STUDIES OF COMBINE TYPES OF GRAIN SORGHUMS

by

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INTRODUCTION

Due to economic changes, new methods of crop production and the introduction of the combine harvester into the sorghum-producing area, the farmer has naturally experimented with the combine harvester in his search for more economical methods of harvesting. Early trials by farmers and experiment station men showed that many of the known sorghum types were not adapted to the combine method of harvesting, because they were too tall, lodged badly, and did not ripen uniformly. With this information at hand and recognizing the possibilities of the combine as a more efficient method of harvesting, the search began for new types of grain sorghums better adapted for combine harvesting. Plant breeders in Texas, Oklahoma and Kansas began to study material on hand, look for new strains and to produce new types by hybridization. Two new varieties, Wheatland and Beaver, representing combine types of grain sorghum, have been extensively tested and distributed to farmers in Kansas and Oklahoma. There were approximately 50,000 acres of Wheatland grown in Kansas in 1932. At the present time there are a number of new types being tested and many more promising selections are still in the breeding and testing nurseries.

The studies reported herein deal with the adaptability of some of these new types to the combine method of harvesting.

Height of plant, anchorage or root pull, breaking resistance of the stalk, lodging, moisture content of the stalk and grain, are the main characters considered. Other factors taken into consideration are resistance to kernel smut and milo disease, grain yields and market classification.

A combine type of grain sorghum may be defined as one which does not grow to a height of much more than 40 inches, produces a profitable yield, has well exserted heads, ripens all heads about the same time, matures before damaging freezes occur, remains erect a reasonable time after grain is sufficiently dry to store and threshes clean with a minimum of cracking.

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Mr. Frank J. Zink, of the Department of Agricultural Engineering, who repaired the stalk pulling machine and designed and built the stalk breaking apparatus.

REVIEW OF LITERATURE

There are only a few articles in the literature relating to combine sorghums while much has been published on sorghums in general.

The writer has not attempted to review all the literature pertaining to sorghums. Only those papers dealing with combining of grain sorghums, combine types and a few related references on technic are cited.

To aid in developing the discussion, the literature reviews are divided into four parts, as follows:

1. Reasons for use of the combine harvester.
2. Difficulties encountered.
3. Adaptation and yield.
4. Technic and miscellaneous papers.

Reasons for Use of the Combine Harvester

In an early report by Martin et al (15), they state that farmers began using the combine for harvesting grain sorghums about 1922 in their desire to find methods that require little hand labor. In a later publication, Martin et al (16) point out that grain sorghums are grown to a less extent than wheat and corn in many sections where the three crops are adapted because they require a large amount of hand labor in harvesting and threshing. They conclude that through the use of the combine harvester, grain sorghums should replace much of the corn grown in the central and southern Great Plains area.

Smith and Spilman (24) in reporting on the use of the combing harvester-thresher in northwestern Texas, state that the absence of any satisfactory mechanical means of harvesting the grain sorghums has caused the plains farmer to experiment with the combine.

Conrad and Stirniman (3) working in California on irrigated land and under different climatic conditions, found that root cutting hastened the drying of the sorghum plant. They state that combining is increasing because the work can be easily and cheaply done.

Ellsworth and Baird (5) found that the combine was practical under certain conditions and considered the weather as the most important limiting factor in the use of the combine for harvesting grain sorghums. The costs as compared to other methods of harvesting the grain sorghums were:

Harvesting Costs per Bushel

	cents
Combine	4.2
Header	5.2
Hand topping	11.2
Row binder	17.5

Finnell (6) considers the combine harvester practical for the harvesting of grain sorghums in the high plains region of Oklahoma.

Reynoldson et al (21) in preparing a summary of combine harvester results in the corn belt, list the advantages of the combine as follows: (1) It lowers the cost of harvesting; (2) it reduces the amount of labor required; and (3) it shortens the harvesting period.

Murphy (19) states that the principal advantage of a combine type sorghum is the economy of harvesting.

Difficulties Encountered

Martin et al (16) state that harvesting of grain sorghums is hindered by the irregularity of ripening and drying of the crop.

According to Ellsworth and Baird (5) weather at harvest time was the most important limiting factor in the use of the combine for harvesting grain sorghums.

Smith and Spilman (24) found that the lack of uniformity in ripening and the tendency of the stalks to lodge after frost were limiting factors.

Conrad and Stirniman (3) conclude that the principal cause of difficulties is the high moisture content in the stalks, leaves and sometimes in the seed.

Martin et al (16) believe that lodging is perhaps the most serious handicap to machine harvesting of grain sorghums. These investigators found that the average moisture content is higher in grain harvested with the combine before frost than in that harvested after frost.

Finnell (6) concludes that grain sorghum harvesting problems now largely resolve themselves into a search for high yielding varieties with straight necks which are resistant to lodging.

Adaptation and Yield

Martin et al (16) state that the grain sorghums, in spite of their greater productivity and acre value, are grown to a less extent than wheat or corn in many sections where the three crops are adapted. Martin (13) states that grain sorghums largely replace corn in the Southwest where the annual precipitation is less than 25 inches because of their superior drought resistance.

Coles and Wagner (2) report that sorghums are the most consistent producers of grain and feed of any crops grown in southwestern Kansas.

Finnell (7), in reporting on new varieties for western Oklahoma, states that the yield of Beaver, a combine type, is comparable to that of Dwarf Yellow milo, a standard grain sorghum.

Parker (20), in describing progress made in breeding grain sorghums for combine harvesting, states that the yields of combine types of grain sorghums varied from 40 to 65 bushels per acre on the five-acre experimental fields at the Hays Branch Experiment Station.

Martin (12), after studying some of the factors related to yield in three varieties of grain sorghum, concludes that yield is more closely correlated with the number of heads per acre than with the size of the head or weight of grain per head.

Martin et al (17) found that a mean temperature above 80 degrees Fahrenheit at heading time results in smaller heads, shorter plants and lower yields than mean temperatures slightly lower than 80 degrees Fahrenheit.

Karper et al (8) consider that temperature and the distribution of the summer rainfall are important factors determining the optimum time of planting. Planting should be done in so far as possible so that the crop can bridge over the mid-summer drought.

The early history of some of our present combine types is given in a paper by Sieglinger (23) in which he states that F_1 heads of a natural cross of milo and kafir were selected in 1919 from a field of kafir. These heads were planted and during later years dwarf straight-necked types were selected. One of these selections was later back-crossed to Dwarf Yellow milo, and one of the selections from this cross was named Beaver and distributed to Oklahoma farmers in 1928. One of the selections of the original cross was found to have high yielding ability and after being tested in Oklahoma and at Hays, Kansas, was named Wheatland and distributed to Kansas farmers in 1931.

Aicher (1) states that the most important function of a grain sorghum is to yield grain in large quantity. Wheatland is the best combine variety available to date. The stalks are short, sturdy and more resistant to lodging than any other combine variety of commercial importance. Beaver, the first combine type to appear, does not yield as well as Dwarf Yellow milo. The heads do not grow sufficiently above the leaves to make a suitable combine type.

Kiltz et al (10) state that Wheatland is the most promising variety for combine harvesting at Dalhart, Texas. Preliminary tests indicate that Wheatland is a close yield competitor of Dwarf Yellow milo. Beaver lodges more readily than Wheatland. Beaver averaged about 100 pounds of grain per acre less than Dwarf Yellow milo over a five-year period at Goodwell, Oklahoma. At Woodward, Oklahoma, Beaver and Wheatland are recommended combine varieties. Wheatland has yielded more than Dwarf Yellow milo and Beaver.

Swanson and Laude (25) state that the plant height of Wheatland varies from 24 to 39 inches, depending upon seasonal conditions. The stalks are short and sturdy, giving it strength to resist lodging to a greater degree than any other known variety of commercial importance. Farmers have found Wheatland well suited for harvesting with a combine. The heads of Beaver are slightly pendant and are somewhat obscured in the upper leaves. The stalk of Beaver is dry and not as resistant to lodging as Wheatland. The yield of Wheatland at Hays for the three-year period, 1930 to 1932, is 44.2 bushels per acre, Beaver 37.4 and Dwarf Yellow milo, 45.6.

Technic and Miscellaneous Papers

Salmon (22) reported results obtained with an apparatus for testing the strength of wheat straw. He states that in general it was observed that the straw of soft wheats which show resistance to lodging was more difficult to break than that of the hard wheats which lodge easily. The straw of varieties intermediate as to their tendency to lodge occupied an intermediate position with respect to breaking strength. Correlation studies of breaking strength and lodging were made, using 25 varieties grown for three years. The correlation coefficients are as follows:

	r
1927	-.310 ± .085
1928	-.416 ± .114
1929	-.583 ± .093

Koehler et al (11) describe a machine for measuring the pulling resistance of corn plants. They found that corn grown from Diplodia-infected seed had smaller root systems. The diseased plants offered less resistance when pulled than disease-free checks.

Van den berg (26) in reporting his studies of heterosis in sorghum, states that breaking resistance is probably not the most dependable indication of plant strength.

Martin (14) considers that recurving in sorghums is the result of thick heads being forced out of the side of a too narrow sheath while the peduncle is flexible and unlignified. He concludes that the selection of compact-headed types of milo or durra for erectness appears futile.

Martin et al (16) concluded that dwarf, erect, uniform grain sorghums can be harvested satisfactorily with properly adjusted combines.

Smith and Spilman (24), after experimenting with the combine to harvest grain sorghums, concluded that it is necessary for the grain sorghums to remain standing in the field until after frost in order that the grain may dry sufficiently for storage.

Melchers et al (18) reported the testing of 80 varieties, selections and hybrids in the various groups of sorghums. Five physiologic forms of kernel smut were used in these tests. Of the varieties, selections and hybrids so far grown, one selection of Spur feterita and three of Red Amber x feterita remained immune from all five forms of smut.

Elliott et al (4) describe the general symptoms of the crown, root and shoot rot of milo as a dwarfing of the plants, yellowing of lower leaves, the production of very small or no heads, and sometimes the decay of the central shoot. These symptoms are usually accompanied by a dark red discoloration of the central cylinder of the roots and of the interior crown. This red discoloration may spread throughout the crown and up into the lower nodes of the stalk.

MATERIALS AND METHODS

The materials studied and upon which the various tests were made consisted of two standard varieties of grain sorghums, namely Dwarf Yellow milo, C. I. No. 332, and Western Blackhull kafir, C. I. No. 906, and eleven crosses of Dwarf Yellow milo with other varieties. Club and Ajax were also included.

A three-row plot, 50 feet long, of each variety was planted in the sorghum breeding nursery at Manhattan for study in 1931. These three-row plots provided enough plants for studies of plant height, anchorage or root pull, breaking resistance of the stalks, lodging, and moisture content of the stalks and grain. A smutted series consisting of a single row of each strain was grown in 1931. A late seeded series was also planted but poor stands were obtained.

The same varieties were grown in single rows at Manhattan in 1932. The 15 strains used in the studies of combine sorghums in 1931 and 1932 are as follows:

Row no. 1931	Row no. 1932	C. I. or Sel. no.	Variety
2	1	322	Dwarf Yellow milo
5	300	871	Beaver
8	301	918	Wheatland
11	4*	1-2	(Wheatland x Dwarf Yellow milo)
14	5	27317	(Kafir x Dwarf Yellow milo)
17	6	916	[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6
20	302	28202	(Kansas Orange x Dwarf Yellow milo)
23	8	919	Custer
26	9	H. C. 305	White Custer
29	10	H. C. 311	[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]
32	11	H. C. 312	[Dwarf feterita x Smith (Kafir x milo)]
35	12	902	Kalo (Yellow kafir)
38	13	901	Club
41	14	968	Ajax
44	15	906	Western Blackhull

* No stand

These same strains were studied in the lodging nursery at the Hays Branch Experiment Station in 1932. The data on Wheatland, Beaver and Kalo collected by Mr. A. F. Swanson, in charge of cereal experiments at the Hays Branch Experiment Station, over a period of four years, have been summarized and are included in this thesis.

Plant height was measured in the field and is the average for the plot.

Twenty-five main stalks were selected at random for breaking resistance studies.

Anchorage or root pull was determined with the machine shown in Plate II.

Lodging was determined by allowing a half row of each variety to remain standing in the field until about December 1, when counts of down plants were made.

Because of the small numbers and ease of calculation, the rank method of correlation, as described by Henry L. Garrett in "Statitics in Psychology and Education", pages 189 to 192, was used to determine the correlation between lodging and plant height, breaking resistance and anchorage.

Moisture content of stalks was determined by chopping the stalks without the leaves in a hand-power feed cutter and drying to a constant weight in an electric oven.

Moisture content of the grain was determined in the Brown-Duval moisture tester.

Resistance to kernel smut, Sphacelotheca sorghi, was determined by inoculating seed of each variety before planting and counting the smutted heads.

The reaction to milo disease was observed only on the combine types grown in the milo disease nursery at the Garden City Branch Experiment Station.

Yields, except those reported in Table I, were obtained from reports of Mr. A. F. Swanson, of the Hays Branch Experiment Station, and from other experiment station workers.

EXPERIMENTAL RESULTS

Agronomic Data

Agronomic data on 15 varieties of grain sorghums grown at Manhattan in 1931 and 1932 are shown in Tables I. and II. In 1931, (Wheatland x Dwarf Yellow milo) 1-2 headed July 26, two days earlier than Wheatland. Beaver headed August 4, (Kafir x Dwarf Yellow milo) No. 27317, (Kansas Orange x Dwarf Yellow milo) No. 28202, and Dwarf Yellow milo headed August 6. White Custer headed August 10, the latest of the 15 varieties. In 1932, Beaver headed August 10, as late as White Custer and H. C. No. 311. H. C. No. 312 headed July 26, the earliest of 14 varieties grown in 1932.

Yields varied from 38 bushels per acre for (Wheatland x Dwarf Yellow milo) 1-2 to 83 bushels per acre for H. C. No. 312. Yields of single rows are not reliable and are not included in tables of yields presented in a later section.

The test weights vary from 45.8 pounds for Ajax to 58.1 pounds for Kalo. The test weight of Wheatland was 52.6 pounds and of Dwarf Yellow milo, 55 pounds.

Table I. Agronomic data on 15 varieties of grain sorghums grown in 50-ft. rows, Manhattan, Kansas, 1931.

