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SORGHUM PRODUCTION IN KANSAS

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TABLE OF CONTENTS

A FIELD OF BLACKHULL KAFIR GROWN ON THE AGRONOMY FARM, MANHATTAN, KAN.

SORGHUM PRODUCTION IN KANSAS[1]

H. H. LAUDE AND A. F. SWANSON

INTRODUCTION

Sorghum is the most important crop for feed in central and western Kansas and has much value in the eastern, particularly the southeastern, part of the state. More than three million acres of sorghum were grown annually in Kansas from 1915 to 1930, as shown by reports of the State Board of Agriculture. Sorgos which are grown for silage, hay, and fodder were planted on about one-half of that acreage.

Among the sorghums grown primarily for grain, kafir occupied a little more than one million acres, milo about one-fourth of a million acres, and feterita about one hundred thousand acres. The importance, history, and varieties of sorghum in Kansas are discussed in another publication.[3]

The methods of growing sorghum have much to do with the quality of the feed and the yield per acre. The seed bed, vitality of seed, date and rate of planting, and cultivation of the crop are among the more important factors that influence the successful production of sorghum. The purpose of the crop, whether for grain, silage, fodder, or hay must be considered in connection with the methods of production. Varietal differences as to length of growing season, size of plants, and tillering habits may influence the time and rate of seeding.

PREPARATION OF THE SEED BED

A good seed bed is of primary importance. Losses in yield occur when the number of plants per acre are insufficient to occupy the land fully. When the stand is thin and uneven the crop usually is irregular in height and maturity, difficult to harvest, and weedy. The best quality of seed cannot overcome the disadvantages of a poor seed bed. Unsatisfactory stands and slow early growth are perhaps the most common difficulties encountered in growing sorghum. These troubles usually can be avoided by careful and correct preparation of the seed bed.

The ideal seed bed for sorghum has an abundance of stored moisture, and the soil is warm, mellow, and in good tilth. Under such conditions the seed germinates quickly and the plants grow vigorously. Several methods may be used in getting a satisfactory seed bed. The methods employed will depend principally upon available equipment, cost, type of soil, and climatic conditions.

Acknowledgment.—In the preparation of this bulletin valuable assistance of the Division of Cereal Crops and Diseases, Division of Dry-land Agriculture, and the Division of Forage Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, in securing the experimental results reported herein is gratefully acknowledged. The authors are also deeply indebted to A. L. Hallsted, in charge of Dry-land Agriculture, Hays, Kan., for data regarding cultural and rotation methods; L. C. Aicher, superintendent, Fort Hays Agricultural Experiment Station, for suggestions in regard to harvesting sorghum, and to R. E. Getty, formerly in charge of Forage Crop Investigations at the Fort Hays station.

1. Contribution No. 222 from the Department of Agronomy and No. 12 from the Fort Hays Agricultural Experiment Station.

2. Associate Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

3. Swanson, A. F., and Laude, H. H. Varieties of sorghum in Kansas. Kan. Agr. Expt. Sta. Bul. 266. 1933.

PREPARING THE SEED BED IN CENTRAL AND WESTERN KANSAS

In central and western Kansas sorghum is commonly planted with a lister in rows about 3 1/2 feet apart. Sometimes the ground is disked once or twice before planting. With this method the furrow bottoms may be cold and wet, and after a day or two of drying weather the soil around the seed may bake and dry, resulting in poor germination. Because of the depth of the furrows and steepness of the sides, dashing rains may bury the seed so deeply that it cannot emerge, or they may cover the seedlings enough to cause a loss of stand. Because of these hazards, farmers sometimes plant at heavy rates to make up for the loss of young plants. Thus it happens that stands are too thick in spots and too thin elsewhere for satisfactory yields.

The yields of sorghum may be increased from 25 to 50 per cent by thorough preparation of the seed bed. Experiments reported in Table I were made on the Fort Hays Agricultural Experiment Station by the Division of Dry-land Agriculture, United States Department of Agriculture, and show that the highest yields of sorghum were obtained from blank listing (fig. 1) in late fall or early spring. The ridges were leveled as soon as weeds started in the spring and at planting time the lister or the two-row planter with furrow openers was run in the original furrows a little shallower than the first time. Thus the seed was placed in warm, mellow soil that had been exposed to the weather during the winter and early spring on the tops and sides of the ridges. (Fig. 2.)

TABLE I.—Yields of sorghum for different methods of seed-bed preparation

Hays, Kansas, 1924 to 1931

Method of Preparation.	Average yield per acre.
	Bus.
Blank listed in late fall, curled in to destroy weeds, and old furrows nosed out with lister at planting time	36.5
Blank listed in early spring, curled in to destroy weeds, and old furrows nosed out with lister at planting time	35.6
Blank listed in late fall, curled in to destroy weeds, and ridges split with lister at planting time	31.0
Plowed in fall, planted in shallow furrows with lister or furrow-opener planter	33.8
Disked in early spring, listed at planting time	31.6
Listed at planting time without any previous tillage	21.9

The average yield of kafir by this method was 36.5 bushels per acre when listing was done in the fall and 35.6 bushels for early spring listing. The yield was 31 bushels per acre, or 5.5 bushels lower, when the seed was planted in blank-listed ridges split at planting time, than when the seed was planted in the old furrows. Planting in shallow furrows on plowed land gave 2.8 bushels higher yield than planting in split ridges, probably because the ground was warmer and more moist. Where neither blank listing nor fall plowing was practiced, early spring disking increased the yield from 21.9 bushels to 31.6 bushels per acre.

At the Garden City branch station, the average yield of kafir from 1914 to 1927, when listed at planting time without previous preparation of the soil, was 8.1 bushels per acre. Where the land was listed in the fall, ridges worked

down, and rows nosed out, the yield was 18.1 bushels per acre. Six other methods which involved about the same amount of labor yielded from 11.3 to 17.1 bushels.[4]

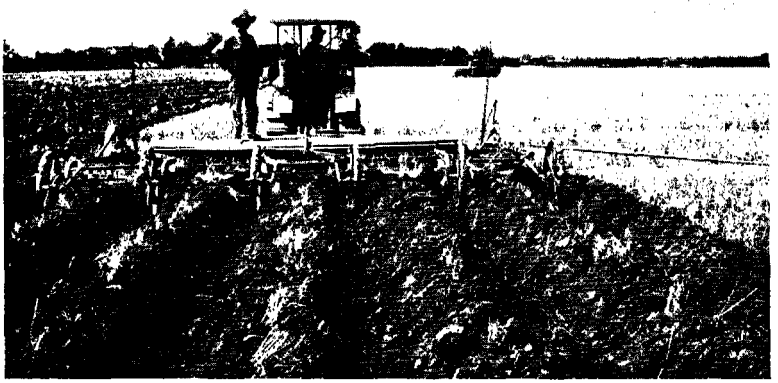

FIG. 1.—Blank listing land for sorghum.

FIG. 2.—Blank-listed rows catch snow during winter, and alternate freezing and thawing mellow the land.

The experiments indicate that the best method of preparing land for sorghum in central and western Kansas is the one that will provide warm, mellow, moist soil in which the seed will germinate quickly and uniformly. It is also important to reduce to a minimum the danger of washing and covering, which usually can be done effectively with a planter that has disk furrow openers that make a wide furrow bottom and short gentle slopes. A lister may be used in nosing out the old rows, but it may not scour well in loose, moist

4. Coles, E. H., and Wagner, F. A. Crop production in southwestern Kansas. Kan. Agr. Expt. Sta. Bul. 239:1-30. 1927.

soil. Alternate freezing and thawing mellow the land that was blank listed in the fall or winter. The heat of the sun during March and April warms the soil and starts the germination of weed seed.

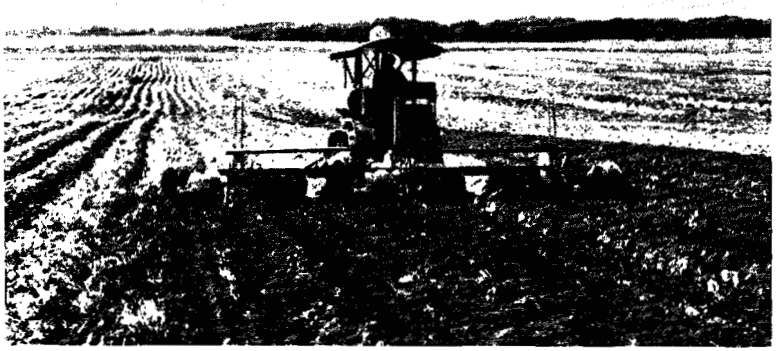

FIG. 3.—"Pulling in" blank-listed rows with a curler or weeder previous to nosing out with a planter at planting time.

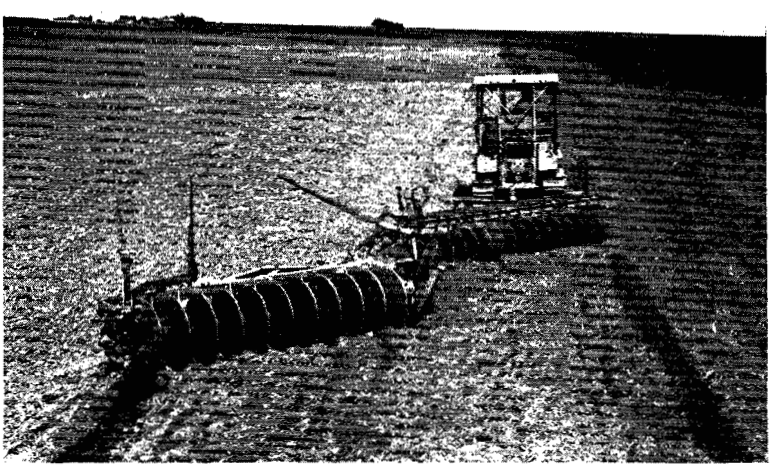

FIG. 4.—One-waying land for sorghum. This may follow the operation shown in figure 3.

The ridges should be leveled as shown in figure 3 as much as two weeks before planting, so that all of the weeds covered by that operation will have died when the sorghum is planted. The rows should be slightly crowned, so that the drainage will be away from the old furrows into the ridges. This will tend to keep the soil in the furrows from puddling in case of heavy rains.

It is desirable to use the same number of units on the hitch in planting as were used in the blank-listing operation and to run in the same set of rows to avoid difficulty in getting the planter to follow the old row.

It usually is necessary to kill more than one crop of weeds before planting. This can be done effectively with the one-way plow, as shown in figure 4. If the blank-listed rows are entirely obliterated by several cultivations with the one-way, it may be advisable to plant at right angles to the old rows. Straighter rows can be obtained by this method than by planting in the old furrow, especially if the number of planting units is not the same as the number of units used in blank listing, or if, because of several cultivations, the original furrows cannot be followed easily. On the other hand, planting at right angles to the blank-listed furrows is sometimes less satisfactory, be-

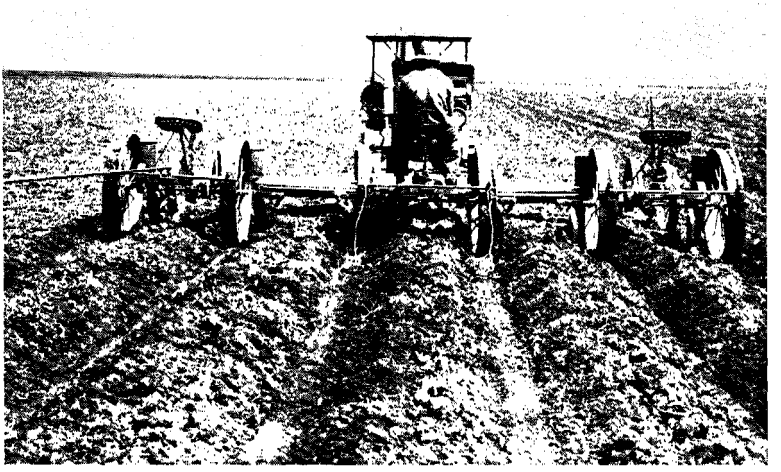

FIG. 5.—Nosing out old furrows with disks attached to the runners of two-row planters. This permits the sorghum seed to be dropped in a warm, mellow seed bed.

cause the soil in the blank-listed ridges may be colder and in poorer tilth than that in the furrows. If planting is deferred until June the difference is not so great. Small weeds usually are covered more effectively by following the blank-listed furrow than by planting at right angles to the old rows.

In sandy soils, or in regions of the state where the rainfall is limited, farmers have sometimes obtained good results by harrowing down the ridges instead of leveling them with the curler or weeder. The harrow does not entirely fill the furrows, which may be a disadvantage, since heavy rains are apt to make the soil soggy in the furrow bottoms. In some cases good results have been secured by using the one-way plow two or three times in place of blank listing. The planter with disk furrow openers, sometimes known as the loose ground lister, is then used for planting. (Fig. 5.) This method has the advantage of low cost, but run-off from heavy spring rainfall is not so well controlled.

If a planter with furrow openers is not available, the land may be listed about 4 inches deep at least several weeks before planting time. The lister with planting attachment is then run in the furrows deep enough to scour and throw the soil out on the ridges to cover the young weeds. Ordinarily the seed

can be placed in warm soil by this method if it is not planted until June. Such a seed bed usually can be improved by disking the land before the first listing operation. The disadvantage of this method is that the steep furrow sides and deep, narrow-bottomed rows may cause the seedlings to be washed out or covered by heavy rains.

PREPARING THE SEED BED IN EASTERN KANSAS

The seed bed for sorghum in eastern Kansas, where the annual precipitation is as much as 30 to 32 inches, ordinarily can be prepared to best advantage by plowing the land in the fall, disking perhaps twice in the spring, and harrowing just before planting. Early spring plowing usually gives good results, especially for those soils which may run together badly during the winter. Listing is advisable only in the lightest soils and where erosion of the ridges and bottoms of the furrows is not likely to be serious. The advantages of listing without its disadvantages can be secured by using planters with large disk furrow openers, and ordinarily the best stands and the highest yields are obtained by planting the crop in this way.

CULTIVATION OF SORGHUM

Sorghum should be cultivated principally for two reasons: To control weeds and to keep the soil in condition to absorb rain. Cultivation should bc no deeper than necessary to accomplish these purposes. Ordinarily more cultivation is needed in eastern than in western Kansas and in wet than in dry seasons.

