heads		
					Grain, bushels	Forage, tons	Erect	Inclined	Pendent
Dwarf Yellow milo:									
3	34	1.18	67	89	20.3	1.80	67	30	3
6	37	1.25	70	93	20.9	1.76	75	23	2
9	37	1.27	73	97	21.6	1.75	62	30	8
12	42	1.33	67	98	23.4	1.62	90	7	3
15	38	1.33	71	100	23.2	1.69	67	20	13
18	39	1.36	71	100	26.5	1.88	60	28	12
21	39	1.41	69	100	26.3	1.91	58	27	15
24	39	1.45	70	100	26.3	1.68	60	22	18
27	38	1.41	71	100	26.5	1.64	65	25	10
30	38	1.45	69	100	25.9	1.50	58	30	12
33	38	1.47	72	100	26.3	1.62	40	40	20
36	38	1.53	70	100	25.7	1.52	42	33	25
Dwarf Blackhul kafir:									
3	42	1.28	74	97	25.6	2.38	...	...	...
6	40	1.32	72	99	25.5	2.43	...	...	...
9	40	1.49	75	100	24.1	2.37	...	...	...
12	41	1.55	75	97	23.2	2.15	...	...	...
15	42	1.60	76	100	22.7	1.99	...	...	...
18	42	1.73	75	100	23.0	1.98	...	...	...
21	41	1.71	75	100	21.7	1.81	...	...	...
24	42	1.75	75	100	21.3	1.73	...	...	...
27	42	1.79	75	100	20.7	1.69	...	...	...
30	43	1.80	75	100	22.4	1.79	...	...	...
33	44	1.89	74	100	22.0	1.79	...	...	...
36	42	1.90	75	100	21.4	1.76	...	...	...

produced, whether they be from close- or wide-spaced plants, or whether the heads be small or large. Kafir and milo had average shelling per cents of 74.6 and 70, respectively, for the 10-year period. It is a fact that milo grain does not thresh out of the head as well as kafir grain and this may account for the lower threshing per cent of milo, but incomplete threshing of grain from the head is characteristic of milo.

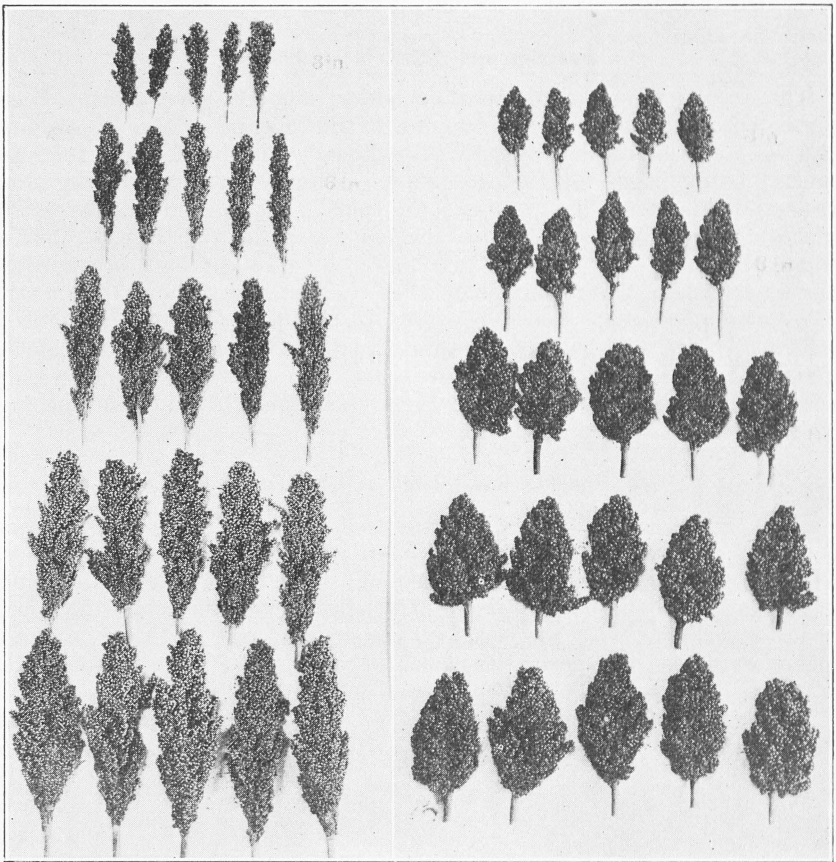

Fig. 8. Dwarf Blackhul kafir heads (left) and Dwarf Yellow milo heads (right) from plants spaced 3, 6, 9, 15, and 27 inches apart in the row at Lubbock, 1925. Increasing the space between plants increases the size of the head but the best yields of kafir are produced from the closer spacing. Milo yields increase as the space between plants increases (Table 16).

Spacing of Plants and the Effect Upon Yield in Various Regions

The preceding discussion has dealt with the general effects of spacing on two distinct types of grain sorghum, kafir and milo. The principles involved in the effects of spacing are similar for other varieties and are undoubtedly applicable to other regions. For example, kafir, or any non-tillering type of sorghum, will probably require closer spacing to produce maximum yields than does milo, no matter where the crops are grown. From the practical standpoint, however, it is desirable to know exactly the spacing which will produce the highest yield of grain in a given locality. This information is available from experiments in spacing conducted at six different stations in Texas. The results are presented in detail for each station in the following pages:

Spacing and Yields at Lubbock

The results of spacing experiments at Lubbock have already been presented in the preceding discussion of the general effects of spacing and only a brief resume need be given here. The reader may refer to the preceding pages for further details. Two types of grain sorghum, kafir and milo, were included and the spacing was varied from 3 to 36 inches for both. The optimum spacing for kafir was 3 to 9 inches. When planted at this distance kafir has yielded 15 per cent, or approximately 4 bushels, more grain than when the distance was over 18 inches. The optimum spacing for milo proved to be 18 to 36 inches. Planted at this distance milo has yielded approximately 20 per cent, or 5 bushels, more grain than when thickly planted, 3 to 9 inches. The annual yields and the average yields of grain of these two crops with different spacing distances are shown in Table 16.

Spacing and Yields at Chillicothe

Early results with spacing of milo and kafir at Chillicothe cover a period of five years. The spacings used were 4, 8, 12, and 16 inches. This range of spacings is not great enough to show the effect of spacing upon the yield of milo but a later plant-spacing test of milo is included in an experiment with row spacing, and in that test 6, 12, 18, and 24 inches were used and cover the period of years, 1924 to 1930, inclusive, excepting 1928 when the milo crop was destroyed by chinch bugs.

The results of spacing in the early years are shown in Table 20 and those with milo plant-spacing in the width of row test are shown in Table 26.

The average grain yields of kafir from the 4-, 8-, 12-, and 16-inch spacings for the early period of years were 19.4, 23.7, 21.2, and 20.0, respectively. About 8 inches appears to be the proper spacing for kafir.

The average grain yields of milo from the 4-, 8-, 12-, and 16-inch spacings from this early test are not significantly different. In the later test, the grain yields in normal rows for 6, 12, 18, and 24 inches were 26.0, 28.8, 24.5, and 27.0 bushels to the acre, respectively. Small differences in yield should not be considered significant because in several years during which the experiment was conducted the chinch-bug damage was severe and was unequally distributed over the plats. No significant reduct'on in grain yield resulted from spacing as wide as 24 inches, and considering the results with plant spacing in wider rows, also shown in Table 26, the indications are that spacing 12 to 24 inches in the row will return greater yields than spacing 6 inches.

From the standpoint of forage yields, the results at Chillicothe conform exactly to those at Lubbock. Close spacing resulted in higher forage yield than wide spacing. With kafir the average forage yields from the 4-, 8-, 12-, and 16-inch spacings were 4.04, 3.68, 3.66, and 2.98 tons to the acre, respectively. The corresponding yields of milo were 3.44, 3.03, 2.89, and 2.69 tons to the acre.