1931 row no.	C. I. or Sel. no.	Variety	Date headed	Kernel smut %	Plant height in.	No. of stalks in 3 rows	% lodged	Yield Bu. per acre	Test weight lbs.	Condition of grain when harvested Oct.	Condition of grain when harvested Dec.	Seed color
2	332	Dwarf Yellow milo	8- 6	0	57	395	91	63.7	55.0	Bright	Disc.,	R.Y.:
5	871	Beaver	8- 4	2	37	187	28	50.2	(*)	±bright	Dull	do
8	918	Wheatland	7-28	2	35	361	3	48.3	52.6	Disc.	(Very) (dull)	do
11	1-2	Wheatland x Dwarf Yellow milo	7-26	0	30	403	5	38.5	50.5	±dull	Dull	do
14	27317	Kafir x Dwarf Yellow milo	7-28	19	34	354	12	46.5	54.8	Bright	do	do
17	916	[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	7-28	3	32	358	2	49.0	56.6	do	±dull	do
20	28202	Kansas Orange x Dwarf Yellow milo	7-28	1	37	374	38	55.9	57.1	do	Slight disc.	do
23	919	Custer	8- 1	2	40	343	30	47.6	56.3	do	±dull	do
26	HC 305	White Custer	8-10	8	43	356	35	53.3	58.2	±bright	do	White
29	HC 311	[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	8- 5	3	46	400	60	43.0	55.5	Bright	Dull	R.Y.
32	HC 312	[Dwarf feterita x Smith (Kafir x milo)]	7-29	3	57	333	96	83.9	55.2	do	do	White
35	902	Kalo (Yellow kafir)	8- 2	10	54	391	19	64.2	58.1	do	±dull	R.Y.
38	901	Club	8- 3	28	60	355	50	73.5	55.4	do	do	White
41	968	Ajax	8- 4	1.5	51	446	47	54.8	45.8	±dull	Dull	do
44	906	Western Blackhull	8- 2	2	65	363	65	75.8	57.9	Bright	±dull	do

, = discolored   : = reddish yellow   (*) = No test weight taken

Table II. Agronomic data on 14 varieties of grain sorghums grown in 50-ft. rows, Manhattan, Kansas, 1932.

1932 row no.	C. I. or Sel. no.	Variety	Date headed	Plant height in.	No. of stalks per row	Kernel smut %
1	332	Dwarf Yellow milo	8- 2	43	26	0
300	871	Beaver	8-10	34	--	0
301	918	Wheatland	7-29	32	--	0
5	27317	Kafir x Dwarf Yellow milo	7-27	39	86	0
6	916	[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	8- 3	33	49	2
302	28202	Kansas Orange x Dwarf Yellow milo	7-29	40	96	1
8	919	Custer	7-31	36	92	2
9	HC 305	White Custer	8-10	41	56	9
10	HC 311	[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	8-10	43	81	5
11	HC 312	[Dwarf feterita x Smith (kafir x milo)]	7-26	52	67	3
12	902	Kalo (Yellow kafir)	7-28	46	116	25
13	901	Club	7-28	55	147	3
14	968	Ajax	8- 4	49	61	0
15	906	Western Blackhull	7-28	58	84	10

Plant Height

Height of three of the older varieties of milo and of two recently developed combine types is illustrated in Plate I. Height of plants in the varieties grown at Manhattan in 1931 varied from 30 to 65 inches. (Wheatland x Dwarf Yellow milo) 1-2 averaged 30 inches, Wheatland 35 and Beaver 37 inches. Dwarf Yellow milo averaged 57 inches, Kalo 54 and Western Blackhull 65 inches. The plant height of the 15 varieties grown at Manhattan in 1931 and 1932 is shown in Table III.

Table III. Average plant height of 15 varieties of grain sorghums grown at Manhattan, Kansas, in 1931 and 1932.

Variety	Plant height - in. 1931	1932	2-yr. av.
Western Blackhull	65	58	61
Club	60	55	57
[Dwarf feterita x Smith (Kafir x milo)]	57	52	54
Kalo (Yellow kafir)	54	46	50
Ajax	51	49	50
Dwarf Yellow milo	57	43	50
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo] H.C. 311	46	43	44
White Custer	40	41	41
Kansas Orange x Dwarf Yellow milo	37	40	38
Custer	40	36	38
Kafir x Dwarf Yellow milo No. 27317	34	39	36
Beaver	37	34	35
Wheatland	35	32	33
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	32	33	32
(Wheatland x Dwarf Yellow milo) 1-2	30	(*)	30

(*) No stand

Plate I. Plant height of milo and its derivatives.

	Height inches
1 - Standard Yellow milo	93
2 - Early White milo	
3 - Dwarf Yellow milo	79
4 - Kafir x Dwarf Yellow milo No. 27317	46
5 - Beaver	49

Plate I. Plant height of milo and its derivatives.

Those varieties less than 45 inches in height may be combined, provided they have the other characteristics needed. With varieties above 45 inches in height, it is necessary to cut a longer section of the stalk, thereby increasing the amount of stalk material going into the machine. The shredded stalk or pumace is difficult to separate from the grain and if it contains large amounts of moisture, it may be one of the causes of storage losses.

The taller types are more likely to lodge as shown by correlation studies, pages 42 to 51 and Fig. 2. Observations made at Hays in 1932 show that late seeding tends to increase the height of the plant, see Table IV. This tends to increase the amount of lodging.

Anchorage or Root Pull

Van den Berg (26) studied the anchorage or root pull of F_1 sorghum hybrids and plants of female parents and found that hybrid vigor was expressed in a larger root system and heavier root pull, as well as in above-ground parts. Van den Berg did not make any studies of root pull in relation to lodging. The equipment and methods of determining the anchorage or root pull are shown in Plate II. A small self-recording dynamometer was used to measure the

Table IV. Height of plant of grain sorghums grown in the lodging nursery at Hays, Kansas, 1932. (*)

Variety	C. I. or Sel. no.	Date of planting: May 15	June 1	June 15	Av. for 3 dates
		Plant height - inches			
Dwarf Yellow milo	332	43	49	55	49
Beaver	871	30	33	37	33
Wheatland	918	30	36	37	34
(Wheatland x Dwarf Yellow milo)	1-2	30	33	34	32
Kafir x Dwarf Yellow milo	27317	35	40	42	39
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo)] -6	916	33	36	37	35
Kansas Orange x Dwarf Yellow milo	28202	38	45	47	43
Custer	919	36	43	42	40
White Custer	HC 305	45	50	49	48
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	34	40	40	38
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	44	48	54	48
Kalo (Yellow kafir)	902	47	55	55	52
Club	901	45	55	57	52
Ajax	968	41	49	53	48
Western Blackhull	906	51	56	63	56

(*) Data furnished by A. F. Swanson.

Plate II. Machine used to determine anchorage or root pull.

pull in pounds. A three-eighths inch rope was tied to the base of the stalk by means of two half hitches, as shown in Plate III. This also illustrates how the rope was tied to equalize the pull on each side of the stalk.

Twenty-five plants of each variety, which grew as near equal distances from neighboring plants as could be found, were pulled. The average anchorages of the 15 varieties are given in order of rank as follows:

	Anchorage or root pull pounds per plant		
	Mean	P.E.	Range
Beaver	211.4	± 9.2	95 - 330
White Custer	185.2	± 9.3	90 - 320
Dwarf Yellow milo	177.0	± 8.6	95 - 300
Wheatland	170.0	± 4.5	130 - 245
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo] H.C. 311	156.0	± 6.1	95 - 240
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	147.8	± 7.3	90 - 275
[Dwarf feterita x Smith (Kafir x milo)] H.C. 312	144.0	± 5.9	95 - 270
Kalo (Yellow kafir)	134.1	± 6.9	65 - 275
Western Blackhull	132.4	± 6.6	80 - 250
(Wheatland x Dwarf Yellow milo)1-2	128.6	± 7.0	55 - 295
Club	125.6	± 5.5	50 - 230
Kansas Orange x Dwarf Yellow milo	122.2	± 4.9	75 - 225
Custer	120.6	± 4.0	65 - 185
Kafir x Dwarf Yellow milo No. 27317	109.2	± 2.7	85 - 145
Ajax	92.4	± 4.3	45 - 140

The average anchorage or root pull varied from 92 pounds for Ajax, a variety 51 inches tall, to 211 pounds for Beaver, only 37 inches tall. Wheatland has an average anchorage of 170 pounds, the greatest of any of the desirable

Plate III. Self-recording dynamometer and method of tying to stalk.

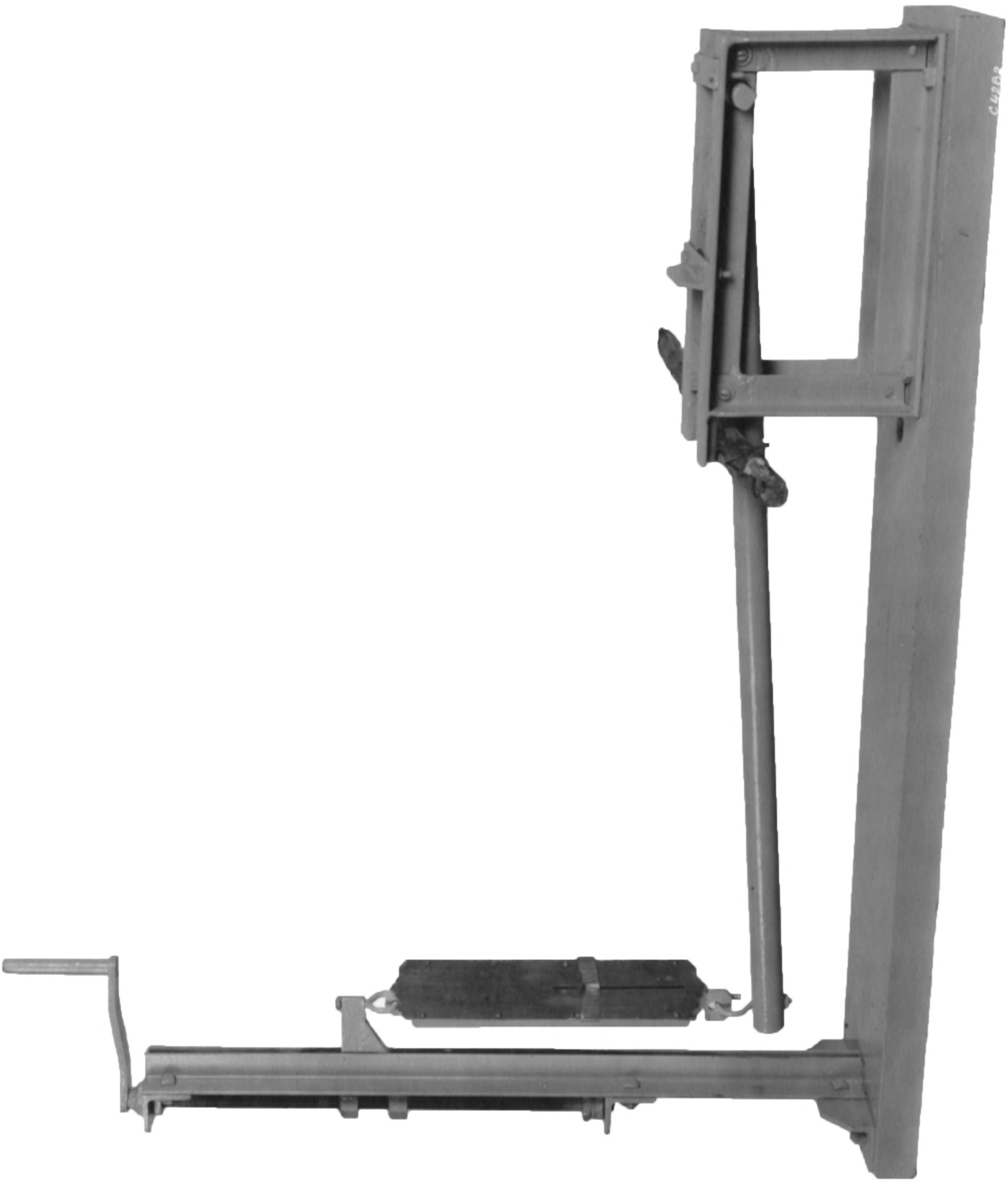
combine types except Beaver. Kafir x Dwarf Yellow milo No. 27317 has an average root pull of 109 pounds, the smallest anchorage of the combine types. Dwarf Yellow milo, one parent of the combine types, has an average anchorage of 177 pounds. Anchorage values of 134 and 125 pounds were recorded for Kalo and Club, respectively. There seems to be no observable character of a normal sorghum plant that indicates how firmly it is rooted in the soil. Anchorage or root pull has been correlated with lodging and will be discussed more fully in the chapter on correlation.

Breaking Resistance of Stalk

It seemed possible that there might be inherent differences in strength of stalk of grain sorghums measurable mechanically, as reported by Salmon (22) for wheat. To measure the breaking resistance of stalks, the apparatus shown in Plate IV. was designed and built by Prof. Frank J. Zink, of the Department of Agricultural Engineering, Kansas State College.

Twenty-five main stalks of each variety were selected at random for tests of breaking resistance. The stalks were cut at the ground level, stripped of their leaves and

Plate IV. Apparatus used to determine breaking resistance of the stalk.



leaf sheaths and broken at the second node for the taller varieties and at the third or fourth node for the dwarf types. The same stalks were then broken at the middle portion of the nearest internode above, which was not injured by the node break. Data on breaking resistance at the nodes and internodes of stalks of 15 varieties are presented in Table V., in which the strains are ranked according to average breaking resistance.

Beaver has an average breaking resistance of 180 pounds, the highest recorded for any variety. Ajax has a mean breaking resistance of 65 pounds, the lowest for any variety. Wheatland has a breaking resistance of 111 pounds and (Wheatland x Dwarf Yellow milo) 1-2, 95 pounds, the least resistance value for any one of the combine types.

The average breaking resistance at the internode is less than at the node in all varieties, as shown graphically in Fig. 1. The data obtained indicate very high correlation between breaking resistance at the node and internode.

Breaking studies were made at the Hays Branch Experiment Station in 1932 on twelve of the same varieties as studied at Manhattan. Material from plots planted on three dates and from the special five-acre combine test was available for braaking resistance tests at Hays. The plants used were mature and had been killed by frost.

Table V. Average breaking resistance of stalks at the node and internode of 15 varieties of grain sorghums, Manhattan, Kansas, 1931.