The cheapest and most effective cultivations are those given in preparation of the land before the sorghum is planted. When sorghum is grown in rows, the principal tillage after planting, in central and western Kansas, is usually given with disk weeders having one large disk and one shovel on each side of the row. Soil is thrown away from the plants by the disks at the first cultivation while the shovels loosen the soil next to the plants and sometimes are set to throw a little soil to them. (Fig. 6, A,) In the second operation the plants are usually large enough so that the disks can be set to fill the furrows with soil and give support to the plants. In this operation the shovels are set to loosen the ridges. (Fig. 6, B.) A later cultivation should be shallow and may be given with shovel cultivators to best advantage.

If the plants shade the ground, July cultivation is likely to do more harm than good, particularly if the fibrous surface roots are pruned, and if dry weather prevails at the time of the operation. When the rows are extremely weedy, sled weeders with knife sweeps are the most effective. A greater number of cultivations are ordinarily necessary to control weeds in early-planted than in late-planted sorghum.

The same general plan for cultivating sorghum is advisable in eastern Kansas. However, efficient and inexpensive cultivation ordinarily can be given once, and sometimes twice, with the spike-tooth harrow while the sorghum is small, especially if it was planted with furrow openers.

Exhaustive experiments with corn[5] have shown that on a well-prepared seed bed there was no gain from cultivating the land beyond the minimum necessary to keep it free from weeds and in condition to absorb rain. Observations seem to indicate that the same principle applies to sorghum.

Experiments conducted by the Oklahoma Agricultural Experiment Station in the eastern part of that state for a period of eight years, showed that where kafir was grown without tillage and weeds were allowed to grow, the

5. Salmon, S. C. Corn production in Kansas. Kan. Agr. Expt. Sta. Bul. 238:1-42. 1926.

yield was 13 bushels per acre, compared to 22.5 bushels where weeds were scraped off but the ground was not stirred. Shallow cultivation gave a yield of 22.8 bushels and deep cultivation a yield of 20.9 bushels.[6]

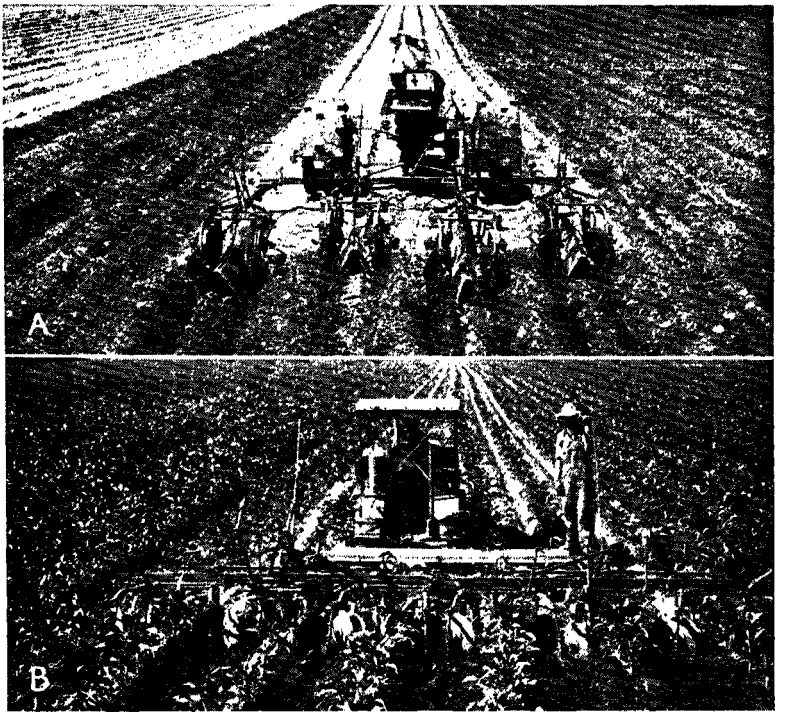

FIG. 6.—Cultivating the young sorghum crop with a disk cultivator or weeder. (A) Throwing the soil away from the plants. (B) Throwing the soil to the plants.

PLANTING SORGHUM

RATES OF SEEDING AND SPACING IN CULTIVATED ROWS

Sorghum that is grown for grain, fodder, or silage is usually planted in rows 42 inches apart, although the rows are often 40 or 44 inches apart. West of the 100th meridian the practice of leaving every other row blank is sometimes followed as a means of overcoming moisture deficiency. Another practice is to plant two rows and leave one blank. In this method it usually is advisable to plant seed in all of the rows. If a thin stand results all of the rows are left, but if the stand is thick the plants in certain rows are destroyed at the first cultivation. The surving plants will then make use of soil moisture and nutrients from the vacant areas.

Many experiments have been conducted in the grain-sorghum belt to determine the best rate to plant the different varieties of sorghum, a complete report of which is given in Technical Bulletin 131 of the United States Department of Agriculture.[7]

6. Murphy, H. F. Cultural methods for corn and grain sorghums on Oklahoma soils. Okla. Agr. Expt. Sta. Bul. 150:1-7. 1925.

7. Martin, John H., Sieglinger, J. B., *et al.* Spacing and date-of-seeding experiments with grain sorghums. U. S. Dept. Agr. Tech. Bul. 131:1-46. 1929.

At the Fort Hays station grain and forage yields were secured for Dawn kafir from 1919 to 1928 with plants spaced 6, 12, and 18 inches apart in rows 40 inches wide, and 3, 6, and 9 inches apart in rows 80 inches wide. (Table II and fig. 7.) Thus the same number of plants per acre were grown in 40-inch

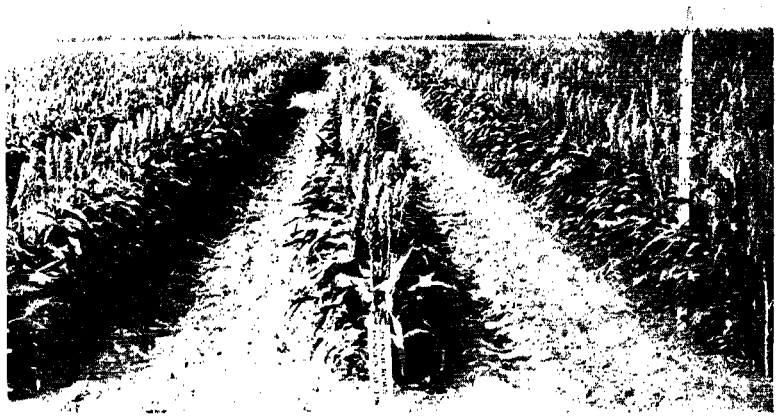

FIG. 7.—Dawn kafir in 80-inch rows spaced 3 inches apart in the row.

TABLE II.-Yields of Dawn and Pink kafir for different spacings between rows and between plants in the row

Hays, Kansas

Spacing		Yield per acre of Dawn kafir (a).		Yield per acre of Pink kafir (b)
Between rows	Between plants in the row.	Air dry forage.	Grain.	Grain
	Ins	*Tons.*	*Bus.*	*Bus.*
Rows 40 inches apart	6	4.30	38.5	39.1
	12	3.83	36.7	**37.3**
	18	3.27	32.4	**33.7**
	24			**32.1**
Average		3.80	35.9	33.6
Rows 80 inches apart	3	3.38	31 5	37 .9
	6	**2.75**	**29.7**	**34.7**
	9	*2.60*	**25.4**	33.1
	12			30.3
Average		2.91	30.9	34.1
Double spacing between pairs of 40-inch rows	4			**38.6**
	8			37.7
	12			**34.2**
	16			**31.2**
Average				**35.4**

A bushel of kafir grain is 56 pounds
(a) Nine-year average, 1910 to 1928 (no data for 1926).
(b) Seven-year average 1919 to 1925.

as in 80-inch rows The highest yields of both grain and forage were secured from rows 40 inches apart and when the spacing between plants was 6 inches.

Similar experiments were made with Pink kafir, with the exception that double spacing between pairs of 40-inch rows was also included. The grain yields, as shown in Table II, were slightly lower where the rows were 80 inches apart, but there was little difference in yield between 40-inch rows and double spacing between pairs of 40-inch rows

Dwarf Yellow milo made the highest yields at Garden City when the plants were spaced 12 inches apart, and because of its tendency to tiller it made relatively high yields when spaced 18 to 24 inches, as shown in Table III. Experiments in Oklahoma and Texas also have shown that it is not advisable to plant milo as thick as kafir. Feterita grown at Hays responded best to 8-inch spacing in the row, as shown in Table 111.

TABLE III.—Grain yields of milo and feterita for different spacing distances in rows 40 inches apart

Dwarf Yellow milo at Garden City.		Feterita at Hays.	
Distance between plants in the row.	Av. yield per acre, 1914–1918.	Distance between plants in the row.	Av. yield per acre, 1921–1925.
Ins.	*Bus.*	*Ins.*	*Bus.*
6	20.9	4	18.8
12	24.9	8	21.1
18	23.1	12	18.9
24	22.5	16	17.8
		24	14.1

In general the experiments have shown that kafir and most other grain sorghums make the highest yield of both grain and forage when the plants are spaced 6 to 8 inches apart in rows 40 to 44 inches apart. Varieties, such as Dwarf Yellow milo, which tiller vigorously and are capable of producing large heads under favorable conditions, do best when the spacing is from 12 to 15 inches between plants in the rows. When forage sorghums are planted in row 40 to 44 inches wide, the highest tonnage may be expected by spacing the plants 4 to 6 inches apart. The forage yield usually is highest when the crop is planted in close drills, but the grain yield is ordinarily highest in cultivated rows. The advantage of the wide rows for grain production is relatively greater in dry than in more favorable seasons.

The number of heads and tillers per plant tend to be greater when the plants are thin in the rows, but the number per acre is generally lower than in thick stands. The increase in tillering due to wide spacing is illustrated in Table IV for Dawn kafir.

Wide spacing in the rows usually delays maturity of the crop from one to three days. Varieties that tiller vigorously and produce large heads, and that do relatively better with wide spacing in the rows or in wide rows, do not necessarily outyield varieties that are adapted to closer spacing and that have smaller heads and fewer tillers.

TABLE IV.—Average number of tillers per plant of Dawn kafir for different spacings between plants in the row, and for rows 40 and 80 inches wide

Hays, Kansas

Distance between plants in the row.	Av. number of tillers per plant, eight years, 1919 to 1928 (a).	
	Rows 40 inches apart.	Rows 80 inches apart.
Ins.		
3	.....	1.09
6	1.29	1.41
9	.....	1.76
12	1.95	.....
18	2.37	.....

(a) No count of tillers obtained in 1923 and 1926.

AMOUNT OF SEED TO PLANT

The pounds of seed per acre that are required to secure an adequate stand is one of the uncertain or speculative features of growing sorghum, since much depends on the condition of the seed bed, the vitality of the seed, the size of the seed, and the uncontrollable elements of weather at planting time. Care ful observations have shown that the percentage of germination in the field usually is much lower than under the more favorable conditions of the seed laboratory.

In extensive experiments at Amarillo, Tex., five varieties of sorghum that germinated 95 to 98 per cent in the laboratory gave actual field stands from 11 to 61 per cent on different dates of planting.

Experiments conducted in 1931 at the Fort Hays station showed that the average germination for 30 varieties of sorghum was 34 per cent in the field as compared to 80 per cent in the laboratory. Seed that germinated above 90 per cent in the laboratory gave an average germination of 60 per cent in the field. Seed with a laboratory germination test of 70 per cent gave a 2 to 7 per cent stand in the field. Seed of high vitality planted under favorable conditions may be expected to germinate 50 per cent with normal weather. If heavy rain occurs at or soon after the time of planting, a total loss of stand may result, especially if the crop was planted in deep lister furrows. Seed that has low germination test in the laboratory will usually give even poorer results in the field.[8]

The size of sorghum seed as indicated by the number in a pound varies considerably, as shown in Table V.

There are 13,068 feet of row in an acre when the rows are 40 inches apart. A full stand of plants spaced 6 inches apart in the row would require 26,136 plants. The amount of seed needed to plant an acre, assuming that every kernel will grow, can be roughly estimated from Table V. It is advisable, however, to plant from three to four times that amount, to allow for variation in the field germination as compared to laboratory tests, unsatisfactory seed-bed conditions, and losses that may result after the plants come up. It is usually better to plant somewhat too much than too little seed.

8. Vinall, H. N., Getty, R. E., and Cron, A. B. Sorghum experiments on the Great Plains. U. S. Dept. Agr. Dept. Bul. 1260:1-88. 1924.

TABLE V.—Number of seed per pound for five varieties of sorghum

VARIETY.	Size of seed.	Number of seed per pound (a).
Sumac	Small	37,000
Dwarf kafir	Intermediate	24,000
Kansas Orange	Intermediate	23,000
Western Blackhull	Intermediate to large	17,000
Dwarf Yellow milo	Large	12,000

(a) The estimates for Dwarf kafir, Kansas Orange, and Sumac were made at Amarillo, Tex. The estimates for Western Blackhull and Dwarf Yellow milo were made at Hays, Kan.

PROPER PLANTING PLATES TO USE

Plates made especially for sorghum should be used in the planter. No rule can be given as to the number of holes to use, since both size of plates and drive gears differ widely in planters. It is neither feasible nor desirable to drill holes in the plates so small as to drop but one seed at a time, for such holes are quickly clogged. If three or four seeds can get through at once, and the holes are reamed out on the under side, there is little danger of stoppage Holes eleven-sixty-fourths of an inch in diameter are satisfactory for small seeds of the Sumac type; for seeds of the kafir type, holes three-sixteenths of an inch in diameter, and for seeds such as feterita and milo, holes nine-thirty-seconds to one-fourth of an inch in diameter are satisfactory.

The planter can be adjusted for the desired rate of planting by driving over a hard road surface with the planting unit engaged. The seed will drop without being covered and the number of kernels per linear foot can be counted.

Corn plates should not be used in planting sorghum, as the stands invariably will be too thick if conditions are at all favorable for germination, and the distribution of the seed will be irregular.

TIME TO PLANT

Sorghum should be planted at such a time as to avoid low temperatures during germination, extremely high temperatures during the blooming and filling periods, and to provide ample time to ripen before the first killing frost in the fall.

It has been suggested by Vinall and Reed,[9] and observed by other workers, that the date of planting should be so arranged that germination and early growth will take place during the period of moderately high temperatures, and the blooming and filling at such a time as to avoid the highest temperatures. With the possible exception of germination, the blooming and filling periods are the most critical stages through which the crop must pass. At that time the plants require a large amount of water in order to carry on their normal functions. If temperatures of 100 deg. F. or higher with deficient moisture occur then, the yield of both grain and forage is often greatly reduced. Injury from high temperature is most likely to occur during the last two weeks of July and the first week of August.

