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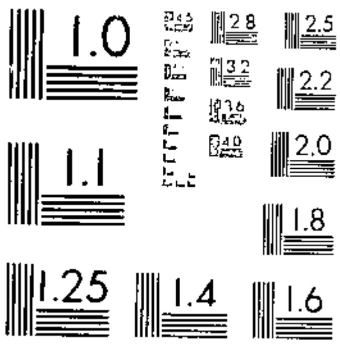

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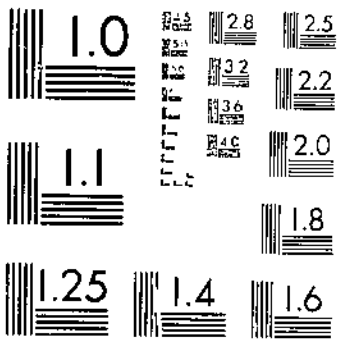

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RESISTANCE OF SORGHUMS TO THE CHINCH BUG[1][2]

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United States Department of Agriculture, Bureau of Plant Industry, in Cooperation With the Kansas Agricultural Experiment Station

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INTRODUCTION

The biological control of insects as related to host resistance is a relatively new field of study in which recent development has been rapid. The data presented, gathered at Manhattan, Kans., at intervals during a period of more than 15 years, and during a 5-year period at Lawton, Okla., indicate the possibility of reducing injury by chinch bugs (*Blissus leucopterus* (Say)) to sorghums (*Sorghum vulgare* Pers.) by host resistance.

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[3] The authors express appreciation to C. E. Leighty, principal agronomist in charge, Division of Dry Land Agriculture, M. A. McCall, principal agronomist in charge, Division of Cereal Crops and Diseases, and Assistant Chief, Bureau of Plant Industry, and to L. E. Call, director, Kansas Agricultural Experiment Station, for the support given to this project, and to G. A. Dean, head of Department of Entomology, and R. I. Throckmorton, head of the Department of Agronomy, Kansas Agricultural Experiment Station, for their advice and encouragement. Acknowledgment is made of the active part taken by the late J. W. McColloch and by W. P. Hayes, former members of the Department of Entomology, Kansas station, in the earlier investigations at Manhattan; and to J. H. Martin, senior agronomist, Division of Cereal Crops and Diseases, and H. H. Laude, agronomist, Kansas station, for valuable technical advice and assistance. Several State and Federal agronomists have kindly supplied seed of sorghum varieties, selections, and crosses for these experiments.

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Because efficient control of the chinch bug cannot always be effected economically by cultural practices, by creosote barriers, or by destruction of the bugs in hibernation, it is necessary to seek other satisfactory solutions of the problem. One of the most promising methods of control is the breeding of resistant varieties of sorghum suitable for regions that are frequently and heavily infested with chinch bugs.

At Manhattan, Kans., outbreaks of chinch bugs have persisted for varying periods, usually from 2 to 3 years, but sometimes much longer. There is so much uncertainty about the duration of chinch bug outbreaks in this section that it is not a safe practice for the growers of corn and sorghums to depend upon natural agencies as a control measure. At Lawton, Okla., chinch bugs occur in damaging numbers nearly every year.

No variety of sorghum has been found immune from chinch bug injury, but a number of varieties are highly resistant. The use of adapted resistant varieties is recommended in conjunction with the application of effective control measures.

While the development of resistant varieties of sorghums as a means of reducing chinch bug injury is very promising, it must be emphasized that young plants of all varieties are killed by a sufficiently heavy infestation of bugs. However, the period of survival of resistant varieties is much longer than that of the more susceptible varieties.

The four methods of obtaining adapted varieties of sorghums resistant to chinch bugs are: (1) Testing the chinch bug resistance of varieties suited to the region; (2) testing the regional adaptation of varieties known to be resistant to chinch bugs; (3) selecting resistant strains from adapted varieties; and (4) hybridization.

REVIEW OF LITERATURE

The general subject of host resistance to insects and related subjects has been reviewed by Forbes (*26*),[4] Treherne (*66*), Brues (*6*, *7*), Graham (*30*, *pp. 47–51, 133–135*), Wardle and Buckle (*69*, *pp. 1–16*), McColloch (*49*), Lees (*46*), Wardle (*68*, *pp. 1–40*), Mumford (*53*), Mumford and Hey (*54*), Felt and Bromley (*19*), Imms (*42*, *pp. 240–249*), Parker and Painter (*60*), Hunter and Leake (*41*, *pp. 39–41, 82–83, 170, 251, 316–318*), and MacLeod (*51*).

Homopterous insects have been shown in some cases to be unable to maintain the insect population on certain varieties of crop plants. This has been especially true of *Amphorophora rubi* (Kalt.) on Herbert raspberry (*70*, *pp. 18–23*); of *Eriosoma lanigerum* (Hausm.) on Northern Spy apple (*47*); of *Myzus houghtonensis* (Troop) on individual gooseberry plants (*18*); and of *Illinoia pisi* (Kalt.) on alfalfa (*4*).

Varieties resistant to one or more species of insects have been reported in wheat, oats, corn, sorghum, sugarcane, grasses, cotton, alfalfa, broadbeans, onions, grapes, currants, strawberries, apples, citrus fruits, tea, and willows.

The life history and habits of the chinch bug, under Kansas conditions, have been discussed by Headlee and McColloch (*33*).

Chinch bugs feed normally on various species of the grass family. A fairly complete list of known host plants, including sorghum, is given by Horton and Satterthwait (*38*). Bugs may sometimes be collected on dicotyledonous plants and occasionally feed on them, but without

[4] Italic numbers in parentheses refer to Literature Cited, p. 53.

material damage to the plants. In Kansas and Oklahoma the usual order of food preference among small grains is barley, wheat, and oats.

Hayes and Johnston (*32*) made observations on an invasion of chinch bugs among nearly 100 species of native and introduced grasses at Manhattan, Kans., and found that—

> the different species showed different degrees of resistance to injury, and later some of them exhibited marked ability to recover from the attack. Native, perennial species with harsh tissues were able to survive chinch-bug injury and showed the most marked ability to recover.

As early as 1879 Thomas (*65*) suggested the early seeding of spring grains, the growing of crops on which the chinch bugs do not feed, and the separating of crops as methods of control. In 1888 Osborn (*55*) recommended the manipulation of dates of planting and the planting of immune crops such as clover, buckwheat, and flax.

The food habits of the chinch bug furnished the basis for the recommendations by Burlison and Flint (*8, 9*), Flint and Burlison (*22*), Flint et al. (*23*), and Henson and Drake (*35*) for controlling chinch bug injury by cropping practices.

RESISTANCE TO CHINCH BUGS IN SORGHUMS

Cottrell et al. (*13, p. 35*), in 1900, reported that kafir plants when small were killed by heavy attacks of chinch bugs, but that corn was destroyed more readily. Ball and Leidigh (*3*), Churchill and Wright (*11*), Cunningham and Kenney (*14, pp. 18–19*), Getty (*28, 29*), Hayes (*31*), Swanson and Laude (*64*), Vinall et al. (*67*), Daane and Klages (*15*), Kiltz et al. (*45*), and others mention the high susceptibility of milo to chinch bugs, and several report the relative resistance of sorghum varieties. The intermediate reaction of feterita and kaoliang, hegari, and the resistance of the kafirs, darso, and certain sorgos has been reported.

Borman (*5*) assumed erroneously that resistance depended upon the juiciness of the sorghum stalk.

Hayes (*31*) observed that milo crosses exhibiting hybrid vigor were not injured by chinch bugs. Hayes and Parker [5] collected data on the resistance of sorghum varieties and hybrids to chinch bug injury. Some of their data on the inheritance of chinch bug resistance are included in this bulletin. Whitehead [6] made some preliminary studies on the cause of resistance and susceptibility in the F_1 generation of Kansas Orange × Dwarf Yellow milo hybrids.

Parker (*59*) described the reaction of certain sorghum varieties and hybrids to chinch bugs, as observed at Manhattan, and showed that chinch bug resistance is a heritable character.

RESISTANCE TO CHINCH BUGS IN CORN

Flint (*21*), Burlison and Flint (*9*), Flint and Hackleman (*24*), and Flint and Larrimer (*25*) have reported observations and experiments on chinch bug resistance in corn. Flint, Dungan, and Bigger (*23*) have shown that several varieties of corn are resistant but none is chinch bug proof. Corn varieties appeared to depend for their resistance upon certain vegetative characters, since practically as many bugs occurred on the resistant as on the nonresistant varieties.

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[5] HAYES, W. P., and PARKER, J. H. RESISTANCE OF CERTAIN SORGHUM VARIETIES AND HYBRIDS TO CHINCH BUG INJURY. 1922. [Unpublished report. Kans. Agr. Expt. Sta.]

[6] WHITEHEAD, F. E. SOME PHASES IN THE RELATION OF CHINCH BUGS TO SORGHUMS. 1924. [Unpublished M. S. thesis. Kans. State Agr. College.]

Holbert et al. (*36*, *37*) suggested that some inbred lines of corn carry dominant factors for chinch bug resistance while others carry dominant factors for susceptibility.

Painter, Snelling, and Brunson (*57*), reporting on field trials of selfed lines and F_1 crosses at Manhattan, Kans., and Lawton, Okla., showed that vigorous F_1 crosses were better able to survive chinch bug attack than the much less vigorous selfed lines, though there were clear-cut differences among the selfed lines tested. Wide differences among open-pollinated varieties were also reported.

RESISTANCE TO OTHER INSECTS IN SORGHUMS

McColloch (*48*) found that all sorghums are attacked by the corn leaf aphis (*Aphis maidis* Fitch), but that apparently there is a difference in the injury of the different varieties.

Ball (*1*), Ball and Hastings (*2*), Dean (*17*), and Gable, Baker, and Woodruff (*27*), and others have reported on the infestation of sorghums by the sorghum midge (*Contarinia sorghicola* (Coq.)). Quickly maturing varieties, such as feterita and milo, planted early, usually produce grain before the midge appears in sufficient numbers to do serious damage. All sorghums appear to be susceptible, although Ball and Hastings (*2*) reported that Sumac sorgo seemed to be partially resistant, probably due to the very short glumes, and Karper et al. (*44*) state that "for some reason darso and Schrock seem to produce seed better under midge conditions than other varieties."

The sorghums have been known to be relatively resistant to grasshopper injury since the early studies of grasshoppers by Riley et al. (*61*) in 1877. They stated that "of cereals, corn is their favorite * * *. All other cereals are to their taste, except sorghum and broomcorn, which are often left untouched." Helder (*34*) reproduced a photograph showing the contrast in grasshopper injury to corn and sorghum. Dean and Kelley (*16*) report that "sorghum except when very small is not readily attacked by grasshoppers." Milliken (*52*), Hume (*39*), and Hume and Franzke (*40*) have also reported on the greater susceptibility of corn to grasshopper injury compared with sorghums.

LIFE HISTORY OF THE CHINCH BUG WITH RELATION TO CONTROL MEASURES

At Manhattan, the chinch bug usually has two generations each year. Adult insects fly from hibernation quarters in the bunch grasses to the small-grain fields where the eggs of the first generation are laid. Wheat and other small grains mature before most of the bugs become winged, consequently this insect migrates on foot to fresh food plants, especially sorghums and corn. Later, upon reaching maturity some of the adults fly to new hosts. The progeny of these adults sometimes damage the susceptible varieties of sorghum. Because of the migration on foot, the creosote barrier can be used rather effectively in retarding the migration, but some bugs will pass the barrier and enter the field. The injury from these bugs and their progeny can be reduced by growing a resistant variety of sorghum. Winter burning of hibernating places is an efficient method of reducing the numbers of chinch bugs in Kansas. Some bugs are killed directly by fire, but perhaps a greater number are killed by cold weather after their winter protection has been destroyed.

At Lawton, Okla., three full generations of chinch bugs develop each year, according to Snelling (*63*). The life cycle is illustrated in figure 1. The first seasonal brood reaches the adult stage in small grain and attains the winged form about the time these crops mature. The migration from the small grains to sorghum and corn usually is accomplished by flight, and the creosote barrier is rendered ineffective. Winter burning of hibernating places is largely ineffective as a control measure because the mild winters permit the bugs to survive even when most of their protective cover has been destroyed. The growing of sorghums isolated from small grains, especially barley and wheat, aids materially in reducing injury.

EFFECT OF CHINCH BUG INJURY UPON THE DISTRIBUTION OF KAFIR AND MILO

The distribution of kafir and milo in Kansas is shown in figure 2. Kafir is grown throughout the State but is heaviest in the southeastern section. Milo is grown chiefly in the southwestern part of the State. Reports of damage from chinch bugs, also indicated in figure 2, were compiled by the department of entomology of the Kansas Agricultural Experiment Station from 1870 to 1923. These maps show that chinch bugs are not a serious limiting factor in sorghum production in western Kansas, where milo is grown successfully. In eastern Kansas, however, where chinch bugs are more often present in damaging numbers, milo is of necessity replaced by the more resistant kafirs.

In Oklahoma and Texas, as well as in Kansas, milo is confined largely to the portion of the States west of the line of an average annual precipitation of 25 inches. This line also corresponds roughly to the separation between the tall-grass and the short-grass regions.

LOCATION, CONDITIONS, AND METHODS OF EXPERIMENTATION

Investigations to determine the variation in reaction of sorghum varieties to chinch bug injury and the possibilities of the development of resistant types of sorghum were originally pursued by the Kansas Agricultural Experiment Station at Manhattan. Because of the lack of infestation in consecutive years the project was extended in 1930 to the United States Dry Land Field Station, Lawton, Okla., where a chinch bug infestation is assured nearly every year. The Lawton station had another advantage for these investigations in that the bugs migrated by flight and distributed themselves rather uniformly over the entire nursery.

At Manhattan, the chinch bug nursery was planted so that the bugs moved on foot into the ends of the sorghum rows from wheatfields close at hand. This resulted in severe injury or death to the plants nearest the wheat, and frequently a gradually decreasing injury toward the opposite end of the row. The extent and sharpness of this receding injury varied with different varieties and in different seasons (fig. 3, *B*). From these chinch bug nurseries, quantitative data were secured on the percentage of plants killed or injured. Notes on chinch bug injury also were secured from the sorghum-breeding nursery, the varietal plots, and tests in other parts of Kansas.

Chinch bug damage occurred at Manhattan in each of the 8 years from 1921 to 1928 and in 1932, 1933, and 1934, and to a less extent

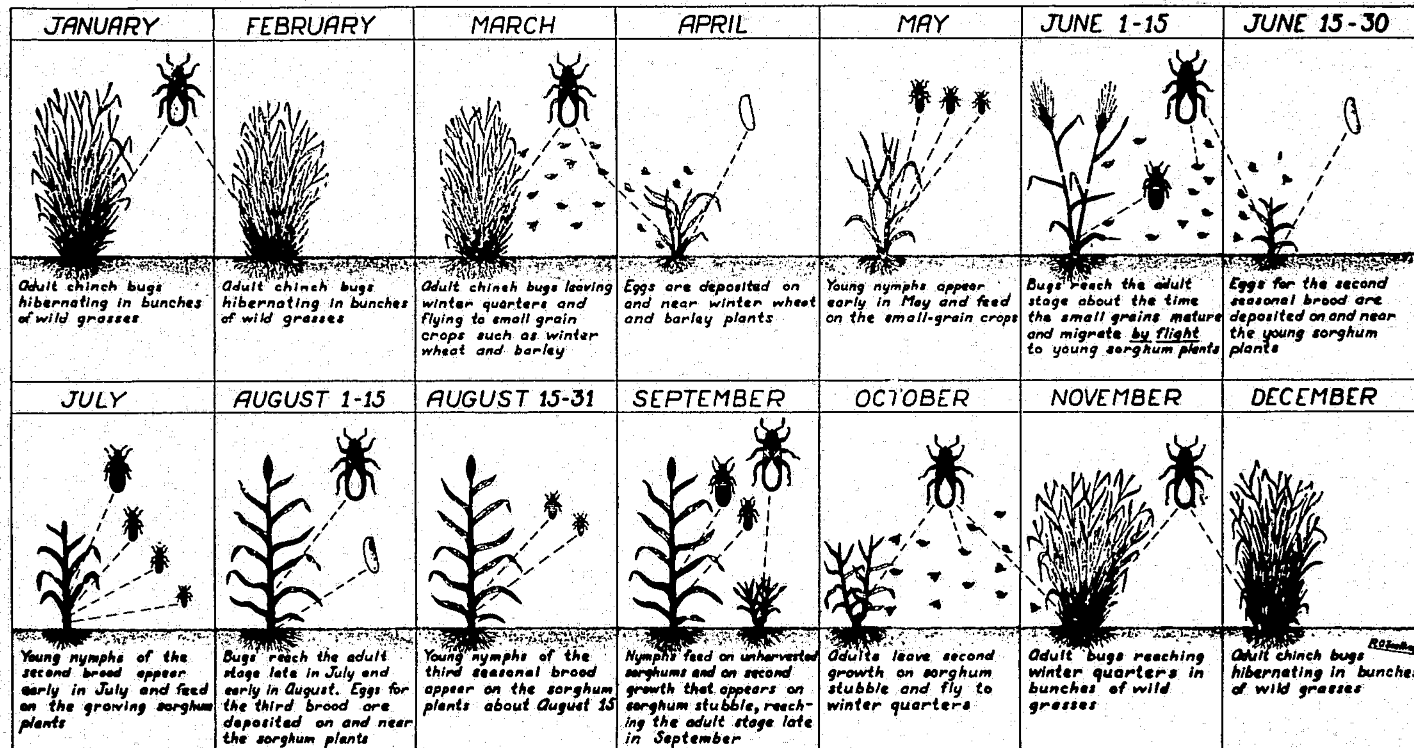

FIGURE 1.—Life history of the chinch bug at Lawton, Okla.