Variety	C. I. or Sel. no.	Breaking resistance of stalks: Node: Mean P.E. (Pounds)	Node: Range (Pounds)	Internode: Mean P.E. (Pounds)	Internode: Range (Pounds)
Beaver	871	180 ± 6	117-255	148 ± 5	84-222
White Custer	HC 305	143 ± 5	66-270	123 ± 5	75-234
Western Blackhull	906	138 ± 4	87-216	118 ± 6	78-177
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo] -6	916	138 ± 5	69-240	112 ± 4	66-162
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	135 ± 5	72-231	112 ± 4	78-171
Club	901	123 ± 4	66-171	99 ± 4	57-168
Kalo (Yellow kafir)	902	121 ± 4	72-168	96 ± 5	48-171
Custer	919	118 ± 4	72-177	97 ± 3	51-144
Dwarf Yellow milo	332	116 ± 4	75-198	88 ± 2	63-126
Kafir x Dwarf Yellow milo	27317	113 ± 3	81-168	94 ± 2	72-126
Wheatland	918	111 ± 4	75-192	95 ± 3	63-168
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	105 ± 4	66-144	82 ± 3	45-132
Kansas Orange x Dwarf Yellow milo	28202	102 ± 3	66-159	92 ± 3	66-126
Wheatland x Dwarf Yellow milo	1-2	95 ± 3	60-156	72 ± 4	51-144
Ajax	968	65 ± 3	39-120	51 ± 2	36- 81

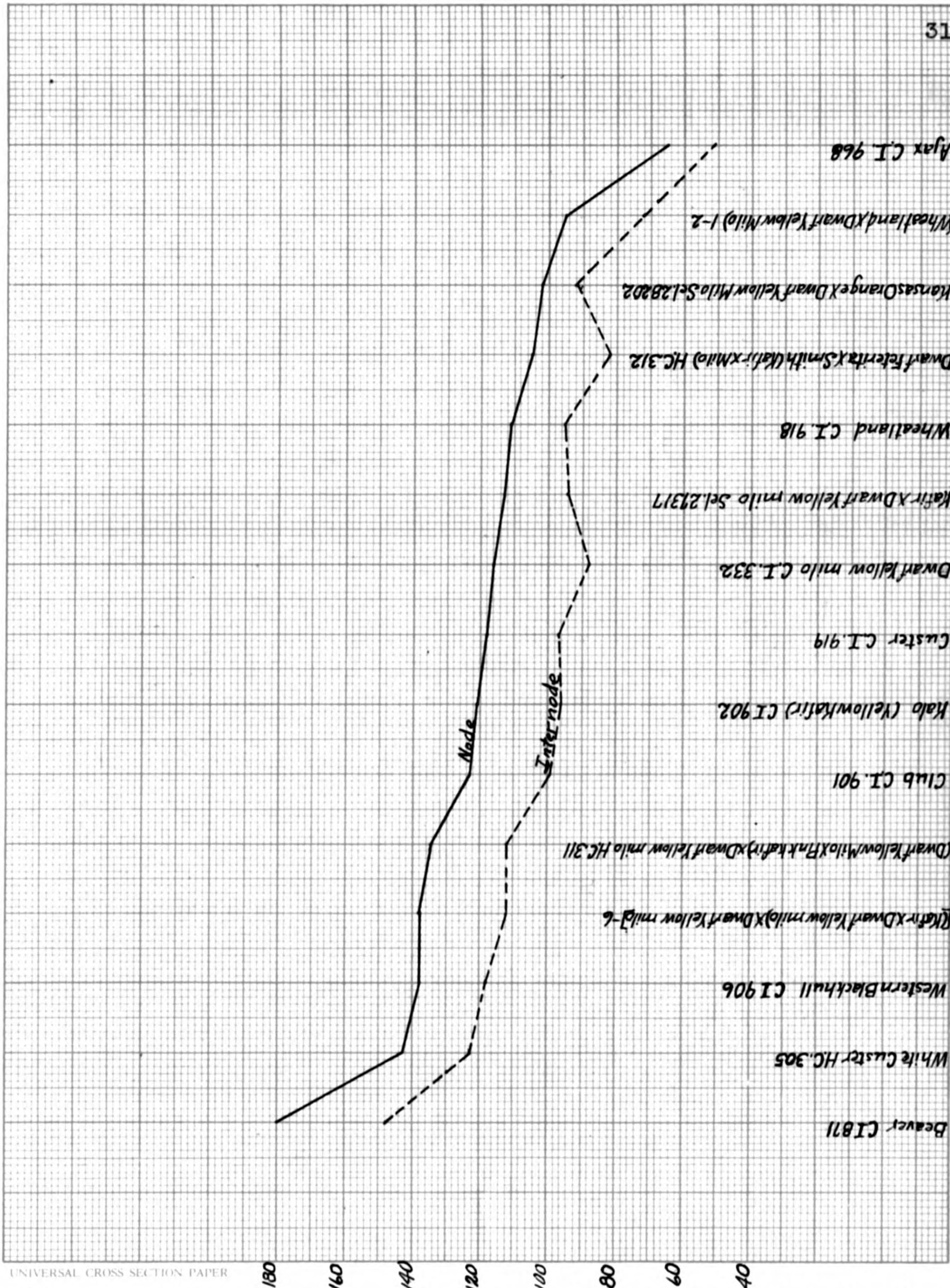


Fig. 1. Average breaking resistance at the node and internode of stalks of 15 varieties of grain sorghums, Manhattan, 1931.

The average breaking resistance values obtained at Hays in 1932 are shown in Table VI., and are used in studies of correlation between lodging and breaking resistance.

On the May 15 date of seeding, the highest breaking resistance was 32.8 pounds for Beaver and the lowest 14 pounds for Custer. The breaking resistance of Wheatland was 23.2 pounds and of Kafir x Dwarf Yellow milo No. 27317, 25.6 pounds.

On the May 31 date of seeding, Beaver ranked first with a breaking resistance of 28 pounds, and Dwarf Yellow milo the lowest with nine pounds. In this series, Wheatland has a mean breaking strength of 24 pounds, and Kafir x Dwarf Yellow milo No. 27317, 26.2 pounds.

On the June 15 date of planting, Beaver and Kafir x Dwarf Yellow milo No. 27317 each have a mean breaking resistance of 32.8 pounds. Ajax has the lowest breaking resistance, 8.2 pounds.

The breaking resistance values of the eight varieties grown in the five-acre special combine test at Hays in 1932 are as follows:

Table VI. Data on lodging and plant characters related to lodging of twelve varieties of grain sorghums, Hays, Kansas, 1932.

Variety	C. I. or Sel. no.	May 15 seeding			May 31 seeding			June 15 seeding		
		Lodging %	Breaking resistance	Plant height in.	Lodging %	Breaking resistance	Plant height in.	Lodging %	Breaking resistance	Plant height in.
Wheatland	918	0	23.2	30	0	24.0	36	0	24.0	37
Wheatland x Dwarf Yellow milo	1-2	0	21.4	30	2	14.4	33	1	23.4	34
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC311	0	24.8	34	0	18.8	40	0	26.6	40
Beaver	871	1	32.8	30	0	28.0	33	0	32.8	37
Kafir x Dwarf Yellow milo	27317	1	25.6	35	3	26.2	40	1	32.8	42
White Custer	HC305	1	17.8	45	0	15.4	50	4	28.6	49
Kansas Orange x Dwarf Yellow milo	28202	2	28.2	38	6	24.6	45	15	25.8	47
Custer	919	2	14.0	36	6	9.6	43	3	19.4	42
Ajax	968	2	14.4	41	11	7.2	49	39	8.2	53
Kalo (Yellow kafir)	902	6	14.4	47	24	9.2	55	12	17.0	55
Dwarf Yellow milo	332	10	15.2	43	21	6.0	49	84	17.4	55
[Dwarf feterita x Smith (kafir x milo)]	HC312	10	20.6	44	17	22.2	48	81	18.6	54

	Breaking resistance pounds per stalk
Wheatland	26.5
Custer	25.3
Beaver	23.7
Club	22.1
Kalo	22.1
(Wheatland x Dwarf Yellow milo) 1-2	21.3
Two-foot milo	19.8
Day milo	12.1

Wheatland, which stands up well in the field, has stalk breaking resistance of 26 pounds, the greatest of the eight varieties tested. Two-foot and Day milo, varieties which often lodge in the field, have stalk breaking resistance of 19.8 and 12.1 pounds, respectively.

Diameter of Stalks

The diameters of the nodes and internodes of stalks used for the breaking resistance studies made at Manhattan in 1931 were recorded. The average diameters for each variety, with data on lodging and other characters, are given in Table VII., page 37 in the following section, on lodging. The nodal diameters do not show much variation. Beaver has the largest diameter at the node, 2.4 cm. (Wheatland x Dwarf Yellow milo) 1-2 has the smallest diameter at the node, 1.9 cm. Kalo, Ajax and Western Blackhull all have nodal diameters of 2.0 cm. The diameters at the internode also have a rather narrow range, from 1.6 cm. for several varieties to 2.1 cm. for Beaver.

Lodging

To meet the requirements of a combine type, a variety of grain sorghum must be resistant to lodging. In their early observations, Smith and Spilman (24) state that sorghums have a tendency to lodge soon after frost. Martin (16) concludes that lodging is a serious handicap to machine harvesting. Finnell (7) states that one of the problems in developing a combine grain sorghum is the search for a type resistant to lodging. Serious lodging of Kalo (Yellow kafir) in the sorghum breeding nursery at Manhattan is shown in Plate V.

The percentages of lodging as observed at Manhattan in 1931 and reported in Table VII., are totals of both types of breaking, near the base of the plant and of the peduncle. The total lodging varied from two per cent for a hybrid combine type, [(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6, to 96 per cent for H. C. No. 312, a hybrid 57 inches tall and not considered a combine type. Wheatland lodged only three per cent, Beaver 28 per cent, and Dwarf Yellow milo lodged 91 per cent.

Plate V. Serious lodging of Kalo (Yellow kafir) in the sorghum breeding nursery at Manhattan, Kansas.

Table VII. Data on lodging and plant characters related to lodging of 15 varieties of grain sorghums, Manhattan, Kansas, 1931.

Variety	C. I. or Sel. no.	% lodged	Plant height in.	Anchorage in pounds per plant	Breaking resistance Lbs. per stalk: Node	Breaking resistance Lbs. per stalk: Internode	Stalk diameter cm.: Node	Stalk diameter cm.: Internode
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	916	2	32	147	138	112	2.2	1.9
Wheatland	918	3	35	170	111	95	2.0	1.6
Wheatland x Dwarf Yellow milo	1-2	5	30	128	95	72	1.9	1.5
Kafir x Dwarf Yellow milo	27317	12	34	109	113	94	2.1	1.8
Kalo (Yellow kafir)	902	19	54	134	121	96	2.0	1.6
Beaver	871	28	37	211	180	148	2.4	2.1
Custer	919	30	40	120	118	97	2.1	1.7
White Custer	HC 305	38	43	185	143	123	2.3	1.9
Kansas Orange x Dwarf Yellow milo	28202	38	37	127	102	92	2.3	1.8
Ajax	968	47	51	92	65	51	2.0	1.6
Club	901	50	60	125	123	99	2.2	1.6
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	60	46	156	135	112	2.2	2.0
Western Blackhull	906	65	65	132	138	118	2.0	1.7
Dwarf Yellow milo	332	91	57	177	116	88	2.1	1.8
[Dwarf feterita x Smith (kafir x milo)]	HC 312	96	57	140	105	82	2.2	1.9

Lodging of the taller types can be partly accounted for by the fact that a large head at the top of the stalk has a greater leverage, thereby increasing the strain on the stalk. The taller types are also more exposed to the wind which causes some lodging, especially when the stalks have thawed after a hard freeze.

Van den berg (26) in his study of hybrid vigor concluded that the breaking resistance may not be the most dependable indication of the strength of a plant. The inherent ability to react in a certain manner to a given set of environmental conditions probably explains the fact that plants of one variety may remain standing in the field while another variety may be badly lodged. The sum total of all environmental factors affecting the growth of a plant influences its ability to resist lodging.

More recent studies and tests of combine types of grain sorghums at the Hays Branch Experiment Station, described in the unpublished reports of Mr. A. F. Swanson, in charge of cereal experiments at Hays, have shown that lodging is an important factor in determining the desirability of any variety as a combine type. Data on lodging of 13 varieties grown in the lodging nursery at Hays in 1931 are presented in Table VIII. This nursery was planted on June 1.

Table VIII. Percentages of basal and peduncle lodging and total lodging of 13 varieties of grain sorghums as observed on five dates at Hays, Kansas, 1931.

Variety	No. of stalks per row	Dates counts made														
		Oct. 22			Nov. 4			Nov. 18			Nov. 25			Dec. 12		
		L	B	T	L	B	T	L	B	T	L	B	T	L	B	T
Dwarf Yellow milo	144	10	8	18	17	9	26	44	13	57	57	13	70	57	13	70
Beaver	110	0	0	0	0	4	4	0	15	15	1	24	25	1	26	27
Wheatland	107	0	0	0	0	4	4	0	6	6	0	6	6	0	6	6
(Wheatland x Dwarf Yellow milo) 1-2	179	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2
Kafir x Dwarf Yellow milo No. 27317	83	0	4	4	1	8	9	1	20	21	1	25	26	1	28	29
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	88	0	2	2	1	8	9	1	10	11	2	15	17	2	15	17
Custer	93	0	11	11	0	22	22	0	30	30	0	32	32	0	35	35
White Custer	83	0	0	0	0	2	2	0	5	5	0	6	6	2	7	9
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo] HC 311	107	0	5	5	5	17	22	8	17	25	8	20	28	8	23	31
[Dwarf feterita x Smith (Kafir x milo)] HC 312	94	0	0	0	0	5	5	1	6	7	2	12	14	4	18	22
Kalo (Yellow kafir)	127	2	28	30	3	45	48	6	48	54	11	80	91	14	77	91
Club	105	10	0	10	11	10	21	11	15	26	18	20	38	18	20	38
Western Blackhull	81	0	0	0	1	0	1	4	1	5	4	1	5	7	1	8
Averages				6.1			13.3			20.1			27.6			29.7

L = lodging at base B = breaking at peduncle joint T = total of L and B

These data indicate that as the autumn season advances an increased amount of basal and peduncle lodging occurs. On October 22, 1931, Dwarf Yellow milo had a total lodging of 18 per cent. This gradually increased to 70 per cent on December 12, 1931. Kalo on the same dates had 30 and 91 per cent lodging. On October 22, Wheatland, a variety much more resistant to lodging, had no broken stalks. The first lodging recorded for Wheatland was on November 4, and then was only four per cent of broken peduncles. On December 12, the total lodging of Wheatland was only six per cent. No lodging was recorded for (Wheatland x Dwarf Yellow milo) 1-2 until November 25, when there was only one per cent of broken peduncles.