Sorghum is not so drought resistant as is often claimed for the crop, but rather is drought escaping. It is, therefore, desirable to arrange the time of

9. Vinall, H. N., and Reed H. R. Effect of temperature and other meteorological factors onthe growth of sorghums. Jour. Agr. Research 13:133-147. 1918.

planting so as to bring the plants into bloom just after the hottest weather of summer has passed, but early enough for them to ripen before frost. The length of time required for varieties grown in Kansas to mature varies from 85 to 135 days. The average length of time from the last killing frost in spring to the first frost in fall ranges from about 200 days in southeastern Kansas to 155 days in northwestern Kansas.

The sorghums are warm-weather plants and require warmer soil temperatures for germination than corn. The optimum growing temperature for sorghum is about 92° F. and relatively little growth will take place below 65° F. For this reason the entire period of frost-free days cannot be utilized, since the mean daily temperature is below 65 degrees for part of the period. Generally the number of days for optimum growth will be about 65 per cent of the frost-free days. It is more important that relatively high mean temperatures prevail during the seedling and young-plant stages than during the very last of the ripening period. For this reason sorghum should not be planted until the ground is thoroughly warm and in good tilth as a result of thorough tillage.

For the most of the grain-sorghum belt of western and north central Kansas the optimum period of growth for sorghum can be said to lie between May 20 and September 10. Sorghum planted earlier than May 20 is likely to encounter cold weather during the period of germination, and after September 10 the mean temperatures may be so low that the crop makes little progress in its late stages of growth and ripening. In southeastern and south central Kansas, where the longest seasons prevail, conditions are usually satisfactory from about May 5 to September 25.

Varieties of sorghum differ not only in time required to mature but also in the amount of injury that may be caused by low temperature. Feterita is easily injured by low temperature during germination and early growth. The milos and the kafirs may grow slowly during the seedling stages in cool temperatures which retard the growth of Freed, Amber, and Sumac little if at all. The earlier the variety, the later it can be sown and still have time to mature. The later the variety, the earlier it must be planted in order that it may ripen before frost. The range of maturity for some of the best-known sorghums grown in Kansas, as determined at the Fort Hays station, is as follows:

Less than 100 day.	Black Amber Freed
101 to 110 days	Red Amber Feterita Leoti Red Early Sumac Modoc Wonder
111 to 120 days	Dwarf Yellow milo Dawn kafir Western Blackhull Pink kafir Red kafir
121 days or more	Standard Sumac Atlas Standard Blackhull

Sorghum has been planted about May 15, June 1, and June 15 at the Fort Hays Agricultural Experiment Station to determine the best date for planting the different varieties. The grain and forage yields for the different dates and for representative varieties for the seven-year period. 1925 to 1931, are shown in Table VI.

TABLE VI.—Average grain and forage yields per acre of sorghum planted May 15, June 1, and June 15

Hays, Kansas, 1925 to 1931

Identification No.	Variety.	Days to mature.	Grain yields.				Forage yields.			
			May 15.	June 1.	June 15.	Av.	May 15.	June 1.	June 15.	Av.
			Bus.	*Bus.*	*Bus.*	*Bus.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
13605†	Atlas sorgo	123	22.8	22.2	21.2	22.1	4.25	4.57	4.54	4.45
907*	Juicy Pink kafir	119	37.5	38.9	34.1	36.8	3.56	3.66	3.51	3.58
906*	Western Blackhull kafir	118	43.3	43.2	41.4	42.6	3.61	3.74	3.54	3.63
432*	Pink kafir	118	34.6	39.8	37.6	37.3	3.41	3.66	3.67	3.58
340*	Dawn kafir	117	37.1	37.4	36.4	37.0	3.55	3.50	3.75	3.60
957*	Red kafir	117	35.9	35.6	38.7	36.7	2.92	3.02	3.25	3.06
904*	Dawn kafir selection	116	39.8	33.1	35.9	36.3	3.65	3.41	3.56	3.54
35038‡	Standard Sumac sorgo	115	21.7	25.8	20.1	22.5	3.96	4.83	4.61	4.47
332*	Dwarf Yellow milo	114	35.3	42.7	36.0	38.0	.....	.....	.....	.....
	Corn	113	19.7	28.5	28.8	25.7	2.22	2.51	2.70	2.48
6610†	Leoti Red sorgo	110	24.1	29.0	27.0	26.7	3.71	4.03	4.11	3.95
872*	Wonder	109	38.9	43.2	44.5	42.2	.....	.....	.....	.....
905*	Modoc	108	37.6	42.1	43.5	41.1	3.01	3.33	3.65	3.33
6611†	Early Sumac sorgo	106	22.4	29.0	30.2	27.2	3.26	3.67	3.69	3.54
182-1*	Feterita	103	34.6	39.4	41.7	38.6	2.76	3.15	3.03	2.98
971*	Dwarf Freed	98	28.2	33.1	35.3	32.2	.....	.....	.....	.....
Average		.....	32.9	35.7	34.9	.....	3.47	3.71	3.74	.....

* Number of the Division of Cereal Crops and Diseases.
‡ Number of the Division of Foreign Plant Introduction.
† Number of the Division of Forage Crops and Diseases.
A bushel of sorghum grain is 56 pounds.

In general the best grain yield of the late varieties was obtained by planting May 15 and of the early varieties June 15. Greater difficulty was encountered in securing stands the middle of May, which accounts, in part, for the lower yields for that date. It was also noted that varieties planted on May 15 were frequently injured more severely by drought in July and early August than when planted on later dates. When planted June 1 most varieties came into pollination and fruiting just after the most extremely unfavorable high temperatures. The late varieties planted as late as June 15 did not always mature fully, and in some cases were harvested when the seed was still in the milk or soft-dough stage.

The average yields of forage were about the same for planting June 1 and June 15. Most of the varieties that made their highest yield when planted as early as June 1, matured somewhat later than the varieties that yielded best when planted June 15. The forage yields for planting May 15 were frequently reduced by drought in July and early August.

At the Garden City branch station five grain sorghums, two sorgos, and Sudan grass were planted on May 15, May 30, June 15, and June 30, each year for the four-year period, 1922 to 1925.[10] (Table VII.)

TABLE VII.—Average yields per acre of sorghum planted May 15, May 30, June 15, and June 30

Four-year period, 1922 to 1925, Garden City, Kansas.

Date of planting	May 15.	May 30.	June 15.	June 30.
Grain Varieties.	*Bus.*	*Bus.*	*Bus.*	*Bus.*
Dwarf Yellow milo	12.2	15.8	15.0	11.9
Dawn kafir	14.4	16.9	15.4	12.6
Standard feterita	10.1	14.6	16.9	16.2
Sunrise	16.5	24.7	15.5	12.1
Average	13.3	18.0	15.7	13.2
Forage Varieties.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Standard Sumac	3.05	3.51	3.75	.....
Red Amber	2.03	1.92	1.80	1.46
Sudan grass	2.59	2.74	2.63	1.48

Dwarf Yellow milo, Dawn kafir, and Sunrise made their highest yields when planted May 30, as indicated in Table VII. When planted at that time they usually headed after the warmest weather. The lower yields for planting May 15 probably were due to colder soil and the shorter time for preparing the seed bed.

The altitude at Tribune, Kan., is nearly 800 feet higher and the number of frost-free days fewer than at Garden City. The yields of both forage and grain for sorghums planted about May 20 and June 5 at the Tribune station are shown for representative varieties in Table VIII.

The yields of forage are consistently higher at Tribune for sorghum planted June 5 than for that planted May 20, but there is no marked difference between the two dates as to yield of grain, which indicates that soil moisture at

10. Coles, E. H., and Wagner, F. A. Crop production in southwestern Kansas. Kan. Agr. Expt. Sta. Bul. 239:1-30. 1927.

TABLE VIII.—Average grain and forage yields per acre of sorghum planted May 20 and June 5

Six-year period, 1926 to 1931, Tribune, Kansas.

Date of planting	May 20.		June 5.	
VARIETY.	Forage.	Grain.	Forage.	Grain.
	Tons.	*Bus.*	*Tons.*	*Bus.*
Dwarf Yellow milo	1.75	8.2	2.02	11.2
Pink kafir	2.39	4.9	2.70	3.8
Sunrise	2.00	8.2	2.42	8.1
Freed	1.65	12.3	1.80	10.0
Greeley	1.84	14.4	2.06	15.4
Pink Freed No. 14	1.55	14.6	1.80	17.5
Early Sumac	2.95	9.6	3.30	7.8
Leoti Red	2.96	7.6	3.57	7.7
Red Amber	3.09	10.8	3.23	10.6
Average	2.24	10.1	2.43	10.2

planting time or other field conditions are of primary importance. Thus in the Tribune territory it is advisable to plant grain sorghum May 20 to May 25, or as soon thereafter as sufficient moisture and otherwise favorable seed-bed conditions can be obtained.[11]

Because of the short growing season in northwestern Kansas, only early-maturing varieties can be depended upon to ripen seed, and those varieties should be planted as soon as the ground is warm, provided moisture is available at that time. The last week of May is ordinarily the best time to plant sorghum in northwestern Kansas.

In northeastern and north central Kansas, sorghum may be planted from May 20 to June 10. Planting should be somewhat later in wet soils, which warm slowly, than in the drier soils.

THE DRILL METHOD OF PLANTING SORGHUM FOR GRAIN

The introduction of dwarf grain sorghums suited to combine methods of harvesting has suggested the use of both the furrow drill (fig. 8) and the ordinary grain drill as a means of planting the crop. The danger of weed infestation, due to inadequate preparation of the seed bed before planting, seems to be the chief limitation in the use of these drills. If weeds are likely to be a serious problem, the only safe way to grow sorghum for grain is in cultivated rows.

The furrow drill and the common drill have been tested at the Fort Hays station in comparison with a lister which spaced the rows 42 inches apart, (Fig. 9.) The seed bed in each case was prepared by blank listing followed by "curling in." The land was maintained in good tilth by several operations with the one-way which induced germination of weed seeds and conservation of moisture. The final crop of weeds was killed with the one-way just before the sorghum was planted The results obtained are shown in Table IX. The

11. Stinson, T. B., and Laude, H. H. A report of the Tribune Branch Agricultural Experiment Station. Kan. Agr. Expt. Sta. Bul. 250:1-36. 1930.

period of experimentation is not long enough to draw final conclusions, but the results indicate that the close-drill method may be used successfully with dwarf varieties when field conditions are favorable and weed growth can be controlled. The drill method has its best adaptation in the western half of Kansas where weed infestation is held in check by limited rainfall.

FIG. 8.—Planting dwarf grain sorghum with a furrow drill in rows 14 inches apart.

TABLE IX.—Comparative grain yields of dwarf sorghums planted with grain drills and in listed rows 42 inches apart

Fort Hays Agricultural Experiment Station, Hays, Kansas

METHOD OF PLANTING.	Average yield per acre.			
	Wheatland.	Custer.	Dwarf Freed.	Kalo.
Three-year Period, 1930 to 1932				
	Bus.	*Bus.*	*Bus.*	*Bus.*
14-inch furrow drill	43.3	30.9	32.1	51.3
42-inch listed rows	45.5	34.9	35.1	53.5
Two-year period, 1931 to 1932				
14-inch furrow drill	42.8	35.1	33.3	53.4
8-inch common drill	45.0	36.2	34.7	52.3
42-inch listed rows	33.1	28.7	26.4	50.8

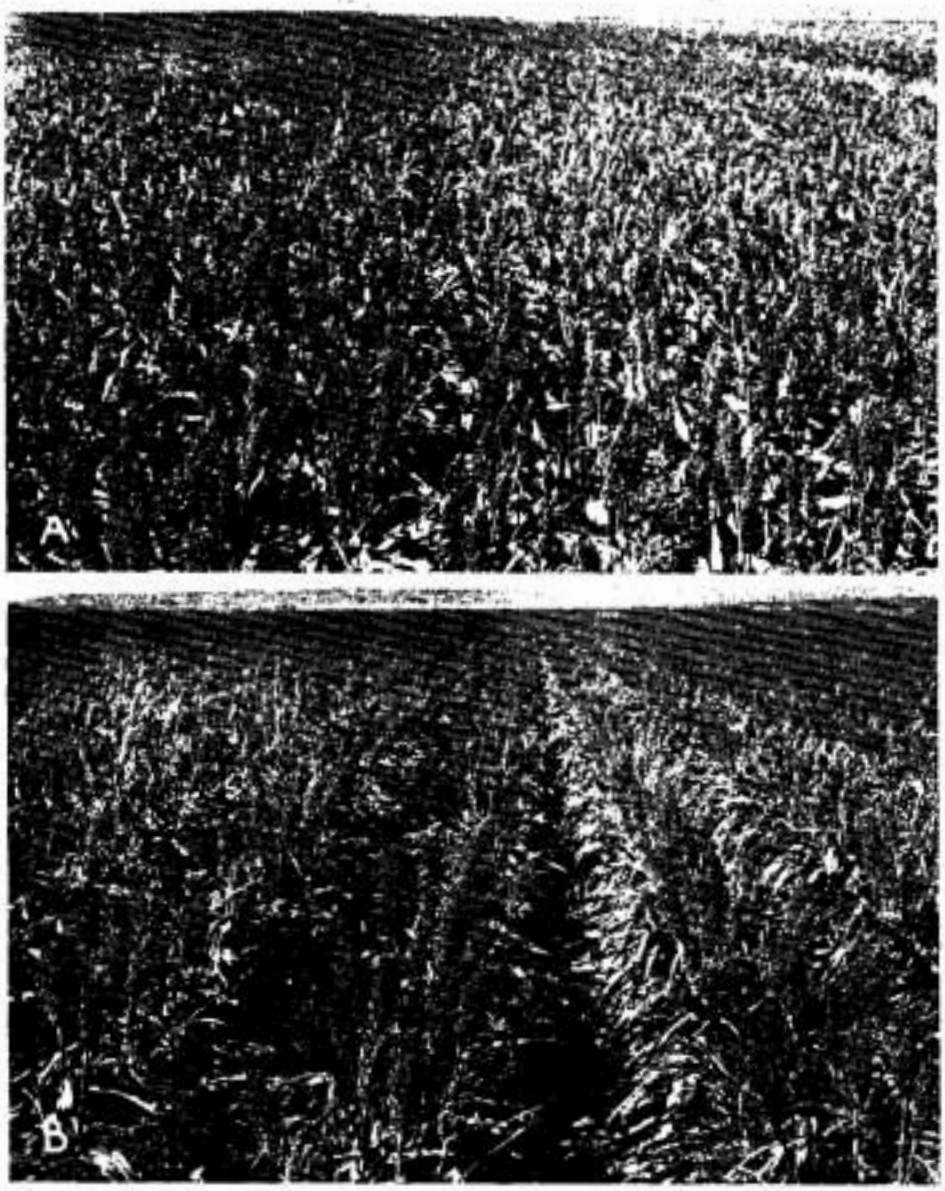

FIG. 9.—(A) Wheatland seeded with a 14-inch furrow drill on a seed bed prepared by the same method used in growing wheat. (B) Wheatland seeded in 42-inch rows.