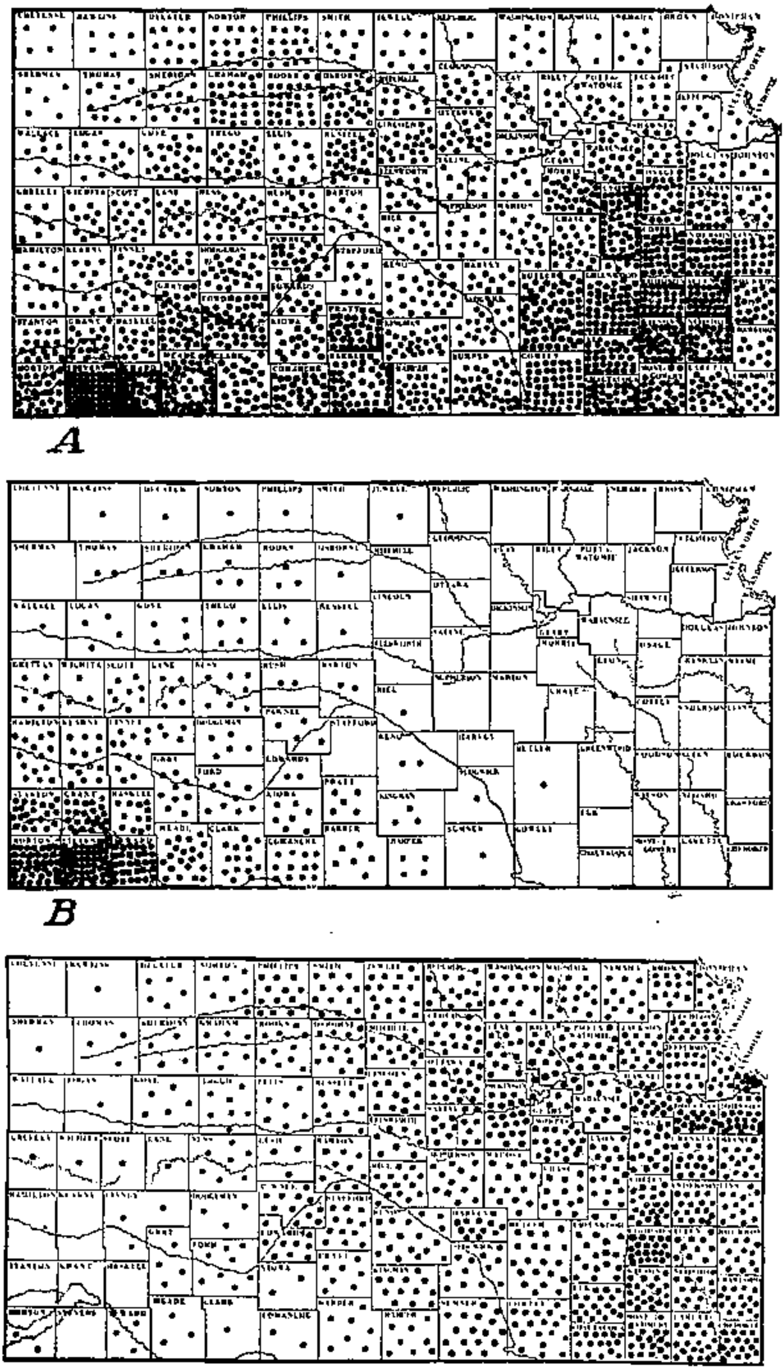

FIGURE 2.—Average acreage of kafir (*A*) and milo (*B*) in Kansas, 1920–29 (each dot represents 500 acres); (*C*) distribution of chinch bugs in Kansas (each dot represents a year in which chinch bug damage was reported in the particular county during the period 1870-1923).

in other years. In 4 of these years the damage was due almost entirely to adults of the first generation that migrated by flight, and by their progeny.

In 1921, the damage was light and susceptible varieties were injured to the extent of 20 percent. In 1922, the first chinch bug nursery was

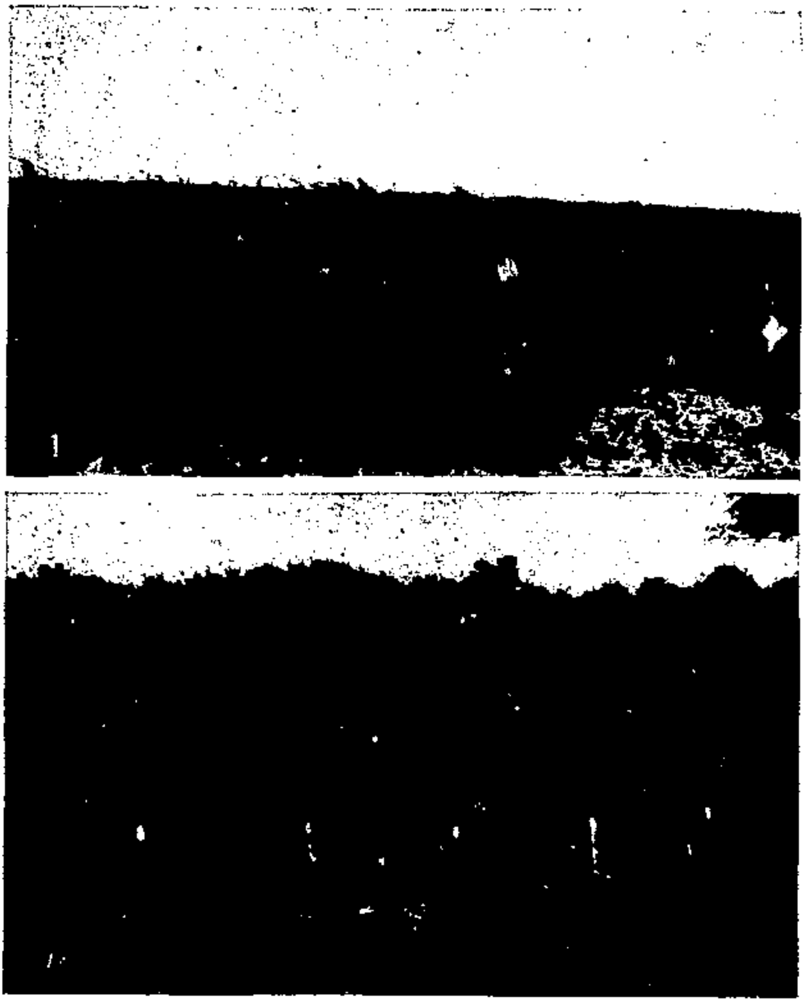

FIGURE 3.—*A*, Chinch bug injury to entire rows of susceptible sorghum varieties when the bugs flew in and were distributed rather uniformly over the nursery at Lawton, Okla., 1930. Left to right, Bishop kafir, feterita, Kansas Orange sorgo, Dwarf Yellow milo, Blackhull kafir, Early Pink kafir. A vigorous F_1 natural hybrid plant is the only survivor in the row of Dwarf Yellow milo. *B*, Injury to the ends of the rows when the bugs walked into the nursery at Manhattan, Kans., 1927.

planted specifically to obtain data on differential resistance in sorghums. A few varieties and a number of F_3 hybrid selections of Kansas Orange × Dwarf Yellow milo were grown. The infestation was moderate, the milos being damaged only about 50 percent. The chinch bug infestation in the 1923 nursery, when the F_4 lines of Kansas Orange × Dwarf Yellow milo were studied, was less severe than in 1922. In 1924, the chinch bug nursery, consisting of F_5

lines of Kansas Orange × Dwarf Yellow milo, was destroyed by chinch bugs except for a single plant in one row. The plants were only 2 inches high when the bugs migrated into the nursery. The rows showed great differences in the rate of killing of the plants. One selection, from row no. 136, was especially resistant. In 1925, the infestation was severe and relatively few plants survived. In the sorghum-breeding nursery the infestation was moderate and notes were secured on some strains not grown in the chinch bug nursery. In 1926 and in 1927 the infestation was moderate in the chinch bug nursery.

Conditions at Lawton, in the southwestern part of Oklahoma, are so favorable to the chinch bug that the insect has been present, usually in large numbers, at some time during the growing season every year since the establishment of the Lawton station in 1915. The average precipitation at Lawton is about 30 inches, but the rainfall is so variable and so torrential in character and the seasons frequently are so long and hot that more or less protracted periods of drought are common. Damage from drought often coincides with chinch bug injury.

Numerous crops that serve as hosts for the chinch bug are grown throughout southwestern Oklahoma. Barley, wheat, oats, corn, sorghums, Johnson grass, and broomcorn are all grown in this section. Their periods of growth are such that ample food for this insect is provided throughout the long growing season.

Native grasses constitute the chief plant cover, but herbaceous plants and Johnson grass are well interspersed. Both native vegetation and Johnson grass offer ample protection for chinch bugs during the relatively mild winters in this section.

Considerable damage was done in 4 of the 5 years that the studies were carried on at Lawton.

In 1930 the sorghum crop in southwestern Oklahoma was subjected to both drought and chinch bug injury, and almost the entire crop was destroyed.

Late freezes in the spring of 1931 were unfavorable to the chinch bugs, and they were not present in sufficient numbers in the early part of the season to reveal any clear-cut varietal differences. The sorghum crop developed normally well into the season before the bugs had increased to damaging numbers. The weather conditions were favorable to the growth and development of sorghums, and high yields of grain and forage resulted. Chinch bugs were abundant in 1932, but the weather was favorable to the growth and development of sorghums. The more resistant varieties produced high yields of grain in the early plantings, but the susceptible varieties did not yield so well. All late plantings were practically destroyed, principally by chinch bugs. The conditions during 1933 and 1934 were very similar to those of 1930. Chinch bugs were abundant in damaging numbers early in the season, and severe drought prevailed from May until August. In most instances the grain crop was a complete failure and forage yields of most varieties were greatly reduced. Sorghum may recover from drought under some conditions, but after an established infestation of chinch bugs recovery seldom occurs.

The number of strains in the chinch bug nursery at Lawton was increased from about 60 varieties, selections, and crosses in 1930 to more than 800 in 1934. In most cases the plots consisted of only a

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single row 100 feet long, in which the plants were spaced 6 inches apart in 1930 and 9 inches apart in the other years. Thus, 200 plants of each variety were available for study in each plot in 1930 and about 130 plants in each of the other years. Ten of the varieties were planted in triplicate 60-foot rows in 1931 and 1932. The more important varieties and strains were planted on three dates each season. Kansas Orange sorgo, Blackhull kafir, Dwarf Yellow milo, and feterita were planted as checks in 1930 and Atlas sorgo, Dwarf Yellow milo, and Blackhull kafir from 1931 to 1934. The check varieties were planted in three distributed plots on each date of planting. Plantings were made on May 20, May 30, and June 6 in 1930. In the first planting all of the extremely susceptible varieties were killed, and the intermediate types were badly injured, many failing to produce seed. Many plants of the more resistant varieties survived and matured some seed. All of the varieties in the second and third plantings were completely destroyed while the plants were small.

In order to maintain seed at Lawton it was decided to make the first planting on an earlier date. The approximate dates of April 15, May 5, and June 1 from 1931 to 1934, inclusive, proved very satisfactory. The earliest planting usually furnished sufficient seed for the following year and also showed the adaptation of the varieties under a light infestation of chinch bugs. The second planting revealed the greatest differential resistance of the varieties. The third planting, while usually destroyed by chinch bugs, furnished information concerning the rate at which young sorghum plants were killed.

The principal data recorded were the original stands, the number of surviving plants at several intervals, and the grain yields. Counting the surviving plants at regular intervals showed the rate at which injury took place.

The most striking symptom of chinch bug injury is the discoloration of the foliage when incipient wilting is produced. Feterita and other white-seeded varieties show a yellow discoloration of the basal leaves, while milo and other varieties having the plant pigment that produces a colored pericarp show a red discoloration of the basal leaves. One other early indication of chinch bug injury is the wilted appearance of the plants. In determining the relative resistance, general notes on the degree of wilting and discoloration, and the development of heads and grain supplement the record of plants killed and grain produced. A count of the number of heads produced is useful in conjunction with notes on the development of heads and the quality and yield of grain.

In 1930, measurements of the height of 20 plants in each variety were made at weekly intervals to determine the effect of chinch bug injury on the rate of growth. It has since been found that climatic factors can affect the rate of growth as much as or even more than moderately severe infestations of chinch bugs. Observations have shown, however, that the rate of growth is retarded in varying degrees by chinch bugs.

At Manhattan, the reduction in height of plants at the end of the rows nearest the wheat stubble, as a result of chinch bug injury, has given some supplementary evidence of resistance. Plants near the ends of the rows which are close to the source of infestation are much more seriously injured than other plants in the row. The amount of reduction in height from dwarfed to normal plants in the row differs in the resistant and susceptible groups of varieties.

Sorghum plants, weakened by chinch bug injury, lodge more easily than those that are uninjured, but they do not lodge so easily as corn that has been injured. At Lawton, lodging, caused by chinch bugs, has not been great enough to yield any definite information on differential resistance as related to strength of stalk.

In these tests some varieties were not homozygous for resistance or susceptibility. Measuring the degree of injury to varieties that are partially destroyed is rather difficult.

Some varieties appeared to increase in resistance to chinch bug injury owing to natural selection for adaptation or for resistance to chinch bugs and drought.

Several of the sorghum breeders in the Great Plains have furnished seed of new varieties, selections, and hybrids that have shown promise at their experiment stations, and these new types have been tested for chinch bug resistance one or more years at Lawton and at Manhattan or at both.

EXPERIMENTAL RESULTS

RESULTS AT MANHATTAN, KANS.

The percentages of injured or dead plants of sorghum varieties in the chinch bug nursery at Manhattan in 1925, 1926, and 1927 are given in table 1. In 1925 the infestation was severe and many of the plants in the nursery were killed. At the time when the notes were taken in 1926 the infestation was not severe, while at no time in the season of 1927 was the infestation sufficient to kill the susceptible strains.

In spite of this wide range in severity of infestation there is a general agreement in the degree of injury of varieties. The milos and feteritas are susceptible while most of the kafirs and sorgos are relatively resistant. The selection of Red Amber sorgo × feterita, tested in 1926 and 1927, showed a high degree of resistance. Lasley sorgo is much more susceptible than Kansas Orange.

TABLE 1.—*Percentage of plants of sorghum varieties injured or killed by chinch bugs at Manhattan, Kans.*

Variety	Record no.[1]	Plants injured or killed		
		1925	1926	1927
		Percent	*Percent*	*Percent*
Sorgo (forage sorghums):				
Kansas Orange	F. C. 9108	[2] 67	27	3
Kansas Orange (Goodland)	Ks. 23410	72	----	8
Kansas Orange (white seeded)	Ks. 23351	70	----	----
Black Amber	F. C. 7038	67	----	7
Red Amber	F. C. 7038	84	----	6
Leoti Red	F. C. 6610	50	----	10
Red Amber × feterita	K. B. 2513	----	3	8
Standard Sumac	Ks. 24311	63	----	18
Early Sumac	F. C. 6613	79	----	14
White African	Ks. 23443	75	----	
Lasley	Ks. 23315		63	----
Honey	----	----	----	30
Kafir:				
Blackhull	Ks. 24280	68	----	3
Sunrise	C. I. 472	75	----	8
Reed	C. I. 628	75	----	4

[1] Many varieties of sorghum are commonly designated by letters or other abbreviations indicating the origin of the seed. The meanings of such designations for the varieties mentioned throughout this bulletin in text and tables are as follows: F. C.=accession number, Division of Forage Crops and Diseases; Ks.=Kansas Agricultural Experiment Station; K. B.=Kansas Botany number; C. I.=accession number, Division of Cereal Crops and Diseases; La.=Lawton; T. S.=Texas station; H. C.=Hays Cereal number; Wdw.=Woodward; Odw.=Goodwell; Trib.=Tribune; C. E.=Cooperative experiment number of Kansas Agricultural Experiment Station.