The average lodging counts for 1931 and 1932 of 13 varieties planted at Hays on May 15, June 1 and June 15 are presented in Table IX. By December 1, Dwarf Yellow milo had lodged 40 per cent in the May 15 date of planting. In the June 15 date of seeding, this lodging had increased to 86 per cent. In the same series, Beaver was lodged one and ten per cent, Wheatland six and 25 per cent. Kalo in the May 15 date of seeding had lodged 28 per cent and in the June 15 planting, 48 per cent. In the May 15 date of planting, Club lodged 39 per cent and in the June 15 planting, 61 per cent.

Table IX. Average lodging at the base and peduncle of 15 varieties of grain sorghums planted on three dates, Hays, Kansas, 1931 and 1932.

Variety	C. I. or Sel. no.	Planted May 15			Planted June 1			Planted June 15		
		L	B	T	L	B	T	L	B	T
Dwarf Yellow milo	332	19	21	40	38	8	46	83	3	86
Beaver	871	0	1	1	1	13	14	5	5	10
Wheatland	918	0	6	6	0	3	3	15	10	25
Wheatland x Dwarf Yellow milo	1-2	0	3	3	0	2	2	10	30	40
Kafir x Dwarf Yellow milo	27317	1	5	6	1	15	16	6	7	13
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo] -6	916	0	11	11	1	8	9	11	23	34
Kansas Orange x Dwarf Yellow milo (*)	28202	0	2	2	1	5	6	0	15	15
Custer	919	1	13	14	0	21	21	10	31	41
White Custer	HC 305	0	1	1	1	4	5	14	35	49
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	1	1	2	4	12	16	9	3	12
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	6	16	22	5	15	20	22	48	70
Kalo (Yellow kafir)	902	3	25	28	8	50	58	14	34	48
Club	901	15	24	39	24	11	35	39	22	61
Ajax (*)	968	2	0	2	8	3	11	39	0	39
Western Blackhull	906	4	0	4	23	1	24	37	2	39
Averages		3.8	9.7	13.6	8.1	12.5	20.6	21.0	19.4	40.6

(*) Data for 1932 only.
L = lodging at base B = breaking at peduncle joint T = total of L and B.

The average lodging percentages of all varieties in the three dates of planting are as follows:

May 15	13%
June 1	20%
June 15	40%

Lodging or breaking over of the grain sorghum stalk occurs in two places. The type of breaking-over which is commonly known as lodging occurs near the base of the plant and is more often observed in the taller varieties. The second type of breaking is found at the base of the peduncle. This second type of breaking-over occurs in sorghums of various heights. A study of the data in Table VIII. indicates that breaking at the base of the peduncle accounts for a rather high proportion of lodging losses in the combine types of grain sorghums. The two types of lodging as observed in Wonder kafir are clearly illustrated in Plate VI.

Correlation of Lodging and Other Plant Characters

Since the number of varieties upon which data are available is small, the rank method was used in making all correlation studies between lodging and plant height, anchorage and breaking resistance. The rank method of correlation is described by Henry L. Garrett, in "Statistics in Psychology and Education", pages 189 to 193. The

Plate VI. Two types of lodging of Wonder kafir grown at Hays, Kansas. (Left) broken near the base, (right) broken peduncle.

formula $= 1 - \frac{6\Sigma D}{N(N^2-1)}$ gives only an approximate value for "r". The value of "r" is then found by interpolation from a table given by Garrett.

Manhattan. Correlation studies were made on material grown at Manhattan in 1931. Percentage of lodging and plant height show significant correlation, "r" equals -.8116 ± .0062. The negative value of "r" is due to the system of ranks used; the variety with the tallest plants was given rank 1, and the variety with the least lodged plants was given rank 1. This high correlation indicates that the tall varieties have a greater tendency to lodge than the dwarf types. The correlation between lodging and plant height is shown graphically in Fig. 2.

There is no correlation between lodging and anchorage or root pull. The value of "r" is .0075 ± .1823. Data on these two characters are shown graphically in Fig. 3.

No significant correlation was found between lodging and breaking resistance. The value of "r" is approximately .0196 ± .0182. The relation between these two characters is shown graphically in Fig. 4.

Hays. In order to supplement data collected at Manhattan, during 1931, additional studies of the relation between lodging and plant characters were made at Hays in 1932. The methods used in making breaking studies at Hays

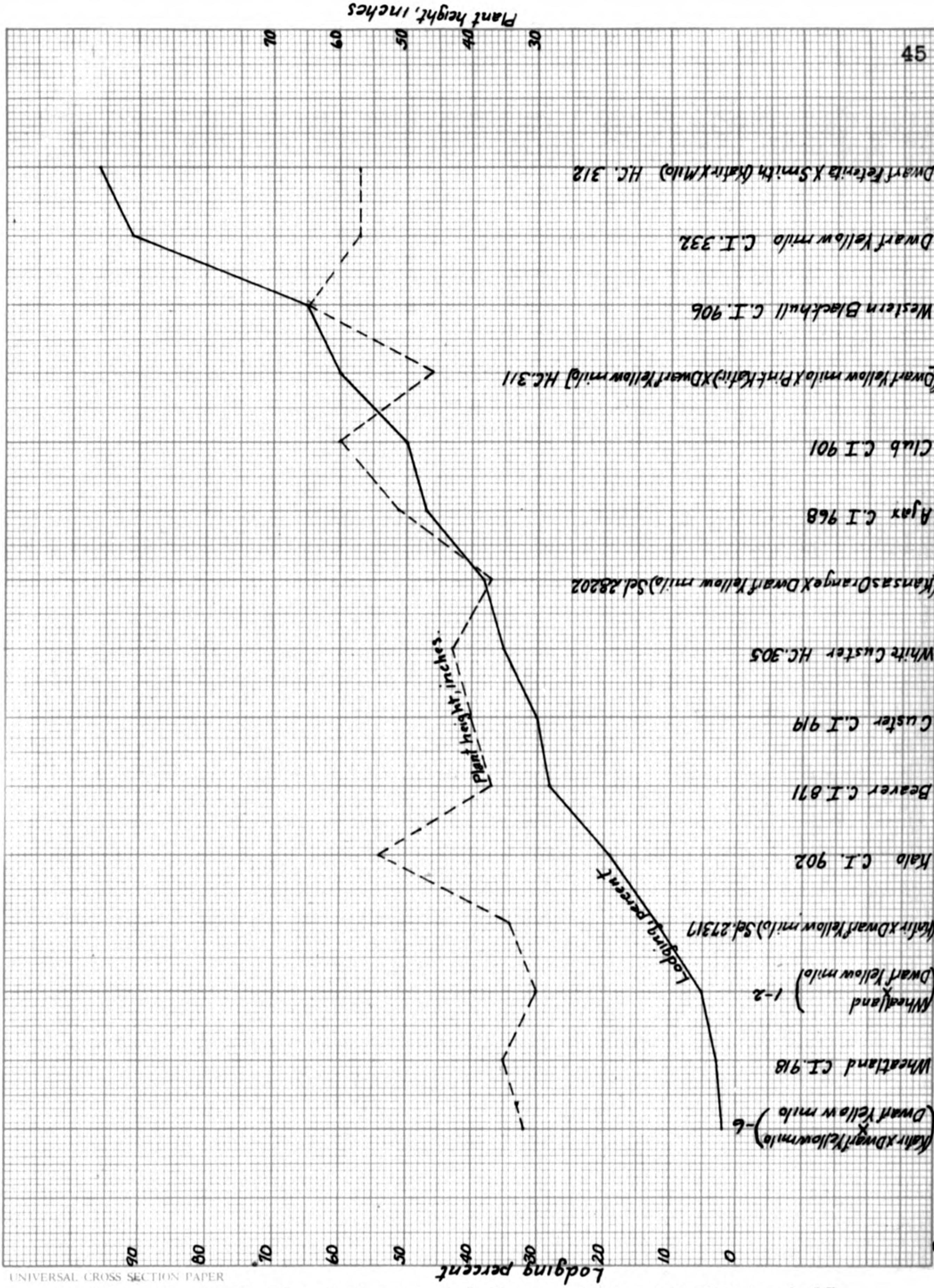


Fig. 2. Relation between lodging and plant height of 15 varieties of grain sorghums, Manhattan, Kansas, 1931.

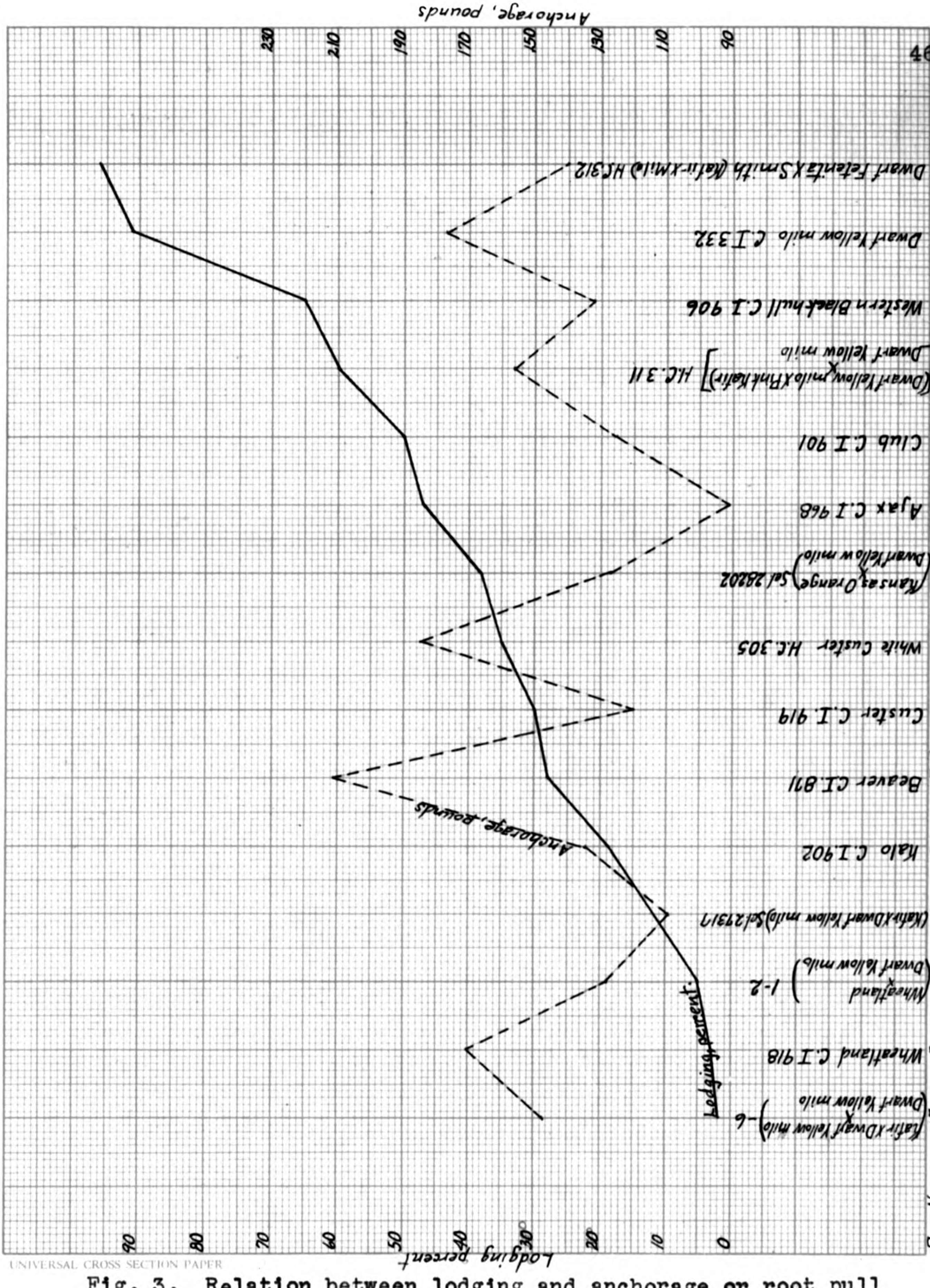


Fig. 3. Relation between lodging and anchorage or root pull of 15 varieties of grain sorghums, Manhattan, Kansas. 1931.