Table 20.—Spacing of milo and kafir plants in the row and the yields of grain and forage at Chillicothe.

Distance between plants	Grain yield, bushels to the acre					
	1907	1908	1914	1915	1917	Average
Blackhul kafir:						
4 inches	*25.7	27.1	6.8	26.4	11.2	19.4
8 inches	31.3	31.3	10.4	28.6	16.8	23.7
12 inches	29.8	27.7	10.7	27.9	9.8	21.2
16 inches	30.0	29.6	12.1	21.4	7.0	20.0
Dwarf Yellow milo:						
4 inches	34.5	13.9	23.8	30.0	6.1	21.7
8 inches	31.8	23.4	19.3	26.4	5.1	21.2
12 inches	26.1	29.7	21.8	28.6	2.5	21.7
16 inches	31.1	17.9	21.8	27.1	6.7	20.9
	Forage yield, tons to the acre					
Blackhul kafir:						
4 inches	3.37	2.88	7.63	3.70	2.60	4.04
8 inches	3.54	2.96	6.48	3.20	2.24	3.68
12 inches	3.18	2.99	5.88	3.20	3.04	3.66
16 inches	3.13	3.13	4.45	2.30	1.87	2.98
Dwarf Yellow milo:						
4 inches	3.13	2.38	5.66	4.65	1.39	3.44
8 inches	3.02	2.45	4.49	3.89	1.30	3.03
12 inches	2.23	3.10	4.15	4.18	.82	2.89
16 inches	2.78	2.38	4.18	4.00	1.46	2.96

*Calculated.

Variations in spacing of milo plants had a marked influence upon the development or suppression of suckers. The average number of stalks to plant for a 6-year period was 1.21, 1.80, 2.42, and 2.58, respectively, for the 6-, 12-, 18-, and 24-inch spacings in normal rows (Table 26). That the number of stalks to plant increased directly as plant space increased was undoubtedly the result of the interaction of a number of factors, the most important of which were shading and the amount of moisture in the soil. When plants were crowded in the row, competition for sunlight and soil-moisture was so keen that suckers were almost entirely suppressed, and even some plants died. Only 21 suckers per 100 plants developed when the plants were 6 inches apart, 80 suckers developed when the plants were 12 inches apart, and 158 suckers developed when the plants were 24 inches apart.

The unequal suckering of milo in the various spacings had a tendency to equalize the forage yields, but since 16,583 stalks developed per acre in the 24-inch spacing and 30,722 in the 6-inch spacing, the closer spacing returned the higher yield. The forage yields produced by these two spacings were not in proportion to the number of stalks produced, because larger plants developed with the wider spacing.

Spacing and Yields at Spur

Spacing experiments with milo were conducted at Spur during the years from 1914 to 1928 with several years omitted. The test was planted in most years but when the stands were not reliable the test was abandoned for that year. Grain yields from this experiment are presented in Table 21.

Table 21.—Spacing of Dwarf Yellow milo plants in the row and the yields of grain at Spur.

Distance between plants, inches	Grain yield in bushels to the acre										
										Average	
	1914	1915	1916	1919	1920	1924	1925	1927	1928	Years grown	Excluding 1914, 15, 27
3	54.1	36.1	25.4	75.5	55.4	2.0	62.7	38.0	24.0	41.5	40.8
6	......	......	25.1	64.8	62.1	5.1	61.8	20.5	23.4	37.5	40.4
9	53.8	28.1	27.0	69.3	68.0	5.8	60.8	33.8	28.4	41.7	43.2
12	76.4	28.8	27.3	71.5	69.5	11.4	49.8	41.1	35.5	45.7	44.2
15	69.4	29.1	28.6	61.2	71.9	12.8	51.0	......	43.6	46.0	44.9
18	......	......	32.7	53.9	63.6	13.9	54.6	45.3	39.7	43.4	43.1
21	49.6	......	31.7	66.3	60.1	13.8	59.3	......	34.7	45.1	44.3
24	......	29.5	28.8	63.8	54.2	15.4	42.3	49.1	35.8	39.9	40.1
27	......	......	30.4	60.0	55.4	17.3	41.8	......	25.2	38.4	38.4
30	......	......	32.4	69.9	42.4	18.7	39.7	......	26.9	38.3	38.3
33	......	......	31.1	65.9	52.3	17.9	35.8	......	23.9	37.8	37.8
36	......	18.5	28.3	61.6	48.3	17.4	29.5	42.6	36.1	35.3	36.9

A rather wide range of spacing, from 3 to 36 inches, with 3-inch intervals, was used at Spur and the results covering this range are complete for six of the nine years reported upon. When the average yields for these six years are considered, it is seen that the 6-inch spacing produced 40.4; the 12-inch spacing, 44.2; the 18-inch spacing, 43.1; and the 24-inch spacing, 40.1 bushels to the acre. The 21-inch spacing yielded 44.3 bushels, or about the same as the 12- and 18-inch spacings. The lowest yield, 36.9 bushels, was produced from the 36-inch, or widest spacing. The difference of about one bushel between the 12- and 18-inch spacings, and a similar difference with the 21-inch spacing, is probably not significant, but the optimum spacing for milo during this period of what might be considered favorable years was apparently around 18 inches. While the results at Spur indicate the most desirable spacing of milo to be 9 to 21 inches, a somewhat smaller space per plant than the optimum space per plant at Lubbock, it will be noticed that with the exception of one year, 1924, yields shown were good to abnormally good, indicating excellent seasonal conditions. Under those circumstances close spacings would be expected to return good yields. Had more years such as 1924, or other poorer years, been included there is no doubt but that wider spacings would have returned higher yields and more nearly have substantiated the results at Lubbock.

Spacing and Yields at Big Spring

Dwarf Yellow milo and Dawn kafir have been grown with different spacings, ranging from 6 inches to 30 inches, at 6-inch intervals, in 44-inch rows, for the period of years from 1918 through 1926 (Table 22). The highest yield with milo, 24.7 bushels, resulted from a spacing of 18 inches but the yield from spacing 30 inches was only slightly lower, 24.4 bushels. The lowest yield was made by the 6-inch spacing and was 2.3 bushels below the yield of the 18-inch spacing.

Table 22.—Spacing of milo and kafir plants in the row and the annual and average yields of grain at Big Spring, 1918-1926, inclusive.

Spacing, inches.	Grain yield, bushels to the acre									
	1918	1919	1920	1921	1922	1923	1924	1925	1926	Aver.
Dwarf Yellow milo:										
6	0	46.1	41.2	20.5	32.5	43.1	8.9	8.2	1.5	22.4
12	0	37.5	41.6	29.4	33.8	36.6	11.1	12.6	3.5	22.9
18	0	60.7	39.5	24.4	31.1	35.5	13.6	12.6	4.5	24.7
24	0	63.4	25.6	27.7	28.2	32.1	12.1	12.6	6.6	23.1
30	8.0	47.6	39.8	35.9	26.1	30.9	10.0	11.6	9.4	24.4
36	9.4	......	......	......	......	......	......	......	......	......
Dawn kafir:										
6	1.0	46.8	43.9	15.9	21.1	23.3	.3	17.7	28.6	22.1
12	1.3	32.7	21.6	21.6	19.3	20.4	5.6	15.3	28.1	18.4
18	2.7	31.4	26.3	15.0	15.2	18.8	7.2	15.8	24.4	17.4
24	4.0	27.3	27.0	17.9	13.6	16.3	4.9	14.5	21.4	16.3
30	4.9	20.4	34.3	12.6	10.5	15.8	8.3	12.3	19.3	15.4
36	4.5	......	......	......	......	......	......	......	......	......