[2] Average of 2 plots.

TABLE 1.—*Percentage of plants of sorghum varieties injured or killed by chinch bugs at Manhattan, Kans.*—Continued

Variety	Record no.	Plants injured or killed		
		1925	1926	1927
Kafir—Continued.		*Percent*	*Percent*	*Percent*
Dawn	C. I. 340	75		11
Weskan	F. C. 9171	72		
Pink	C. I. 432	68		5
Red selection	Ks. 20111	73		
Feterita:				
Feterita	C. I. 182-1	96	58	30
Spur	C. I. 623	98		10
Red leaf	Ks. 24202	95	28	39
Feterita-kafir derivatives:				
Kafirita	C. I. 812	49	33	
Kafir × feterita	Ks. 24287		68	
Peirce	Ks. 24285	64	9	
Wonder	C. I. 872	70		
Milo:				
Standard Yellow	C. I. 234			60
Standard White	C. I. 352			55
Dwarf Yellow	C. I. 332	[3] 91	[3] 51	[4] 52
Do	Ks. 24246		80	
Dwarf White	Ks. 1953	85	39	[2] 61
Double Dwarf Yellow	Ks. 27421			60
Early White	C. I. 480			37
Milo derivatives:				
Milo cross	Ks. 27422			11
Do	Ks. 27423			4
Do	Ks. 27424			10
Milo × kafir	Ks. 24232	67		
Do	Ks. 24231	68	60	
Bison	Ks. 24377			14
Smith Early	Ks. 24374		42	
Other varieties:				
Hegari	C. I. 750	81	14	19
Schrock	C. I. 616	81		10
Darso	C. I. 615	68		11
Freed	Ks. 27410		29	32
Do	C. I. 350	73		
Kansas Orange sorgo × feterita	Ks. 24303		41	
Oklahoma Johnny	Ks. 27443			17
Buff durra	Ks. 25404	84		24
Shallu	C. I. 85	88		26
Kaoliang	Ks. 25405	92		38
Broomcorn				5
Sudan grass × sorghum	Ks. 27442			11

[2] Average of 2 plots. [3] Average of 6 plots. [4] Average of 4 plots.

RESULTS AT LAWTON, OKLA.

The percentage of sorghum plants killed at Lawton in 1930, 1932, 1933, and 1934 is shown in table 2. Natural selection by chinch bugs and perhaps by climate may have taken place in some varieties. Hence, many strains grown in later years may not be identical with those grown elsewhere under the same record number. If a strain was received without a number, it was given a Lawton (La.) number. Selections made at Lawton are also given "La." numbers. Relatively few very susceptible varieties were grown during all 4 years, but most of them were grown at least 2 years before they were discarded.

The infestations of chinch bugs in 1930, 1933, and 1934 were of about equal intensity and were greater than in 1932, but the relative degree of injury among the varieties was similar in the four seasons. The varieties and hybrids that differed in their reaction in most cases probably had undergone some natural selection. In 1930, when bugs were numerous, 79 percent of the plants of the Modoc variety were killed. In 1932, under a light infestation of bugs, only 12 percent of the plants were killed, which was in accord with the decrease in the number of chinch bugs. In 1933 and 1934, the reaction was inconsistent with the heavy infestations and only 5 percent of the plants were killed in each of these seasons. The seed from which the 1933 and 1934 crops were grown came from rows that had been subjected to natural selection under chinch bug infestations for two seasons and in which the susceptible plants were killed.

TABLE 2.—*Percentage of plants killed and degree of plant development of sorghum varieties, selections, and crosses grown in the chinch bug nursery at Lawton, Okla., 1930 and 1932–34* [1]

Variety	Record no.	Plants killed				2-year average, 1932-33	4-year average	Degree of plant development [2]			
		1930	1932	1933	1934			1930	1932	1933	1934
Sorgo (forage sorghums):		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.				
Atlas (checks)	C. I. 800	20	7	20	5	14	13	B	A	EY	DY
Atlas × Sunrise	Ks. 32101	----	----	7	4	----	----	----	----	D	DY
Sunrise	C. I. 472	40	2	8	5	5	14	D	A	D	C
Atlas × Early Sumac	La. 31304	----	18	50	----	34	----	----	B	E	----
Do	F. C. 9166	----	----	38	22	----	----	----	----	E	D
Do	F. C. 9165	----	----	34	6	----	----	----	----	D	B
Do	Hays 1930-51-56 [3]	----	----	22	----	----	----	----	----	D	----
Do	Hays 1930-51 [3]	----	----	13	3	----	----	----	----	D	B
Do	Hays 1930-67	----	----	11	5	----	----	----	----	E	B
White African × Sumac	F. C. 10187	----	6	84	19	45	----	----	A	E	E
Early Sumac × feterita	F. C. 9162	----	----	56	2	----	----	----	----	D	C
Red Amber × feterita	Ks. 32130	----	----	62	20	----	----	----	----	C	B
Do	K. B. 2513	20	1	17	2	9	12	B	A	A	C
Red Amber	F. C. 7038	----	5	18	----	12	----	----	AX	CX	----
Leoti Red	F. C. 6610	67	20	20	52	25	42	E	A	D	D
Kansas Orange [4]	F. C. 8108	38	7	21	2	14	17	BY	A	EY	DY
Waconia Orange	La. 332200a	----	----	47	8	----	----	----	----	B	B
African Millet	F. C. 9111	----	12	24	1	18	----	----	A	DY	DY
Sourless	F. C. 9074	----	2	41	----	22	----	----	A	C	----
Standard Sumac	F. C. 1712	----	22	30	25	26	----	----	A	D	E
Early Sumac	F. C. 6611	42	50	21	5	36	30	D	C	D	AX
Kafir:											
Blackhull (checks) [5]	C. I. 71	37	7	37	9	22	23	EY	A	DY	DY
Reed	C. I. 628	40	0	8	5	4	15	D	C	D	C
Hydro	C. I. 1023	----	1	46	12	24	----	----	C	E	E
Dawn	C. I. 340	33	----	30	13	----	----	D	----	D	D
Do	C. I. 904	30	2	5	2	4	12	D	A	B	C
Western Blackhull [5]	C. I. 906	23	1	47	10	24	20	C	A	C	C
Texas Blackhull	F. C. 8962	40	----	----	9	----	----	D	----	----	D
Sharon	C. I. 813	42	1	8	5	5	14	D	A	C	D
Eason	T. S. 21103	----	----	69	15	----	----	----	----	C	E
Pink	C. I. 432	36	1	19	0	10	14	D	A	C	E
Juicy Pink	F. C. 9091	55	1	44	5	23	26	E	A	C	E
Early Pink	Ks. 29372	63	----	----	----	----	----	E	----	----	----
Meade Red	Ks. 29306	43	4	41	51	23	35	D	A	C	E
Double Dwarf Red	La. 331148	----	----	100	100	----	----	----	----	F	F
Feterita:											
Feterita [6]	C. I. 182	98	39	24	43	32	51	F	B	BX	CX
Spur	C. I. 623	92	42	18	65	30	64	E	B	C	E
Dwarf	Ks. 29333	98	----	----	----	----	----	F	----	----	----
Extra Dwarf	T. S. 6312	----	----	100	34	----	----	----	----	C	CX
Feterita and kafir derivatives:											
Ajax	F. C. 6020	99	30	68	33	44	55	F	C	D	E
(Feterita × kafir) × kafir	F. C. 8951	85	2	43	----	23	----	E	C	D	----
Chiltex	C. I. 874	100	22	23	52	23	49	E	C	C	E
Chiltex selection	La. 31300	----	27	24	----	26	----	----	C	C	----
Premo	C. I. 873	86	8	25	----	17	----	D	C	C	----
Kafirita	C. I. 812	----	16	7	10	12	----	----	A	B	C
Peirce	Ks. 24285	100	15	32	----	23	----	C	C	C	----
Wonder	C. I. 872	58	19	17	----	18	----	C	B	BX	----
Club	C. I. 901	84	8	33	6	21	33	E	A	C	C
Club selection	La. 331143a	----	----	1	10	----	----	----	----	C	C
Dwarf Club	H. C. 334	----	----	42	11	----	----	----	----	D	C

[1] Planted May 29, 1930; May 4, 1932; May 8, 1933; and May 1, 1934.
[2] Degree of development denotes the combined action of chinch bugs and other environmental factors: A=Development normal; B=development nearly normal, grain fair to good; C=most plants headed, grain shriveled; D=most plants reached booting stage, few heads, no grain; E=most plants died at or just before booting stage; F=very susceptible, most plants died before booting stage; X=some injury evaded due to early maturity; Y=greater injury because of late maturity.
[3] Hays, Kans., row numbers of Division of Forage Crops and Diseases.
[4] Used as checks in 1930.
[5] Kansas Agronomy Farm strain in 1930.
[6] Used as check in 1934.

TABLE 2.—*Percentage of plants killed and degree of plant development of sorghum varieties, selections, and crosses grown in the chinch bug nursery at Lawton, Okla., 1930 and 1932–34*—Continued

Variety	Record no.	Plants killed				2-year average, 1932–33	4-year average	Degree of plant development			
		1930	1932	1933	1934			1930	1932	1933	1934
Feterita and kafir derivatives—Continued.		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*				
White darso	K. B. 3002	42	6	26		16		C	C	C	
Do	Ks. 30108			12						C	
Dawn kafir × darso	Wdw. 23		2	39		21			A	O	
Do	Wdw. 28		3	14		9			C	C	
Sharon kafir × darso	Wdw. 12		2	8		5			A	C	
Do	Wdw. 48–12			32	2					C	A
Do	Wdw. 52–20			10	6					B	A
Do	La. 3265			34	2					C	C
Dawn kafir selection × (Kansas Orange sorgo × Dwarf Yellow milo).	Ks. 32132			69	30					D	E
Dwarf feterita × (milo × kafir).	H. C. 301	63	32	7		20		D	C	C	
Do	H. C. 302	44	10	8		14		C	B	B	
Do	H. C. 312		27	2	18	15			B	A	B
Dwarf feterita × Dwarf Freed.	H. C. 336			3	18					BX	CX
Dwarf feterita × kafir	C. I. 960			11	14					C	B
Feterita × durra	Wdw. 182H		95						F		
Feterita × knollang (Woodward selection 1).			72	100	45	86			F	D	CX
Milo:											
Dwarf Yellow (checks)	C. I. 332	100	100	100	100	100	100	F	F	F	F
Dwarf Yellow selection	G. C. 30–1		100	100	100	100			F	F	F
Day	Wdw. 187		100	100	100	100			F	E	F
Sooner	C. I. 917	100	100	69		85		F	CX	CX	
Early Yellow	T. S. 21195			73						CX	
Cream	La. 3012	100						F			
Early White	F. C. 5888	100						F			
Dwarf White	F. C. 8927	99						F			
Extra Dwarf White	T. S. 13352		100	100		100			F	F	
Double Dwarf	Ks. 29254	100						F			
Milo derivatives:											
Bishop	C. I. 814	100	88	100		94		F	F	F	
Dwarf Bishop	Ks. 3322			100						F	
Desert Bishop	C. I. 870		100	100		100			F	F	
Manko	F. C. 5991	29	5	87		46		E	E	F	
Fargo	C. I. 509		70	96	100	83			E	E	F
Bison	Ks. 24377	100						F			
Kalo	C. I. 902	77	81	25	60	55	62	E	F	CX	E
Early kalo	C. I. 1009			S	17					OX	CX
Custer	C. I. 919	78	29	100		65		F	E	F	
Custer selection	La. 331092			100						F	
White Custer	H. C. 305		96	100		98			F	F	
Pink kafir × Dwarf Yellow milo.	C. I. 903	86	7	100	92	54	71	E	C	D	F
Do	Ks. 3061		31	77		54			D	D	
Do	Ks. 3070		5	100		53			C	D	
(Pink kafir × Dwarf Yellow milo) × Dwarf Yellow milo.	H. S. 311		100	100		100			F	F	
Beaver	C. I. 871	96	100	100	100	100	99	E	E	E	F
Wheatland	C. I. 918	98	47	100	100	74	86	F	E	F	F
Wheatland × Dwarf Yellow milo.	Wdw. 1–2		100		100				F		F
(Kafir × milo) × Dwarf Yellow milo.	Wdw. 31–70		23	100		62			C	E	
Do	Wdw. 8		20	76		48			C	C	
Kafir × Dwarf Yellow milo.	C. I. 808		33	100		67			D	E	
Do	Ks. 27–317		5	46	47	26			C	C	D
Do	C. I. 895		3	72		38			C	D	
Do	C. I. 896		12	52		32			C	D	
Do	C. I. 897		7	59		33			C	C	
Do	C. I. 898		0	100		50			C	F	
Do	Wdw. 8–2–6		57	100		79			C	F	
Kafir × Dwarf Yellow milo.	Wdw. 21–2–3–1		13						C		
Do	Wdw. 20–2–2–1		11	100		56			C	F	
Do	Wdw. 26–3–3–1		26	100		63			C	F	
Do	Wdw. 38–1–2–1		50	100		75			D	F	
Do	Ks. 3048		5	49		27			C	C	
Do	C. E. 1824	100						F			
Dwarf White milo × Blackhull kafir.	La. 31162		4	8	1	6			A	O	A
Early White milo hybrid	Ks. 3219			34	36					CX	CX

TABLE 2.—*Percentage of plants killed and degree of plant development of sorghum varieties, selections, and crosses grown in the chinch bug nursery at Lawton, Okla., 1930 and 1932–34*—Continued

Variety	Record no.	Plants killed				2-year average, 1932–33	4-year average	Degree of plant development			
		1930	1932	1933	1934			1930	1932	1933	1934
Milo derivatives—Continued.		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*				
Dwarf White milo × hegari	H. C. 282	30	1	72	----	37	----	C	C	C	----
Dwarf Yellow milo × hegari	Wdw. 11–2	----	----	45	45	----	----	----	----	C	C
Do	Wdw. 10–1	----	----	38	98	----	----	----	----	D	E
Durra × Dwarf Yellow milo	La. 31340	----	60	----	----	----	----	----	F	----	----
Dwarf Yellow milo × Dwarf Freed.	H. C. 303	60	5	----	----	----	----	E	B	----	----
Kansas Orange sorgo × Dwarf Yellow milo	Ks. 30–33	68	8	71	53	40	50	E	C	C	D
Do	Ks. 26–568	41						C			
Do	Ks. 24–138	20	2	3	3	3	7	B	A	B	A
Other varieties:											
Hegari	C. I. 750	98	11	44	----	28	----	F	C	C	----
Mobray	La. 31-335	----	23	38	----	31	----	----	B	E	----
Grohoma	C. I. 920	37	22	38	----	30	----	D	B	D	----
White Grohoma	La. 31-355	----	36	28	23	32	----	D	D	E	----
Schrock	C. I. 616	52	----	19	14			D	----	D	C
Darso	C. I. 615	56	2	20	8	16	24	C	A	B	A
Darso × Fargo	Gdw. A301	----	----	18	17	----	----	----	----	B	C
Freed	C. I. 350	84						E			
Dwarf Freed	C. I. 971	70	13	14	75	14	43	BX	A	CX	D
Freed × Pink kafir	Trib. 14	79						E			
Do	Trib. 36	----	61	37	----	49	----	----	B	C	----
Greeley	Ks. 3218	----	----	10	28	----	----	----	----	CX	DX
Weskan	F. C. 9171	37	3	8	1	6	12	D	A	C	B
Modoc	C. I. 995	79	12	5	5	9	25	D	C	C	B
Cheyenne	La. 331105	----	----	25	33	----	----	----	----	C	DX

One of the most plausible explanations for an unusual reaction of a variety to chinch bug injury is the peculiar adaptation of the variety to seasonal conditions. In 1930, a season of heavy infestation, all of the Sooner milo plants were killed. One plant in the Sooner row survived, but it was an F_1 natural hybrid. The infestation of bugs in 1932 was relatively light, but all the Sooner milo plants again were killed. In 1933, the infestation was very heavy, but only 69 percent of the plants of Sooner were killed. This variety matures early and apparently the only reason that 31 percent of the plants survived a heavy infestation of chinch bugs in 1933 was that the plants were early enough to evade the heaviest injury that occurred after the surviving plants had reached maturity. Growth and development of later maturing varieties, such as Dwarf Yellow milo, were retarded by a drought that occurred about the time the Sooner milo plants were reaching maturity.