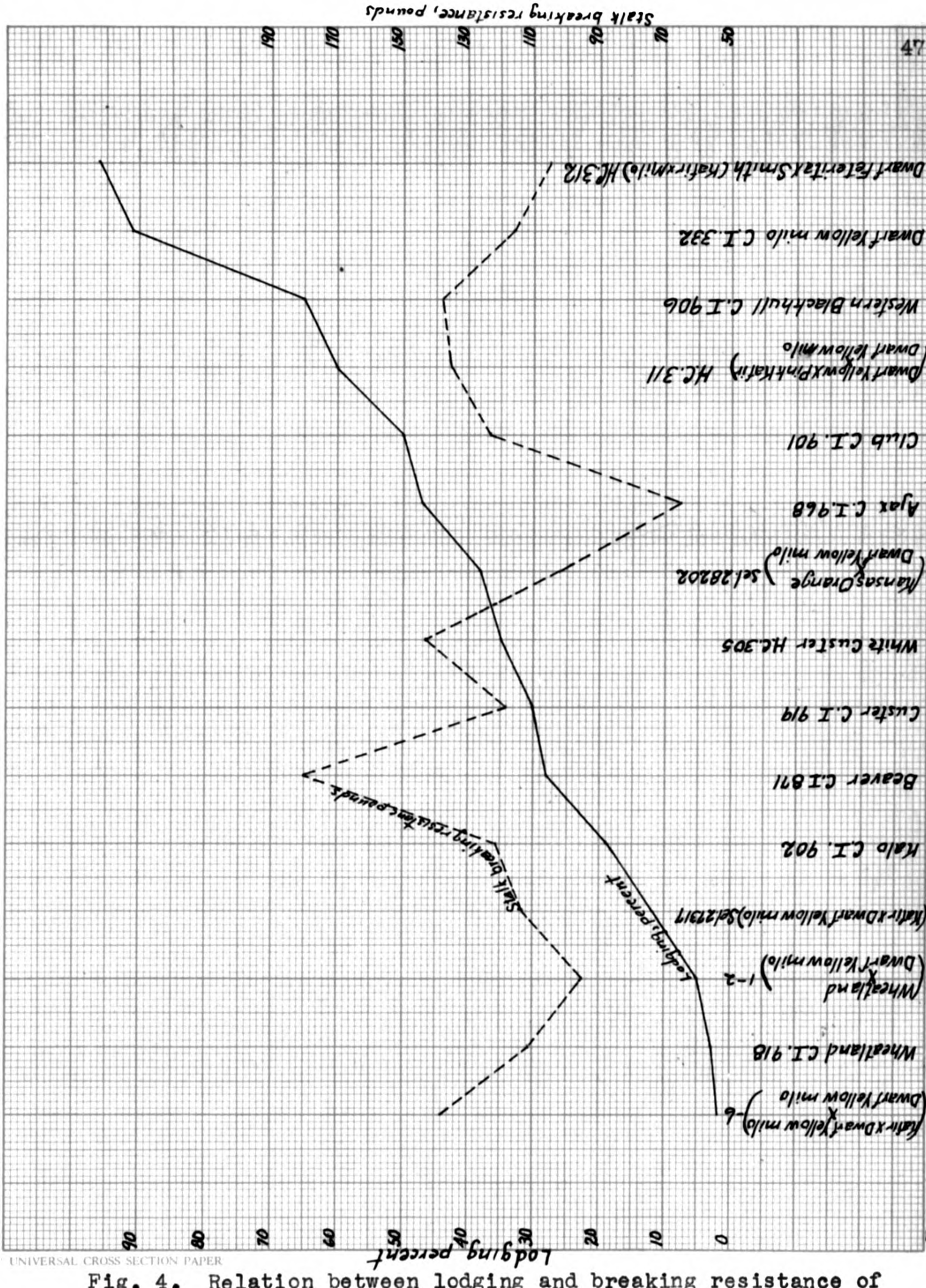


Fig. 4. Relation between lodging and breaking resistance of stalks (lower node) of 15 varieties of grain sorghums, Manhattan, Kansas, 1931.

were the same as at Manhattan, except that the breaking was done at what appeared to be the weakest node. This weakest node was assumed to be the one just below the first internode that showed definitely increased elongation above the average of the basal internodes. These studies were made about three weeks after killing frosts had occurred. At this date the stalks apparently had lost relatively little moisture. Only 12 of the 15 varieties studied at Manhattan were available at Hays. Plants from three dates of seeding, May 15, May 31 and June 15, as well as from the five-acre combine plots, were available for these studies.

Significant correlation was found between lodging and height in the May 15 planting, "r" = -.7174 ± .0989. This high value indicates that the taller the plant, the greater the tendency to lodge.

Significant correlation was also found between lodging and plant height in the May 31 planting, "r" = -.6159 ± .1265. While this value is smaller than that for the May 15 date of seeding, a similar relationship between lodging and plant height is indicated.

High correlation between lodging and plant height was observed in the June 15 date of planting, "r" = -.8417 ± .0594. This higher correlation in the latest date of planting is in agreement with data on lodging secured in the lodging nursery at Hays in 1931, as shown in Table VIII. This point is further illustrated in the fact that the later the date of seeding up to June 15, the taller the plants and the more lodging. This is shown in Table IV.

In studying the correlation between lodging and breaking resistance in the varieties planted May 15, the value of "r" was found to be .5176 ± .1492, a value too low to have much significance.

In the May 31 date of seeding, there is significant correlation between lodging and breaking resistance, "r" = .5914 ± .1325. This value for "r" indicates that there may be some association of these two characters in the varieties planted at Hays on May 31, 1932.

In the June 15 date of seeding, correlation between lodging and breaking resistance gave a value for "r" of .6935 ± .1057. This value indicates a higher relationship between lodging and breaking resistance than in either of the two earlier dates.

Data on lodging, breaking resistance and plant height of eight varieties grown in five-acre combine test plots at Hays in 1932 are given in Table X.

Table X. Lodging, breaking resistance and height of plants of eight varieties grown in the five-acre combine plots, Hays, Kansas, 1932.

Variety	Lodging %	Breaking resistance Lbs. per stalk	Plant height in.
Wheatland	0	26	34
Beaver	1	24	38
(Wheatland x Dwarf Yellow milo) 1-2	3	21	34
Custer	3	25	42
Two-foot milo	6	20	30
Day milo	9	12	34
Kalo (Yellow kafir)	28	21	58
Club	35	22	58

In the study of correlation between lodging and height, "r" = -.5176 ± .1827. This value is not statistically significant. Two short varieties, Two-foot and Day milo, 30 and 34 inches tall, have an intermediate rank in lodging. These two varieties are early and their normal growth and development had been arrested by the summer drought. This may account in part for the fact that these varieties lodged much more than Wheatland and Beaver. However, Early White milo, one of the parents of these varieties, lodges badly and may have contributed genetic factors for weak stalks.

Correlation between lodging and breaking resistance gave a value for "r" of .6486 ± .1447. This value is significant and indicates that there is association between the characters lodging and breaking resistance in the varieties studied.

Moisture Content of Stalks

The same stalks from which heads were used to make grain moisture tests were used for stalk moisture determinations. The stalks were first stripped of their leaves, then cut into half inch lengths in a small hand power feed cutter. The entire sample was then weighed and dried at a temperature of 85 to 105 degrees Centigrade in an automatic electric oven until a constant weight had been attained.

Manhattan. Weather data are presented in Table XI. The stalk samples of all strains grown at Manhattan in 1931 gradually lost moisture during each interval between tests, except for the samples collected on October 16, which were influenced by rain on October 13. While stripping the leaves of the samples collected on October 16, it was observed that there was considerable free water from the recent rain held by the leaf sheaths. This free water probably accounts for the increased stalk moisture for samples taken on this date. Data on moisture content of stalks of 15 varieties grown at Manhattan in 1931 are given in Table XII. and shown graphically in Fig. 5.

Table XI. Weather records during the months of September, October, November and December, 1931 and 1932, Manhattan, Kansas.

	1931				1932			
	Sept.	Oct.	Nov.	Dec.	Sept.	Oct.	Nov.	Dec.
Day	Precipitation				Precipitation			
1	4.64	.06			.80			
2								
3	.01					Tr.		
4		.65		Tr.			Tr.	
5		.01						
6								
7							.22	
8				.07				.03
9			.10	.17		.13		.02
10				.07		.09		.13
11		.58	.71	.11	.02			.10
12		.05			.33			
13		.48	.26					
14	Tr.		1.28		Tr.			
15	Tr.					.21	.02	
16			.11					
17			.37					
18	Tr.							
19			.07		Tr.			
20					.77			
21	1.13	Tr.			.16			
22	.92		.37		1.52	.15		.57
23			1.41			.02		
24	.18							.47
25	.33							
26			.25					
27		.21	.13		.43			
28								
29			.06					
30				Tr.				
31								
Total	7.21	2.04	5.12	.53	4.03	.60	.24	1.32
	Temperature				Temperature			
High	104	92	83	64	97	88	73	68
Low	45	33	20	18	42	27	5	-14

Table XII. Percentage of moisture in sorghum stalks at various dates, Manhattan, Kansas, 1931.

Variety	C. I. or Sel. no.	Sept. 18	Oct. 3	Oct. 16	Oct. 29	Average
Dwarf Yellow milo	332	79.8	77.2	75.4	72.8	76.3
Beaver	871	75.9	74.7	70.4	73.2	73.5
Wheatland	918	73.2	72.9	73.1	70.1	72.3
Wheatland x Dwarf Yellow milo	1-2	70.8	70.7	73.5	67.5	70.6
Kafir x Dwarf Yellow milo	27317	75.7	72.8	76.8	72.4	74.4
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo] -6	916	74.1	70.7	74.3	71.4	72.6
Kansas Orange x Dwarf Yellow milo	28202	76.7	73.4	77.8	73.6	75.4
Custer	919	82.2	76.5	76.0	72.1	76.8
White Custer	HC 305	80.2	78.6	78.1	76.8	78.4
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	78.8	76.4	78.3	73.7	76.8
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	81.3	78.7	76.0	76.4	78.1
Kalo (Yellow kafir)	902	78.5	76.3	74.2	75.0	76.0
Club	901	80.0	77.2	75.5	73.8	76.6
Ajax	968	73.8	67.0	66.9	67.7	68.8
Western Blackhull	906	78.8	77.6	75.0	74.3	76.4
Averages		77.3	74.7	74.7	72.7	74.8

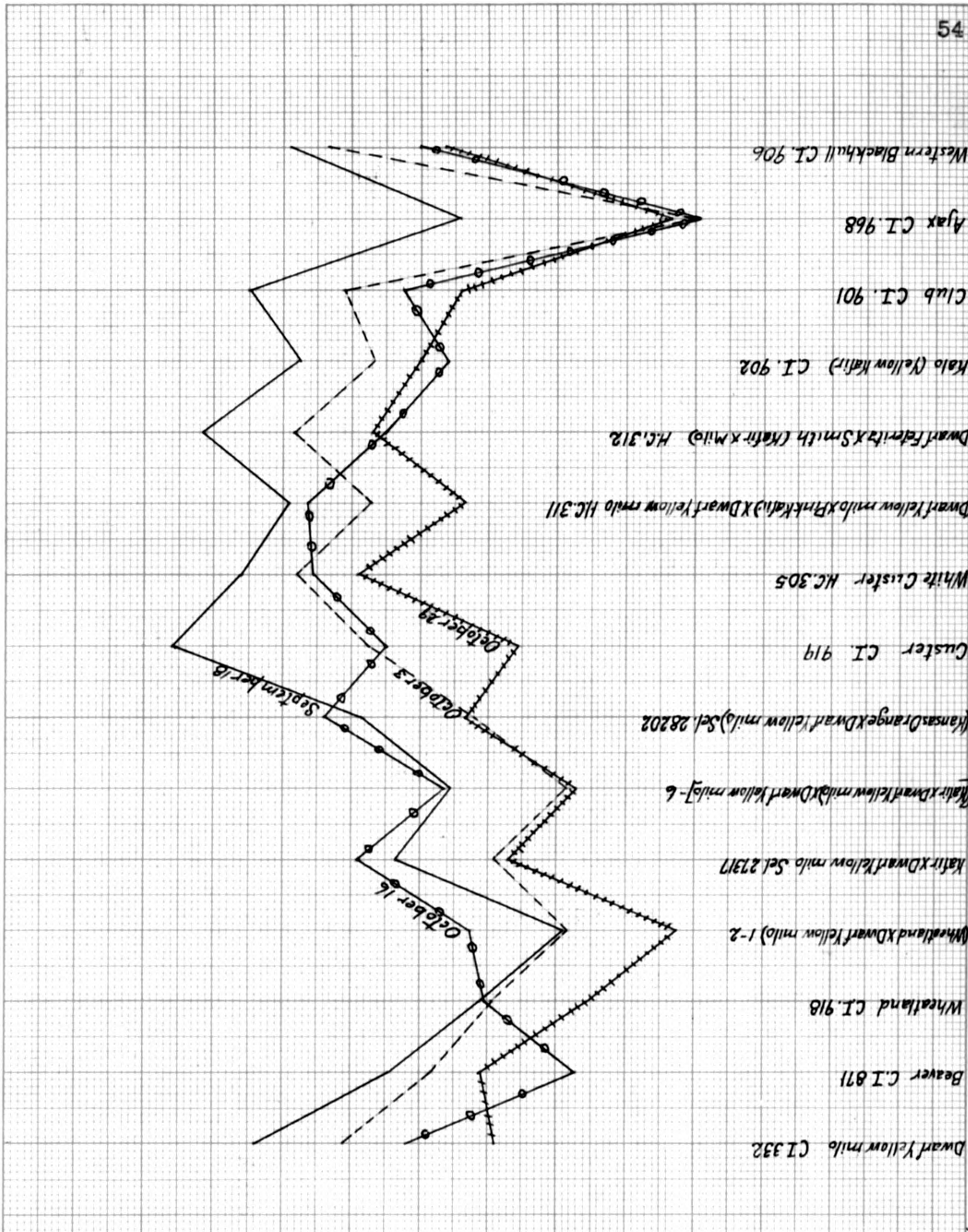


Fig. 5. Moisture content of stalks of 15 varieties of grain sorghums, Manhattan, Kansas, 1931.

Stalks of Custer contained 82.2 per cent moisture on September 18. On the same date, (Wheatland x Dwarf Yellow milo) 1-2 had 70.8 per cent moisture, the lowest of any variety. The total loss of moisture from Wheatland during the period September 18 to October 29, was only 3.1 per cent, and for Custer, 10.1 per cent.

While the effect of the frosts which occurred on October 17 and 18 was noticeable in killing and shattering of the leaves and in the drying of the grain, these frosts were evidently not severe enough to cause much loss of moisture from the stalks. The loss of moisture between October 16 and 29 averaged only two per cent, or about the average loss for other periods between tests.

It is evident that light frosts that kill the leaves aid in drying the grain but do not exert much influence on the moisture content of the stalks. Grain moisture samples were taken on November 13 but before the stalks could be gathered rain began falling, hence no determinations of moisture in stalks are reported for this date.

Hays. Studies of moisture content of stalks made at Hays in 1932 by Mr. A. F. Swanson and the writer are reported in detail in the annual report of Cereal Investigations at Hays. These data are summarized in the following table:

	Five-acre combine plots Hays, November 8, 1932 Per cent of moisture	
	Stalk	Peduncle
Wheatland	76.6	71.4
(Wheatland x Dwarf Yellow milo) 1-2	78.3	70.2
Two-foot milo	79.7	65.4
Custer	78.2	75.4
Beaver	79.2	75.5
Day milo	75.9	49.4
Kalo	79.9	57.1
Club	82.9	70.3
Wheatland, 14-inch rows, furrow drill	74.4	47.6
" 14-inch " , common "	74.3	46.3

Day milo has moisture content of 75.9 per cent, the driest of any of the eight varieties. Stalks of Wheatland have 76.6 per cent moisture, and stalks of Club have 82.9 per cent moisture, the highest of the eight varieties.