The yields of kafir decreased consistently as space per plant increased. The highest yield of 22.1 bushels was produced by the 6-inch spacing and the lowest, 15.4 bushels, by the 30-inch spacing. As at Lubbock, an adverse season caused the largest yields to be made on the wider spaced plats.

These results, for both kafir and milo, are in exact agreement with those at the Lubbock station except that at Big Spring there is not as great a reduction in the yield of milo, on account of close spacing. Average yields for the wider spacings were approximately two bushels above the yields of close spacings. The reason the wider spacing showed a smaller increase in yield at Big Spring than at Lubbock was that the experiment was conducted in 44-inch rows at the former and in 36-inch rows at the latter station.

While the response of kafir and milo to plant-spacing shows that, on the average, kafir is more productive when spaced about 6 inches and milo more productive when spaced 18 to 30 inches, during individual seasons the results are the reverse of the average yields for the period. This same condition exists at all other stations and indicates the similarity of growing conditions over a large area represented by the five stations and to a consistent reaction of varieties to spacing and soil-moisture conditions.

Spacing and Yields at Dalhart

Dwarf Yellow milo and Dawn kafir were grown with different spacings within the row at Dalhart from 1919 to 1926, inclusive. The spacings used were 6, 12, 18, 24, and 30 inches in 44-inch rows (Table 23).

Table 23.—Spacing of milo and kafir plants in the row and the annual and average yields of grain at Dalhart, 1919-1926, inclusive.

Spacing, inches	Grain yield, bushels to the acre								
	1919	1920	1921	1922	1923	1924	1925	1926	Aver.
Dwarf Yellow milo:									
6	54.5	30.1	38.9	8.5	26.6	33.2	35.9	38.0	33.2
12	53.6	27.9	38.9	12.5	31.6	31.3	21.8	42.0	32.5
18	54.3	25.2	34.3	11.8	31.6	30.4	22.0	38.8	31.1
24	52.9	28.4	31.3	11.2	31.4	23.4	24.8	39.3	30.3
30	50.5	35.7	......	......	......	......	......	......	......
Dawn kafir:									
6	26.5	39.1	33.6	0	23.2	44.3	48.4	30.7	30.7
12	28.0	27.9	30.4	6.7	25.0	38.8	47.7	28.2	29.1
18	32.7	24.3	33.9	8.3	24.3	33.0	42.1	25.4	28.0
24	33.9	21.0	27.1	11.2	27.7	29.6	38.6	26.8	27.0
30	21.7	20.8	......	......	......	......	......	......	......

The Dwarf Yellow milo average yields decreased as the space per plant increased. The highest yield of 33.2 bushels was made by the 6-inch spacing and the lowest yield of 30.3 bushels was made by the 24-inch spacing. However, a difference in yield of less than one bushel between the 6-inch and 12-inch spacings cannot be considered significant and were it not for the unexplainable high yield of the 6-inch spacing in 1925, the 12-inch spacing would have produced the highest average yield. The row width at Dalhart was 44 inches and it would be expected that larger yields of milo would result from thicker spacings if the rows are widened. In addition, planting thicker in 44-inch rows so as to have the same number of plants to the acre as in 36-inch rows will produce fewer suckers. Also, on sandy soils and at the higher altitude of Dalhart milo plants grow more spindling and have a tendency to produce fewer suckers. These factors, therefore, would tend to produce unlike results with milo at Lubbock and Dalhart. When understood, however, there is no disagreement in results at the two stations but apparently for optimum yields milo should be spaced at least six inches closer in the row under conditions such as prevail in the Dalhart region.

Over the period of years, as at other stations, Dawn kafir yields decreased with wider spacing, but in occasional individual years wide spacing induced greater yield. These results are explained on the same basis as those at Lubbock. The average yield of Dawn kafir in the 6-inch spacing is 30.7 bushels and the yields show a gradual decline to 27.0

bushels for the 24-inch spacing, a difference of 3.7 bushels for these extremes in spacings.

In the dry year of 1922, 6 inches proved to be too close for kafir but in 1920 this same close spacing yielded 11 bushels more than any other spacing. The average difference in yield between the 6- and 12-inch spacing is only 1.6 bushels but the same trend and relationship prevails throughout all spacings involved. This difference is, therefore, considered to be a real one and to indicate that 6 inches is as wide as kafir should be spaced in the row for best results.

Summary: Effect of Spacing of Plants on Yield

A summary of the results with plant spacing of Dwarf Yellow milo and Dwarf Blackhul kafir is presented in Table 24. The average yields of milo and kafir from all stations where spacing experiments have been conducted show kafir to be more restricted in its spacing requirements than milo. Milo has the ability to sucker when conditions are favorable for tillering and spacings as wide as 30 inches are not incompatible with high production. Kafir, on the other hand, tillers but little under any circumstances and it is important that stands average about 6 to 8 inches if best production of grain is to be expected (Fig. 9). As an average of all stations, a reduction of approximately 4 bushels resulted from spacing kafir 24 inches instead of 6 inches. With milo the difference in favor of the wide spacing over the close spacing amounts to approximately two bushels but there is some variation from station to station. The greatest reduction in yield of milo due to very close spacing occurred at Lubbock and amounted to approximately 5 bushels.

Table 24.—Summary: The effects of different spacings of milo and kafir plants on yield at Lubbock, Chillicothe, Spur, Big Spring, and Dalhart.

Spacing, inches	Grain yield, bushels to the acre					
	Lubbock	Chillicothe	Spur	Big Spring	Dalhart	Average
Dwarf Yellow milo:						
6	20.9	26.0	40.4	22.4	33.2	28.6
12	23.4	28.8	44.2	22.9	32.5	30.4
18	26.5	24.5	43.1	24.7	31.1	30.0
24	26.3	27.0	40.1	23.1	30.3	29.4
30	25.9	....	38.3	21.4	....	29.5
Dwarf Blackhul (Dawn) kafir:						
6	25.5	23.7	....	22.1	30.7	25.5
12	23.2	21.2	....	18.4	29.1	23.0
18	23.0	20.0	....	17.4	23.0	22.1
24	21.3	....	....	16.3	27.0	21.5
30	22.4	....	....	15.4	....	18.9

The true relationship between grain yields and plant spacing of kafir and milo is undoubtedly the result of the unlike tillering habits of the two varieties. Results in keeping with these for other varieties may be expected, the spacing requirements being dependent upon the tillering habits. Varieties that tiller freely require greater plant space than those that tiller but little (Fig. 6).

Forage yields are not summarized but the results from Lubbock and Chillicothe are in exact agreement. The highest yields in each case were produced from close spacing with both kafir and milo with a consistent decrease as plant space was increased. From the standpoint of yields of roughage alone, close spacing of all varieties is preferable and in addition the forage produced from closely spaced plants is of better quality.

Fig. 9. Close spacing of kafir produces high yields of grain and forage. Standard Blackhul kafir 153, a pure line growing at the Lubbock station.

On the basis of these experiments it can be concluded that sparsely-tillering types, such as the kafirs, Darso, and sorghums of similar habit, including the kaoliangs, should be spaced closely, 6 to 8 inches in the row, for maximum yields of both grain and forage. Hegari and feterita tiller quite freely but as they are important forage types, they should be planted so as to allow 6 to 12 inches between plants in the row. If forage is a primary consideration, a spacing of around 6 inches is desirable. The milos are freely-tillering in habit, and as they are grown primarily for grain production for best results they should be given more row space per plant, 12 to 24 inches. When milo is spaced even as wide as 30 inches, usually no reduction in grain yield occurs.