Atlas sorgo, originated from a cross between Blackhull kafir and Sourless sorgo, is highly resistant to chinch bugs and well adapted to Lawton conditions. This dual-purpose variety has white, palatable grain, is leafy, and has sweet, juicy stalks resistant to lodging (*58*). Atlas is more resistant to chinch bugs and produces higher yields than Standard Sumac sorgo, a variety widely grown in the Lawton section.

Among the kafirs, Dawn is very resistant, while Meade Red is moderately susceptible. Double Dwarf Red kafir is much more susceptible than any other kafir. This very dwarf strain does not develop normally and has crinkled leaves and poorly exserted heads even in the absence of chinch bugs.

In the group of feterita-kafir derivatives, Club is more resistant than Ajax and Chiltex. The two latter varieties are selections from kafir × feterita made at Texas Substation No. 12, at Chillicothe, Tex. Chiltex is grown to some extent in southwestern Oklahoma but is limited in its adaptation because of its susceptibility to chinch bugs. Club is a selection made in a row of Dawn kafir at the Fort Hays (Kans.) Branch Experiment Station and may be a natural cross between Dawn kafir and feterita.

A white-seeded selection of Sharon kafir × darso, Woodward no. 52–29, is resistant to chinch bugs and appears promising because of its ability to produce satisfactory grain yields under drought conditions.

In the group of milo derivatives, Beaver is as susceptible as the true milos and Wheatland also is very susceptible. These two varieties, well suited for harvesting with a combine, are not adapted to Lawton conditions, irrespective of chinch bugs. Kalo is less severely injured by chinch bugs than Beaver and Wheatland. A selection of kafir × milo, Kansas 27–317, is more resistant to chinch bugs than Beaver or Wheatland and is better adapted to Lawton conditions than these varieties.

Two selections of Kansas Orange × Dwarf Yellow milo show a striking difference in chinch bug reaction. Kansas 30–33, a short, combine type, is moderately susceptible, while a tall strain, Kansas no. 24136, is the most resistant strain tested at Lawton during the 4-year period. These selections are described in more detail in the section of this bulletin dealing with advanced hybrids.

In the group of miscellaneous varieties, hegari is more susceptible than most of the kafirs. Hegari has the capacity to produce high yields under favorable soil and climatic conditions, but is erratic in its behavior and is not dependable under adverse growing conditions.

Darso is moderately resistant to chinch bugs and produces good yields of grain even in unfavorable seasons. The brown, bitter seed of darso is an undesirable character.

Greeley, a selection from Pink kafir × Freed, bred at the Tribune (Kans.) Branch Experiment Station, escapes serious injury from chinch bugs because of its earliness. Modoc, another selection from the same cross, made at the Fort Hays station, has shown increasing degrees of resistance during the 4 years it has been grown at Lawton. Cheyenne escapes severe chinch bug injury because of its earliness but is not actually resistant.

The range in average percentage of plants killed is from 7 percent for a highly resistant selection of Kansas Orange sorgo × Dwarf Yellow milo to 100 percent for the very susceptible Dwarf Yellow milo. The three varieties used as checks show significant differences in chinch bug reaction. Atlas is most resistant, 13 percent of the plants having been killed. Blackhull kafir is moderately resistant, 23 percent of the plants having been killed. Dwarf Yellow milo is highly susceptible and has had 100 percent of the plants killed in each of the 4 years.

The degree of plant development (indicated by letter symbols), together with chinch bug resistance, furnishes a reliable index of the adaptation of sorghum varieties to Lawton conditions.

VARIETIES TESTED BOTH AT MANHATTAN AND LAWTON

Twenty-two varieties have been tested for chinch bug resistance both at Manhattan and at Lawton during a period of 4 to 7 years. Data on chinch bug injury of these varieties are presented in table 3. The varieties are ranked according to average percentage of plants killed in the years tested. These averages are not strictly comparable, as all varieties were not grown in the same years. The average for each variety is compared with percentages of plants killed of two standard varieties in the same tests. Kansas Orange sorgo is used as the standard resistant variety and Dwarf Yellow milo as the susceptible one. The range in percentages of plants killed by chinch bugs in these tests is 16 to 34 for Kansas Orange and 74 to 98 for Dwarf Yellow milo.

The ranking of the varieties in table 3 is about the same as that of the same varieties tested at Lawton. The data obtained in earlier years at Manhattan support those obtained at Lawton in recent years under more consistently severe chinch bug infestations.

The average chinch bug injury of the 22 varieties tested at both stations ranges from 10 percent of plants killed in the very resistant Red Amber sorgo × feterita to 85 percent for the highly susceptible Dwarf Yellow milo.

TABLE 3.—*Percentage of plants of sorghum varieties killed by chinch bugs at Manhattan, Kans., and Lawton, Okla.*

Rank	Variety	Record no.	Plants killed			Years averaged (Manhattan and Lawton)	Grain yield per acre at Lawton	
			Variety named	Kansas Orange in same tests	Dwarf Yellow milo in same tests		1931 (light infestation)	1932 (heavy infestation)
			Percent	*Percent*	*Percent*		*Bushels*	*Bushels*
1	Red Amber sorgo × feterita	K. B. 2513	10	16	84	6	34.9	28.4
2	Kansas Orange sorgo × Dwarf Yellow milo.	Ks. 24-136	10	23	91	6	32.8	24.4
3	Atlas sorgo	C. I. 899	22	24	85	7	36.4	34.8
	Pink kafir	C. I. 432	22	23	91	6	29.9	24.4
5	Kafrita	C. I. 812	23	25	88	5	39.0	30.8
	Sunrise kafir	C. I. 472	23	23	91	6	33.2	30.8
	Reed kafir	C. I. 628	23	23	91	6	32.0	30.3
8	Kansas Orange sorgo	F. C. 9108	24	24	85	7	31.8	29.2
9	Blackhull kafir[1]	C. I. 71	27	23	91	6	29.8	30.2
10	Red Amber sorgo	F. C. 7038	28	25	80	4	28.7	33.1
11	Darso	C. I. 615	29	23	91	6	36.2	34.0
12	Dawn kafir	C. I. 340	34	26	89	5		
13	Early Sumac	F. C. 6611	35	23	91	6	24.5	5.[illegible]
	Schrock	C. I. 616	35	26	89	5		
15	Leoti Red sorgo	F. C. 6610	39	23	91	6	19.4	17.0
16	Wonder	C. I. 872	41	33	98	4	27.3	19.1
17	Peirce	Ks. 24-285	44	32	88	5	33.0	23.9
18	Hegari	C. I. 750	45	27	82	6	20.7	16.7
19	Feterita	C. I. 182	55	24	85	7	21.8	10.9
20	Spur feterita	C. I. 623	56	23	91	6	[illegible]	9.7
21	Dwarf White milo	Ks. 19-53	69	34	74	4		
22	Dwarf Yellow milo	C. I. 332	85	24	85	7	17.8	.0

[1] Kansas Agronomy Farm strain, C. I. no. 613, in all tests at Manhattan, and at Lawton in 1930.

A selection of Kansas Orange sorgo × Dwarf Yellow milo, Kansas 24136, is also highly resistant. Several varieties of kafir and sorgo have shown resistance at both stations. Both ordinary feterita and Spur feterita are susceptible but are not so severely injured by chinch bugs as the milos (fig. 4). The small number of very susceptible strains

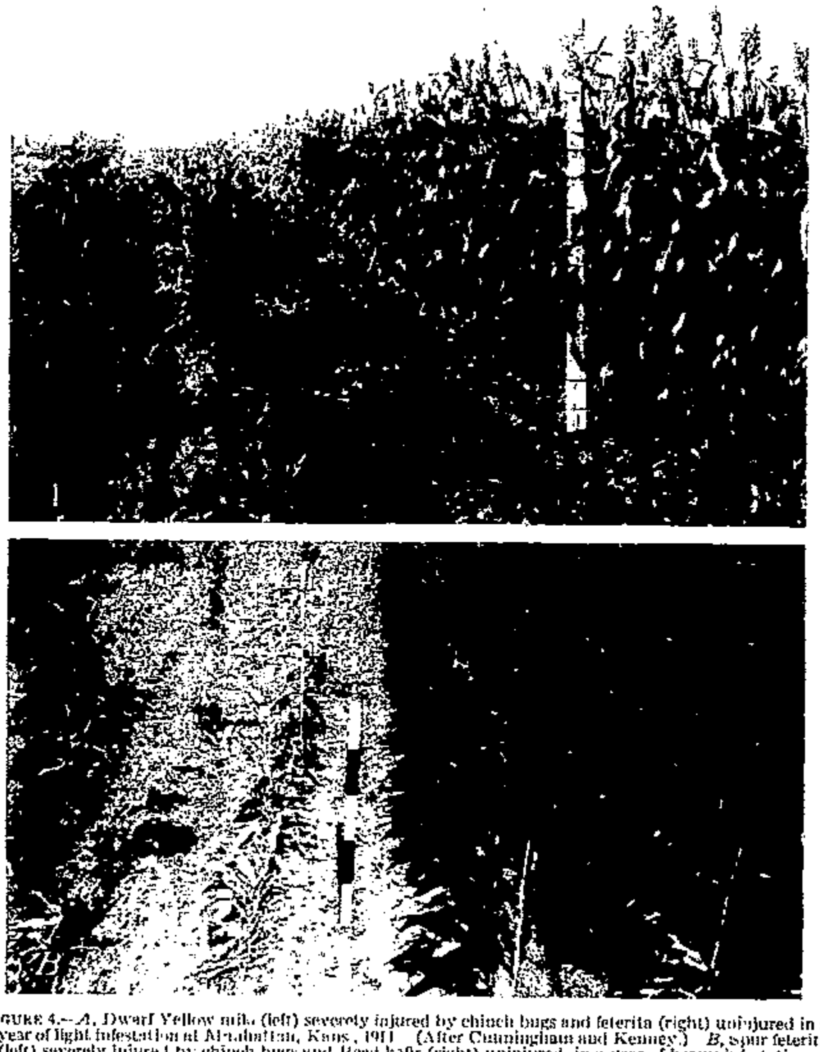

FIGURE 4.—*A*, Dwarf Yellow milo (left) severely injured by chinch bugs and feterita (right) uninjured in a year of light infestation at Manhattan, Kans., 1911. (After Cunningham and Kenney.) *B*, Spur feterita (left) severely injured by chinch bugs and Reed kafir (right) uninjured, in a year of heavy infestation at Lawton, Okla., 1933.

listed in table 3 is due to the fact that such types were discontinued in the Lawton tests when they proved to be susceptible.

Grain yields of 19 varieties grown in the sorghum chinch bug nursery at Lawton in 1931, a year of very light chinch bug infestation, and in 1932, a season of very heavy infestation, also are given in table 3. While these data are not fully dependable because of the fact that each variety was grown in only a single 100-foot row, they do show a significant relation between chinch bug reaction and yield. A similar relationship for 40 varieties grown in 1932 is shown graphically in figure 5.

In nearly all cases (table 3) the grain yields were higher in 1931 under light chinch bug infestation than in 1932 under heavy infestation. The average acre yields of grain were 29.5 bushels in 1931 and 22.9 bushels in 1932. In a few varieties the yields show extreme deviations in the 2 years. Thus, Early Sumac sorgo produced 24.5 bushels in 1931 and only 5.8 bushels in 1932. The yields of feterita and Spur feterita show similar differences. Dwarf Yellow milo produced 17.8 bushels in 1931 and failed to produce grain in 1932. The

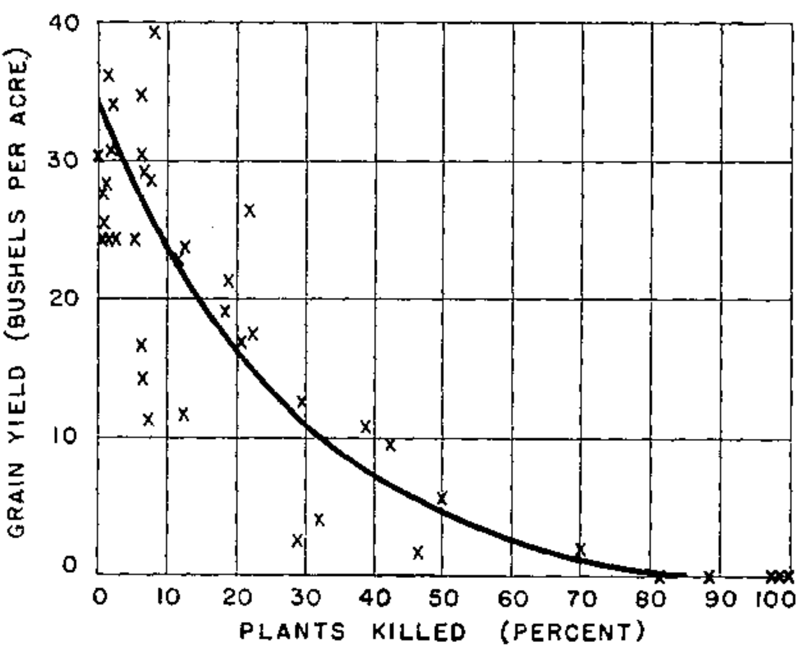

FIGURE 5.—Relation between chinch bug reaction and grain yields of 40 varieties of sorghum planted at Lawton, Okla., on May 4, 1932.

yields of three varieties were slightly higher in 1932 than in 1931, but the differences are small, probably not significant, and all occur in the moderately resistant group. Without exception the more susceptible varieties yielded less in 1932 than in 1931 and in several cases much less.

COOPERATIVE SORGHUM TESTS IN SOUTHEASTERN KANSAS

Some data on chinch bug resistance have been obtained on sorghum varieties grown in cooperative varietal yield tests on farms in southeastern Kansas. These tests were conducted by the Kansas station and the data were supplied by A. L. Clapp, of the Department of Agronomy, who had charge of these experiments. Each plot consisted of four rows the length of the field.

The chinch bug damage to four varieties grown on five farms in each of five counties in 1932 is shown in table 4. The damage was estimated by noting the injury to the entire plot. The 4-year average percentage of injured plants of these varieties at Lawton is presented for comparison. Although the tests in southeastern Kansas were under conditions differing widely from those in the chinch bug nursery at Lawton, they also indicate that Kalo is more susceptible than the other three varieties.

Grain yields of these four varieties in the cooperative experiments in southeastern Kansas showed Kalo yielding an average of 27.7 bushels and the other varieties 26.5 to 29.5 bushels in 1930 and 1931, when there was no apparent damage from chinch bugs, but in the other 2 years (1932 and 1933), with heavy chinch bug injury, Kalo yielded an average of 31 bushels and the other three varieties 35.5 to 39.8 bushels per acre. Chinch bug damage was chiefly responsible for the lower yield of Kalo in the latter 2 years.

TABLE 4.—*Chinch bug damage to sorghum varieties in cooperative tests on farms in five counties in southeastern Kansas in 1932*

Variety	C. I. no.	Estimated damage in county of[1]—					Average	
		Allen	Franklin	Lyon	Butler	Cowley	25 tests	Lawton, Okla. (4 years)
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Western Blackhull kafir	900	5	10	10	10	40	15	20
Pink kafir	432	10	15	10	10	40	17	14
Club	901	10	15	8	5	50	18	33
Kalo	902	45	50	25	25	80	45	62

[1] Average of 5 tests in each county.

RATE OF KILLING OF SORGHUMS

The dates on which various percentages of the plants of each of 27 varieties of sorghum were killed by chinch bugs during the heavy infestation at Lawton in 1930 are shown in table 5. The data were taken from the planting of May 20. Death of more than 15 percent of the plants of several of the most susceptible varieties had occurred by July 2, 6 weeks after planting. The Bison variety was entirely killed by July 13. The rate of killing of two resistant and two susceptible varieties is shown graphically in figure 6.