Studies of moisture content of sorghum stalks made at Manhattan and Hays in 1931 and 1932 show that the stalks of grain sorghums have a relatively high moisture content long after the grain is sufficiently dry to combine and store safely.

Moisture Content of Grain

Since the stalk of the sorghum plant has a tendency to remain green if favorable growing conditions prevail long after the grain is considered ripe, some investigators and farmers have thought that it was necessary to allow the grain sorghums to remain standing in the field well into the winter season before harvesting.

Martin et al (16) state that sorghums harvested after frost contained less moisture than those harvested before frost. Smith and Spilman (24), after experimenting with the combine, concluded that it was necessary to allow the grain sorghums to stand in the field until after frost in order for the grain to become sufficiently dry to store.

It was thought that moisture determinations made on the grain over a period beginning before frost and extending over a considerable time after frost might indicate when the grain could be safely harvested and stored, avoiding some of the losses reported by earlier workers.

1931. In 1931, moisture determinations were started on September 18 and continued every two weeks until November 13. At this time a period of rainy weather began, followed by freezing and thawing temperatures and many cloudy days. Clear, drying days occurred again about December 10. Samples for final moisture tests were taken on December 26.

Data on moisture content of grain collected on six dates in 1931 are presented in Table XIII., and shown graphically in Fig. 6. The September 18 samples show a variation from 20.7 per cent for Kafir x Dwarf Yellow milo

Table XIII. Percentage of moisture in grain of 15 varieties of sorghums grown at Manhattan, Kansas, 1931.

Variety	C. I. or Sel. no.	Sept. 18	Oct. 3	Oct. 16	Oct. 29	Nov. 13	Dec. 26	Average
Dwarf Yellow milo	332	30.0	16.0	13.8	12.2	16.0	14.8	17.1
Beaver	871	23.6	16.1	13.9	12.9	17.1	14.2	16.3
Wheatland	918	23.1	17.1	13.9	12.3	17.1	14.2	16.3
Wheatland x Dwarf Yellow milo	1-2	21.5	15.5	13.0	12.2	17.3	14.9	15.7
Kafir x Dwarf Yellow milo	27317	20.7	16.0	14.1	12.2	17.0	15.1	15.8
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	916	22.5	18.4	14.2	12.9	17.3	15.0	16.7
Kansas Orange x Dwarf Yellow milo	28202	21.7	16.2	14.9	13.2	17.2	16.0	16.5
Custer	919	29.2	17.9	16.0	13.4	18.2	15.1	18.3
White Custer	HC 305	30.3	18.3	16.3	13.0	17.4	15.1	18.4
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	22.0	18.8	15.9	14.0	17.3	15.2	17.2
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	26.7	17.2	15.9	13.2	18.0	15.4	17.7
Kalo (Yellow kafir)	902	28.5	17.1	14.9	13.1	17.1	15.3	17.6
Club	901	28.1	20.8	16.4	13.3	17.9	15.0	18.6
Ajax	968	27.0	18.9	15.9	13.1	18.2	14.4	17.9
Western Blackhull	906	32.3	21.4	17.2	13.3	17.0	15.0	19.3
Averages		25.8	17.7	15.1	13.0	17.3	14.9	17.3

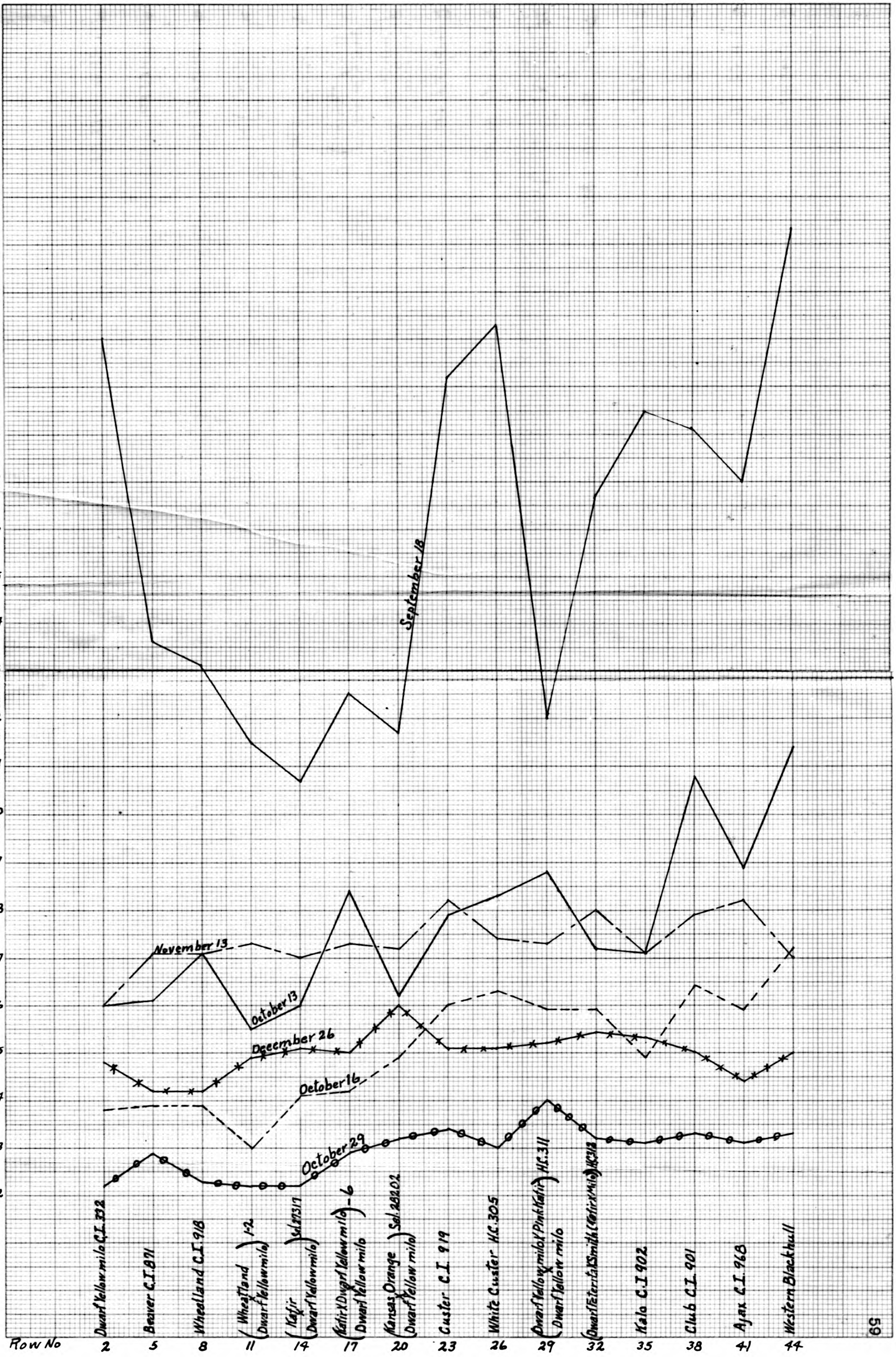


Fig. 6. Moisture content of grain of 15 varieties of sorghum grown at Manhattan, Kansas, 1931.

No. 27317, to 32.3 per cent for Western Blackhull kafir. During the next two weeks, the moisture content of grain of all varieties except Club and Western Blackhull dropped to 18.9 per cent or below. Each testing date, except November 13, showed a gradually decreasing grain moisture content. The minimum was reached on October 29, about ten days after the first frost. The test made on November 13 showed an average increase in grain moisture content of 4.3 per cent, due to a light rain on November 11 as recorded in weather data given in Table XI. This increase in moisture content following a rain or a period of high humidity presents another hazard to be considered in the combine harvesting of grain sorghums. The last test, taken on December 26, which was preceded by ten days of moderately bright and drying weather, showed a decrease in moisture content from November 13, but no strain reached the minimum as recorded on October 29.

The moisture tests made in 1931 indicate that combining of grain sorghums should not be attempted too early in the autumn because of the high moisture content of the grain. Grain that is generally considered sufficiently ripe to be harvested with the binder and set in the shock to cure would have a moisture content of approximately 15 to 20 per cent or more. The weather data and the moisture determinations indicate that the period for safe combine harvesting would ordinarily be about ten days after the first killing frosts. Thus, on October 29, 1931, the grain moisture content had become low enough, below 14 per cent, to store safely and without spoilage. At a later date, November 13, the sorghum grain had absorbed enough moisture from a light rain which fell on November 11 to be too high for safe storage. The moisture tests made on December 26 indicated that the grain had not dried sufficiently to store without damage, even though there had been at least ten days of drying weather before this date.

The data obtained in 1931 indicate that there was a period of ten days to two weeks before the light rain of November 11 when the grain sorghums could have been harvested with a combine at Manhattan and stored without danger of heating. The data also suggest that if harvest is delayed very long after the grain becomes dry, it may later absorb enough moisture from precipitation or from the humid atmosphere to go out of condition if combined and stored. If harvest is too long delayed, severe losses from lodging may occur.

1932. Plantings of the same strains were made in the sorghum breeding nursery at Manhattan in 1932 for further testing. The data on moisture content of grain obtained in 1932 are presented in Table XIV., and shown graphically in Fig. 7. Since only a small amount of material was available, moisture tests were not started until October 13. These tests were continued at weekly intervals until November 5, for all strains. Additional moisture tests of most strains were made on November 11, November 18 and December 1. On October 13, all strains except Kafir x Dwarf Yellow milo No. 27317 and Kansas Orange x Dwarf Yellow milo No. 28202 had over 14 per cent moisture in the grain. This is considered the maximum moisture content for safe keeping. The minimum moisture content for most strains was reached on October 21, about ten days after killing frosts occurred. Moisture determinations made on October 28 were only slightly different from those of October 21. Those made on November 5 and November 11 showed small increases due to light rains which occurred during the intervening periods. These results are similar to those obtained in 1931 and indicate that an increased moisture content of the grain may be expected after even a small amount of precipitation. On November 18 and December 1, small decreases occurred but the moisture content of most strains at this late date did not reach the minimum moisture content recorded on October 21.

Table XIV. Percentage of moisture in grain of 14 varieties of sorghums grown at Manhattan, Kansas, 1932.

Variety	C. I. or Sel. no.	Oct. 13	Oct. 21	Oct. 28	Nov. 5	Nov. 11	Nov. 18	Dec. 1	Average
Dwarf Yellow milo	332	14.8	12.2	11.9	12.1	12.8	12.0	11.7	12.5
Beaver	871	16.7	11.3	11.5	12.0	13.3	12.5	(*)	
Wheatland	918	14.4	10.8	11.8	12.6	12.9	12.2	11.5	12.7
Kafir x Dwarf Yellow milo	27317	13.2	11.7	12.3	12.9	13.5	12.4	12.2	12.6
[(Kafir x Dwarf Yellow milo x Dwarf Yellow milo] -6	916	15.2	12.0	12.6	13.3	(*)	(*)	(*)	
Kansas Orange x Dwarf Yellow milo	28202	13.3	11.5	12.7	13.0	13.7	12.8	12.0	12.7
Custer	919	16.7	12.0	12.5	13.6	14.4	(*)	(*)	
White Custer	HC 305	19.9	12.2	12.7	13.8	13.9	(*)	(*)	
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	21.6	12.9	13.7	13.7	14.4	13.9	12.7	14.9
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	15.0	12.4	12.9	13.3	14.5	12.7	12.6	13.3
Kalo (Yellow kafir)	902	14.5	12.1	12.9	13.2	13.9	13.4	12.5	13.2
Club	901	19.8	13.1	12.8	13.5	14.0	13.0	12.4	14.0
Ajax	968	19.5	13.3	13.8	13.5	14.1	13.7	13.4	14.4
Western Blackhull	906	14.9	12.9	13.6	13.1	13.8	13.1	12.3	13.8
Averages		16.4	12.1	12.7	13.1	13.7	12.9	12.3	

(*) No seed available for testing.

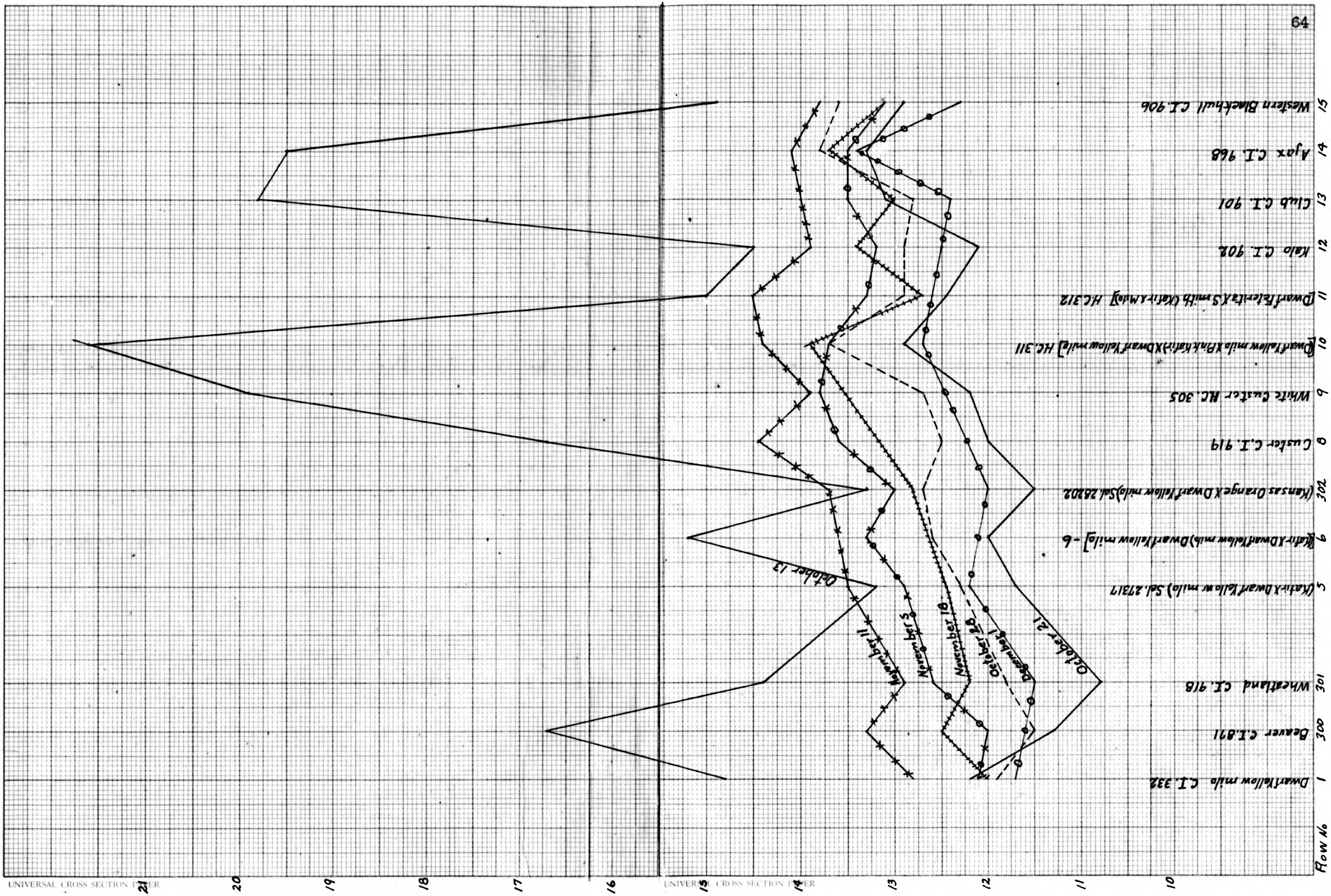


Fig. 7. Moisture content of grain of 14 varieties of sorghum, Manhattan, Kansas, 1932.