EXPERIMENTS ON RATES OF PLANTING

Results of spacing experiments at all stations have shown conclusively that grain sorghum varieties differ in spacing requirements. Thicker stands are required with non-suckering varieties than with suckering varieties. These desired spacings are usually not obtained except by hand thinning unless unusual care is exercised in planting seed at a rate that will insure spacing of plants the desired distance apart. The tendency is to plant too much seed of tillering varieties, resulting in reduced yields of grain, and non-tillering varieties are frequently not planted thick enough. It is, therefore, important to know the rate of seeding necessary to produce stands of certain desired distances between plants when seed of good germination is planted. Milo and kafir are, respectively, typical of tillering and non-tillering varieties, and an experiment at Chillicothe was planned by Mr. H. N. Vinall of the Office of Forage Crops and Diseases to seed these two varieties at rates of 1, 2, 3, 4, and 5 pounds to the acre. This experiment was conducted from 1925 to 1930 in an attempt to correlate the quantity of seed sown with the actual stand obtained. The distances between plants resulting from these rates of seeding are shown in Table 25.

Table 25.—Rate of planting milo and kafir in 40-inch rows and the resulting space between plants at Chillicothe.

Pounds of seed to the acre	Space between plants, inches					
	1925	1926	1927	1929	1930	Average
Dwarf Yellow milo:						
1	13.7	14.8	23.3	15.2	14.5	16.3
2	7.1	7.3	10.4	7.1	7.8	7.9
3	5.2	5.8	6.3	4.2	4.5	5.2
4	3.7	4.5	4.4	3.8	3.6	4.0
5	2.7	2.3	3.6	3.0	3.0	2.9
Dwarf Blackhul kafir:						
1	11.0	9.2	12.6	14.0	14.2	12.2
2	6.1	5.6	6.4	7.4	5.8	6.3
3	3.7	2.9	4.1	4.4	4.4	3.9
4	2.7	2.2	2.8	3.5	3.5	2.9
5	2.0	1.8	1.8	2.9	2.6	2.2

Planting in each instance was made in the field in a well prepared seed bed at about the usual date of planting sorghums, using seed of good germination. The seed were planted in a shallow lister furrow. At least two plantings were made each season, but when heavy, washing rains or drying-out of the soil prevented good germination or emergence, the results are not included. For instance, in 1928 several plantings were made but no results are recorded because heavy rains and soil crusting interfered with emergence.

The planting of one pound and of two pounds of milo seed to the acre resulted in average stands of 16.3 inches and 7.9 inches between plants. When one pound and two pounds of kafir seed were planted to the acre, distances of 12.2 inches and 6.3 inches between plants were obtained.

When planted at the same rate thicker stands were obtained with kafir than with milo because kafir seed are smaller than milo seed. An actual count of good, plump seed used in 1925 showed milo to have 13,115 seed and kafir 18,154 seed to the pound.

These results indicate that if the crop is to be grown for grain the planting of one pound of milo to the acre should give an adequate stand under good conditions for germination and when good, sound seed are used. The planting of one pound of kafir is hardly sufficient but the planting of two pounds should place the plants about six inches apart, which distance spacing experiments have shown to be about the optimum for this variety.

Hegari and feterita are also two important varieties of grain sorghum. Hegari seed are about the same size as kafir seed and feterita seed are slightly larger than milo seed but both hegari and feterita have soft, starchy seed, which ofttimes germinate poorly unless soil and temperature conditions are favorable. Since both of these are also important forage varieties and should be spaced six to twelve inches in the row, hegari will require two to three pounds and feterita three to four pounds of seed to the acre, depending upon the time of planting.

GRAIN SORGHUM IN NORMAL, PAIRED, AND WIDE ROWS, AND INTERPLANTED WITH COWPEAS

The number of plants in a given area can be increased or decreased by varying the width of the row as well as by varying the plant space in normal rows. The number of plants to the acre may be reduced by one-half if the plant space in a normal row is doubled. Likewise, the number of plants to the acre may be reduced by one-half if the row space per plant remains the same and the width of row is doubled. Provided plants of grain sorghum are able to feed over a sufficiently large area, it would naturally follow that yields would be the same from rows twice the normal width if the plants in the row were spaced twice as thick. It is apparent that there may be certain advantages in planting the crop in wider rows. Any reduction in actual length of row to be traversed in planting, cultivation, and harvesting would be an advantage. Also, in sections where grain sorghum and wheat are grown in rotation, rows planted wide enough apart to allow clean cultivation of the wide middle with a disk and seeding of wheat with a drill between the rows of grain sorghum would be an advantage. Furthermore, there is some interest in growing cowpeas interplanted with grain sorghum to maintain soil fertility.

Experiments with certain phases of grain sorghum production in normal and wide rows and when interplanted with cowpeas have been conducted at Chillicothe, Lubbock, Spur, Big Spring, and Dalhart. Normal rows are those of ordinary width. Paired rows are those that result from leaving every third row unplanted. Wide rows result from leaving every other row unplanted.

Spacing of Rows and Interplanting with Cowpeas at Chillicothe

Experiments to determine the influence of growing sorghums in normal, in paired, and in wide rows upon production of grain and forage have been conducted at Chillicothe with milo, kafir, and feterita. Different spacing of plants in the row were used with all the different row widths. Milo plants were spaced 6, 12, 18, and 24 inches in normal rows; 4, 8, 12, and 16 inches in paired rows; and 3, 6, 9, and 12 inches in wide rows. These spacings per plant allowed for 26,136, 13,068, 8,712, and 6,534 plants to the acre in each of the different row spacings. Kafir and feterita plants were spaced 16 and 8 inches in normal rows, 8 and 4 inches in wide rows, and 6 inches in paired rows, allowing plants at the rate of 17,424 and 34,848 to the acre in normal and wide rows, and 34,848 to the acre in paired rows. Cowpeas were grown in alternate rows with kafir and with feterita. The plants were spaced 8 inches in the row, making 17,424 sorghum plants to the acre.

Experiments with kafir and feterita, and with these two varieties alternated in rows with cowpeas, were conducted from 1918-1922, inclusive, and those with milo from 1924-1930, inclusive, except 1928, when chinch bugs destroyed the milo crop. Chinch bugs have interfered with production of milo in each year of the experiments except in 1924. The damage has not been uniform over the total area of the tests and small differences in yield, therefore, should not be considered as having significance.

Effect of Spacing of Rows Upon Grain Yields

Grain yields appear to be slightly influenced by width of row but there seems to be no consistent difference from year to year in favor of any particular width of row. The results with milo over the period of six years are slightly in favor of paired rows over normal rows and of normal rows over wide rows (Table 26). The average grain yield for paired, normal, and wide rows, considering all spacings in the row, are, respectively, 28.0, 26.6, and 25.6 bushels to the acre.

Results with Dwarf Blackhul kafir and feterita from 1918-1922, inclusive, are shown in Table 27. Average grain yields of kafir in wide rows, normal rows, and paired rows, when spacing in each case was such as to allow 34,848 plants to the acre, were, respectively, 18.2, 17.1, and 16.0 bushels to the acre. Average grain yields of feterita, with the same number of plants to the acre for normal, wide, and paired rows, were, respectively, 27.4, 25.0, and 24.2 bushels to the acre. Inconsistent yields in individual years are responsible for the conflicting results and it seems probable, in the light of the forage yields and the yields from other stations, that grain yields of normal rows should be slightly higher than from paired rows, and yields from paired rows slightly higher than from wide rows.

Table 26.—Dwarf Yellow milo in normal, paired, and wide rows and the yields of grain and forage at Chillicothe, 1924-30, inclusive.