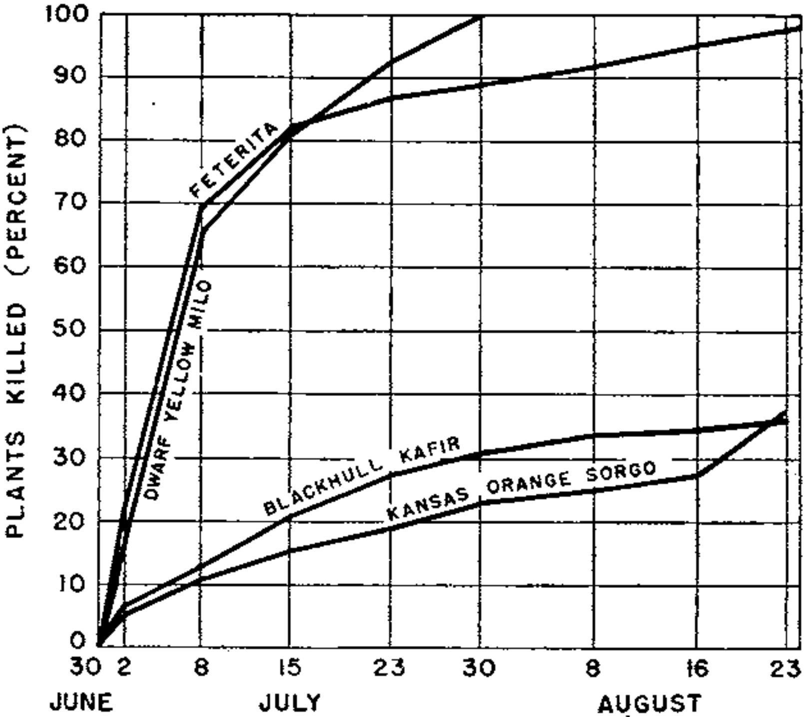

FIGURE 6.—Rate of killing of four sorghum varieties at Lawton, Okla., in 1930. Surviving plants had reached maturity on August 23.

TABLE 5.—*Rate of killing of sorghums at Lawton, Okla., in 1930*

Variety	Record no.	Plants killed on dates indicated							
		July 2	July 8	July 15	July 23	July 30	Aug. 8	Aug. 16	Aug. 23
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Kansas Orange sorgo × Dwarf Yellow milo	Ks. 24-136	0.0	0.0	3.8	14.3	19.1	19.1	19.1	20.2
Atlas	C. I. 899	1.6	2.1	6.5	8.6	14.5	14.5	18.8	20.2
Red Amber sorgo × feterita	K. B. 2513	3.5	12.0	18.5	22.0	25.5	28.5	28.5	28.5
Pink kafir	C. I. 432	7.4	9.5	17.9	22.6	25.2	28.4	30.5	35.8
Grohoma	C. I. 920	7.0	8.0	15.0	21.5	31.5	35.5	35.5	36.5
Blackhull kafir (average of checks)	C. I. 71	6.2	12.5	20.7	27.7	31.1	34.0	34.5	37.1
Kansas Orange (average of checks)	F. C. 9108	5.2	10.8	15.8	19.3	23.1	25.2	27.9	38.0
Dawn kafir selection	C. I. 904	6.3	12.8	20.3	20.3	31.1	37.0	37.0	39.2
Sharon kafir	C. I. 813	5.0	9.5	23.0	29.0	33.5	38.0	39.0	41.5
Early Sumac	F. C. 6611	2.5	14.0	28.5	33.0	37.5	40.0	41.0	42.5
Darso	C. I. 615	18.0	28.9	41.2	42.8	45.4	47.4	47.4	50.2
Wonder	C. I. 872	11.5	22.1	34.7	41.6	49.5	50.5	51.0	58.0
Leoti Red	F. C. 6610	12.8	18.7	40.6	50.3	59.9	65.3	66.9	67.4
Kalo	C. I. 902	12.6	35.1	38.2	44.8	51.0	65.3	71.0	77.4
Club	C. I. 901	5.5	29.0	45.5	68.0	74.5	79.5	81.0	81.0
Spur feterita	C. I. 623	6.0	37.5	53.5	65.0	90.0	91.0	91.5	91.5
Beaver	C. I. 817	9.0	75.5	93.5	95.0	95.5	95.5	95.5	[1] 96.0
Wheatland	C. I. 918	13.6	49.5	61.5	68.0	74.5	84.5	92.5	[1] 97.5
Feterita (average of checks)	C. I. 182	21.5	68.5	81.7	87.0	89.2	92.0	95.5	[1] 98.3
Ajax	F. C. 6620	22.0	71.0	87.0	96.0	98.5	98.5	99.0	[1] 99.0
Bishop	C. I. 814	14.0	62.5	78.5	98.0	98.5	99.5	99.5	[1] 99.5
Sooner milo	C. I. 917	22.4	79.2	95.5	99.0	99.6	99.6	99.6	[1] 99.6
Chiltex	C. I. 874	16.0	30.5	60.0	86.5	96.0	99.0	100.0	-----
Dwarf Yellow milo (average of checks).	C. I. 332	17.7	65.5	81.1	92.8	100.0	-----	-----	-----
Cream milo	La. 30-12	18.0	83.0	90.0	100.0	-----	-----	-----	-----
Double Dwarf milo	Ks. 29-254	18.0	77.0	98.5	100.0	-----	-----	-----	-----
Bison	Ks. 24-377	9.2	98.3	100.0	-----	-----	-----	-----	-----

[1] All or nearly all plants remaining were field hybrids.

EFFECT OF TIME OF PLANTING ON CHINCH BUG INJURY AT LAWTON, OKLA.

Chinch bugs will attack sorghums during any part of the vegetative period, but older plants are better able to withstand the attack. The plants in the earlier plantings have been larger at the time the chinch bugs migrated to the sorghum fields and consequently show the least injury and produce the highest yields. The late May and early June plantings are frequently completely destroyed by the bugs.

The data on time of planting presented here are for only a 2-year period, but they confirm the results obtained in several years of previous experiments with date of planting of sorghum varieties at Lawton (*45*). The grain yields obtained from 40 varieties and strains of sorghum planted April 13, May 7, and June 1, 1931, are presented in table 6. In this exceptional season chinch bug injury was very light and did not affect the grain yields to any appreciable extent. The April 13 and June 1 plantings produced nearly the same average yield. Yields from the May 7 plantings were lowered somewhat by hot, dry weather during the heading and blooming period.

TABLE 6.—*Percentage of sorghum plants killed by chinch bugs in 1932, and grain yields in 1931 and 1932, at Lawton, Okla.*

Rank in chinch-bug resistance	Variety	Record no.	Plants killed, 1932: Date of planting: Apr. 15	Plants killed, 1932: Date of planting: May 4	Plants killed, 1932: Date of planting: June 8	Plants killed, 1932: Average of 3 dates	Grain yields per acre, 1932: Date of planting[1]: Apr. 15	Grain yields per acre, 1932: Date of planting[1]: May 4	Grain yields per acre, 1932: Average of 3 dates	Grain yields per acre, 1931: Date of planting: Apr. 13	Grain yields per acre, 1931: Date of planting: May 7	Grain yields per acre, 1931: Date of planting: June 1	Grain yields per acre, 1931: Average of 3 dates
			Percent	*Percent*	*Percent*	*Percent*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1	Kansas Orange sorgo	F. C. 9108	0.0	7.1	70.0	25.7	44.7	29.2	24.6	42.8	35.0	17.5	31.8
2	Blackhull kafir	C. I. 71	4.2	6.5	71.0	27.2	44.3	30.2	24.8	27.6	30.7	31.2	29.8
3	Atlas sorgo	C. I. 899	.2	6.7	78.9	28.6	70.3	34.8	35.0	35.2	38.5	35.7	36.4
4	Kansas Orange sorgo × Dwarf Yellow milo	Ks. 30-33	.7	7.5	82.6	30.3	42.0	11.1	17.7	14.3	11.8	22.2	17.1
5	Darso	C. I. 615	.0	2.2	91.1	31.1	53.7	31.0	29.2	34.5	23.3	32.8	30.2
6	Sharon kafir	C. I. 813	1.4	.8	96.3	32.8	55.8	27.6	27.8	22.8	26.5	27.5	25.6
7	Pink kafir	C. I. 432	.0	.7	98.5	33.1	53.5	24.4	26.0	35.0	26.5	28.1	29.9
8	Dawn kafir	C. I. 904	3.0	1.5	95.5	33.3	51.8	36.1	20.3	27.6	22.2	24.4	24.7
9	Juicy Pink kafir	F. C. 9091	.0	.7	99.3	33.3	56.2	25.5	27.2	31.0	25.4	30.7	30.0
10	Sunrise kafir	C. I. 472	3.0	2.2	95.6	33.6	63.2	30.8	31.3	29.7	35.5	31.4	33.2
11	Reed kafir	C. I. 628	1.2	.0	100.0	33.7	49.[illegible]	30.3	26.7	33.8	35.0	27.2	32.0
12	Kansas Orange × Dwarf Yellow milo	Ks. 24-136	.0	2.2	100.0	34.1	56.9	24.4	27.1	34.5	25.9	37.1	32.5
13	Milo × hegari	H. C. 262	5.0	1.3	98.8	35.0	45.6	24.5	24.4	31.1	28.1	39.9	33.0
14	Dwarf Yellow milo × Dwarf Freed	H. C. 303	.7	5.2	99.3	35.1	52.0	24.4	25.5	15.9	17.4	29.7	21.0
15	Modoc	C. I. 905	1.4	11.9	92.6	35.3	54.1	22.8	25.6	29.2	15.9	25.9	23.7
16	White darso	K. B. 3002	.0	6.2	100.0	35.4	55.8	16.7	25.0	36.9	18.4	31.1	25.8
	Red Amber × feterita	K. B. 2513	5.0	1.3	100.0	35.4	46.8	25.4	26.1	32.7	36.9	35.0	34.9
18	Pink kafir × Dwarf Yellow milo	C. I. 903	.7	6.7	99.3	35.6	33.1	14.3	15.8	20.7	23.3	19.6	21.2
19	Premo	C. I. 873	.7	7.5	100.0	36.1	61.5	28.7	30.1	33.4	38.1	33.4	35.0
20	Club	C. I. 901	1.4	8.2	99.3	36.3	65.0	39.3	34.1	38.7	41.3	47.2	42.4
21	Dwarf Freed	C. I. 971	.0	12.7	100.0	37.6	48.1	11.7	18.3	19.6	14.8	19.6	18.0
22	Peirce	Ks. 24-255	5.2	12.7	100.0	39.3	55.2	22.6	26.4	41.4	33.3	27.0	33.9
23	Leoti Red	F. C. 6610	.0	20.2	100.0	40.1	48.6	17.0	21.9	21.2	19.6	17.5	19.4
24	Wonder	C. I. 872	2.2	18.7	100.0	40.3	56.9	19.1	25.3	28.6	20.1	32.8	27.2
25	Grohoma	C. I. 920	.0	21.6	100.0	40.5	51.8	26.5	26.1	29.2	41.3	38.7	36.4
26	Chiltex	C. I. 874	.0	22.4	100.0	40.8	57.6	17.5	24.4	23.9	16.0	18.0	19.6
	Dwarf feterita × Smith (milo × kafir)	H. C. 302	5.7	18.7	100.0	40.8	47.0	21.2	22.1	27.0	30.7	26.5	28.1
28	Ajax	F. C. 6620	.6	29.9	100.0	43.3	45.4	12.7	19.4	38.7	38.6	40.8	39.3
29	Dwarf feterita × Smith (milo × kafir)	H. C. 301	2.2	32.1	100.0	44.8	41.6	4.2	15.2	25.9	14.3	22.8	21.0
30	Spur feterita	C. I. 623	.0	42.2	100.0	47.4	40.8	9.7	16.8	46.9	35.0	29.2	37.0
31	Custer	C. I. 910	17.1	29.1	99.3	48.5	15.3	2.7	6.0	19.1	21.2	26.5	22.3
32	Early Sumac sorgo	F. C. 6611	.0	50.0	100.0	50.0	49.2	5.8	18.3	24.9	26.5	22.2	24.5
33	Wheatland	C. I. 918	7.4	46.8	100.0	51.4	21.4	1.9	7.8	10.2	11.6	14.6	12.1

[1] All varieties failed completely in June 8 planting.

TABLE 6.—*Percentage of sorghum plants killed by chinch bugs in 1932, and grain yields in 1931 and 1932, at Lawton, Okla.*—Continued

Rank in chinch bug resistance	Variety	Record no.	Plants killed, 1932				Grain yields per acre, 1932			Grain yields per acre, 1931			
			Date of planting			Average of 3 dates	Date of planting		Average of 3 dates	Date of planting			Average of 3 dates
			Apr. 15	May 4	June 8		Apr. 15	May 4		Apr. 13	May 7	June 1	
			Percent	*Percent*	*Percent*	*Percent*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
34	Fargo	C. I. 809	3.0	70.2	100.0	57.7	73.8	2.1	25.3	30.2	24.7	31.2	28.7
35	Kalo	C. I. 902	1.4	81.4	100.0	60.9	40.7	.0	13.6	26.0	21.2	29.1	25.4
36	Bishop	C. I. 814	4.6	88.1	100.0	64.2	41.2	.0	13.7	41.4	16.4	30.2	29.3
37	Sooner milo	C. I. 917	2.2	100.0	100.0	67.4	22.7	.0	7.6	15.4	10.6	5.8	10.6
38	Dwarf Yellow milo	C. I. 332	3.9	100.0	100.0	68.0	43.0	.0	14.3	15.9	8.8	28.6	17.8
39	Feterita	C. I. 182	93.5	38.8	100.0	77.4	15.6	10.9	8.8	20.9	22.3	22.3	21.8
40	Beaver	C. I. 871	100.0	100.0	100.0	100.0	.0	.0	.0	2.9	4.9	14.6	7.5
Average			6.9	25.6	96.7	43.0	46.5	18.1	21.5	28.0	24.8	27.7	26.8

The season of 1932 was more nearly typical of the Lawton section. Migration of the bugs from the small grains to the sorghums took place about the time the plants in the April 15 planting were heading and consequently this planting failed to show any appreciable chinch bug injury. All of the varieties in the May 4 planting were injured to some extent and some of the more susceptible varieties were destroyed by chinch bugs. The plants on the June 8 planting were only about 6 to 8 inches tall when the bugs migrated and were severely injured within a few days. The average yield for the 40 varieties on the April 15 planting was 46.5 bushels to the acre. In

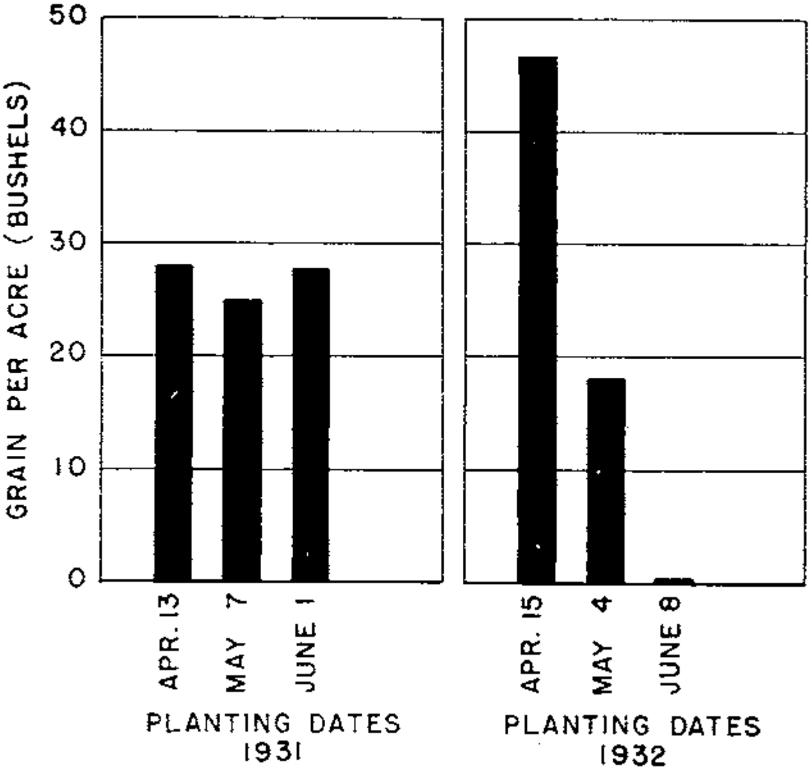

FIGURE 7.—Average grain yields of 40 varieties of sorghums grown at Lawton, Okla., from three dates of planting under a very light infestation of chinch bugs in 1931 and under a heavy infestation in 1932.

the May 4 planting, the average yield was 18.1 bushels to the acre. The June 8 planting was a complete failure. The average grain yields for the three dates of planting in 1931 and 1932 are shown graphically in figure 7.

The percentage of plants killed in 1932, also given in table 6, was 6.9 percent in the April 15 planting, 25.6 percent in the May 4 planting, and 96.7 percent in the June 8 planting. Most of the surviving plants among the susceptible varieties were field hybrids and probably survived the chinch bug attack because of their hybrid vigor.