Moisture determinations made during 1932 show the same general trends as in 1931, though the changes in moisture content during the period of testing are not as great. When the precipitation records of the two seasons are compared, it will be noted that the weather conditions are responsible for the differences observed during the two seasons;

Year	Precipitation Oct.	Nov.	Dec.
1931	2.04	5.12	.53
1932	.60	.24	1.32

Light frosts occurred on October 1, 5 and 11, 1932, but these frosts were not heavy enough to kill the leaves of the sorghum plants. These frosts and the low rainfall aided in the drying of the grain in 1932. Heavier frosts occurred October 20 and succeeding nights which killed the leaves and aided materially in the drying of the grain. On October 21 the grain was dry enough to combine and place in storage without danger of losses due to heating. In 1931 and in 1932 the grain became dry enough to combine and store safely about ten days after the first killing frosts. A moisture determination made on November 5, 1932, following a trace of rain the night before, shows an average increase in moisture content of four-tenths per cent. This again illustrates the capacity of the sorghum grain to absorb considerable moisture from rain or a damp atmosphere. A rain of .22 inch on November 7 is reflected in the higher grain moisture content of samples collected on November 11.

The results of the grain moisture determinations made in 1931 and 1932 indicate that there is a time beginning about ten days after a killing frost where combining may be satisfactorily done and the grain is dry enough to store without loss. There seems to be no good reason for putting off combine harvesting of grain sorghums until very late fall or early winter, as late fall rains, snow and wind are likely to increase field losses.

Disease Resistance

Kernel smut. A single 50-foot row of each strain grown in 1931 was planted with seed inoculated with a composite of five forms of kernel smut, *Sphacelotheca sorghi*. A similar test of smut resistance was made in 1932. Data on kernel smut infection obtained in the sorghum breeding nursery in 1931 and 1932 are presented in Table XV. Data from the sorghum smut nursery of the Department of Botany are also given in Table XV. All of the 15 varieties tested are infected in one or more trials by one or more of the

Table XV. Kernel smut infection of 15 varieties of grain sorghums tested at Manhattan, Kansas, 1930 to 1932.

Variety	C. I. or Sel. no.	Botany Nursery 1930	Botany Nursery 1931	Botany Nursery 1932	Agronomy Nur. 1931	Agronomy Nur. 1932
Dwarf Yellow milo	332		2.4			
Beaver	871				2	
Wheatland	918		.9		2	
Wheatland x Dwarf Yellow milo	1-2		8.5			
Kafir x Dwarf Yellow milo	27317				19	
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	916				3	2
Kansas Orange x Dwarf Yellow milo	28202				1	1
Custer	919	5.8			2	2
White Custer	HC 305				8	9
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311				3	5
[Dwarf feterita x Smith (Kafir x milo)]	HC 312				3	3
Kalo (Yellow kafir)	902	18.2	9.6		10	25
Club	901	8.0	13.7		28	3
Ajax	968				1.5	
Western Blackhull	906	29.4	38.3		2	10.6

five physiologic forms of *Sphacelotheca sorghi* used in these experiments.

The data on smut infection for 1931 and 1932 do not give a true picture of the smut reaction of the varieties tested, since other strains of sorghums grown in the same nursery and known to be susceptible had only a low percentage of smutted heads. It should be possible for the plant breeder to produce and select combine types of grain sorghums highly resistant to kernel smut since a number of highly resistant varieties are known.

Milo disease. This relatively new disease is known as the root, crown and shoot rot of milo. It was first found in fields of Dwarf Yellow milo in the Great Plains region. It is now found on the Garden City and Hays Branch Experiment Stations and on the branch experiment stations at Chillicothe and Dalhart, Texas. It has also been reported from northwestern Oklahoma, northwestern New Mexico and southeastern California.

The varieties included in the studies of combine types have been tested in the milo disease nursery at the Garden City Branch Experiment Station. Their reaction to the milo disease is as follows:

Variety	C. I. or Sel. no.	Resistant or susceptible
Club	901	R
Ajax	968	R
Western Blackhull	906	R
[Dwarf feterita x Smith (Kafir x milo)]	HC 312	R
White Custer	HC 305	R
[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo]	HC 311	R and S
Kansas Orange x Dwarf Yellow milo	28202	Med. R
Wheatland	918	S
Kafir x Dwarf Yellow milo	27317	S
Wheatland x Dwarf Yellow milo	1-2	S
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	916	S
Beaver	871	S
Custer	919	S
Kalo (Yellow kafir)	902	S
Dwarf Yellow milo	332	S

It has not yet been possible to produce the disease artificially with any organism isolated from diseased plants. Plants grown in diseased soil become infected. Distinct progress has been made toward producing a resistant strain by the selection of apparently disease-free plants in the milo disease nursery at Garden City. The mode of inheritance of resistance to milo disease is not well known at the present time. Crosses between resistant and susceptible strains of Dwarf Yellow milo and between milo and Club kafir, a resistant variety, were made in the greenhouse during the winter of 1932-1933 to provide material for inheritance studies.

The plant breeder has an opportunity to produce combine types resistant to milo disease since several good varieties are known which are highly resistant to the milo disease.

Grain Yields

Hays. Three of the 15 varieties, Wheatland, Beaver and Kalo, have been grown in the special five-acre combine test for four years at Hays. Agronomic data on these three varieties for the period 1929 to 1932, are given in the following table:

Variety	% lodged	Losses Bu. per A. Dropped heads	Lodging	Yield Bu. per A. As combined	Total	% Grain moisture
Wheatland	8	2.0	3.9	40.8	45.3	13.6
Beaver	10	2.1	1.4	34.2	38.2	14.3
Kalo (*)	36	9.9	13.6	26.5	44.4	13.9

(*) Three-year average, 1929, 1931 and 1932. The 1930 crop was 96 per cent lodged and was harvested with a binder.

Wheatland has proved very satisfactory as a combine sorghum. The four-year average yield of Wheatland is 45.3 bushels and the average loss due to lodging and dropped heads is only 5.9 bushels per acre. Beaver has a four-year average yield of 7.1 bushels per acre less than Wheatland. Kalo is too tall and too apt to lodge to be a satisfactory combine type. The average field loss from lodging and dropped heads for Kalo is 23.5 bushels per acre.

The yields of five varieties in the five-acre combine plots at Hays for two years are as follows:

Variety	Bushels per acre 1931	1932	2-yr. av.
Kalo	39.1	61.1	50.1
Wheatland	17.4	69.2	43.2
(Wheatland x Dwarf Yellow milo) 1-2	24.9	56.0	40.7
Beaver	22.3	54.1	38.2
Custer	20.4	48.8	34.5

As an average for two years, Kalo has a 7.1 bushel lead over Wheatland. Wheatland with a yield of 43.2 bushels per acre is the highest yielding combine type and has produced 2.5 bushels more grain per acre than Beaver.

The yields given in this table represent the total grain production. Field losses from Kalo are high, and Wheatland is the highest yielding variety if the yields of grain actually combined are considered.

Yields of eight varieties grown in the five-acre combine test at Hays in 1932 are as follows:

Variety	Bu. per A.
Wheatland (14-inch rows, furrow drill)	72.7
" (14-inch " , common ")	69.7
" (42-inch rows)	69.2
Club	67.8
Kalo (Yellow kafir)	61.1
(Wheatland x Dwarf Yellow milo) 1-2	56.0
Beaver	54.1
Custer	48.8
Day milo	47.7
Two-foot milo	43.6

In this test Wheatland outyielded all other varieties. The yield of Wheatland planted by the usual method is 69 bushels per acre, or 15 bushels more than Beaver. Club yielded almost 68 bushels per acre and Kalo, 61 bushels.

Wheatland has been compared with Dwarf Yellow milo, Beaver, Kafir x Dwarf Yellow milo No. 27317, and Kalo for three years in a variety test planted on three dates. The average yields for the years 1930 to 1932 are as follows:

	Bushels per acre			
	Planted			
Variety	May 15	June 1	June 15	Average
Kalo (Yellow kafir)	39.5	58.3	62.0	53.2
Dwarf Yellow milo	37.9	48.3	50.2	45.4
Wheatland	35.2	42.1	56.6	43.3
Dwarf Yellow milo x kafir No. 27317	28.2	42.3	53.9	41.4
Beaver	28.9	37.7	45.7	37.4
Averages	33.9	45.7	53.7	44.1

Kalo has an average yield of 53.2 bushels or about eight bushels more than Dwarf Yellow milo and ten bushels more than Wheatland. The average yield of Wheatland is only two bushels per acre less than Dwarf Yellow milo.

The erect heads, strong stalks and ease of combining Wheatland more than offset this small difference in yield. The selection of Kafir x Dwarf Yellow milo No. 27317, illustrated in Plate VII., has almost the same average yield as Wheatland, and appears equal to this variety in the plant characteristics that are so important in a combine type. All varieties produced much higher yields in the June 1 than in the May 15 date of seeding. Yields in the June 15 series are somewhat higher than in the June 1 series.

Garden City. Yields of three varieties at the Garden Branch Experiment Station, grown on unirrigated land, are given in the following table:

Variety	Bushels per acre			
	1930	1931	1932	3-year average
Wheatland	13.2	28.2	19.5	20.3
Beaver	18.4	28.2	12.6	19.7
Dwarf Yellow milo	22.4	25.9	8.6	19.0

In this test, Wheatland has an average of 20.3 bushels per acre, or 1.2 bushels more than Dwarf Yellow milo and 0.6 bushel more than Beaver. The average yields of the three varieties are not significantly different.

Tribune. Yields obtained at the Tribune Branch Experiment Station are as follows:

Plate VII. Three rows of Kafir x Dwarf Yellow milo No. 27317, a typical combine type grain sorghum.

Variety	Bushels per acre 1930	1931	1932	3-year average
Greeley	34.1	18.3	11.9	21.4
Dwarf Yellow milo	23.0	18.7	9.6	17.1
Beaver	22.6	9.4	7.6	13.2
Wheatland	18.9	5.2	1.9	8.6

Greeley, a selection made at the Tribune Branch Experiment Station and well adapted to that area, has a three-year average yield of 21.4 bushels per acre. Wheatland has yielded 12.8 bushels less than Greeley during the same period. Dwarf Yellow milo has yielded more than the two new combine types, Beaver and Wheatland. In contrast to the results obtained at Hays, Beaver has produced higher yields than Wheatland.

Cooperative tests on farms. Wheatland has been tested for two years in cooperative variety tests in comparison with other grain sorghums in four sections of Kansas. These sections are shown in Fig. 8. The average yields for 1931 and 1932 are as follows:

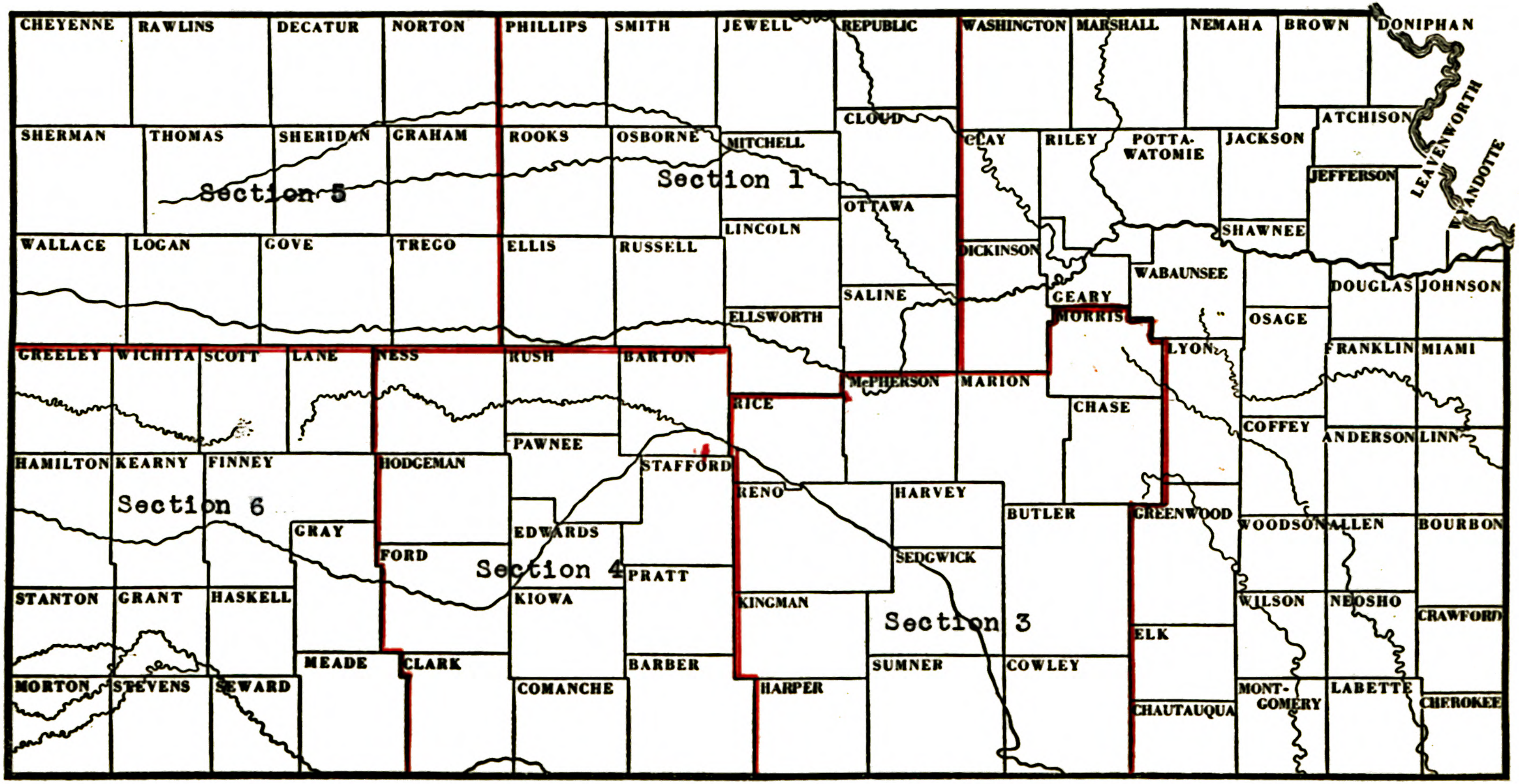


Fig. 8. Map of Kansas showing sections used for comparison of crop yields.