In larger fields on the Fort Hays station in 1930 the drill method compared favorably with the row method, but in 1931 it failed because the young plants were covered by torrential rains. In several cooperative experiments with farmers in central Kansas the furrow-drill method was not a success because of weeds, but in the western part of the state good crops were grown from furrow-drill seeding. Varieties that grow taller than five feet are less apt to lodge in cultivated rows than when planted with the grain drill.

In planting dwarf sorghums for grain with a drill it is important that the rate of seeding be not more than when the crop is planted in rows. Four pounds to the acre have proved satisfactory. Adapters for the drill holes or

a change of gears is neceasary in adjusting the grain drill to seed sorghum at the proper rate. When drilled at more than 10 pounds per acre the sorghum usually has a tendency to produce hay rather than grain. Dwarf Freed, however, may be seeded somewhat thicker than most other varieties.

After the plants have emerged and reached a height of 3 inches, a light harrowing will destroy, to some extent, weeds that may have germinated on the ridges made by the furrow drill.

ADAPTED VARIETIES OF SORGHUM

A full discussion of varieties of sorghum adapted to Kansas is given in another publication[12] and, therefore, only brief mention will be made here of a few of the principal varieties suited to different sections of the state. Sorghum varieties may be grouped in accordance with their primary use, whether for grain or for forage, including silage, fodder, and hay.

FORAGE VARIETIES

The best varieties of sorghum for forage in Kansas are Atlas, Kansas Orange, Early Sumac, and Leoti Red. Atlas and Kansas Orange are large late-growing varieties and, therefore, are adapted only in the eastern, southeastern, and south central parts of the state as far northwest as Nemaha, Clay, Pawnee, and Meade counties. Farther northwest these varieties may not ripen before frost but will produce good yields of excellent forage.

Atlas is preferable to Kansas Orange in southeastern Kansas because it is more resistant to lodging and has white, palatable grain similar to kafir, whereas Kansas Orange has light brown, slightly bitter grain. In experimental tests Kansas Orange averaged somewhat higher in yield of grain than Atlas and about the same in yield of forage.

Early Sumac and Leoti Red mature earlier than Atlas and Kansas Orange and, therefore, are adapted farther northwest than the latter varieties. The forage of Early Sumac and Leoti Red is fine, leafy, and of excellent quality, and the grain is dark colored and somewhat bitter. These varieties are smaller than Atlas and Kansas Orange and, therefore, yield less, especially where the later varieties ripen before frost.

It should be noted that some other sorghums, particularly kafir, have considerable value for forage, and that milo and feterita have relatively low forage value.

GRAIN VARIETIES

Sorghum grown principally for grain includes varieties of kafir, milo, and feterita and varieties that have been derived from these by selection or crossing. Standard Blackhull kafir is the best white-seeded variety in southeastern Kansas. Because of its late maturity other varieties, such as Pink and Western Blackhull, are better adapted north and west of Manhattan and Wichita. An adapted strain of Red kafir tested by the Agricultural Experiment, Station has out-yielded other varieties of kafir in the eastern half of Kansas. Pink kafir is adapted north and west of the Standard Blackhull area as far as Mitchell, Ellis, Ness and Meade counties, beyond which the growing season is too short for it. Western Blackhull is well adapted as far west as Rooks, Lane, and Stanton counties, where it is the highest-yielding variety of kafir now available.

Dwarf Yellow milo outyields all other grain sorghum in southwestern Kansas and is well adapted in the west half of the state, except in the region north-

12. Swanson, A. F., and Laude, H. H. Varieties of sorghum in Kansas. Kan. Agr. Expt. Sta. Bul. 266. 1933.

west of a line from Graham to Greeley counties, where the growing season is too short for it. Dwarf Yellow milo is not adapted in the east half of Kansas, because of its suseptibility to chinch-bug injury.

Wheatland is well suited for harvesting with the combine, since it is short, has erect heads, and is resistant to lodging after it is ripe. It makes high yields and is adapted in central, south central, and southwestern Kansas. It is highly susceptible to chinch-bug injury and, therefore, is not a safe crop east of Rice and Reno counties.

Standard feterita, chiefly because of its early maturity, is the best grain sorghum now available in northwestern Kansas as far southeast as Smith, Trego, and Wichita counties.

HARVESTING SORGHUM

HARVESTING A GRAIN CROP OF SORGHUM

There are four general methods of harvesting sorghum for grain: (1) Hand topping, (2) cutting with a row binder or corn binder, (3) topping with a header, and (4) heading with a combine, including several modifications. The different methods of harvesting sorghum have been studied cooperatively by the United States Department of Agriculture and the agricultural experiment stations of Kansas and Oklahoma.[13]

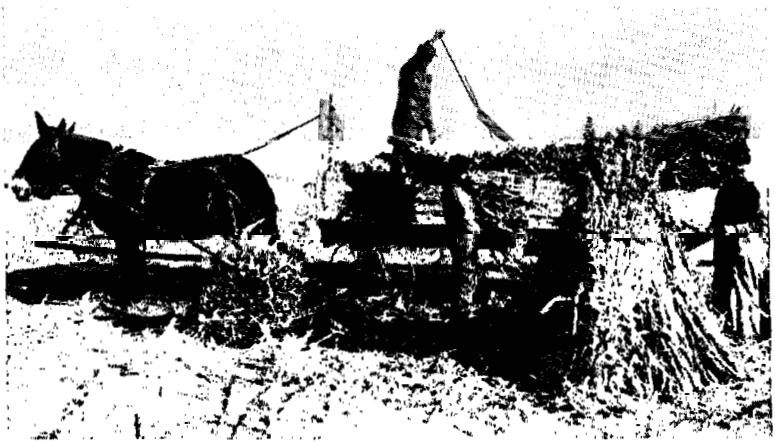

FIG. 10. — Topping Pink kafir with a cheese knife, preparatory to threshing the grain.

The Hand Method. — The oldest and simplest but the least efficient method is that of cutting heads by hand in the field from the standing stalks. This method is too expensive and tedious to be recommended, but may be justifiable when the acreage is small and when time and labor costs are not important factors. By this method one man with a team and wagon can harvest from 1 1/2 to 2 acres a day, depending on the thickness of stand and yield of the crop. Hand harvesting is facilitated by having thin stands so that the heads will grow relatively large. The topped heads should be stacked in narrow ricks to cure.

13. Martin, John H., *et al.* Harvesting grain sorghums. U. S. Dept. Agr. Farmers' Bul. 1577:1-16. 1928.

The Row Binder. —The row binder, or corn binder, is the most satisfactory machine for harvesting when high quality seed for planting purposes is desired and when both grain and stovcr are wanted. The crop is cured in shocks of 12 to 15 bundles and should be threshed as soon as thoroughly cured. The entire bundle may be put through the threshing machine, or if the bundles are too long the heads may be cut off. A cheese-knife arrangement consisting of a long blade fastened to a suitable frame on the wagon rack or barge is satisfactory for topping the bundles. (Fig. 10.) One man handles the blade from the wagon while one or two men place the bundles under the blade from the ground. When the wagon is loaded the heads are taken to a centrally located machine to be threshed or are ricked in preparation for threshing. The combine also may be used for threshing by moving from shock to shock to thresh the heads as they are topped by a special sickle bar attachment on the platform.

The great advantage of cutting with a binder, regardless of how the bundles are threshed, is that the standing crop can be harvested before frost and generally before any lodging takes place. The crop should not be cut until the grain at the base of the heads is nearly hard. This system of harvesting usually gives an excellent quality of grain which keeps well in storage. The disadvantage of the binder-thresher system is that considerable labor and high-powered machinery are used, which increases the cost of gathering the crop.

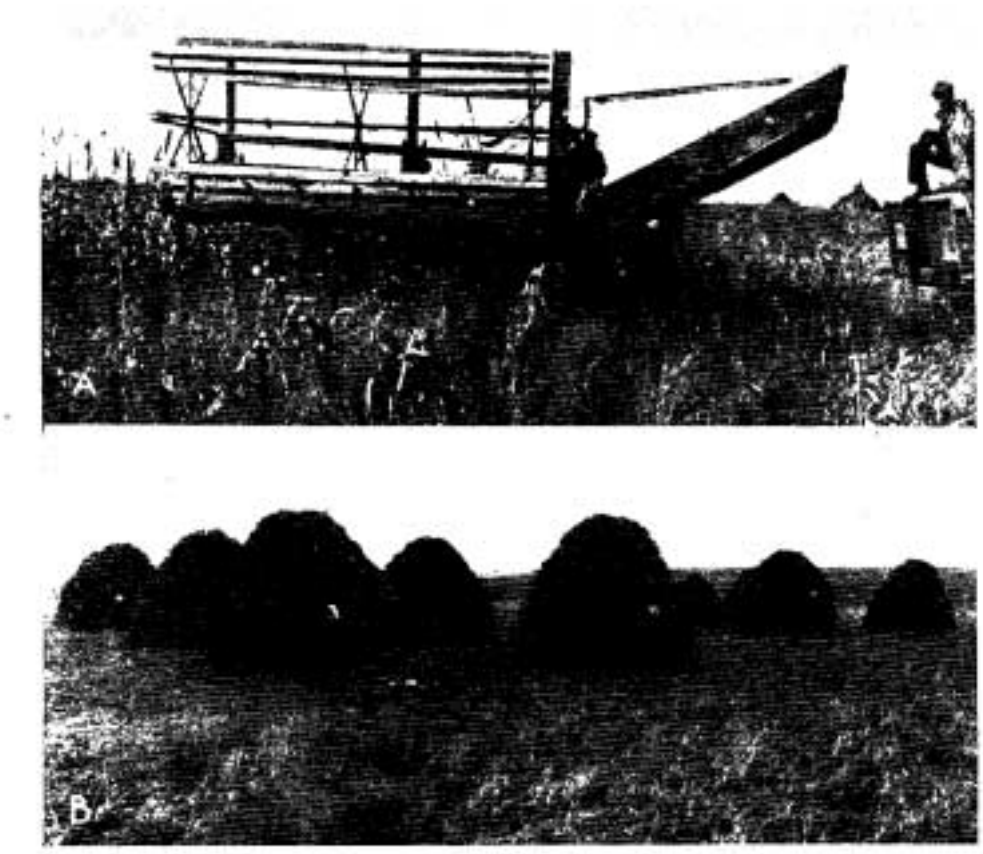

FIG. 11.—(A) A header with the platform elevated high enough for use in topping sorghum. (B) Stacks of heads which were cured for a week or longer in small piles in the field. The stacks may be threshed at a convenient time.

The Header. — In the wheat belt headers can be used for topping the standing crop. The heads are taken from the barges and placed in small piles or ricks to dry for one to two weeks. The heads may be threshed as soon as dry, or they may be stacked in larger ricks, holding from 80 to 100 bushels. (Fig. 11.) These larger ricks may be round, about 10 feet in diameter and from 10 to 15 feet high, or they may be long, 3 to 4 feet high and 4 to 7 feet wide at the bottom. These can be threshed when convenient. Loss of grain by molding and shattering may be avoided by placing the rick on a layer of sorghum stover. Straw or hay is less satisfactory for this purpose than sorghum stover because the grain is more apt to mold.

It is usually advisable to make the reel solid by bolting extra slats to the reel arms. This reduces the number of heads that are thrown out by the reel. The bottom of the reel slats should just clear the sickle bar. If the platform does not have sufficient adjustment it may be necessary to reverse the supporting arms under the platform in order to raise the cutting bar high enough to handle a tall crop properly

Two men with a header can harvest and rick about 13 acres a day, assuming that one-half of the time is taken to unload. Unloading may be done more quickly with a team if the low side of the barge is hinged and ropes fastened at that side are laid across the floor and up the high side. When the barge is loaded the ropes are thrown over the load, the low side is turned down on its hinges, and the team hitched to the ropes rolls the entire load off onto the ground.

Sorghum may be harvested more cheaply and more rapidly with the header than with the row binder or by hand, but the loss of grain is usually greater when the header is used.

The Row Header.--Special kafir headers or row headers have been devised which can be attached to an ordinary wagon box and driven by a chain and sprocket gear bolted to the rear wagon wheel. These machines are satisfactory when the crop is uniform in height and when no lodging has occurred. The row header will harvest from 4 to 5 acres a day, which is more economical and faster than harvesting by hand. The heads are ricked in the usual manner.

The Harvester-Thresher or Combine. — The combined harvester-thresher has been used successfully for harvesting and threshing grain sorghum, either in one operation or in two operations, when certain modifications in the machine are made.

Dwarf varieties can be harvested and threshed more efficiently with a combine than by any other method, when weather conditions are favorable in the fall. Favorable conditions for combining occur when the crop has ripened normally by late September, preferably during a period of dry weather followed by a killing frost. A few days of further drying weather after a severe freeze usually will reduce the moisture content of the grain sufficiently to eliminate much of the danger from heating in storage.

Conditions unfavorable for the use of the combine are deferred maturity due to rainy weather and late killing frost, which permit the sorghum to continue growing until the last of October. While sorghum can be combined with a moisture content of the grain as high as 18 to 20 per cent, such grain cannot be stored safely unless it is put through special artificial driers to reduce the moisture content to 14 to 15 per cent for winter storage and 12 to 13 per cent for summer storage. In Kansas direct combining of sorghum probably should be confined to the area west of Salina and Wichita, largely because of the moisture problem involved in storing the grain in the more humid area east of these points.

When conditions are favorable for the combine method of harvesting, the

grain losses are low if the machine is adjusted correctly. (Fig. 12.) Experiments at, the Fort Hays station in 1931 indicated a loss of leas than 1 pound to the acre from the tailings. A solid reel, such as described for the header, is needed to prevent the heads from being thrown out. The greatest losses come from lodged plants and broken-over heads, which either cannot be reached by the cutting bar or are dropped when cut.

It is necessary to run the cylinder at a speed of only 350 to 400 revolutions per minute, as compared to 900 revolutions generally used for threshing wheat. Other moving parts of the machine, such as the fan and shakers, should be run at the same speed as for wheat. Sometimes a reduction in the number of teeth in the concaves may need to be made. Dry grain may be cracked if the speed of the cylinder is too high.