The grain yields of all varieties, except those of Beaver, which were zero in both cases, were lower in the May 4 than in the April 15

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planting of 1932. In some of the susceptible varieties the differences in yield on the two dates were very wide.

INHERITANCE OF RESISTANCE TO CHINCH BUG INJURY

EARLY HYBRID GENERATIONS

Three F_1 hybrids involving feterita and kafir were grown at Lawton in 1932 (fig. 8 and table 7). These were feterita × Dawn (C. I. 340), feterita × Dawn kafir selection (C. I. 904), and feterita × Western Blackhull. In the parental varieties the feterita plants were killed July 7 when about 5 inches high, while all of the kafir parents reached maturity without any apparent injury and produced well-developed heads. The F_1 plants of all three crosses were very similar and exhibited marked hybrid vigor but matured at approximately the same time as the kafir parents. Seed of these F_1 heads was saved and the F_2 plants were grown in 1933.

TABLE 7.—*Plants of sorghum varieties and their F_1 and F_2 generation hybrids killed by chinch bugs at Lawton, Okla., 1932–33*

Hybrid or parent	C. I. no.	1932, F_1 generation: Total plants	1932, F_1 generation: Plants killed Aug. 8		1932, F_1 generation: Date all plants killed	1933, F_2 generation: Total plants	1933, F_2 generation: Plants killed Aug. 29	
		Number	*Number*	*Percent*		*Number*	*Number*	*Percent*
Feterita	182	5	5	100.0	July 7	132	40	30.3
Feterita × Dawn kafir [1]		10	0	.0		265	56	21.1
Dawn kafir	340	13	0	.0		134	52	38.8
Feterita	182	6	6	100.0	July 7	128	44	34.4
Feterita × Dawn selection [1]		6	0	.0		286	34	11.9
Dawn kafir selection	904	9	0	.0		134	12	9.0
Feterita	182	5	5	100.0	July 7	128	44	34.4
Feterita × Western Blackhull kafir [1]		4	0	.0		254	82	32.3
Western Blackhull kafir	906	5	0	.0		133	85	63.9
Dwarf Freed	971	14	9	64.3				
Dwarf Freed × Dwarf Yellow milo [1]		14	14	100.0	Aug. 1			
Dwarf Yellow milo	332	15	15	100.0	July 18			
Feterita	182	15	15	100.0	July 7	132	40	30.3
Feterita × Dwarf Yellow milo [1]		19	0	.0		192	114	59.4
Dwarf Yellow milo	332	17	17	100.0	July 18	134	134	100.0
Sharon kafir	813					131	87	66.4
Sharon kafir × Dwarf Yellow milo [2]						267	164	61.4
Dwarf Yellow milo	332					134	134	100.0
Blackhull kafir	[3] 613					134	78	58.2
Blackhull kafir × Spur feterita [1]						349	155	44.4
Spur feterita	623					75	23	30.7

[1] Crosses made by J. H. Martin.
[2] Cross made by J. B. Sieglinger, Woodward, Okla.
[3] Kansas Agronomy Farm strain.

In the cross feterita × Dawn kafir (C. I. 340), 265 F_2 plants were grown, of which 21.1 percent were killed by chinch bugs. The Dawn parent suffered a loss of 38.8 percent of the plants, and a few of those that survived failed to develop grain. The feterita parental row suffered 30.3 percent killing, but because of the earliness of the variety the surviving plants produced heads that were filled with shriveled grain.

In the cross feterita × Dawn kafir selection, 286 F_2 plants were grown and only 11.9 percent were killed by chinch bugs. The percentage was less than in the cross between feterita and Dawn kafir, and corresponded with the difference in the resistance of the two strains of kafir. Many of the surviving F_2 plants attained nearly normal development. Many heads were produced and they were well filled

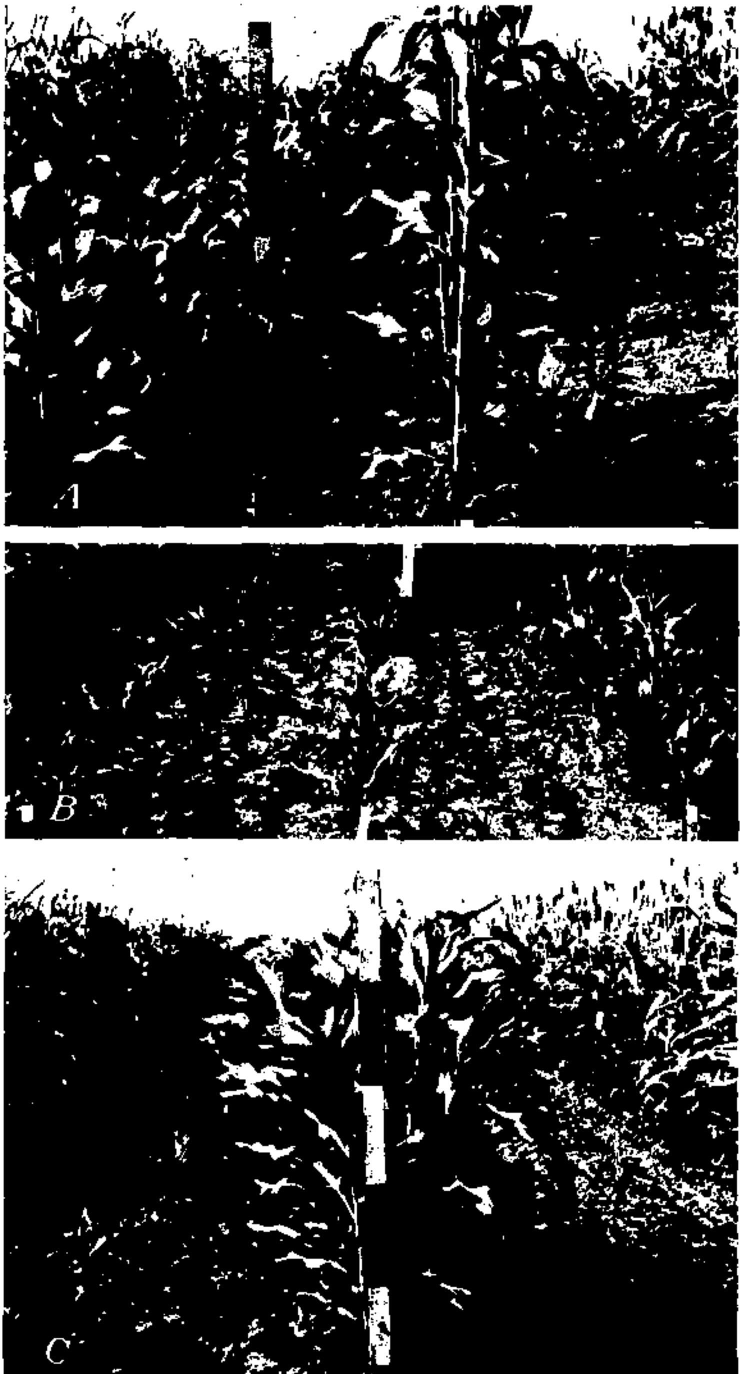


FIGURE 8.—Chinch bug reaction of F_1 sorghum hybrids and their parents at Lawton, Okla., 1932: *A*, Dawn kafir (left), feterita × Dawn kafir (center), and feterita completely killed (right); *B*, Dwarf Yellow milo (left), Dwarf Yellow milo × Dwarf Freed (center), and Dwarf Freed (right); *C*, Dwarf Yellow milo (left), feterita × Dwarf Yellow milo (center), and feterita completely killed (right). The hybrids showing heterosis were resistant.

with good-quality grain. Varying degrees of hybrid vigor were apparent in the F_2 generation, as was indicated by the size of the F_2 plants. The feterita parent was killed to the extent of 34.4 percent while the percentage for Dawn was only 9. Thus, the average injury to the F_2 plants was only slightly greater than the injury to the more resistant parent and much less than in the feterita parent.

In the cross feterita × Western Blackhull kafir, 254 F_2 plants were grown, of which 32.3 percent were killed by the chinch bugs. The Western Blackhull parent had 63.9 percent of dead plants, and the surviving plants failed to develop beyond the boot stage. The feterita parent had 34.4 percent of dead plants, but the surviving plants evaded the peak of chinch bug infestation and produced heads that were filled with shriveled grain.

The average percentage of plants killed in each of the three F_2 feterita-kafir hybrids was lower than in feterita. Two of the three hybrids had fewer plants killed than the kafir parents. In the third cross, the percentage of plants killed was slightly higher than in the resistant kafir parent.

These results suggest that resistance may be dominant in these crosses, although the continued manifestation of heterosis in the F_2 generation of these crosses may have increased the average resistance of the population.

The F_1 generation plants of Dwarf Freed × Dwarf Yellow milo did not exhibit hybrid vigor and all were killed by chinch bugs (fig. 8, *B*, and table 7). These F_1 hybrids were more resistant than the milo parent, as shown by the fact that some of them survived until August 1, while all of the milo plants were killed by July 18. The loss of plants in the Dwarf Freed parent was 64.3 percent, and the surviving plants that reached maturity appeared stunted and produced poorly developed heads.

The feterita × Dwarf Yellow milo hybrid was of particular interest, since both parents especially milo are susceptible to chinch bug injury (fig. 8, *C*, and table 7). The feterita plants did not attain a height of more than 5 inches and all were killed by July 7. Some of the milo plants survived until July 18 but were killed when about 10 inches high. The plants of the F_1 generation made a luxuriant growth, exhibited marked heterosis, and were late, but they survived a heavy late infestation of bugs and produced a little seed that matured about October 10. Hybrid vigor probably was chiefly responsible for the chinch bug resistance of the hybrid.

The average of the F_2 population of the feterita-milo cross, grown in 1933, was intermediate between the parents in chinch bug resistance, as shown by the data in table 7. Feterita, usually susceptible, had only 30.3 percent of the plants killed. Its earliness allowed the plants to partly evade injury by maturing before the peak of the chinch bug infestation. All of the plants of Dwarf Yellow milo were killed. In a population of 192 F_2 plants 59.4 percent were killed. This is higher than in the feterita-kafir crosses, in which a resistant parent was involved.

In another cross, Blackhull kafir × Spur feterita, the F_1 plants of which were grown at Manhattan in 1932, the 349 plants of the F_2 generation grown at Lawton in 1933 showed 44.4 percent killing. The surviving hybrid plants were badly injured and only a few plants produced partially exserted, poorly developed heads with inferior grain. Blackhull kafir, a late variety poorly adapted to the severe conditions of 1933, had 58.2 percent killing and the surviving plants did not develop beyond the boot stage. Spur feterita, an earlier variety, had a mortality of 30.7 percent, but only the strongest of the surviving plants reached the heading stage and no grain was formed.

In the Sharon kafir × Dwarf Yellow milo cross, the F_1 generation of which was grown at Woodward, Okla., 61.4 percent of the 267 F_2 plants grown at Lawton in 1933 were killed by chinch bugs. The surviving plants were badly injured and did not develop beyond the boot stage. The Sharon kafir parent had 66.4 percent of the plants killed, and only the strongest survivors produced a few partially exserted heads and these contained no grain. All of the milo plants were killed.

One hundred F_3 lines of this cross and two rows of each parent were grown at Lawton in 1934. The percentages of plants killed by July 13, when maximum differences in resistance were apparent, are shown graphically in figure 9.

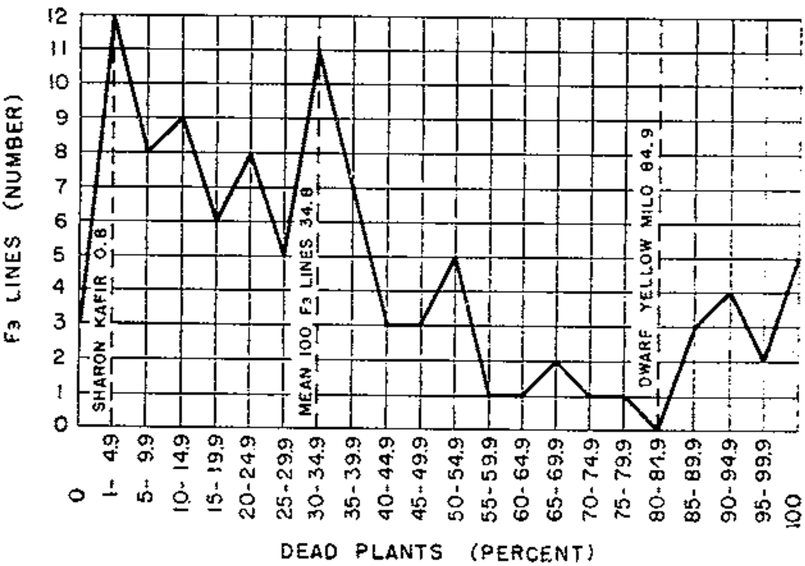


FIGURE 9.—Percentage of dead plants in the parent varieties and F_3 lines of the cross Sharon kafir × Dwarf milo at Lawton, Okla., 1934.

This distribution suggests that resistance is dominant or partially dominant in this cross. The apparent dominance of resistance may be due in part to a carry-over of the marked hybrid vigor from the F_1 generation of this cross. The modal class of the F_3 lines is almost the same as that of the resistant parent. Another high point in the curve occurs in the 30-to-34.9-percent class, near the mean. Fifteen F_3 lines were about as resistant as the Sharon kafir parent and 14 F_3 lines were as susceptible as or more susceptible than Dwarf Yellow milo.

These lines also were classified again for resistance by visual inspection on July 16. Each line was described in comparison with the parents (table 8 and fig. 10) as (1) resistant, (2) intermediate or segregating, and (3) susceptible.

Grouping of the F_3 lines into three resistance classes is shown in table 8.

FIGURE 10.—*A*, Segregation for chinch bug resistance in a heterozygous F_3 row of Sharon kafir × Dwarf Yellow milo; *B*, F_3 rows of the same cross, showing segregation for resistance, Lawton, Okla., 1934.

TABLE 8.—*Reaction to chinch bugs of 100 F_3 lines of Sharon kafir × Dwarf Yellow milo*

Variety or hybrid	Number of plants observed	Plants calculated (3:1 ratio)	Class average of plants killed
			Percent
Sharon kafir (resistant)			0.8
F_3 hybrids (resistant)	37 } 74	75	10.1
F_3 hybrids (intermediate)	37		30.5
F_3 hybrids (susceptible)	26	25	76.2
Dwarf Yellow milo (susceptible)			81.9

The observed figures as classified give a very close fit to the calculated 3:1 ratio and might be taken to indicate that one main factor pair governs chinch bug resistance in this cross. However, it is probable that the inheritance of chinch bug resistance is more complex and is influenced not only by other factors directly affecting chinch bug reaction but also by genetic factors controlling such plant characters as earliness, vigor of early growth, character of leaf sheath, and others.

The occurrence of several lines apparently homozygous for intermediate reactions to chinch bugs is not in agreement with a single factor hypothesis. Further studies of subsequent generations are needed to determine the genotype represented in the F_3 phenotypes here described.

A third method of classifying the 100 F_3 lines of Sharon kafir × Dwarf Yellow milo grown at Lawton in 1934 consisted of describing each line as to degree of plant development, heading, and grain production, as used and defined in table 2. These descriptions were made on July 24 independent of the other two classifications. The data are shown in table 9.

TABLE 9.—*Plant development of 100 F_3 lines of Sharon kafir × Dwarf Yellow milo*

Variety or hybrid	Degree of plant development July 24 [1]	Lines	Class average of plants killed July 13	Variety or hybrid	Degree of plant development July 24 [1]	Lines	Class average of plants killed July 13
		Number	*Percent*			*Number*	*Percent*
Sharon kafir	D		0.8	Sharon kafir × Dwarf Yellow milo.	E	50	24.4
Sharon kafir × Dwarf Yellow milo.	B	4	.8	Do	F	27	72.9
Do	C	5	3.1	Dwarf Yellow milo	F		81.9
Do	D	14	10.6				

[1] See footnote 2, table 2.

The percentage of plants killed is highest in class F, which represents very poor plant development.

Nine F_3 lines had more complete plant development than the Sharon kafir parent, and 73 F_3 lines were superior to the Dwarf Yellow milo parent in degree of plant development. The superiority of some of the F_3 lines was due to their earliness and ability to head under adverse environmental conditions imposed by both drought and chinch bugs.