Manner of planting	Desired row space, inches	To the acre: Plants desired	To the acre: Actual: Plants	To the acre: Actual: Stalks	No. of stalks to plant	Grain yield, bushels to the acre: 1924	1925	1926	1927	1929	1930	Aver.	Forage yield, tons to the acre: 1924	1925	1926	1927	1929	1930	Aver.
Normal	6	26136	25291	30722	1.21	37.1	11.3	37.4	39.5	20.2	10.5	26.0	3.63	1.64	4.05	2.73	3.63	1.04	2.79
Paired	4	26136	24614	26786	1.09	33.7	13.6	38.8	38.2	23.1	11.6	26.5	2.85	1.76	3.58	2.93	2.66	1.13	2.49
Wide	3	26136	23480	23300	.99	33.2	12.5	36.0	36.4	20.2	12.3	25.1	2.81	1.76	3.02	2.04	2.24	1.11	2.16
Normal	12	13068	12993	23379	1.80	53.3	12.6	52.4	38.5	6.2	9.5	28.8	4.22	1.56	4.34	2.80	2.33	.74	2.67
Paired	8	13068	12857	19430	1.51	51.4	16.3	49.6	39.5	8.5	12.4	29.6	3.36	1.94	4.10	2.67	1.50	1.16	2.46
Wide	6	13068	12975	16999	1.31	44.5	17.6	36.9	36.3	8.5	10.7	25.8	3.38	1.90	3.36	2.43	1.50	.87	2.24
Normal	18	8712	8696	21048	2.42	42.1	9.9	39.8	41.9	3.2	10.0	24.5	3.52	1.15	3.09	2.54	1.92	.83	2.18
Paired	12	8712	8673	19093	2.20	38.3	18.8	35.0	44.2	10.4	10.8	26.3	2.77	1.85	2.57	2.49	1.97	1.01	2.11
Wide	9	8712	8439	15455	1.83	36.1	18.6	30.7	32.6	13.4	11.4	23.8	2.52	2.27	2.06	1.96	1.76	.90	1.91
Normal	24	6534	6534	16853	2.58	47.4	14.3	43.4	37.5	6.2	13.0	27.0	3.32	1.73	3.59	2.66	1.76	1.02	2.35
Paired	16	6534	6403	15185	2.37	41.3	26.7	43.1	34.3	16.9	13.8	29.4	3.03	2.70	3.44	2.17	1.94	1.11	2.40
Wide	12	6534	6534	13615	2.08	38.2	24.1	37.7	28.0	22.6	16.1	27.8	2.71	2.29	2.80	1.89	2.41	1.15	2.21

Table 27.—Dwarf Blackhul kafir and feterita with rows normal, paired, wide, and alternated with cowpeas. Yields of grain and forage at Chillicothe, 1918-22, inclusive.

Manner of planting	Row space to the plant	No. of plants to the acre	Grain yield, bushels to the acre: 1918	1919	1920	1921	1922	Aver.	Forage yield, tons to the acre: 1918	1919	1920	1921	1922	Aver.
Dwarf Blackhul kafir:														
Normal	16	17424	0	24.8	30.1	16.3	13.4	16.9	.88	2.28	2.27	1.85	1.50	1.76
Wide	8	17424	4.5	22.9	31.4	15.9	16.0	18.1	.75	2.03	2.33	1.36	1.01	1.50
Normal	8	34848	0	25.6	29.5	22.8	7.7	17.1	1.00	2.49	2.49	2.11	1.76	1.97
Wide	4	34848	0	23.3	33.1	20.1	14.5	18.2	.86	2.13	2.33	1.89	1.26	1.69
Paired	6	34848	0	*23.5	29.2	16.0	11.5	16.0	*.79	*2.04	2.34	1.32	1.36	1.57
Alternated with cowpeas	8	17424	0	16.1	30.9	11.8	4.1	12.6	.74	1.56	2.12	1.11	.97	1.30
Feterita:														
Normal	16	17424	1.8	37.2	34.7	29.1	26.4	25.8	.34	2.42	2.23	1.32	1.15	1.49
Wide	8	17424	3.3	28.9	32.8	22.1	27.9	23.0	.48	1.73	1.67	.96	.92	1.15
Normal	8	34848	1.5	39.0	37.0	30.7	28.8	27.4	.30	2.48	2.26	1.51	1.18	1.55
Wide	4	34848	2.1	31.5	35.2	30.1	25.9	25.0	.49	1.86	2.12	.98	.92	1.27
Paired	6	34848	*1.7	*34.8	35.5	20.0	28.8	24.2	*.33	*2.33	2.16	1.36	1.01	1.44
Alternated with cowpeas	8	17424	1.3	22.8	29.2	18.3	22.9	18.9	.39	1.89	1.50	.78	.89	1.09

*Calculated.

Effect of Spacing of Rows Upon Forage Yield and Tillering

There seems little doubt that early in the season, when the plant root systems are small, plants in normal rows are able to use more of the available soil moisture and plant food than plants in either paired or wide rows. This condition probably continues until the root systems occupy the entire area between the rows, at which time the plants are well along in their growth. That plants in normal rows utilize more completely the available moisture and plant food is indicated by their higher yields of forage. Forage yields from paired rows and from wide rows of milo are quite consistently lower than those from normal rows but the greatest differences occur where plants are spaced thickly in the row (Table 26). The forage yields of milo in normal, paired, and wide rows, the plants in these row widths being spaced 12, 8, and 6 inches apart, respectively, and each area having 13,068 plants to the acre, were 2.67, 2.46, and 2.24 tons to the acre. The plants in these different row spacings tillered at unequal rates and over the six-year period normal rows produced 23,379 stalks to the acre against 19,430 for the paired and 16,999 for the wide rows. The average number of stalks per plant in normal, paired, and wide rows were, respectively, 1.80, 1.51, and 1.31. The forage yields reflect the difference in number of stalks produced per acre in the various row widths. As might be expected from the results previously presented on tillering as influenced by plant spacing in the row, the largest amount of tillering also took place in this test where the plants were given the greatest space in the row. That the amount of sunlight has an important bearing upon the extent of tillering is shown by the amount of tillering that occurred on plants given equal space in the row but in different widths of row. Plants in normal rows, given a space of 6 inches, produced 21 tillers per 100 plants, and plants in wide rows, given the same space, produced 31 tillers. Corresponding figures for plants spaced 12 inches apart in the two row widths were 80 and 108 tillers per 100 plants. If the amount of tillering depended entirely upon moisture supply, plants in wide rows would have been expected to tiller enough to produce as many stalks to the acre as the narrow rows; or instead of 31 tillers, 142 tillers should have been produced, and instead of 108 tillers, 260 tillers should haye been produced. Crowding and shading appear to have a marked influence upon the amount of tillering. Since the differences in the amount of tillering in the wide and the narrow rows have been small but have been consistent from year to year, it seems likely that this small increase in tillering in the wide rows is due to the fact that the plants in the wide rows have more available soil-moisture.

Forage yields from paired rows and wide rows of kafir and feterita were consistently lower than those from normal rows (Table 27). Kafir and feterita, spaced 8 inches in normal rows, produced 1.97 and 1.55 tons to the acre; spaced 6 inches in paired rows, 1.57 and 1.44 tons; and spaced 4 inches in wide rows, 1.69 and 1.27 tons.

Alternate Rows with Cowpeas

Both grain and forage yields of kafir and feterita were lower when every alternate row was planted to cowpeas than when every row was planted to grain sorghum, or than when every second row was left blank (Table 27). With kafir and feterita spaced in such a manner to leave 17,424 plants to the acre, grain yields in normal rows were 16.9 and 25.8 bushels, as compared with 12.6 and 18.9 bushels where alternate rows were devoted to cowpeas. The corresponding forage yields of the two varieties in normal rows were 1.76 and 1.49 tons to the acre, and when alternated with cowpeas, were 1.30 and 1.09 tons to the acre.

The difference in yield of kafir in favor of normal rows over rows alternated with cowpeas was 4.3 bushels of grain and .46 ton of forage to the acre. The difference in yield of feterita in favor of normal rows was 6.9 bushels of grain and .40 ton of forage to the acre. In these experiments with kafir and feterita the introduction of a crop of cowpeas in alternate rows with these sorghums has resulted in a reduction in the yield of both grain and forage amounting to approximately 25 per cent.