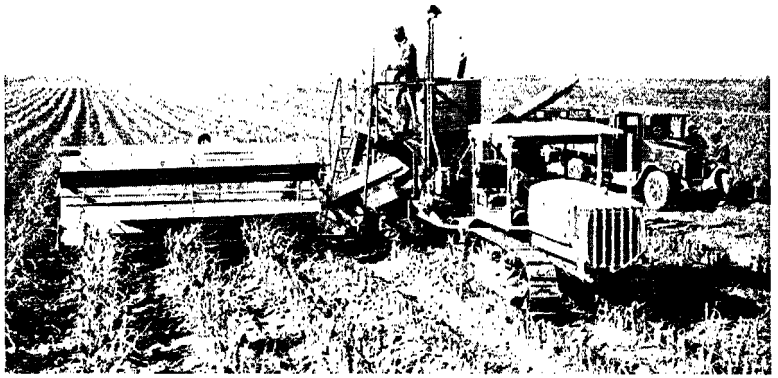

FIG. 12.—Harvesting a dwarf variety of sorghum with the combine.

The chief difficulty in combining sorghum from the standing stalk is the trouble from broken stalks in the grain and the presence of stalks with high moisture. Experiments at Hays in 1931 showed that, even after drying weather and a hard freeze, the portion of the stalk below the upper node or joint contained about 64 per cent of moisture, while that portion in the head, and the neck or peduncle which supports the head, contained 22 per cent of moisture. It is therefore desirable to cut the stalks above the upper node. This usually can be done when a dwarf erect variety is grown, but is ordinarily impossible with varieties that have goose-neck heads that bend over. Varieties as tall as 5 feet can be combined if the crop is uniform and no lodging has occurred, but it may be difficult to cut them above the upper node. A considerable amount of broken stalks with a higher percentage of moisture may easily cause the stored grain to go out of condition.

During the last decade plant breeders have tried to produce varieties of sorghum that are dwarf, uniform, resistant to lodging, and with heads well exserted from the sheath or boot. These efforts have met with a fair degree of success in the production of Wheatland.

The Swather-Dump-Box Method.—When sorghum ripens late it may be feasible to top the crop with a swather attachment, which is available for most combines. The topped heads are carried to a dump-box about 5 by 9 feet, mounted a little off center on the axle between two wheels and attached to the swather as shown in figure 13. When sufficient heads have accumulated

in the dump-box to make a sizeable pile, the box is tripped so that the heads slide out of the box on the ground at regular intervals to form windrows across the field. The size of the pile should be determined by the maturity of the crop and the moisture in the soil. The heads are permitted to dry for one or more weeks. The combine with the pick-up attachment is then driven near to the piles. Two or three men pitching the heads onto the pick-up, with one man to operate the outfit, can thresh from 800 to 900 bushels of grain a day Additional men are needed to haul the grain away. It may not always be pos-

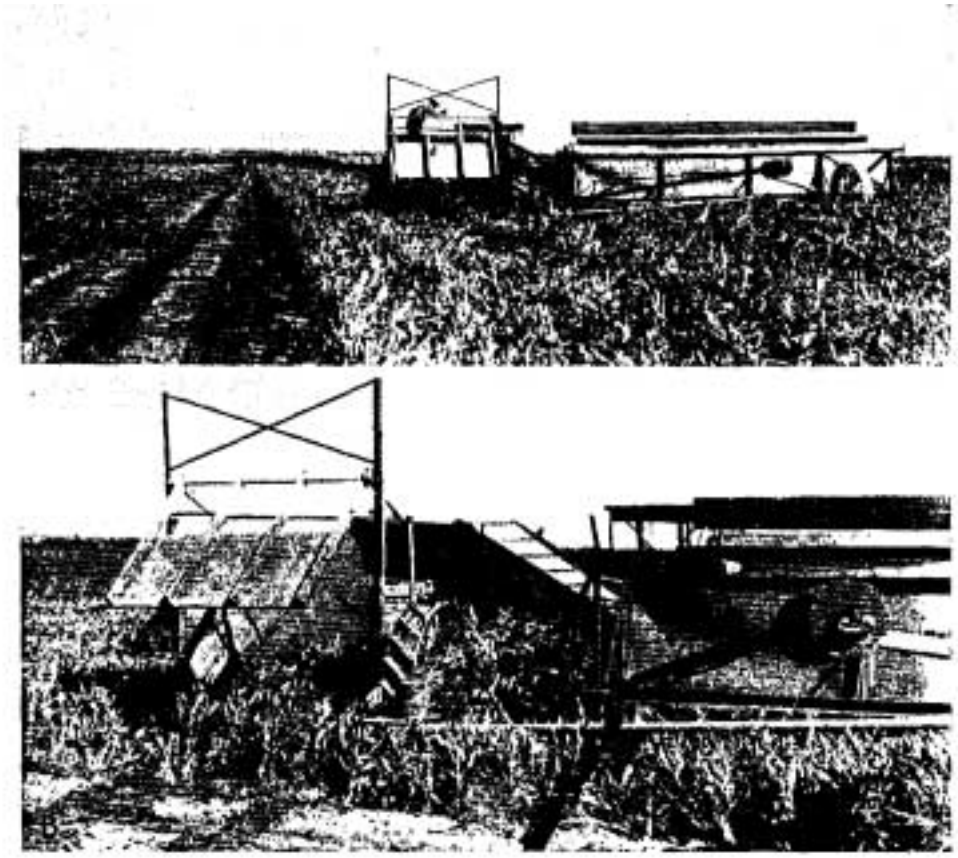

FIG. 13.—(A) The swather and dump-box in operation. A pile of heads is being dropped. Later these piles are approached with the combine and threshed, or the piles may be hauled to a centrally located machine to be threshed. (B) A close-up view of the dump-box.

sible to obtain grain of high quality by this method, as some may be spoiled by early fall rains. The rainfall in central and western Kansas is usually light during the last of September and October and the temperatures are sufficiently high to dry excess moisture readily. The advantage of the system is that the crop can be put into piles before frost and before much lodging has taken place, provided the seed has hardened at the time of cutting.

Root Cutting and Combining.—Experiments have been conducted in California[14] in which U-shaped root cutters sever the roots of the sorghum plants

14. Conrad, John P., and Stirniman, E. G. Improved methods of harvesting grain sorghum. Calif. Agr. Expt. Sta. Bul. 477:1-41. 1929,

6 inches below the surface of the ground. With the roots thus cut, the plants are no longer able to make use of the available moisture supply and in the course of a week or ten days are sufficiently dried so that the heads can be combined direct. This method has not been tried in Kansas, but in Califonia it is claimed that the date of combining can be advanced considerably and the grain will be dry enough to store when threshed. Not all varieties respond favorably to root cutting, some are inclined to wilt so badly after the root cutting operation as to lodge before the crop has dried. Strong wind also may cause severe lodging after the roots are cut.

HARVESTING AND HANDLING PURE SORGHUM SEED

When sorghum is grown for pure seed, several precautions are necessary in addition to those required to produce grain for feed or market. It is necessary to plant the crop on land that is not contaminated with volunteer sorghum. The field must be isolated at least 40 rods from any other sorghum in order to avoid cross pollination. A greater distance is desirable if Sudan grass, broom corn, or Amber sorgo is in the vicinity. Only pure seed should be planted. Off-types and mixtures should be removed, if possible, before the heads have shed pollen. Hybrids can generally be distinguished by their greater height and vigor. Other mixtures can be detected by such differences as color of grain or hull, type of heads, or appearance of leaf or stalk when height of plants is the same

The crop should be harvested with a row binder before frost and as soon as 90 to 95 per cent of the seed has hardened. The development of grain on a head of sorghum begins at the top of the head and progresses downward. In case of limited rainfall during the pollination and fruiting period, there may be a difference of more than a week in the maturity of the upper part of the head as compared to the bottom of the head. Also the side of the head not exposed to the sunlight is slower in maturing than the south side. The maturity of heads on late tillers is generally much retarded as compared to those on the main stalks and early tillers. Harvest should usually not be delayed until the late tiller heads are ripe, since the main crop of seed may then be badly discolored and weathered.

After curing in the shock for two or more weeks, the crop can be threshed. If threshed during a period of dry weather there usually will be little contamination by broken stalks, the moisture content will be low, and the glumes will separate from the seed. The grain should be sacked at the machine when intended for seed purposes. The separator should be carefully cleaned if other sorghum has been threshed previously.

The seed should be cleaned and graded to remove all cracked and immature grain and should be stored in such a way as to permit free circulation of air around the sacks. Two sacks may be laid on the floor 6 inches apart. The next two may be laid across these, also 6 inches apart, and so on. Mature, dry seed handled in this way will usually germinate above 95 per cent.

The production and marketing of pure seed is a highly specialized business requiring good threshing and cleaning equipment that can be thoroughly cleaned and accurately adjusted. The reputation of a pure-seed grower is judged by his product.

HARVESTING ROW SORGHUM FOR FODDER AND SILAGE

The row binder is used in harvesting sorghum that is grown in cultivated rows for fodder or silage. Cutting by hand is not justified, because of the great amount of labor involved. The best stage for cutting with a binder is at the time the crop is ripe, or so nearly ripe that the process will be completed

in the shock. It is especially important that the crop be mature for silage purposes, to prevent too great acidity. If a silage crop does not mature before frost, fairly good silage can be made by cutting it within a few days after frost. Immature sorghum when badly withered by drought also has been used successfully for silage in western Kansas.

Much experimental work indicates that the sorghum crop usually is of greatest value when fed as silage. Careful management will do much to reduce the cost per ton of silage. Silage can be made about as satisfactorily from fodder which has stood in shocks (fig. 14) for several weeks or months as it can when the crop is first cut. By this method cheaper labor may sometimes be utilized. The main requisite for making good silage from fodder is the use of an abundance of water to make up for the loss of moisture by drying in the field. Choice of varieties is also a factor. Varieties such as Kansas Orange are more succulent than kafir and consequently require less water to make good silage.

FIG. 14.—A field of well-shocked sorghum fodder.

In recent years several manufacturers have developed a combined harvester and silage cutter which eliminates binding and lifting of bundles and delivers the silage into the wagon ready to be placed in the silo. Where the pit and the trench silos have been found adapted to the drier sections of western Kansas, the use of the combined harvester and silage cutter can well be considered. In the case of the trench silo it may be possible to reduce the cost by using a crawler type of tractor to pack the silage.

STORING SORGHUM GRAIN

A number of factors are involved in the successful storage of sorghum grain. The most important are: (1) Moisture content of the grain at time of storage, (2) percentage of broken kernels, (3) percentage of broken stalks in the grain, and (4) humidity of the air at threshing time. The relative humidity may also be a factor during the period of storage.

Sorghum grain probably passes through about the same change in storage as wheat and other cereals, but it is somewhat more sensitive to storage conditions, since the crop is generally threshed during a season of lower temperatures in which natural drying is not so pronounced. Grain that is to be

stored until the summer following harvest must have a low moisture content and be free from cracked kernels and broken stalks.

Early-maturing adapted varieties in Kansas ordinarily will dry enough for safe storage during a period of two or more weeks early in the fall.

Influence of Moisture.—Storage experiments at the Fort Hays station have shown that sorghum grain with 19 per cent moisture will quickly become moldy and may sour with the coming of warm weather. Grain containing 15.9 per cent moisture heated with the coming of high temperatures in May and later was found to be moldy and heated in the bin. Grain with 12 per cent moisture can generally be stored with safety. It is usually possible to secure grain of low moisture content by harvesting with a binder, curing in the shock, and threshing in dry weather.

Experiments have shown that foggy, damp weather or a light rain may raise the moisture content of ripe sorghum in the field from 3 to 5 per cent, as indicated in Table X.

TABLE X.—Rise in moisture content in the grain of six varieties of sorghum that were left standing in the field after they were ripe

Manhattan, Kansas, 1931 (*a*)

Variety.	Moisture content.		
	Oct. 29.	Nov. 13.	Dec. 26.
	Per cent.	*Per cent.*	*Per cent.*
Dwarf Yellow milo	12.2	16.0	14.8
Beaver	12.9	17.1	14.2
Wheatland	12.3	17.1	14.2
Club	13.3	17.9	15.0
Ajax	13.1	18.2	14.4
Western Blackhull kafir	13.3	17.0	15.0

(*a*) From unpublished data secured by W. H. von Trebra, graduate student, Department of Agronomy, Kansas State College.

A period of drying weather and severe freezes had reduced the moisture by October 29, to 12.2 to 13.3 per cent for the different varieties. A light rainfall of 0.71 inch on November 11 increased the moisture content of the same varieties on November 13, to 16 to 18.2 per cent, which is too high for safe storage. On December 26, after 14 days without rain, the moisture content of the grain was still too high for safe storage.

Sorghum grain which has a sufficiently low moisture content to keep during the cool part of the year may go out of condition with the coming of summer temperatures. Such grain may need to be turned during the spring and early summer to keep it from spoiling.

Influence of Broken Kernels.—Broken kernels, otherwise sound, are more likely to heat than whole kernels, which was found by Coleman *et al.*[15] to be due to their higher rate of respiration. When broken and whole kernels are mixed and stored the broken kernels are likely to become rancid, which may cause the whole lot to go out of condition. Broken kernels, being smaller,

15. Coleman, D. A., Rothgeb, B. E., and Fellows, H. C. Respiration of sorghum grains. U. S. Dept. Agr. Tech. Bul. 100:1-16. 1928.

pack closer and exclude the air and thus increase the risk. Frequently as much as 10 per cent of threshed sorghum grain consists of broken kernels.

Broken Stalks in Grain.-When sorghums are cut with a combine, broken stalks high in moisture content may contribute much moisture to the grain. For example, broken stalks which contain 42 per cent of moisture and are present to the extent of 3 per cent, will contribute about 5 quarts of water for every 20 bushels of grain. This is enough to increase the moisture content approximately 1 per cent, which may often be an important factor in storage.

Ventilators in Bins.—Yentilators have been used in bins to reduce the moisture content of the grain when the initial amount is too high for proper storage, but their effectiveness has not been fully demonstrated. In an experiment at Hays the grain in the vicinity of the ventilators was damaged most. Such ventilators may, however, be beneficial if heated air can be passed through them, but such a set-up is too expensive for practical use.

Artificial Driers.—Commercial driers afford another means of reducing the moisture content of grain. They have been found effective in California, but the expense is high and the cost of transportation is also an item if the grain has to be returned to the farm. Such driers, to be practical, should be centrally operated in a community.