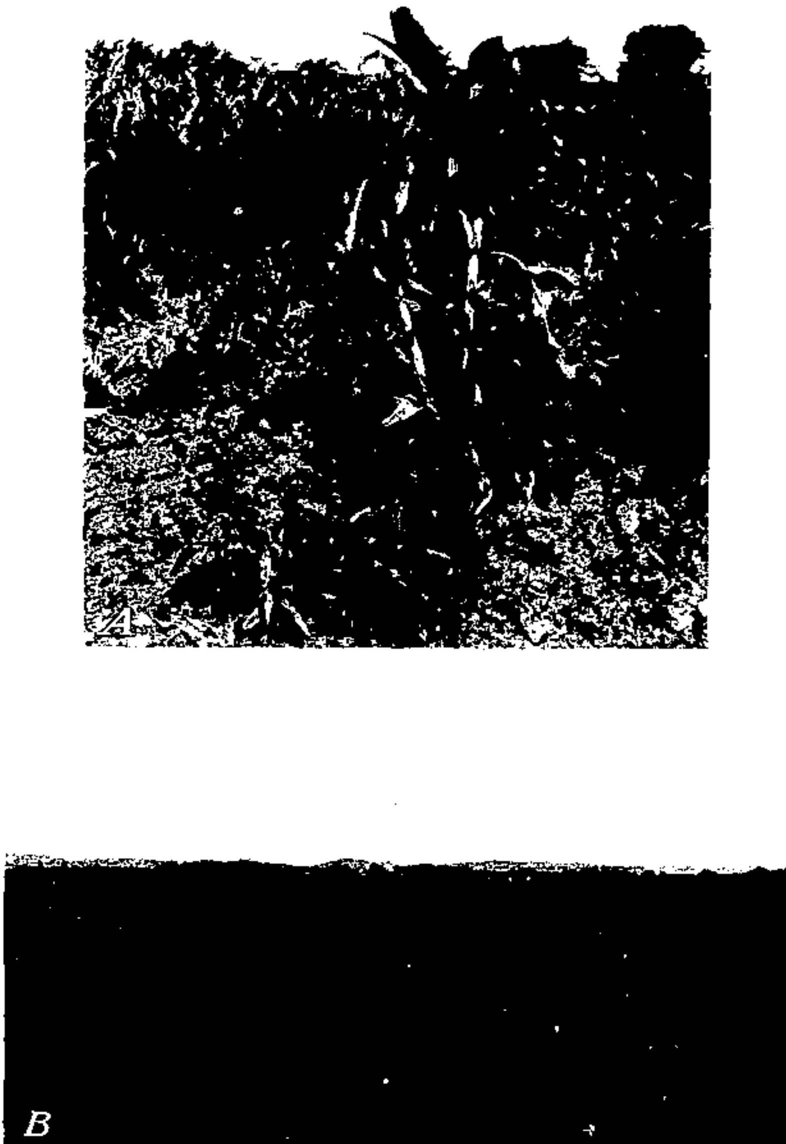


FIGURE 11.—*A*, Vigorous resistant F_1 hybrid plant in a plot of Dwarf Yellow milo at Manhattan, Kans., 1933; male parent unknown; *B*, chinch bug reaction of F_2 rows grown from vigorous F_1 hybrid plants between susceptible milo derivatives and unknown parents, 1934.

In 1934, several F_2 populations from vigorous F_1 natural crosses grown in 1933 were planted in the sorghum-breeding nursery at Manhattan, in direct comparison with the female parent. The male parent of these natural crosses was unknown. As shown in figure 11, *B*, these F_2 generation plants were injured much less by chinch bugs than were the plants of the susceptible female parents. The hybrid vigor manifested by these F_2 generation plants is probably responsible, in part at least, for their resistance to chinch bugs.

The relationship between hybrid vigor and resistance to chinch bugs has been observed in many F_1 natural hybrids at several stations over a period of years (fig. 8, *B*). In the cross Dwarf Yellow milo (susceptible) × Dwarf Freed (intermediate) hybrid vigor was not evident and the F_1 plants were intermediate between the parents for chinch bug resistance. In the cross feterita (susceptible) × Dwarf Yellow milo (susceptible) the F_1 plants showed marked hybrid vigor and a high degree of chinch bug resistance. The F_1 hybrids feterita (susceptible) × Dawn or Western Blackhull kafir (resistant) exhibited hybrid vigor and were highly resistant to chinch bugs. These observations were made on a rather small number of hybrids, but they tend to support the hypothesis that there is an intimate relationship between hybrid vigor and chinch bug resistance.

In most crosses between diverse sorghum varieties, hybrid vigor is manifested in increased height of plant, diameter of stalk, tillering, vigorous root system, and often in lateness (*12*). The high degree of resistance to chinch bugs commonly shown by F_1 sorghum hybrids is partly the result of the vigorous growth of the hybrid plants.

ADVANCED GENERATION HYBRIDS

A cross between Kansas Orange sorgo (resistant) and Dwarf Yellow milo (susceptible) was made at Manhattan in 1919 specifically to produce a variety resembling milo, with the chinch bug resistance of Kansas Orange. The F_3 generation was grown under chinch bug infestation conditions at Manhattan in 1922. As shown in table 10, the Kansas Orange parent had only 5.4 percent of injured plants and the milo parent 50.0 percent. The percentage of injured plants in the F_3 lines ranged from 4.7 to 75.7 (fig. 12). Many of the resistant lines showed marked hybrid vigor. Relatively few head selections were made in the F_3 rows. In making these selections primary attention was given to agronomic characters, especially earliness, yellow seed color, and short stature. The infestation was moderate in 1923, but in 1924 all plants except one in the nursery were killed by the bugs. The correlation between the chinch bug reaction of F_3 and F_4 lines is probably not so high as it might have been with random selection and if more lines had been grown.

FIGURE 12.—*A*, Segregation for chinch bug resistance in a heterozygous F_3 line of Kansas Orange × Dwarf Yellow milo at Manhattan, Kans., 1922; *B*, F_4 lines of the same cross, showing differences in resistance, 1923.

Table 10.—*Chinch bug injury to F_3 and F_4 generation selections of Kansas Orange × Dwarf Yellow milo, Manhattan, Kans., 1922 and 1923*

Pedigree no.	Plants injured		Pedigree no.	Plants injured	
	F_3 (1922)	F_4 (1923)[1]		F_3 (1922)	F_4 (1923)[1]
	Percent	*Percent*		*Percent*	*Percent*
7	4.7	6.3	20	25.4	46.6 47.0
38	5.1	18.7	25	26.5	33.9 18.3 26.5
Kansas Orange (average of checks)	5.4	20.4	28	29.2	18.4
11	5.6	12.3 14.3	27	31.3	28.8 34.0
41	9.1	28.4 17.2 17.5	33	31.4	14.1
9	9.2	20.6	35	31.5	20.6 30.0
12	9.6	10.3 35.1	13	32.8	32.8
36	10.8	29.8	23	41.7	38.7 20.4
16	11.5	18.7 27.4	24	47.0	26.1 4.8
8	13.1	8.1 12.3	Dwarf Yellow milo (average of checks)	50.0	62.8
39	14.0	23.0	31	57.3	23.5 40.0
19	18.7	5.4 11.5	21	59.2	19.3 28.6 23.8
17	19.4	23.4 8.2	22	75.7	13.7
32	20.2	31.7			
29	23.3	5.4 20.3			
18	25.0	10.4 29.9			

[1] F_4 lines from single plant selections out of the F_3 rows of corresponding pedigree number.

A study of the general relation between chinch bug reaction in F_3 and F_4 lines was made on the basis of F_3 quartiles, which is shown in table 11.

The quartile averages for the F_4 lines do not parallel the F_3 averages exactly, but the average injury in the F_4 lines selected from the two more susceptible quartiles in F_3 is higher than in the F_4 lines selected from the two more resistant quartiles of the F_3 generation.

Table 11.—*Quartile grouping for chinch bug injury in the F_3 generation and the average injury in the F_4 generation of selected lines of Kansas Orange × Dwarf Yellow milo at Manhattan, Kans., 1922 and 1923*

Quartiles	Average percentages of injured plants		Quartiles	Average percentages of injured plants	
	F_3	F_4		F_3	F_4
	Percent	*Percent*		*Percent*	*Percent*
I	7.7	19.1	III	28.6	28.2
II	17.2	18.3	IV	52.3	25.7

It is evident from the results of all of the above-named crosses that resistance to chinch bug injury is inherited, but it is impossible, from the data at hand, to draw any conclusions regarding the genetic factors involved. Hybrid vigor has a pronounced influence on apparent chinch bug resistance.

A large number of F_5 lines were grown in the nursery at Manhattan in 1924, but the chinch bug infestation was so heavy on the young plants that all but one were destroyed. The selection Kansas 24136, of this cross, which proved highly resistant in later tests at Manhattan and Lawton, came from the most resistant F_5 line grown in the nursery at Manhattan in 1924 under heavy chinch bug infestation. The infestation in 1924 was so heavy that nearly all lines had very high percentages of injured plants, and the genetic differences known to exist were in many cases masked by the early and sudden attack of chinch bugs while the plants were small. For this reason, no data on the F_5 lines grown at Manhattan in 1924 are presented.

At Manhattan in 1925 a moderate infestation offered an opportunity to study resistance in a number of rows of several advanced hybrids. In a series of 10 F_5 lines of Kansas Orange sorgo (resistant) × feterita (susceptible) the range of injury was rather evenly distributed from 7 to 35 percent. The average injury to these lines is shown in the following tabulation. One of the strains was distinctly more resistant than the Kansas Orange parent. No hybrid strain was as susceptible as the feterita parent, perhaps because chinch bug injury had exerted some selective influence in preceding generations.

Parent and cross:	*Plants injured* *Percent*
Kansas Orange sorgo (parent)	17.0
Kansas Orange × feterita	23.3
Feterita (parent)	86.0
Red Amber sorgo (parent)	43.0
Red Amber × feterita	33.7
Feterita (parent)	85.0

In the cross Red Amber sorgo (moderately susceptible) × feterita (susceptible) 22 F_7 and F_8 lines were studied in 1925. The hybrids showed evidence of transgressive segregation. Fifteen lines were more resistant than the resistant parent. A selection from this cross, K. B. 2513, is the most resistant strain tested during the 6 station years in which it has been tested at Manhattan and Lawton, as shown in table 3. This is good evidence of actual transgressive segregation. These and other data suggest that it is possible to breed into the sorghums a degree of resistance higher than that possessed by any of the old standard varieties. Selections of the cross hegari (moderately resistant) × Dwarf Yellow milo (highly susceptible) were studied for 2 years. In 1925, 61 lines from this cross were examined for resistance and none proved more resistant than hegari. The same is true of a few lines from this cross studied in other years. A selection, H. C. 282, of a cross Dwarf White milo × hegari, made at Hays, Kans., has proved moderately resistant at Lawton, exceeding either parent.

TABLE 12.—*Chinch bug reaction of advanced generation sorghum hybrids and their parents at Lawton, Okla.*[1]

Hybrids and parents	Record no.	Plants killed			
		1930	1932	1933	1934
		Percent	*Percent*	*Percent*	*Percent*
Kansas Orange	F. C. 9108	38	7	21	2
Kansas Orange × Dwarf Yellow milo	Ks. 24-136	20	2	3	3
Do	Ks. 30-33	68	8	71	53
Dwarf Yellow milo	C. I. 332	100	100	100	100
Pink kafir	C. I. 432	36	1	19	0
Pink kafir × Dwarf Yellow milo	C. I. 903	86	7	100	92
Do	Ks. 30-61		31	77	
Do	Ks. 30-70		5	100	
Dwarf Yellow milo	C. I. 332	100	100	100	100
Do	do	100	100		
Dwarf Yellow milo × Dwarf Freed[2]	H. C. 303	60	5		
Dwarf Freed	C. I. 971	70	13		
Dawn kafir selection	C. I. 904		2	5	
Dawn kafir selection × darso	Wdw. 23		2	39	
Do	Wdw. 28		3	14	
Darso	C. I. 615		2	29	
Atlas	C. I. 899		7	20	
Atlas × Early Sumac	La. 31364		18	50	
Early Sumac	F. C. 6611		50	21	
Red Amber	F. C. 7038		5	18	
Red Amber × feterita	K. B. 2513		1	17	
Feterita	C. I. 182		39	24	
Sharon kafir	C. I. 813		1	8	
Sharon kafir × darso	Wdw. 12		2	8	
Darso	C. I. 615		2	29	
Dawn kafir selection	C. I. 901			5	2
Dawn kafir selection × (Kansas Orange × Dwarf Yellow milo).	Ks. 32-132			60	30
Kansas Orange × Dwarf Yellow milo	Ks. 24-136			3	3
Darso	C. I. 615			29	8
Darso × Fargo	Gdw. A30-1			18	17
Fargo	C. I. 908			96	100
Dwarf Yellow milo	C. I. 332			100	100
Dwarf Yellow milo × hegari	Wdw. 10-1			38	98
Do	Wdw. 11-2			45	45
Hegari	C. I. 750			44	

[1] Varieties planted May 20, 1930; May 4, 1932; May 8, 1933; and May 1, 1934.
[2] Showed segregation for various characters.

The chinch bug reaction of a number of advanced generation hybrids at Lawton, together with the reaction of their parents, is shown in table 12. Among the selections from the cross Kansas Orange sorgo × Dwarf Yellow milo, Kansas 30–33, a combine type of grain sorghum, showed more resistance than the susceptible milo parent but less resistance than the resistant Kansas Orange parent. Another selection from the same cross, Kansas 24–136, showed transgressive segregation in being more resistant than Kansas Orange. This strain was selected particularly for its high resistance. A study of the various hybrid selections shown in table 12 indicates that resistance to chinch bugs is inherited independently of many agronomic characters, because resistant selections of widely different character have been isolated. The resistant selection of Kansas Orange × Dwarf Yellow milo, Kansas 24–136, has produced satisfactory yields of grain, but has buff colored seed. It is not leafy and has dry, pithy stalks, making it unsatisfactory for forage. This resistant strain is not recommended because of its failure to meet farmers' requirements for a dual-purpose variety having good forage and an attractive, palatable grain.

A selection of what is supposedly a cross between darso and Fargo, produced at the Panhandle Experiment Station, Goodwell, Okla., showed much more resistance at Lawton than the susceptible Fargo parent and was about equal to the resistant darso parent.

Dawn kafir selection × (Kansas Orange × Dwarf Yellow milo), a cross between two resistant strains grown in 1933 and 1934 was much more susceptible than either parent. The Dawn kafir parent had 5 percent of dead plants in 1933 and only 2 percent in 1934. The Kansas Orange × Dwarf Yellow milo (Kansas 24–136) parent had 3 percent of dead plants both in 1933 and 1934.

Most of the other advanced hybrids listed in table 12 do not show transgressive segregation for resistance but tend toward an intermediate position between the parents.

NATURAL SELECTION AS A FACTOR IN RESISTANCE

Varieties of a sorghum apparently homozygous for agronomic characters but which have never been subjected to chinch bug injury have been shown to be heterozygous for the genetic factors governing resistance or susceptibility when grown in the presence of chinch bugs.

Chiltex, a variety resulting from a cross between kafir and feterita, distributed in 1923 by the cooperative field station at Chillicothe, Tex., was grown in the nursery at Lawton. A light infestation of bugs during the earlier part of the 1931 season at Lawton did not prevent the normal development of the plants. Seed was saved from this crop, and the variety was subjected to a heavy infestation of bugs at Lawton in 1932. Seed was saved from the few surviving plants and threshed in bulk. In 1933 and 1934 this bulk-selected seed was planted in comparison with the original seed, remnant seed being used in the latter year. In 1933, 53.1 percent of the plants of the original Chiltex were killed, as compared with 22.6 percent of the selected strain. In 1934, all the plants of original Chiltex were killed, while only 68.0 percent of the selected strain was killed. The 2-year average killing was 76.5 percent in the unselected and 47.3 percent in the selected Chiltex. The Lawton selection cannot be distinguished from the original Chiltex except when grown in the presence of chinch bugs.

The kafir-milo hybrid, Kansas 27–317, was severely injured by chinch bugs at Lawton in 1932. A single plant survived this serious infestation and was saved and planted in a head row in 1933.

All plants from the original seed lot of Kansas 27–317 were destroyed by chinch bugs, while only 35.2 percent of the plants of the selection were killed. These rows are shown in figure 13. Again in 1934, all plants in the original Kansas 27–317 were killed, compared with 58.0 percent in the Lawton selection. The average loss for the 2 years was 100 percent of the original and 46.6 percent of the selected strain.

Similar results have been obtained with darso, shown in table 13. Seed saved from the single surviving plant of a test in 1932 was grown in 1933 with a loss of only 38.1 percent of the plants, while the original darso suffered a loss of 85.9 percent. In 1934, 31.0 percent of the original darso was killed by chinch bugs, while only 18.7 percent of the selection was killed. The 2-year average killing was 58.5 percent of the unselected darso and 28.4 percent of the selection.