Spacing of Rows at Spur

Experiments with spacing of rows were carried on at Spur with milo for eight years (Table 28). Thinning was done so that there were 9,680 plants to the acre in each of the row widths, making the space between plants 18 inches in normal rows, 12 inches in paired rows, and 9 inches in wide rows. Grain yields from normal, paired, and wide rows were, respectively, 33.7, 33.5, and 33.3 bushels to the acre. With the exception of 1914 and 1930, the yield from wide rows has consistently been lower than from normal and paired rows. The indications are that not much reduction in grain yield occurs from planting in paired rows instead of normal rows but that a slight reduction in yield may be expected ordinarily from planting in wide rows. In only two out of the eight years did wide rows produce a higher yield than normal rows. The largest difference in favor of wide rows occurred, as would be expected, in a very dry year, 1930.

Table 28.—Milo in normal, paired, and wide rows and the yields of grain at Spur.

Width of rows	Grain yield, bushels to the acre								
	1914	1915	1916	1919	1925	1926	1928	1930	Aver.
Normal	45.9	36.0	26.5	41.6	38.9	55.3	20.4	4.9	33.7
Paired	*45.4	31.8	23.8	45.4	40.2	54.1	20.9	6.1	33.5
Wide	52.5	31.0	22.2	40.1	36.8	50.3	18.6	14.8	33.3

*Calculated.

Spacing of Rows at Lubbock

The results with milo in normal rows and paired rows at Lubbock cover a period of four years, 1927-1930, inclusive. Row space per plant was the same in each width of row, making the number of plants to the acre two-thirds as great in the paired rows. The average grain yield from normal rows was 28.8 bushels to the acre while from the paired rows the yield was 26.2 bushels, a difference of 2.6 bushels in favor of the normal rows (Table 29).

Table 29.—Dwarf Yellow milo in normal and in wide rows, the effect on plant characters and on grain yield at Lubbock, 1927-30, inclusive.

Width of row	Height of plant inches	Average No. of stalks to plant	Per cent of plants having suckers	Per cent of heads		
				Erect	Inclined	Pendent
Normal (3–foot)	34	1.8	64	59	29	12
Paired	35	2.5	73	44	45	11

Width of row	Grain yield, bushels to the acre				
	1927	1928	1929	1930	Average
Normal (3–foot)	32.1	46.1	21.9	14.9	28.8
Paired	28.5	42.0	20.1	14.2	26.2

Unequal suckering of plants in the two row widths resulted in almost equal numbers of stalks to the acre. In the narrow rows 17,424 stalks per acre were produced against 16,135 stalks in the paired rows. Planting in the normal rows resulted in more erect heads and fewer inclined heads. In normal rows, 59 per cent of the heads were erect and 29 per cent inclined, while in wide rows 44 per cent were erect and 45 per cent inclined. There was no appreciable difference in the production of pendent heads.

Table 30.—Kafir, milo, and feterita grain yields in bushels, from normal, wide, and paired rows, and rows interplanted with cowpeas at Lubbock, 1913-14.

	Kafir		Milo		Feterita	
	1913	1914	1913	1914	1913	1914
3–foot rows	5.8	56.6	5.2	58.7	3.1	68.9
6–foot rows	4.2	41.2	5.4	54.7	2.6	56.3
Rows in pairs	4.2	....	4.4	....	2.3	....
Rows alternated with cowpeas	3.6	....	2.1	....	1.8	....
Rows in pairs with cowpeas	3.3	....	2.3	....	1.6	....

Some early results at Lubbock, in 1913 and 1914, with kafir, milo, and feterita show a reduction in yield due to planting in paired or wide rows (Table 30). A decrease in yield of 8.5 bushels of kafir, 6.5 bushels of feterita, and 1.9 bushels of milo resulted from growing these sorghums in wide rows instead of ordinary or narrow rows. Milo, in wide rows, has made relatively better yields than kafir or feterita because of its ability to tiller freely and more completely utilize the increased area per plant. A further reduction in yield occurred in 1913 when cowpeas were planted in every second row; also when planted in every third row.

Spacing of Rows at Big Spring

Dwarf Yellow milo and Dawn kafir were grown in normal and in wide rows for a period of three years, 1919 to 1921. Spacing in the row was such that five different numbers of plants to the acre occurred in the rows of the two widths. The spacings between plants in normal rows were 6, 12, 18, 24, and 30 inches, and one-half these distances in wide rows.

A reduction in yield almost invariably resulted from planting in the wider rows (Table 31). The highest average yield of milo, 41.5 bushels, was produced on the 18-inch spacing in normal rows while the corresponding yield in wide rows was 33.2 bushels. In 1921, when the lowest production in the three years occurred, there was, on the average, less difference in yield in favor of the normal rows than in 1919 and 1920. Disregarding the space between plants in the row, normal rows yielded, on the average, 38.7 bushels to the acre and wide rows yielded 30.8 bushels, an increase of approximately eight bushels in favor of rows of ordinary width.

Table 31.—Dwarf Yellow milo and Dawn kafir in normal and in wide rows, and the yields of grain at Big Spring, 1919-21, inclusive.

Manner of planting	Row, space, inches	Grain yield, bushels to the acre			
		1919	1920	1921	Average
Dwarf Yellow milo:					
Normal	6	46.1	41.2	20.5	35.9
Wide	3	43.4	38.5	13.1	31.7
Normal	12	37.5	41.6	29.4	36.2
Wide	6	29.6	26.4	29.3	28.4
Normal	18	60.7	39.5	24.4	41.5
Wide	9	44.3	32.0	23.4	33.2
Normal	24	63.4	25.6	27.7	38.9
Wide	12	42.5	20.5	25.7	29.6
Normal	30	47.6	39.8	35.9	41.1
Wide	15	32.8	32.8	27.3	31.0
Dawn kafir:					
Normal	6	46.8	43.9	15.9	35.5
Wide	3	39.1	30.3	14.1	27.8
Normal	12	32.7	21.6	21.6	25.3
Wide	6	26.5	23.3	16.3	22.0
Normal	18	31.4	26.3	15.0	24.2
Wide	9	28.7	23.9	12.1	21.6
Normal	24	27.3	27.0	17.9	24.1
Wide	12	21.4	24.3	15.3	20.3
Normal	30	20.4	34.3	12.6	22.4
Wide	15	22.3	26.0	13.1	20.5

The results with Dawn kafir are similar to those with Dwarf Yellow milo. Higher yields were made in normal rows than in wide rows (Table 31). The highest average grain yield of Dawn kafir, 35.5 bushels, was produced by a 6-inch spacing in normal rows. The corresponding yield with 3-inch spacing in wide rows was 27.8 bushels. The average grain yield in normal rows, disregarding space between plants, was 26.3 bushels to the acre while the average yield for wide rows was 22.4 bushels, a difference of approximately four bushels in favor of rows of ordinary width.

Spacing of Rows at Dalhart

Dawn kafir and Dwarf Yellow milo were grown in normal and in wide rows in 1919 and 1920. The plants of each variety in normal rows were spaced 6, 12, 18, 24, and 30 inches apart and in order to provide for the same number of plants to the acre in wide rows, the plants were spaced one-half as wide in each case. The results are shown in Table 32. As an average of two years, planting in wide rows resulted in decreased yields, except in one instance, that of milo with a 15-inch stand in the wide rows. With kafir, the average reduction in grain yield due to planting in wide rows amounted to approximately 7 bushels and

Table 32.—Dwarf Yellow milo and Dawn kafir in normal and in wide rows, and the yields of grain at Dalhart, 1919-1920.