FACTORS AFFECTING THE MARKET VALUE OF SORGHUM GRAIN

The factors which affect the keeping qualities of grain sorghum also affect the market value. The excess moisture and foreign material, such as dirt, sand, and broken stalks, not only have no value on the market, but increase the transportation cost and lower the quality of the grain. On the other hand, soundness, brightness, and full maturity tend to enhance the market value of sorghum grain, as they also improve its keeping quality.

Generally the varieties with salmon-yellow color, such as the yellow milos and often red kafir, command the highest price on the market. This is due to the fact that such grain is generally purchased for mixing with poultry feed in order to give color to the base material. White-seeded varieties of kafir are next in market value, although in California preference over either milo or kafir is given to the white-seeded durra, because it is thought to be more palatable to poultry. Grain of brown-seeded varieties is not so well accepted on the market, partly because of prejudice and partly because the brown to reddish-brown color is often associated with bitterness of seed. A mixture of sorghum grain of two colors reduces its attractiveness, and while it may not influence its feeding value, it limits the usefulness of the grain for blending purposes.

GROWING SORGHUM FOR HAY

Good sorghum hay is leafy, fine-stemmed, and relatively easy to cure and handle. The crop requires medium to heavy rainfall for satisfactory results. It is not well adapted where the annual rainfall is less than 20 inches because of frequent burning and low yields as a result of drought.

The method of preparing land for a sorghum hay crop may be the same in general as has been discussed for sorghum to be grown in rows. It is usually satisfactory to plow the ground in the spring after the first weeds start and harrow or disk one or more times to keep the land clean until planting time.

The best date of seeding for a hay crop is in early June, or when the soil is warm and warm weather is assured. The usual method of seeding is with a grain drill, since about one-fourth less seed is required and better germina-

tion and distribution are possible than by broadcasting. Broadcasting, followed by covering with a disk, is sometimes practical for small or irregular tracts, if moisture conditions are so good that no trouble in germination of the seed is expected.

Sorghum planted in close drills usually makes somewhat higher yields of air-dry forage than when grown in cultivated rows, and the quality of hay is superior.

SEEDING RATES IN CLOSE DRILLS FOR HAY

The amount of seed required when sorghum is planted in close drills for hay depends much upon the available soil moisture. Extensive experiments with rates of seeding at Hays, Kan., and Chillicothe, Tex., lead to the conclusion that 30 to 45 pounds to the acre is desirable in that part of the sorghum belt having less than 25 inches average annual rainfall.[16]

The hay was usually too coarse if less than 30 pounds were sown, and the crop was likely to dry up prematurely if as much as 60 to 75 pounds were used. There was little difference in the yield per acre between the various rates of seeding, which ranged from 15 to 75 pounds per acre. On well-prepared land with an abundance of stored moisture Atlas has given good results at the Fort Hays station when seeded at the rate of 75 pounds per acre. This variety is very succulent, and unless the stems are fine, as a result of thick seeding, it is difficult to cure the hay.

In eastern Kansas from 1 to 2 bushels of seed per acre ordinarily are needed to produce hay with fine stems. The Nebraska Agricultural Experiment Station[17] found that the diameter of the sorghum stems decreased with increased rates of seeding, and that when sown at 100 pounds per acre the stems were equal in diameter to those of Sudan grass seeded under the same conditions at 20 pounds per acre.

BEST STAGE TO CUT SORGHUM FOR HAY

The time for cutting sorghum hay depends primarily upon the stage of growth, which influences both the yield and the quality of the hay. Average yields for six years and chemical analyses for three years are reported in Table XI for Red Amber sorgo grown in close drills at the Fort Hays station.

The yields and the nitrogen-free extract, or total carbohydrates, per acre increased as the crop matured, while the protein remained about constant. Higher yields were obtained from later cuttings, but the hay was woody and thus of low quality. The earliest cuttings were too immature and watery to be desirable. It is ordinarily advisable to cut sorghum for hay when it is in the soft-dough stage, which is slightly later than the third stage reported in Table XI.

The time to cut sorghum hay must often be determined by such factors as drought, which causes the crop to dry up, or by lodging, frost, or rush of other work. Some growers prefer to seed late so that the crop will be ready to cut at about the time of killing frost and will not dry too much before the feeding season. Hay that is cured early, however, and is well dried, will keep indefinitely without souring, whereas difficulty may be experienced with late-cut hay.

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16. Vinall, H. N., Getty, R. E., and Cron, A. B. Sorghum experiments on the Great Plains. U. S. Dept. Agr. Dept. Bul. 1260:1-88. (Ref., pp. 84-85.) 1924.

17. Kiesselbach, T. A., and Anderson, Arthur. Annual forage crops. Nebr. Agr. Expt. Sta. Bul. 206:1-45. 1925.

TABLE XI.—Agronomic data and chemical composition of close-drilled Red Amber sorgo when cut at different stages of maturity

Fort Hays Agricultural Experiment Station, Hays, Kansas

Stage of Cutting.	Six-year average.			Three-year average.	
	Days after planting.	Height of plants.	Yield per acre.	Yield per acre.	
				Protein.	Nitrogen-free extract.
		Ins.	*Tons.*	*Lbs.*	*Lbs.*
Before heading	62	41	2.68	578	1,505
Partially headed	74	46	2.93	560	1,977
Bloom to dough	90	48	3.10	578	2,513
Seed ripe	114	50	3.70	555	3,416

Compiled from pages 86 and 87, U. S. Dept. of Agr. Dept. Bul. 1260.

MOWING AND CURING THE CROP

Sorghum hay cures more slowly than finer-stemmed feeds, is injured relatively little by rain: and loses few leaves. The crop may be cured in the swath for as long as a week before it is raked and bunched into large shocks with a hay buck. (Fig. 15.) It may be left in these shocks several months with little loss if the weather is dry.

Fig. 15.—(A) Mowing a crop of sorghum for hay. (B) Sorghum hay in large shocks.

Sorghum hay may be bound with a grain binder if the crop stands up well and is not too coarse and tall. While this method is somewhat expensive, from the standpoint of twine and wear on the binder, it leaves the hay crop in a convenient form to handle with a saving of labor.

It is a wasteful practice to mow and rake sorghum hay into windrows and then turn live stock into the field to help themselves. The practice may have some justificaion, however, when green wheat can be pastured near a field of sorghum hay. Cattle on wheat pasture crave dry feed and will utilize sorghum hay more effectively than would otherwise be the case during the early part of the winter. (Fig. 16.) It has also been observed that at times cattle on wheat pasture may relish somewhat weathered sorghum hay better than hay of bright color.

FIG. 16.—Feeding sorghum on the ground is shown in the foreground. Ricks of sorghum forage in reserve for stormy weather are shown in the background. The feed is pushed to the fence as needed.

GROWING SUDAN GRASS

Sudan grass is primarily grown for pasture and hay. It is one of the best annual cultivated grasses for either purpose. In recent years in the northern states it has largely replaced sorgos as a hay crop, and almost exclusively as a pasture crop. Like other sorghums it can endure considerable drought and will grow at fairly high altitudes, although it is sensitive to low temperatures. The extensive fibrous root system enables the crop to grow as long as there is any available moisture in the soil. It has the ability to discontinue growth, but remain alive, during a period of drought and then revive quickly and grow vigorously when rain comes. Sudan grass tillers abundantly if the stand is thin, but coarser stalks are thus produced.

Sudan grass hybridizes freely with all other sorghums. This feature is particularly serious because of the long blooming period caused by new tillers which are constantly coming into bloom as long as the crop is growing vigorously. Sudan grass should, therefore, not be planted within 60 or 80 rods of any other sorghum if the seed of either field is to be saved for planting.

Grasshoppers relish Sudan grass and may damage the crop considerably. Sudan grass is also very susceptible to chinch bugs, which often injure the crop seriously in eastern Kansas. The methods of controlling these insects are discussed in the section on "Insects Injurious to Sorghum."

Sudan grass, like other sorghums, is not exacting in its soil requirements. It makes a rank growth, and therefore draws heavily upon the soil moisture and leaves the soil in poor physical condition for another crop.

SUDAN GRASS FOR PASTURE

Sudan grass is highly regarded in Kansas as a pasture crop, since it comes into its greatest usefulness in July and August when native pasture is at its lowest production. It is ready to pasture about four weeks after planting and may be pastured until frost. When sown on well-prepared land that has a good supply of stored moisture, Sudan grass has a carrying capacity of from one to three head of cattle per acre. Greater returns can be had by dividing the field into two parts, and pasturing each portion alternately. Because of its great carrying capacity Sudan grass is a useful supplement to native pasture, and particularly so on those farms having only a small acreage available for pasture. All classes of live stock relish Sudan grass. It is not known to cause bloat in cattle, and there is little danger from prussic-acid poisoning if pure seed is planted, but the crop should be pastured cautiously at least for the first few days. The dangers in pasturing are further discussed in the section on "Prussic-acid Poisoning of Sorghum."

PLANTING SUDAN GRASS

A good seed bed for Sudan grass is about the same as for other sorghums, which has already been described. It is desirable that the land be in good tilth and have an ample supply of stored moisture. Cold, wet soils are particularly unsuited to Sudan grass, and, chiefly for this reason, early seeding should be avoided.

Sudan grass ordinarily should be seeded in close drills with a wheat drill, although it may be grown in cultivated rows, especially if seed is desired. Higher yields and a better quality of feed are usually obtained by planting in close drills which require no cultivation, but less seed is required for the wide rows.

Most wheat drills sow Sudan grass seed at about the same rate as wheat; that is, when set for 2 pecks of wheat per acre, about 2 pecks or 15 to 20 pounds of Sudan grass usually will be sown.

From the middle of May to the middle of June is usually the best time to plant Sudan grass, although it may be sown as late as the first part of July or as early as May 1 in southern Kansas. Generally 20 to 25 pounds per acre are recommended for drilled or broadcasted seedings in the eastern more humid regions of Kansas and 12 to 15 pounds in the western sections. As much as 30 pounds per acre is desirable if the seed is not expensive. Thick stands keep down weeds, produce a finer quality of hay and more pasture, and are ready to pasture a little sooner than thinner stands.

When the crop is planted in rows for seed production 3 to 4 pounds of seed to the acre have proved satisfactory in eastern Kansas, and a slightly lower rate of seeding is desirable in the western half of the state.

It is particularly important to obtain Sudan grass that has no mixture of Johnson grass seed because of the danger of infesting the land with the latter, which is difficult to eradicate. It is also important that Sudan grass seed contain no mixture of other sorghums if it is to be planted for pasture, because of the danger of poisoning.

HARVESTING SUDAN GRASS FOR HAY AND SEED

Sudan grass that is grown for seed should be cut with a binder, shocked, and threshed as wheat. All of the seed of Sudan grass does not ripen at any

one time. The crop should, therefore, be cut when it is believed the greatest amount of seed appears ripe, probably just after the earlier heads have ripened. Heavy winds may cause the seed to shatter readily, and if the heads that ripen first are damaged much from this source, a delay in harvesting for a few days may prove profitable.

A mower commonly is used in cutting Sudan grass for hay, although a grain binder may sometimes be used. After a short period of drying, the crop can be bunched and placed in cocks to he cured thoroughly before it is removed to the barn or stack. The best time to cut for hay is just after the first heads have appeared. The hay is a little more palatable at this stage of growth than later. Usually two crops may be harvested for hay, although under very favorable conditions three or even four may be cut, and in case of dry weather where the season is short, only one cutting may be expected. The yield is ordinarily higher for the first than for the succeeding cuttings.

In the more humid areas of Kansas, Sudan grass will yield from 3 1/2 to 4 tons of hay per acre. In the drier regions only 1 1/2 to 2 1/2 tons may be expected, and 5 or more tons is a common yield in the irrigated section of the Southwest.

PRUSSIC-ACID POISONING OF SORGHUM

All sorghums may, under certain conditions of growth, contain a poisonous substance known as prussic or hydrocyanic acid. In certain quantities this poison is so powerful that death of animals may follow within 15 minutes or a few hours. When the amount of the poison is not enough to cause immediate death, the animals may sometimes recover. The poisonous effect of this substance has not been noted in Kansas in sorghum fodder, hay, or silage, but only when animals eat the green sorghum plants.

Exhaustive study of this subject in several states during the past 30 years has indicated that the presence and amount of prussic acid in sorghums varies with the age of the plant, the condition of growth, and the variety.

The amount is greatest in young plants and gradually becomes less as normal plants reach maturity. The amount of prussic acid in older plants, however, is greatly increased if they are stunted by drought or frost, or if the plants are growing in hot, dry weather. The death of an animal has been observed within 15 minutes after it had entered a kafir field on a hot July afternoon. Second-growth sorghum, after the first crop has been removed, is always dangerous for pasture. Such a growth, if killed by hard freezes, is safe after it has dried.

The amount of prussic acid varies in the different sorghums. Collison, of the Florida Agricultural Experiment Station, found less prussic acid in Orange and Amber sorgos than in kafir, milo, and feterita. This agrees with observations in central and western Kansas, which have shown that kafir will kill more quickly than Amber.

It has been found that Sudan grass contains about two-fifths as much prussic acid under a given condition as many of the other sorghums. Consequently animals can eat a larger amount of this crop and not suffer injury. In fact, it is very rare for Sudan grass to kill if it is not contaminated with other sorghums, but the possibility does exist.[18]

Different animals are not equally affected by prussic acid. Horses and hogs are immune to the poison when pasturing on the green sorghum plants. Cattle are highly susceptible to the poison when it is present in amounts sufficient to kill. Sheep seem to be slightly less susceptible than cattle. The sorgos are

18. Vinall, H. N. A study of the literature concerning poisoning of cattle by the prussic acid in sorghum, Sudan grass, and Johnson grass. Jour. Amer. Soc. Agron. 13:287-290. 1921.

now rarely used for green pasture for cattle, since Sudan grass is a better crop for this purpose and is much safer. Many of the losses occur when cattle accidentally break out of pastures into nearby fields of sorghum. Five to six pounds of green sorghum with 0.2 per cent of prussic acid arc sufficient to prove fatal. The amount of prussic acid in Sudan grass is normally very low after the crop has been growing for 45 or more days. It is desirable, however, when Sudan grass is first pastured, to limit the time the animals are permitted to graze. The danger of sorghum poisoning may be somewhat reduced by feeding the animals some starchy concentrate, like the grain of corn, kafir. milo, or feterita, before turning them in on sorghum or Sudan grass pasture.

REMEDIES FOR SORGHUM POISONING

Large doses of cane sirup, molasses, and other forms of sugar, such as glucose and dextrose, act as antidotes to prussic-acid poison. A large dose of Epsom salts and raw linseed oil has been used successfully if the animal is reached in time. Any remedy to be effective must be available for instant use and be administered before the poison has reached the absorptive system of the animal.