Section	Variety	Bushels per acre 1931	1932	2-year average
1	Pink kafir	36.0	32.8	34.4
	Wheatland	37.2	33.6	35.1
4	Dwarf Yellow milo	25.0	37.0	31.0
	Beaver	21.9	22.4	22.1
	Wheatland	24.6	32.8	28.7
5	Kalo	33.3	31.6	32.4
	Greeley	23.7	32.5	28.1
	Wheatland	34.2	27.7	30.9
6	Dwarf Yellow milo	31.2	27.4	29.3
	Beaver	27.3	18.8	23.0
	Wheatland	32.3	28.6	30.4

In the tests in Section 1, Wheatland has an average yield of 35.1 bushels per acre, slightly above Pink kafir. In Section 4, Wheatland has averaged 28.7 bushels or 2.3 bushels less than Dwarf Yellow milo and 6.6 bushels more than Beaver. In Section 5, Wheatland has averaged 30.9 bushels per acre or 1.5 bushels less than Kalo and 2.8 bushels more than Greeley. In Section 6, Wheatland has averaged 30.4 bushels per acre or 1.1 bushels more than Dwarf Yellow milo and 7.4 bushels more than Beaver.

After the 1932 crop was harvested, a questionnaire was sent to those farmers who had purchased certified seed of Wheatland. Yields of Wheatland as reported by 282 of these farmers in five different sections of Kansas (see Fig. 8) are as follows:

Section	No. of growers	Av. yield Bu. per A.
1	57	20.9
3	34	7.9
4	79	12.6
5	63	14.0
6	49	7.9

The highest average yield was obtained in north-central Kansas. Very low yields were secured in south-central counties due largely to chinch bug injury, and in the southwestern part of the state due to drought.

Woodward, Oklahoma. Yields of Dwarf Yellow milo, Beaver and Wheatland at Woodward, Oklahoma, for six years are given in the following table taken from Oklahoma Agricultural Experiment Station Bulletin No. 210:

	Bushels per acre						
Variety	1926	1927	1928	1929	1930	1931	6-yr. av.
Wheatland	36.6	44.9	27.4	38.3	22.9	23.9	32.3
Dwarf Yellow milo	33.8	45.8	23.3	30.3	23.8	23.8	30.1
Beaver	31.1	41.1	21.9	25.9	16.4	18.9	25.9

During this six-year period at Woodward, Oklahoma, Wheatland has averaged 32.3 bushels per acre; 2.2 bushels more than the old standard variety, Dwarf Yellow milo, and 6.4 bushels more than Beaver.

Market Classification

In order to get an official market classification on grain samples of the 15 varieties, samples were submitted under row numbers and without variety names to Mr. O. F. Phillips, chairman, Board of Review, U. S. Federal Grain Supervision, Chicago, Illinois. The following table gives the classification made by Mr. Phillips and his associates:

1932 row no.	Variety	Class: Yellow milo	White kafir	Feterita	White durra
1	Dwarf Yellow milo	x			
5	Kafir x Dwarf Yellow milo No. 27317	x			
6	[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6	x			
8	Custer	x			
10	[(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo] H.C. 311	x			
12	Kalo (Yellow kafir)	x			
300	Beaver	x			
301	Wheatland	x			
302	Kansas Orange x Dwarf Yellow milo No. 28202	x			
15	Western Blackhull		x		
9	White Custer		x		
13	Club		x		
14	Ajax			x	
11	[Dwarf feterita x Smith (Kafir x milo)]				x

According to the present grain standards, those types which appear best suited to the combine method of harvesting are classed as Yellow milo, the class which usually commands a premium on the market.

Quoting from Mr. Phillips' letter of December 14, 1932; "It is quite obvious that some of these cross-bred sorghums will give the average grain inspector something to think about in grading them. Samples Nos. 12, 302 and 8, all of which we have classified as Yellow milo, some inspectors may be inclined to class as Red kafir or as a Mixed kafir and milo because of the deep red coloring".

In view of the classification and remarks of Mr. Phillips, it would be desirable for plant breeders to keep in mind the Grain Standards in making selections from hybrid populations. It should be possible in most cases to select for color and other kernel characters, as well as for plant characters which determine the farm and market values of combine types of grain sorghum.

The selection of Kansas Orange x Dwarf Yellow milo No. 28202, illustrated in Plate VIII., is a very desirable combine type with erect heads and long peduncles. However, this selection has lodged badly in some tests at Hays and Garden City when left standing until late fall or early winter.

Plate VIII. A dwarf selection of Kansas Orange x Dwarf Yellow milo No. 28202, a type with erect heads on long peduncles, well above the leaves, Manhattan, Kansas.

SUMMARY AND CONCLUSIONS

The purpose of this study was to find the relation between such plant characters as breaking resistance of stalks, anchorage or root pull and plant height to lodging, in varieties of grain sorghum suitable for harvesting with the combine. Knowing the relationships of these plant characters to lodging should aid materially in selecting the types most suitable for combine harvesting.

Moisture content of stalks and grain was determined at intervals during the fall and early winter to give some indication of the time when combine harvesting could be done so as to hold field and grain storage losses at a minimum.

Plantings of 15 selections of grain sorghums were made in the sorghum breeding nursery at Manhattan in 1931. Additional studies were made of the same types in 1932. Observations were also made on the same varieties at the Hays Branch Experiment Station in 1932. Some of the results of the five-acre combine tests at Hays are reported in summarized form.

In the 15 varieties studied, plant height varied from 61 inches for Western Blackhull kafir to 32 inches for

[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6. The average plant height of Wheatland and Beaver is 33 and 35 inches, respectively.

The average anchorage or root pull per plant from 25 trials in each variety varied from 92 pounds for Ajax to 211 pounds for Beaver. The average anchorage or root pull of Wheatland is 170 pounds.

The average breaking resistance of the stalks of 15 varieties varied from 180 pounds per stalk for Beaver to 65 pounds for Ajax. The average breaking resistance of the stalks of the combine types is as follows:

	Lbs. per stalk
Beaver	180
[(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo] -6	138
Kafir x Dwarf Yellow milo No. 27317	113
Wheatland	111
Kansas Orange x Dwarf Yellow milo No. 28202	102
(Wheatland x Dwarf Yellow milo) 1-2	95

Lodging counts were made on the 15 varieties at Manhattan and Hays in 1931 and 1932. At Manhattan in 1931, the range in lodging was from two per cent for [(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6 to 96 per cent for [Dwarf feterita x Smith (Kafir x milo)] H. C. No. 312. Wheatland, one of the most promising combine types, lodged only three per cent, (Wheatland x Dwarf Yellow milo) 1-2, five per cent, Beaver 28 per cent, and Dwarf Yellow milo 91 per cent. Lodging data from the special lodging nursery at Hays are reported which indicate that lodging is more severe in the later plantings than in the early plantings.

Two kinds of lodging were observed, breaking over near the base of the plant and at the base of the peduncle.

Correlation studies, using the rank method, were made at Manhattan and Hays, of the relation between lodging and certain plant characters, viz., height, anchorage and breaking resistance.

Results of these correlation studies at Manhattan in 1931 are as follows:

(1) A correlation of -.8116 ± .0062 was obtained between lodging and height of plant. (Tallest variety was given rank 1 and the least lodged variety was given rank 1.)

(2) A correlation of only .0195 ± .0182 was obtained between lodging and breaking resistance of the green stalks tested in late September.

(3) A correlation of only .0075 ± .1823 was obtained between lodging and anchorage or root pull.

The following results were obtained in correlation studies made at Hays in 1932 after frosts had killed the plants. Plots planted on three dates and the special five-acre combine tests were used:

In the May 15 date of seeding:

(1) Correlation between lodging and height of plant, r = -.7174 ± .0989.

(2) Correlation between lodging and breaking resistance of stalks, r = .5176 ± .199.

In the May 31 date of seeding:

(1) Correlation between lodging and height of plants, r = -.6159 ± .1265.

(2) Correlation between lodging and breaking resistance of stalks, r = .5914 ± .1325.

In the June 15 date of seeding:

(1) Correlation between lodging and plant height, r = -.8524 ± .0557.

(2) Correlation between lodging and breaking resistance of stalks, r = .6935 ± .1057.

In correlation studies made on eight varieties grown in five-acre combine test plots at Hays in 1932:

(1) Correlation between lodging and height of plants, r = -.5176 ± .1827.

(2) Correlation between lodging and breaking resistance of stalks, r = .6486 ± .1447.

Height of plant and lodging show significant correlation at both stations.

Studies of correlation between lodging and breaking resistance of green stalks at Manhattan indicate no association of these characters, while similar studies made at Hays after frost indicate some association.

In breeding combine types of grain sorghums, careful attention should be given to plant height and lodging resistance, as well as to yield.

Determination of moisture content of stalks was made on 15 varieties grown at Manhattan in 1931. The highest stalk moisture content, 82 per cent, was recorded for Custer on September 18, the lowest was 67 per cent for (Wheatland x Dwarf Yellow milo) 1-2 on October 29. During the testing period from September 18 to October 29, the range in moisture content of stalks of Wheatland was only three per cent. Moisture content of stalks apparently had little effect upon the drying of the grain.

Moisture content of the grain was determined at regular intervals at Manhattan in 1931. On September 18, 1931, when the grain was considered ripe and before frosts occurred, the moisture content was found to vary from 32 per cent for Western Blackhull to 21 per cent for [(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo]-6. Grain moisture content decreased at each testing date except November 13.

The minimum was reached on October 29, about ten days after the first frost. The test made November 13 showed an average increase in grain moisture content of 4.3 per cent, due to a light rain on November 11. The last test, made on December 26, which followed ten days of moderately bright and drying weather, showed a decrease in moisture content from November 13, but no strain reached the minimum as recorded on October 29.

In 1932 grain moisture tests were started on October 13. At this date the grain moisture content for all varieties, except Kansas Orange x Dwarf Yellow milo No. 28202 and Kafir x Dwarf Yellow milo No. 27317, were above 14 per cent. [(Dwarf Yellow milo x Pink kafir) x Dwarf Yellow milo] H. C. No. 311 contained 22 per cent, the highest moisture content. The minimum moisture content for most strains was reached October 21, about ten days after killing frosts occurred. Tests made on November 5 and November 11 showed small increases in moisture content due to light rains which fell during the intervening period. The last test was made on December 1. Small decreases occurred, but the moisture content of most strains did not reach the minimum as recorded on October 21. As in 1931, all varieties had grain moisture content low enough at the optimum date to be harvested with a combine and safely stored.

The grain moisture content decreases rapidly soon after killing frosts occur. Moisture studies indicate that grain sorghums can be harvested with the combine and safely stored about ten days after a killing frost, if precipitation does not occur too frequently during the fall months. Because of the autumn rains, it is difficult in some seasons to find a time when the grain moisture content is below 14 per cent, the maximum for safe storage.

Observations made in the lodging nursery at Hays in 1931 indicate that the total amount of lodging increases after frost and as the season advances.

If normal growing conditions prevail, height of plant is increased by the later dates of planting. Since plant height and lodging are correlated, more lodging may be expected from late planting.

Grain yield comparisons made at several experiment stations in Kansas and Oklahoma and on farms, which include Dwarf Yellow milo, Wheatland, (Wheatland x Dwarf Yellow milo) 1-2, Beaver, Kalo and Pink kafir, show that Wheatland has the highest average yield of the combine types. In most tests, Wheatland is equal or nearly equal to Dwarf Yellow milo, a standard grain sorghum variety. Wheatland is much superior to Dwarf Yellow milo in that it has erect heads and strong stalks, and yields more than Beaver under most Kansas conditions.

Grain of the strains designated as "combine types" was classified as Yellow milo by the chairman of the Board of Review, U. S. Federal Grain Supervision, Chicago, Illinois.

All varieties studied are more or less susceptible to one or more forms of kernel smut, Sphacelotheca sorghi, although certain strains are resistant to the most common form of kernel smut.

Of the six combine types, five were recorded as susceptible to "milo disease" at the Garden City Branch Experiment Station. Kansas Orange x Dwarf Yellow milo No. 28202 was recorded as partially resistant. Club, Ajax and Western Blackhull are resistant. There are enough resistant strains known to be of value in plant breeding.

Under average seasonal conditions, Wheatland, Beaver, (Wheatland x Dwarf Yellow milo) 1-2, Kafir x Dwarf Yellow milo No. 27317, [(Kafir x Dwarf Yellow milo) x Dwarf Yellow milo] -6, and Kansas Orange x Dwarf Yellow milo No. 28202 may be regarded as satisfactory combine types. Kalo is not well adapted for combine harvesting because it is too tall and lodges too easily. Western Blackhull, Club and

[Dwarf feterita x Smith (Kafir x milo)] are also too tall to be readily harvested with the combine.

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