Manner of planting	Row space, inches	Grain yield, bushels to the acre		
		1919	1920	Average
Dwarf Yellow milo:				
Normal	6	54.5	30.1	42.3
Wide	3	39.1	31.5	35.3
Normal	12	53.6	27.9	40.8
Wide	6	45.9	31.3	38.6
Normal	18	54.3	25.2	39.8
Wide	9	46.6	25.2	35.9
Normal	24	52.9	28.4	40.7
Wide	12	47.7	28.1	37.9
Normal	30	50.5	35.7	43.1
Wide	15	53.9	34.6	44.3
Dawn kafir:				
Normal	6	26.5	39.1	32.8
Wide	3	11.3	39.1	25.2
Normal	12	28.0	27.9	28.0
Wide	6	12.9	30.0	21.5
Normal	18	32.7	24.3	28.5
Wide	9	16.1	28.1	22.1
Normal	24	33.9	21.0	27.5
Wide	12	14.3	22.8	18.5
Normal	30	21.7	20.8	21.3
Wide	15	10.0	22.1	16.1

with milo the difference was approximately 3 bushels in favor of the normal rows. Since the normal rows at Dalhart are wider than at other stations, more extreme differences might be expected between the yields of the two row spacings.

Summary of Spacing of Rows and of Interplanting with Cowpeas

A summary of the results of experiments at all stations with different widths of row, and grain sorghum rows alternated with cowpeas, is presented in Table 33. Considering all the yields with the three varieties, Dwarf Yellow milo, Dwarf Blackhul kafir, and feterita, the results favor planting in normal rows rather than in paired rows or in wide rows. The average decrease in yield when these crops were grown in paired rows as compared with normal rows, was 1.1 bushels to the acre, and the corresponding decrease when grown in wide rows was 4.5 bushels.

The results are fairly consistent in favor of the normal rows but a smaller reduction in yield from using the wider rows occurred at Chillicothe and Spur than at Lubbock, Big Spring, and Dalhart. This smaller reduction is probably actual and is probably the result of the heavier types of soil occurring at Chillicothe and Spur.

Table 33.—Summary: Grain sorghums in normal, paired, and wide rows and alternated with cowpeas, at Chillicothe, Spur, Lubbock, Big Spring, and Dalhart.

	Grain yield, bushels to the acre						
	Normal	Paired	Wide	Alternated with cowpeas	Gain of normal rows over		
					Paired	Wide	Cowpeas
Dwarf Yellow milo:							
Chillicothe	24.5	26.3	23.8	....	—1.8	.7	....
Spur	33.7	33.5	33.3	....	.2	.4	....
Lubbock	28.8	26.2	....	....	2.6	....	....
Big Spring	41.5	....	33.2	....	....	8.3	....
Dalhart	39.8	....	35.9	....	....	3.9	....
Dwarf Blackhul kafir:							
Chillicoth	17.1	16.0	18.2	12.6	1.1	—1.1	4.5
Lubbock	31.2	....	22.7	....	....	8.5	....
Big Spring	35.5	....	27.8	....	....	7.7	....
Dalhart	32.8	....	25.2	....	....	7.6	....
Feterita:							
Chillicothe	27.4	24.2	25.0	18.9	3.2	2.4	8.5
Lubbock	36.0	....	29.5	....	....	6.5	....
Average gain	....	....	....	....	1.1	4.5	6.5

In view of the comparatively small reduction in yield resulting from the use of paired rows, particularly with milo, under certain circumstances paired rows can probably be used to advantage. If the stand obtained in normal rows is too thick, it may be advisable to destroy every third row, thus thinning out the crop and safeguarding it against a larger reduction in yield. Paired rows have an additional advantage in that the larger heads produced in paired rows are an advantage in hand harvesting. Also, if every third row is blank, only two-thirds as many rows must be given careful cultivation as when normal rows are used. This shorter length of row to be traversed may effect a considerable saving of time in planting, in cultivation, especially the first time over, and also in harvesting for both grain and forage.

As an average of the three varieties at all stations, the practice of planting in wide rows resulted in a reduction of 4.5 bushels of grain to the acre. When kafir was planted in wide rows, the average reduction in yield at all stations was 5.7 bushels. With feterita the decrease was 4.4 bushels, and with milo 3.3 bushels, a decrease chargeable to the practice of planting in wide rows. Obviously these losses are too great to withstand unless the use of wide rows is essential to fit in with some other farm practice, such as planting wheat following grain sorghum. When such a practice is followed, milo is the grain sorghum most suitable, for the reason that a smaller reduction in yield is had with this variety than with kafir or feterita when planted in wide rows. Furthermore, milo plants mature early, cease growth and draw less upon the moisture supply after the grain crop is mature.

Closer plant-spacing is necessary in the wider rows than in normal rows; else a further decrease in yield can be expected from planting in paired or wide rows.

Planting in either paired rows or wide rows instead of in normal rows produced lower forage yields of milo, kafir, and feterita (Tables 26 and 27). The forage yields are consistently in favor of normal rows over paired rows and of paired rows over wide rows. Over a period of years, when the plant spacing was about the optimum for grain production, a reduction of about 25 per cent occurred in forage yields when grain sorghums were planted in wide rows instead of normal rows.

No reliable results are available to show the reduction in yield that may be expected from growing cowpeas in every third row, or, in other words, between paired rows of sorghum. However, at Chillicothe, kafir grain yields were reduced 4.3 bushels to the acre and feterita grain yields were reduced 6.9 bushels to the acre, a decrease of about 25 per cent in each variety, as the result of growing cowpeas in alternate rows.

The practice of growing cowpeas in alternate rows with grain sorghums does not seem to be justified unless soil fertility is a limiting factor in production. Water, instead of soil fertility, is the limiting factor in most of West Texas, except on some of the very light sandy soils. If cowpeas are used as a soil-improvement crop in combination with grain sorghums on deep sandy soils, the sorghum stubble is a material aid in the control of soil blowing.

EXPERIMENTS WITH COMMERCIAL SEED DISINFECTANTS

Poor stands of grain sorghums frequently result from planting in cold or wet soil, or from too early planting, and this is particularly true of such soft-seeded varieties as feterita and hegari. Deficiencies in the stands of feterita, due to such causes, are evident in the date of planting experiments at Lubbock (Table 5). The average per cents of a perfect stand secured over an eight-year period with feterita, when planted April 15, May 15, and June 15 were 58, 68, and 94, respectively. A similar lack of perfect stands with early plantings of feterita occurred in date of planting experiments at Chillicothe. From 1926 to 1930 an experiment was conducted at Chillicothe with Spur feterita to determine the possibilities of getting better stands through the use of commercial seed disinfectants. The results are recorded in Table 34. The seed disinfectants, known commercially as Copper Carbonate, Uspulun, Bayer Dust, Semesan, Semesan Jr., and Ceresan were used. From two to three triplicated plantings in one-hundredth-acre field plats were made throughout the spring each year. In each planting the number of plants that emerged from the untreated seed was taken as 100 and the emergence from treated seeds was expressed as a percentage of that figure (34).

Table 34.—Treatment of feterita with commercial seed disinfectants at Chillicothe. Ratio of stands obtained from treated and untreated seed.

Year	Date planted	No treatment	Copper Carbonate	Uspulun	Bayer Dust	Semesan	Semesan, Jr.	Ceresan
1926	April 19	100	143	131	107	...	...	...
	June 14	100	120	133	121	...	...	...
1927	April 27	100	158	179	184	210	...	...
	May 16	100	192	164	184	211	...	...
	June 23	100	121	173	156	132	...	...
1928	April 15	100	103	104	128	135	...	...
	June 13	100	107	105	122	97	...	...
	June 22	100	97	92	104	98	...	...
1929	April 15	100	132	142	131	123	...	...
	May 22	100	151	176	175	147	...	...
	June 14	100	115	120	113	105	...	...
1930	May 8	100	103	...	...	112	110	93
	June 2	100	109	...	...	108	118	116
Average	...	100	127	138	139	134	114	105

The use of all of the seed disinfectants resulted in some increase in germination and emergence. When the stands of all treatments and plantings are compared with stands from untreated seed it is found that treatment with Uspulun, Bayer Dust, Semesan, Copper Carbonate, Semesan Jr., and Ceresan gave increases of 38, 39, 34, 27, 14, and 5 per cent, respectively; Semesan Jr. and Ceresan were used only during the last year and for this year they were about as effective as any other dust.