GROWING BROOM CORN [19]

Broom corn is of minor importance among the groups of sorghum in Kansas, and the importance is decreasing, partly because of the greater use of vacuum cleaners and other improved household conveniences, which have lessened the need for broom-corn brooms and brushes. The highly specialized use of the crop and the limited and fairly constant demand for it account for the frequency of overproduction and the wide and sudden fluctuations in price. The crop can best be handled in districts where the industry has been developed over a period of years, since equipment, trained labor, and local markets will be available there. Nearly all of the broom corn in Kansas is grown in the southwestern corner of the state. A further extension of the broom-corn acreage in Kansas is not advisable at this time.

Broom corn is grown in rows in the same manner as grain sorghums. The same type of seed bed and method of cultivation as described for other sorghums are suited to broom corn. In general, June 1 is a favorable date to plant the crop. A stand in which the plants are from 6 to 9 inches apart in the rows ordinarily produces the best grade of brush The yields of brush are generally 200 to 300 pounds per acre and may be more than 600 pounds under favorable conditions.

At the Fort Hays station, over a period of three years, Black Spanish, a standard variety, yielded 530 pounds of brush to the acre; Scarborough, a dwarf variety, averaged 765 pounds. Observations at other places have shown that Scarborough is the best adapted dwarf variety and Black Spanish the best standard variety for Kansas.

HARVESTING THE BROOM-CORN CROP

A great amount of hand labor is required to harvest, cure, thresh, and bale broom corn in order to prepare it properly for the market. This makes the crop expensive to handle. Some specialized machinery also is needed. Broom corn is harvested either by cutting or pulling, depending upon whether a tall standard variety or a dwarf variety is grown. When one of the standard tall varieties is grown, the crop must first be "tabled" or "broken" before the heads can be cut. "Tabling" or "breaking" consists in walking between two rows of

19. Martin, John H., and Washburn, R. S. Broom corn growing and handling. U. S. Dept. Agr. Farmers' Bul. 1631:1-35. 1930.

broom corn and breaking or bending the stalks diagonally across each other, forming a so-called table of the two rows which is from 2 1/2 to 3 feet high. When so broken the heads extend beyond the rows that form the edges of the table. In the next operation the brush or head is cut off and pulled out of the boot. The heads are laid on the broken stalks or "table" to dry for a short time before being taken to the curing shed. If left for more than 24 hours the brush is likely to become bleached. When dwarf varieties are grown the heads are jerked or pulled from the stalks. This snaps off the stem at the upper joint. The heads are placed on the ground or between stalks and are later brought to the curing shed.

Broom corn should be harvested when the branches of the head have turned from a pale yellow to a pea-green color throughout. The seed will then be in the milk stage. The tendency is to wait too long to harvest, which may cause much of the brush to discolor or twist. For the finest grade of brush harvest should be completed within about a week.

Broom corn may be threshed either before or after curing. It is of better quality when threshed before curing because fewer of the fine branches are knocked off by the thresher when the brush is moist, and flexible. The best quality of broom corn is cured under sheds where the brush is placed on slats from 2 to 3 inches deep. After the brush has cured, if not immediately baled, it is generally bulked into larger piles to make room for new material. In southwestern Kansas much of the crop is cured in ricks 3 to 5 feet high, about 4 feet wide at the bottom and tapering toward the top. High-quality brush cannot be produced by this method, principally on account of damage caused by rain. In further preparation for market the brush is put into bales averaging from 300 to 360 pounds.

MARKET FACTORS FOR BROOM CORN

It is difficult and expensive to produce high-quality brush. The best quality has a bright pea-green color and is free from any discoloration. The brush should be made up of round, straight fibers, approximately 20 inches long and free from coarseness. The best fibers are pliable and not more than one-sixteenth of an inch in diameter, with numerous fine branches near the tip of the brush. Quality of the brush is improved by careful threshing or stripping to remove all of the seed and by placing the heads carefully and neatly in the bale. Defective brush consists chiefly of spikes, crooks, and twisted, coarse, flat, and stemmy fibers. The reddening so often found in brush is due to some injury to the growing plant, excessive moisture, or overmaturity.

INJURIOUS AFTER-EFFECTS OF SORGHUM ON THE LAND

It often has been observed that yields of wheat when planted after sorghum are likely to be somewhat lower than after corn. At Hays, over an 11-year period, the yields of wheat were 4.1 bushels lower when grown after sorghum than after corn. At Manhattan, for the period 1916 to 1921, the average yield of wheat after corn was 18.1 bushels per acre and after kafir 15.1 bushels. Experiments were made to determine the possible causes of the depressing effect of kafir on the yield of wheat.[20]

It was found that the higher yields of sorghum and the consequent greater use of plant-food elements and moisture did not fully account for the lower yields of wheat after sorghum. There was evidence that some decomposition

20. Sewell, M. C. Effect of *Andropogon sorghum* on succeeding crops of *Triticum sativum vulgare*. Bot. Gaz. 75:1-26. 1923.

product from the plant residue of the sorghum had a depressing influence on the growth of wheat.

Later investigations in California[21] showed that the sugar content of sorghum roots may be considerably greater than that of corn roots. This excess of sugars, or carbohydrates, becomes a food, under proper moisture and temperature environment, for the microörganisms which inhabit the soil. These microörganisms, however, cannot make use of this food without drawing on the available nitrates in the soil. There is, therefore, competition between the soil organisms and the higher plants for the nitrates and other plant foods. As a result the growing plants are retarded because of a depleted supply of available nitrogen. This condition lasts for only a few months, or until the sorghum roots have decayed, but in the case of wheat which in Kansas is planted immediately after sorghum harvest, some injury is generally reflected in lower yields.

The detrimental influence of sorghum may be avoided by fallowing the sorghum land the following season. It may also be avoided to a large extent by growing spring crops, especially those that can be planted as late as the latter part of May or in June. By that time available nitrates and other plant foods will have accumulated, and with normal rainfall most of the deficiency in soil moisture caused by the previous sorghum crop will have been overcome. Legume crops are more effective than nonlegumes, and in some cases nitrogenous fertilizers may be used to avoid the depressing effect of sorghum.

SORGHUM IN CROP ROTATIONS

Sorghum has no exacting requirements as to soil or as to place in a rotation, but the crop does best where there is ample plant food and moisture with the land in a good state of cultivation. Its superiority to corn is most evident under adverse conditions, such as on the poorer upland soils and when drought is a factor.

In eastern Kansas sorghum may take the same place as corn in any rotation. However, it is less desirable for wheat to follow sorghum than corn. The first crop after sorghum in eastern Kansas usually should be soybeans, corn, another crop of sorghum, or flax or oats, if the ground is fall plowed. Sorghum does well the first year after alfalfa or sweet clover, where an excess of nitrogen and a scarcity of subsoil moisture may be expected. The earlier varieties of sorghum may be planted where stands of corn have been lost, with only little additional preparation of the land.

Only within recent years has sorghum been accorded a definite place in a rotation system in the wheat belt of central and western Kansas. Frequently the crop has been grown on small or irregular tracts not well adapted to a general rotation, or else in fields convenient to feed lots or silos. More recently the need for diversified farming has been felt, and with the introduction of modern machinery for production, sorghum has been given more consideration in a cropping system.

A cropping system which should be satisfactory in central Kansas might include one or two years of sorghum, one year of barley, oats, or fallow, and two or three years of wheat. The number of consecutive crops of either sorghum or wheat may be determined by climatic conditions or the requirements of the farmer, without affecting the general plan. If the soil moisture is not replaced after a large crop of sorghum a season of fallow may be preferable to either barley or oats.

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21. Conrad, John P. Some causes of the injurious after-effects of sorghums and suggested remedies. Jour. Amer. Soc. Agron. 19:1091-1111. 1927.

A practical four-year rotation for central Kansas might include sorghum, barley, and two years of wheat. The average yields of the crops in such a rotation for seven years on the Fort Hays station are 30.6 bushels per acre for kafir, 27.7 for barley, 27.1 for the first crop of wheat, and 24.9 for the second crop of wheat. It may be desirable in some localities to use oats in place of barley in this rotation or fallow may be used in place of either of the spring small grains.

The cropping system mentioned for central Kansas provides for sorghums to be followed by fallow, a spring small grain, such as barley or oats, or a second crop of sorghum rather than by wheat. The advantage of this plan was discussed in the section on "Injurious After-effects of Sorghum on the Land."

The same general cropping system may be used in western as in central Kansas. It is advisable, however, to increase the proportion of barley to wheat in northwestern Kansas, to increase the proportion of grain sorghums to wheat in southwestern Kansas, and to use fallow more frequently throughout western Kansas. Thus in northwestern Kansas sorghum, fallow, wheat, and barley is a good cropping system. It may be desirable to grow two crops of wheat. Also in the northwestern counties sorghum may be partly replaced by corn, or corn may be included in the rotation preferably after wheat. A satisfactory cropping plan on good sorghum soil, where blowing can be controlled, in southwestern Kansas might include sorghum, sorghum, fallow, wheat. In some cases two crops of wheat may be preferred, or wheat may be followed by barley. Sorghum is preferable to most other crops in the hard-wheat belt where fall-sown wheat has winterkilled.

INSECTS INJURIOUS TO SORGHUM[22]

Sorghum, compared with corn and wheat, is relatively free from insect enemies in Kansas, but a number of insects cause considerable damage from year to year. The most destructive are the chinch bug, the kafir ant, and the corn-leaf aphis. Somewhat less important pests are the corn earworm, grasshopper, maize bill bug, and sorghum webworm, which sometimes damage the growing plants in some sections of the state. The common grain weevils and the Angoumois grain moth cause damage to stored sorghum seed.

CHINCH BUG

The greatest damage to sorghum by the common chinch bug follows the maturity and harvesting of small grain crops, such as wheat, oats, and barley. The partly grown bugs are at that time deprived of their earlier succulent food plants, so they migrate on foot from fields of ripened small grain, or their stubble fields, to nearby sorghum fields, and continue feeding to complete their development.

Chinch bugs are most injurious to young sorghum when this migration occurs, because the plants are too small to offer much resistance, and because the bugs congregate in such large numbers on the young plants. Once the bugs invade the sorghum field, there is no practical or effective means of getting rid of them. They fly to all parts of the field after they become adult, mate, and lay eggs around the roots of grasses in the sorghum field or near the base of the sorghum plants. These eggs hatch into a second generation of bugs which continue to feed upon the sorghum plants, causing more or less serious injury, especially in seasons of low rainfall.

The adult chinch bugs of this generation hibernate in native clump-forming grasses growing in fence corners, along roadsides, in pastures, ravines, and

22. Contributed by Harry R. Bryson, Assistant Entomologist, Kansas Agricultural Experiment Station.

similar places. Bunches of Sudan grass allowed to stand in the field during the winter also furnish suitable overwintering quarters for the bugs. If these grasses are destroyed by burning in early winter the hibernating bugs either will be burned or killed by exposure to the rigors of winter.

The migration of bugs at harvest, from the small-grain fields to the sorghum field, may be prevented by constructing a creosote-post-hole barrier between the small grain field and the sorghum field. This barrier is made by plowing a furrow 6 inches deep between the fields, throwing the soil toward

FIG. 17.—A creosote-post-hole barrier showing method of pouring creosote with a long-handled gallon bucket.

the sorghum field as shown in figure 17. The ridge formed by this soil is smoothed and firmed into a rounded ridge with the steep slope on the furrow side. A longitudinal line of creosote or coal tar is then maintained on the steep side and near the crest of the ridge. A satisfactory way to make this creosote line is to pour the creosote from a long-handled gallon pail with a hole made on the side near the bottom with a ten-penny nail. The creosote should not be allowed to trickle down the ridge into the furrow.

Holes one foot in depth should then be dug with a post-hole auger about a rod apart, adjacent to the creosote line on the side toward the small-grain fields. The holes should have the edges of the entrance slightly rounded. A

tablespoonful of flake Cyanogas should be placed in each post hole every afternoon. The bugs migrate to the creosote line but will refuse to cross it. They walk along the creosote line, fall into the hole, and are killed by the poison gas evolving from the flakes.

It is important that the post holes and ridge be made before the bugs start migrating so that the creosote line can be established quickly when the first bugs leave the small-grain stubble. It is necessary to renew the creosote line every afternoon until all of the bugs have left the stubble field, This period usually lasts 10 days to two weeks.

Further details regarding the construction and maintenance of this harrier are described fully in a circular on chinch bug barriers.[23]

KAFIR ANT

The kafir ant, or "little thief ant," is one of the most serious pests of sorghum in southern and central Kansas. This insect is most injurious when weather conditions retard the normal germination of sorghum seed.

The kafir ant may attack all sorghum seed when planted. The kernels are wholly or partly hollowed out with only the outer cuticle intact. The germ is devoured while the mealy interior is scattered about the soil. This results in a poor stand, as damaged seed do not grow. The presence of these ants and damaged seed reveal the reason for poor germination.

Since the kafir ant is not a mound-forming species, it cannot be destroyed by methods employed in the control of most other ants. The damage is done between the time the seed is planted and its germination, and therefore control methods aid primarily to hasten germination of the seed. No seed treatment has been found which will prevent the attack of these ants. The preparration of an excellent seed bed, in which sorghum will germinate quickly, is highly desirable. Sorghum that is planted before May 10 in southern Kansas may escape injury to a large extent. since the kafir ant does not become active until about that time.

CORN-LEAF APHIS

The corn-leaf aphis is in some seasons a serious pest of sorghum. It may injure the sorghum crop materially in the drier region of western Kansas by the clustering and feeding of large numbers of aphids in the curl, thus hindering the exsertion of the head from the boot. Badly infested heads usually produce a small amount of seed, which is low in vitality. The secretion of honeydew by the aphids forms a sticky mass about the head, which encourages the growth of moulds, which in turn prevent the production of high-quality seed. Aphids apparently winter in the southern states and migrate north, usually reaching Kansas in late May or early June; hence our outbreaks are no doubt due to migration.

Corn-leaf aphids are found early in the season at Manhattan, predominately on young sorghum plants. They apparently leave the sorghum and go to the corn plants at the time the corn begins to tassel. After the corn tassels emerge, the aphids are then found in greatest numbers in the curl of the sorghum plants before the heads appear and at the base of the head from then until in November.

The corn-leaf aphis is a very difficult insect to control because of the rapidity of reproduction, manner of feeding, lack of knowledge regarding its seasonal history, and its general distribution. Early planting appears to be advisable, since injury increases as planting is delayed. The later-maturing varieties suffer more injury than early varieties.

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23. McColloch, J. W. Chinch bug barriers for Kansas conditions. Kan. Agr. Expt. Sta. Circ. 113:1-6. 1925.

OTHER INSECTS

A number of other insects cause some injury to growing sorghum plants and the stored seeds of sorghum. The corn earworm, the larva commonly found in the tips of ears of field corn, injures the heads of sorghum by feeding upon the immature seed and by cutting the small branches from the head. It is sporadic in its damage and abundance, but may become a major pest in the future.

The maize billbug, or elephant bug, also a pest of corn on bottom land, injures sorghum by puncturing the stalks when the plants are small. Grasshoppers occasionally cause damage by eating the sorghum leaves, beginning generally with plants on the borders of fields. The grasshoppers can be controlled readily by scattering poisoned bran mash, using the regular Kansas formula which. stated in terms of both small and larger quantities is as follows :

Kansas Bait

	Small amounts	*large amounts*
Bran	1 pound	20 pounds
White arsenic or Paris green	1 ounce	1 pound
Black strap molasses, sirup, or cheap molasses	3 ounces	2 quarts
Oranges or lemons (including peel)	1/4	3
Water	1 1/2 pints	3 gallons

In preparing the bran mash, mix the bran, white arsenic *(not* arsenate of lead or calcium arsenate) or Paris green thoroughly in a wash tub while dry. Squeeze the juice of the lemons or oranges into the water, chop the remaining pulp and the peel into fine bits, or run them through a meat grinder, and add them to the water. Dissolve the sirup in the water and wet the poisoned bran with the mixture, stirring at the same time so as to dampen the mash thoroughly. More failures are due to imperfect mixing than to any other cause.[24]

The sorghum webworm sometimes injures the heads of sorghum grown in southeastern Kansas. This insect apparently is sporadic in its attacks, causing injury in one season and perhaps not appearing again for several years. The larvæ of this pest spin webs, tying parts of the head together with silk to form a compact mass. The larvæ live in small tubes permeating the mass.

The stored sorghum seed is attacked by pests which injure other grains. Among these the Angoumois grain moth and the common grain weevil are the most important. These may be controlled by fumigation in a tight bin with carbon bisulphide at the rate of 1 pound for each 25 bushels of grain. The carbon bisulphide should be poured on gunny sacks partially buried in the grain and allowed to remain 48 hours.

DISEASES OF SORGHUM[25]

Sorghum grown in Kansas is not attacked by so many diseases as wheat. oats, or corn. Severe losses have been due principally *to* kernel smut. A vigorous seed-treatment campaign has greatly reduced that type of disease. Other diseases are encountered much less frequently and have not been major factors in determining yield. The following diseases will be discussed briefly: (1) Covered kernel smut; (2) loose kernel smut; (3) head smut; (4) root crown and shoot rot of milo; (5) bacterial stripe; (6) bacterial streak; (7) bacterial spot; (8) rust; and (9) mouldy seed.

1. Covered kernel smut, *Sphacelotheca sorghi* (Lk.) Clint., is by far the most prevalent and destructive disease of sorghum found in the state. It is

24. Adapted from Bulletin 242 of the Kansas Agricultural Experiment Station, "Alfalfa Production in Kansas," page 36.

25. Prepared by members of the Department of Botany.

carried from season to season by dormant spores which cling to the exterior of the seed. These spores germinate the following spring at the same time as the sorghum seed, and the fungus penetrates the seedling before emergence. The parasite lives unseen in the sorghum plant until heading time, when it replaces the normal seed with the spores of the disease organism. Smutted heads usually are nearly normal in appearance when they first come out of the boot, but instead of filling with normal grains the glumes contain only masses of black spores enclosed in a whitish or brownish membrane. These spore balls sometimes resemble sorghum kernels in general shape but are more frequently considerably longer than normal kernels. The membrane surrounding the spores is easily broken, thus liberating the black mass of spores. Heads with badly ruptured spore balls usually appear dark brown or black even at a considerable distance. Spores liberated by the rupturing of the membrane walls are distributed by the wind over a considerable area, thus contaminating normal grain growing nearby. More severe contamination occurs if the smut heads are not removed before threshing.

There are at least five known forms of covered kernel smut found in Kansas. These forms are called physiologic forms, since they can be distinguished only by the reaction of several varieties of sorghum to them. Morphologically they are indistinguishable. The most widely distributed form attacks kafir, sorgo, broom corn, and certain other types heavily, but is unable to produce smut in milo, feterita, or hegari.

Another physiologic form occasionally found in Kansas attacks milo and hegari as well as kafir, sorgo, and broom corn, but does not attack feterita. This form has been collected only in western Kansas, Texas, New Mexico, and Oklahoma, where milo is widely grown.

The third form attacks feterita, kafir, sorgo, and broom corn, but is unable to cause smut in milo and certain unimportant varieties of sorghum. This form appears to be very scarce in Kansas, having been collected only once or twice over a period of years. It appears to be encountered somewhat more frequently in the Texas Panhandle, where more feterita is grown, but even there it occurs only infrequently.

The fourth form attacks kafir, sorgo, and broom corn, but is different from form 3 in that it readily attacks White yolo.

The fifth form attacks many of the sorghums, but is separated from the other forms in that it does not attack Pierce kaferita, certain feteritas, and feterita hybrids which are suseptible to the third form.

Since the spores are carried on the exterior of the seed, all five of these forms can readily bc controlled by proper seed treatment.

The treatment recommended for kernel smut of sorghum in Kansas is copper carbonate dust. Applications of 2 ounces of dust, containing 50 per cent of copper, per bushel of seed have given excellent smut control. If the treating compound contains only about 25 per cent copper, 4 ounces per bushel should be used.[26]

2. Loose kernel smut, *Sphacelotheca cruenta* (Kuehn) Potter, is very similar to the covered kernel smut in general appearance, and the two often are difficult to distinguish in the field. In the loose kernel smut, the membrane enclosing the spores is extremely fragile and ruptures very early. Toward the end of the season the membrane often has been entirely lost and most of the spores have been removed by wind and rain leaving the long, pointed, central mass of fibrous tissue exposed. The early and severe rupturing of the spore-ball membrane often causes heads that are smutted with loose kernel smut

26. Melchers, L. E., and Walker, H. B. The copper carbonate dust method of controlling bunt in wheat. Kan. Agr. Expt. Sta. Circ. 107:1-14. 1924.

to have a darker color than those smutted with covered kernel smut. It also frequently happens that the rupturing of the membrane allows the spores to be shed in great quantities over a very short period. The leaves of smutted plants, and often of nearby normal plants, may be blackened by the large numbers of smut spores clinging to them.

Two physiologic forms of loose kernel smut are now known, but only one has been found in Kansas. The kafir, sorgo, and broom corn are susceptible to both forms, while milo and hegari are highly resistant. Feterita is highly resistant to the form found in Kansas and moderately susceptible to the other.

Loose kernel smut is apparently not widely distributed nor abundant in Kansas. The spores are carried on the exterior of the seed and the disease, therefore, can be controlled by the same seed treatment as is recommended for covered kernel smut.

3. Head smut, *Sorosporium reilianum* (Kuehn) McAlp., has never been considered a major sorghum disease in Kansas. In many localities it is encountered only occasionally and then as scattered heads in fields of sorghum. Like corn smut, head smut of sorghum reaches its greatest abundance in the drier parts of the western third of the state. Even there, however, more than a few heads in any field is unusual.

Head smut differs from kernel smut principally in that the entire panicle instead of individual florets is affected, and that the organism is carried over from one season to another in the soil. In head smut all parts of the panicle become infected very early and the panicle branches, spikelets, and florets lose their identity. The smutted panicle usually emerges from the boot as a large smutted mass inclosed in a white membrane, which ruptures and disappears early. The interior of this mass is composed of tough, fibrous shreds intermingled with large quantities of black spores. These spores are carried away by wind and rain, falling to the ground where they overwinter. The spores germinate the following spring at about the time the sorghum seed is germinating. The seedlings become infected, and the organism grows on the interior of the plant until heading time. Since the spores are carried from season to season in the soil instead of on the seed, this disease cannot be controlled by seed treatment.

Very little is known concerning the susceptibility of sorghum varieties to head smut. It is known that the disease occurs on several varieties of sorghum and occasionally on the tassels of corn. Such varieties as Sumac, Freed, Red Amber, especially the latter, usually contain more head smut than the other sorghums.

4. Root crown and shoot rot of milo, a disease to which varieties of milo and many of its hybrid derivatives are especially susceptible, has appeared recently in the southwestern states and in Kansas. This disease seems to be spreading. If the soil is once badly infested, the milo crop and other varieties of sorghum which are susceptible cannot be grown to maturity. Extensive varietal tests have shown that kafir, feterita, sorgo, and some of the other sorghums are resistant.

The disease is recognized by a dwarfing of the plants and lack of heading. Generally the plants will grow to a foot in height before symptoms are noted. The lowest leaves turn yellow along the margins, the yellow color gradually spreading over the leaf and appearing on the leaves above. The plants are severely stunted, produce no heads, or only small ones, and gradually dry and decay. An examination of the stalk at the soil line shows a dark red internal discoloration of the central cylinder extending into the crown and roots.

The cause of this disease is being carefully studied, but no practical control has as yet been discovered. The selection of resistant strains apparently offers the greatest possibility.

5. Bacterial stripe, *Bacterium andropogoni* EFS, is the most prevalent bacterial disease of sorghum in Kansas and can be found nearly every year, It is only on certain varieties and during certain seasons that the disease develops heavily enough to be considered a factor limiting yield. The principal symptom is the occurrence of long, purplish-red stripes and blotches on the leaves, leaf sheaths. and stalks. The stripes may be long and narrow and limited by the parallel veins, or several may merge to form a large irregular elongated blotch. The color of these blotches or stripes is light red to deep purplish red, depending on the variety on which the disease occurs.

The disease is also characterized by exudate from the older lesions, especially on the backs of the leaves. This exudate often appears as drops of sticky moisture early in the morning. This soon dries, leaving a crusty scale that is usually reddish or brown in color. After several days there often is quite an accumulation of these scaly masses on undisturbed leaves.

The stripe disease usually is first noticed at about the time sorghum begins to head. It develops first on the leaves near the ground, and infection gradually spreads upward. It causes severe infection on susceptible varieties, many of the lower leaves being killed by stripe long before frost. Under Kansas conditions the disease has been observed on grain sorghum, grass sorghum, sorgo, and broom corn. In general feterita, White durra, hegari, and Manchu Brown kaoliang are very susceptible, while the milos are highly resistant. Under most circumstances kafir, sorgo, and broom corn are moderately resistant to moderately susceptible. The disease probably is not carried on the seed and, therefore, seed treatment would give no control. It apparently lives over winter in old sorghum refuse in the field and rotation of crops, therefore, helps keep the disease in check. It is most prevalent and severe in seasons marked by more than normal rainfall and is often not seen at all in dry seasons.

6. Bacterial streak, *Bacterium holcicola* Elliott, is very similar to the stripe disease just discussed. The symptoms are much the same, except that the lesions usually are smaller and have light-brown to tan centers with red margins, instead of being red throughout. The bacterial exudate crust is always white to cream in color instead of reddish or brown as in the case of stripe. Streak has been observed only occasionally in Kansas, but was severe on certain varieties at Hays in 1924. In general it seems to be even less abundant than stripe.

7. Bacterial spot, *Bacterium holci* Kenrick, is a sorghum disease relatively unimportant in Kansas. It seldom causes measurable damage except on Sudan grass, which seems to be particularly susceptible. The disease can be found every season on a rather wide range of sorghum varieties, but usually only in small amounts. It is characterized by small, round to elliptical spots on the leaves. The very small spots are solid red throughout. The larger spots have light ashy-gray centers with red margins. The spots seldom reach a diameter greater than a quarter of an inch, and most of them are much smaller.

8. Rust, *Puccinia purpurea* Cke., is a disease frequently seen on sorghum grown in the southern states, but is of infrequent occurrence in Kansas. Occasionally, in seasons of heavy summer rainfall, it appears in considerable abundance in the southern part of the state and as far north as Manhattan.

The rust pustules usually appear on the lower leaves in late August or early

September. Infection gradually moves upward toward the panicle, increasing in amount as it advances. In wet seasons pustules can be found in considerable abundance on the upper leaves, and many of the lower leaves are dried up by rust before frost.

The dark brownish-red spores are borne in pustules on both sides of the leaf and are carried from plant to plant by wind and rain. The disease is not seed carried, and seed treatment is, therefore, not an effective means of control. The only known means of control is through the growing of resistant varieties. Milo is resistant to rust, while feterita is susceptible. Kafir, sorgo, and Sudan grass are moderately susceptible. White durra is susceptible and shallu is resistant, while both resistant and susceptible varieties occur in kaoliang and broom corn.

9. Mouldy seed is frequently encountered in moist seasons, and especially in such varieties as feterita, which have a rough seed coat and a chalky texture. The organisms concerned are principally species of *Penicillium, Rhizopus,* and *Aspergillus,* which are only weakly parasitic under ordinary conditions. Seed frequently becomes so heavily infested with these organisms, however, that the germination is seriously impaired and poor stands result. This is particularly true of feterita seed. In such cases treatment of the seed with copper carbonate as for kernel smut has given increased stands.

PUBLICATIONS ON SOILS, CROPS, AND FARM MANAGEMENT

Previous publications of the station dealing with soils, farm crops, and certain phases of farm management include the following:

Bul. No.

190. Chemical Analyses of Some Kansas Soils. (82 pp.)
225. Forage Crops in Western Kansas. (54 pp., 10 illus.)
238. Corn Production in Kansas. (42 pp., 19 illus.)
239. Crop Production in Southwestern Kansas. (80 pp., 7 illus.)
241. Blackhull Wheat in Kansas. (24 pp., 3 illus.)
242. Alfalfa Production in Kansas. (42 pp., 12 illus.)
246. Country Elevator Margins and Costs of Operation. (60 pp., 77 illus.)
248. Wheat Production in Kansas. (84 pp., 44 illus.)
250. A Report of the Tribune Agricultural Experiment Station. (36 pp., 16 illus.)
251. Types of Farming in Kansas. (111 pp., 42 illus.)
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255. Dairy Farm Organization in Southeastern Kansas. (76 pp., 15 illus.)
260. Soil Fertility. (58 pp., 21 illus.)
262. Tillage Practices for Southwestern Kansas. (17 pp., 2 illus.)

Circ. No.

121. Seasonal Fluctuations of Wheat Prices. (11 pp., 4 illus.)
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