The better germination and emergence resulting from the use of seed disinfectants is due to the fact that these fungicides create a sterile zone on and about the seed which prevents fungi from developing.

In general, the benefits from seed treatments were more pronounced at the early planting dates when soil-temperature conditions were least favorable for good germination of untreated seed. When conditions were more favorable for germination of untreated seed, only small increases resulted from using treated seed.

Better germination and emergence was the only benefit apparent from using treated seed. There appeared to be no appreciable stimulation in growth after emergence. After the plants were four to five inches high the plats were thinned to a uniform distance of twelve inches between plants. Careful observations indicated that at no time was there any stimulation in growth and development of the crop. Grain yields were taken for three years and the yields from treated and from untreated seed were practically identical in all cases.

These seed disinfectants are inexpensive and may be used to advantage in improving the germination of sorghums in certain instances, especially when planting is done early. Also dry-dust treatments are a convenient and an effective means of treating sorghum seed for kernel smut control and where smut is prevalent this is the most important consideration in connection with the use of these compounds. Both Copper Carbonate and Ceresan are practical and economical dry dusts which can be used effectively in the control of sorghum smut. Sorghum seed should be treated with these dusts at the rate of two to three ounces to the bushel of seed and thoroughly mixed to insure a good covering of all the seed. Whenever sorghum seed infected with smut or seed of unknown origin are to be planted, they should be treated for smut.

SUMMARY AND CONCLUSIONS

Texas produces about 47 per cent of the total grain sorghum grown in the United States and also ranks high in yield per acre, averaging 25.4 bushels. Grain sorghums rank third in total production and money value among the crops grown in Texas.

Results of experiments with grain sorghum varieties planted at different dates, different spacings within the row, planted in normal, paired, and wide rows, and in rows alternated with cowpeas, and also experiments on rate of seeding sorghums and treatment of seed with commercial dusts are reported.

These experiments have been conducted for a number of years at the experiment stations at Lubbock, Chillicothe, Spur, Temple, Beeville, Big Spring, and Dalhart. A brief resume of the soil and climatic conditions, as affecting grain sorghum growth and development, is presented for each of the regions represented by these stations.

Dwarf Blackhul kafir produced the highest yields of grain from early planting, March, at Beeville; from medium early planting, May 15, at Lubbock, Chillicothe, Spur, and Temple; and from later planting, June 15, at Dalhart and Big Spring.

Dwarf Yellow milo produced the highest yield from April 1 planting at Beeville; from May 15 planting at Chillicothe and Temple; from June 15 planting at Spur, Big Spring, and Dalhart; and produced approximately the same yield at the Lubbock station when planted May 15 or June 15.

Forage yields are ordinarily increased and better quality of forage is produced from late plantings, so long as planting is done sufficiently early to bring the crop into maturity before frost.

Favorable moisture conditions at time of heading is highly associated with large yields of grain and forage. Unfavorable temperature conditions for growth and development of grain sorghums in the early spring in West Texas prevent maturity before about the middle of August, even when planted at the earliest possible date. The distribution of summer rainfall is such that the period of least rainfall of the summer months occurs at most stations from June 20 until July 20. The yields from all western stations indicate that poor yields are likely to be produced if heading takes place during early July. Planting should be done, insofar as possible, so the crop can bridge over this depression, when the plants are young and not in a critical stage of development, and have the heading period coincide with the more favorable rainfall periods in August and September.

The time of planting has an important bearing upon the length of the growth period of sorghums. Early planting results in retarded early growth with a consequent lengthening of the growth period. Dwarf Yellow milo and Spur feterita mature in approximately 125 days when planted April 15; in 100 days when planted May 15; and in 94 days when planted June 15, while Dwarf Blackhul kafir matures about 10 days later from similar dates of planting.

Good stands were more difficult to obtain on April 15 than on May or June 15 planting dates. Germination of feterita and hegari are particularly poor when planted early.

Later planting of varieties of grain sorghum results in taller, thicker plants and a larger number of suckers, indicating that better growing conditions exist in the summer and fall than in the spring and early summer.

From the results of spacing experiments with grain sorghums it is concluded that sparsely-tillering types, such as the kafirs, Darso, kaoliangs, and sorghums of similar habit, should be spaced closely, 6 to 8 inches in the row, for maximum yields of both grain and forage. Hegari and feterita tiller quite freely but are important forage types and should be planted so as to allow 6 to 12 inches between plants in the row. If forage is a primary consideration, a spacing of around 6 inches is desirable. Freely-tillering types grown primarily for grain production, such as the milos, should, for the best results, be given more row space per plant, 12 to 24 inches. When milo is spaced even as wide as 30 inches, usually no reduction in grain yield occurs.

The difference between milo and kafir in response to spacing is accounted for by marked difference in tillering habits. Milo is a profusely tillering type and kafir a sparsely tillering type. In both varieties the number of tillers increases with the distance between plants. The type of relationship between row space per plant and yield of kafir and milo is shown to be curvilinear rather than linear. In milo the correlation is in the positive direction and normally in the negative direction for kafir.

Larger forage yields of better quality may be expected from the thicker stands with both kafir and milo. Plants grown with wider spacings are slightly taller and have thicker stalks but the larger size of the plant in the wide spacings does not offset the larger number of stalks in the close spacings sufficiently to equalize the forage yields.

Where the crop is to be headed by hand it is desirable, the yields being equal, to have the heads as large as possible. Wider spacing results in larger heads in all varieties. Spacing plants of milo wider than 12 inches apart results in an increase in the number of recurved, or "gooseneck," heads produced.

While the size of the head in both milo and kafir increases almost directly as the space between plants increases, there is no difference in the shelling percentage of the heads produced, whether they be from close- or wide-spaced plants or whether the heads be large or small. As an average for a 10-year period, kafir and milo have had shelling percentages of 74.6 and 70.

Planting of one pound and two pounds of kafir seed to the acre resulted in average stands of 12.2 inches and 6.3 inches between plants. Planting of the same amounts of milo seed resulted in stands of 16.3 inches and 7.9 inches between plants. Planting one pound of sound milo seed to the acre should produce a satisfactory stand, and two pounds of kafir seed should place the plants about 6 inches apart, which distance is about the optimum for kafir. Hegari will require two to three pounds and feterita three to four pounds of seed to the acre, depending upon the time of planting.

Results of planting grain sorghums in normal, paired, and wide rows, considering all the yields of milo, kafir, and feterita, are in favor of planting in normal rows rather than in paired rows or in wide rows. The average decrease in yield when paired rows were used as compared with normal rows, was 1.1 bushels and the corresponding decrease when wide rows were used, was 4.5 bushels. The yield of milo was reduced 3.3 bushels and the yield of kafir was reduced 5.7 bushels when planted in wide rows instead of normal rows. Closer plant-spacing is necessary in wider rows than in normal rows; else a further decrease in yield can be expected when paired rows or wide rows are used. Planting grain sorghums in wide rows instead of normal rows resulted in a loss of about 25 per cent in forage yields.

Grain yields of kafir and feterita were reduced 4.3 bushels and 6.9 bushels, or about 25 per cent when cowpeas were planted in alternate rows with these grain sorghums.

The use of the most effective dry dust seed disinfectants increased germination and emergence of feterita 30 to 40 per cent over that of untreated seed. Benefits from seed treatment were more pronounced from the early dates of planting when soil-temperature conditions were most unfavorable for germination. Copper Carbonate or Ceresan, applied at the rate of 2 to 3 ounces to the bushel of seed, are convenient and effective forms of treatment for sorghum kernel smut.