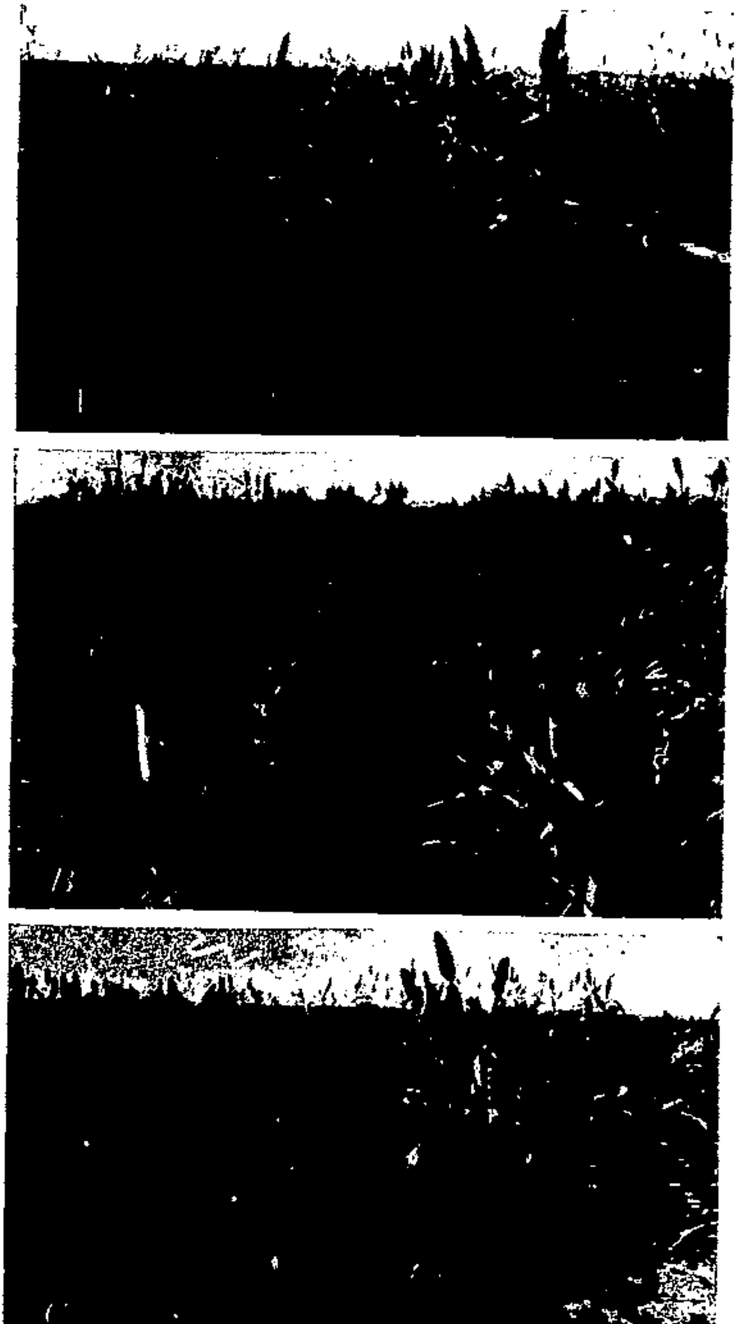


FIGURE 13.—Sorghum varieties and chinch bug resistant selections from them at Lawton, Okla.: *A*, Darso (left), resistant selection (right), 1933; *B*, Chiltex (left), resistant selection (right), 1934; *C*, kafir × milo, Ks. 27-317 (left), resistant selection (right), 1933.

TABLE 13.—*Chinch bug reaction of 3 varieties of sorghum and resistant selections made from them under heavy chinch bug infestation at Lawton, Okla.*

Variety and selection	Record no.	Plants killed		2-year average
		1933	1934	
		Percent	*Percent*	*Percent*
Chiltex	C. I. 874	53.1	100.0	76.5
Chiltex selection	La. 32308	26.6	68.0	47.3
Kafir × milo	Ks. 27-317	100.0	100.0	100.0
Kafir × milo selection	La. 32205	35.2	46.0	40.6
Darso	C. I. 615	85.9	31.0	58.5
Darso selection	La. 32572	38.1	18.7	28.4

The resistant selection of darso should be of immediate practical interest in Oklahoma because darso is a widely grown and popular variety owing to its drought resistance. The resistant selection appears identical with the parental variety in agronomic characters and apparently can be recognized as a distinct type differing from the parent only when grown in the presence of chinch bugs.

The resistant selection of kafir × milo, Kansas 27–317, does not appear to be identical with the parental type in plant height but is very similar in other agronomic characters. These studies of the effects of selection indicate that some varieties are homozygous for the genetic factors determining chinch bug reaction, while other varieties are heterozygous for these factors.

Rows of kafir × milo (Kansas 27–317) and its resistant Lawton selection and of darso and its resistant selection grown in 1934 are illustrated in figure 13.

The selection of surviving plants from standard varieties grown under conditions favorable to chinch bug infestation is a quick method of producing resistant varieties of sorghums. The value of this method is limited by the agronomic characters of the parental variety, but by hybridization it should be possible to combine chinch bug resistance with desirable agronomic characters.

INVESTIGATION OF THE BASIS OF CHINCH BUG RESISTANCE

NATURE OF CHINCH BUG INJURY

The injury and death of numerous plants of many varieties have been observed under field conditions and in controlled experiments. The controlled experiments consisted of confining a certain number of bugs on single plants of resistant and susceptible varieties of comparable age by means of creosote barriers. The bugs used were in the later instars. Upon reaching maturity on the experimental plants most of the bugs left by flight. The number of bugs used in each experiment was estimated by measuring the volume of bugs and counting a unit volume. Most of the plants used in these experiments were Kansas Orange sorgo (resistant) and Dwarf Yellow milo (susceptible). The results were obtained from a sudden attack by a given number of bugs applied at one time on these experimental plants, as contrasted with the continued infestation under field conditions. The data presented in table 14 are representative of a larger number of experiments. The reaction of each of these plants to the bugs was followed in detail. Considerable chance for experimental error exists by reason of individual plant variation, soil and weather conditions, and the effect of these on the bugs. These controlled experiments supplement field observations and give more exact information on the effect of a given number of chinch bugs on young plants of known varieties.

TABLE 14.—*Results of controlled chinch bug infestations on individual plants of a susceptible and a resistant variety of sorghum at Manhattan, Kans., 1927*

Variety and date of infestation	Bugs	Plant height when infested	Days until severely wilted	Days until dead	Remarks
Dwarf Yellow milo:	*Number*	*Inches*	*Number*	*Number*	
July 5	1,175	25.5	----------	----------	Height, July 19, 51 inches.
June 30	1,275	12.5	----------	----------	July 7, plant recovering; height 10 inches.
Do	1,375	28.0	----------	----------	Height, Aug. 10, 59 inches.
July 2	3,900	13.0	3	7	
July 1	6,750	10.5	5	8	
July 6	11,000	28.0	6	14	
Kansas Orange sorgo:					
July 5	1,125	30.0	----------	----------	Height, July 19, 59 inches.
June 30	1,375	12.5	----------	----------	Recovered; height Aug. 10, 89 inches.
Do	1,375	29.0	----------	----------	Height, July 19, 56 inches.
July 2	3,900	11.5	10	13	
July 1 [1]	6,750	10.5	10	14	
July 6	11,000	26.0	9	16	

[1] Plant of resistant strain of Kansas Orange × Dwarf Yellow milo substituted for Kansas Orange.

The number of bugs required to kill a single plant, less than 2 feet high, of either Kansas Orange or Dwarf Yellow milo, under the conditions of these experiments, was between 2,000 and 3,000. These were immature bugs which sometimes left the plants when they became winged.

The reaction of the plant to the feeding of the bugs influences the habits of the insect. At the stage of incipient wilting and discoloration of plant tissue, the bugs frequently feed on the leaf blades in large numbers and with little movement. In the case of a slightly injured plant the heavy feeding is on the leaf sheath. On the other hand, if the plants are not badly injured by the feeding, the bugs fly from the plants as soon as they become adults. The size and vigor of the plant greatly influence the amount of injury that can be caused by a given number of chinch bugs.

In one experiment an infestation of 5,625 bugs killed the main stalk of a Dwarf Yellow milo plant, but several tillers developed from the crown after the population of bugs had decreased. In the resistant Kansas Orange variety this did not take place, and it rarely occurred under field conditions.

Under a sudden, heavy attack of chinch bugs, plants of both varieties withered while still green. The wilting started with the outer, lower leaves and proceeded toward the inner and upper ones. While plants are in this condition a rain will revive them and frequently permits prompt recovery under a moderate infestation of bugs. The time between withering and death usually was longer in Dwarf Yellow milo than in Kansas Orange sorgo, but both withering and death began more quickly in milo.

Prolonged sublethal attacks by the bugs tend to stunt growth in all varieties. This often results in the death of the central leaf curl before that of some of the older leaves. Decay begins at the growing point near the crown where the tissue is usually beyond the reach of the stylets of the bugs and must be a secondary result of the feeding of the bugs. The stunting of growth and death of the central leaf curl are especially characteristic of milo and may represent a different type of susceptibility from that found in other varieties.

Distinctive color reactions in the leaves of the plants attacked are characteristic of injury to sorghums by chinch bugs. The dark red or purple pigment deposited at the site of the punctures (pl. 1, *E*) is apparently the same as that occurring on many varieties at the place of other kinds of wounds. Its relationship to these injuries is unknown. In addition to these blotches of red pigment, the leaves of many varieties turn a suffused yellow or reddish yellow as a result of severe chinch bug injury.

Johnson (*43*) has given good evidence that the reddening and yellowing of leaves of legumes, caused by the potato leafhopper, results from the disruption and clogging of the conducting tissues and the overaccumulation of carbohydrates above the injured area. The reaction occurring among some sorghums appears similar in cause and result.

The injury caused by chinch bugs is primarily the result of a mass attack. Young plants are sometimes covered with bugs and the sap is extracted in a few days. Larger plants react in two ways to the bugs—they are stunted and die quickly, or they become discolored and die at a later stage. Severe stunting with a red discoloration is characteristic of the milos and most of their derivatives. Impeded growth with a yellow discoloration is characteristic of feterita and such sorgos as Honey and Leoti Red. Varieties of hybrid origin may show varying degrees of both kinds of injury, depending upon their parentage.

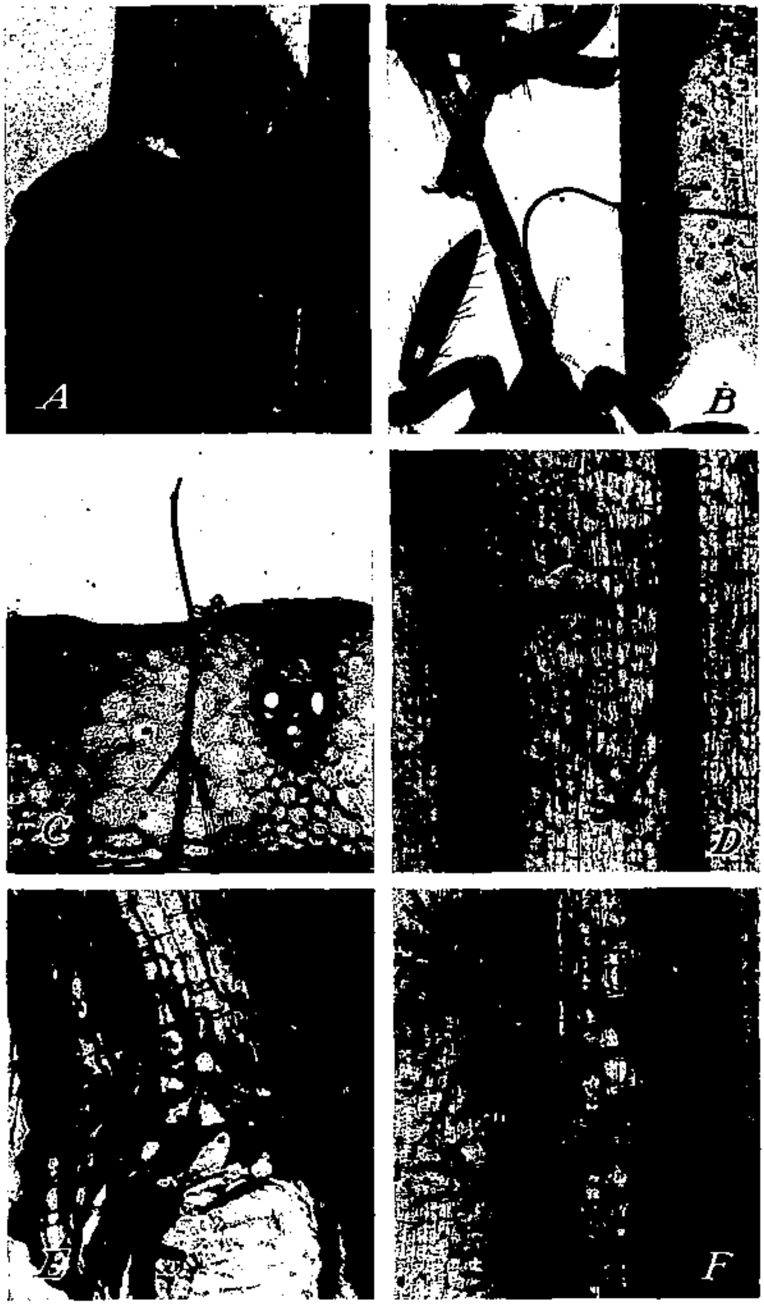
Experiments and observations indicate that injury may result from a combination of one or more of at least four factors:

1. The direct withdrawal of plant fluids from cells and especially from the xylem and phloem tubes, by the chinch bugs.
2. The exudation of plant fluids from punctures left open after the feeding of the insects, with possible attendant interference with root pressure and translocation.
3. A clogging of the plant conductive tissue with stylet sheath material deposited by the bugs.
4. Openings in the plant tissues are provided through which fungi and bacteria can enter. Wound response involving deposition of pigments frequently takes place in the region of chinch bug punctures.

RELATION OF PLANT CHARACTERS TO RESISTANCE

In 1931, the sorghums developed normally at Lawton because of a light infestation of chinch bugs. This permitted detailed descriptions of the gross morphological characters of the varieties. These characters are listed in table 15, in comparison with the chinch bug reaction of the varieties in 1930 at Lawton when the infestation was heavy. Apparently chinch bug resistance or susceptibility is not definitely determined by any one of the gross morphological characters studied. However, some evidence was found of association between a few characters and chinch bug resistance. These are shown graphically in figure 14.

Height of plant shows some relationship with the degree of chinch bug injury. The tall types tend to be resistant, while the dwarf varieties tend to be susceptible. This apparent association probably



A, Chinch bugs feeding on a stalk of Red Amber × feterita, Kansas B 2513, a resistant strain. *B*, Chinch bugs with stylets in a stalk of Atlas (longitudinal section). *C*, Stylet and stylet sheath of chinch bug in leaf sheath of Atlas (cross section). *D*, Stylet sheaths of chinch bug in leaf sheath tissue of Dwarf Yellow milo. Many branches of sheaths, some extending to fibrovascular bundles (whole mount). *E*, Stylet sheaths of chinch bug in plant tissue at base of stalk (crown) of Dwarf Yellow milo. Dark area surrounding stylet sheath is pigment wound response. *F*, Large number of reddish-purple stylet sheaths of chinch bugs in tissue of sorghum plant (whole mount).

TABLE 15.—*Description of plant characters of sorghum varieties in 1931 and chinch bug injury in 1930 at Lawton, Okla.*

Variety [1]	Record no.	Injury	Height of plant	Leafiness of stalk	Coarseness of stalk	Retention of foliage	Lodging habit	Juiciness of stalk	Color of midrib	Sweetness of stalk	Color of plant	Seed			Shattering habit	Color of stigma	Glume				Type of awn	Head			Maturity
		Percent										Color	Size	Subcoat			Color	Shape	Length	Pubescence		Shape	Density	Exertion	
Kansas Orange × Dwarf Yellow milo	Ks. 24-136	20.2	Medium	Medium	Slender	Good	None	Pithy	White	Not sweet	Dark green	Buff	Medium	Present	Some	Creamy	Black	Slender, pointed	Medium	Pubescent	Awnless	Ovate	Medium	Good	Medium.
Atlas	C. I. 899	29.2	Tall	Leafy	do	do	do	Juicy	Gray	Sweet	Light green	White	do	Absent	do	White	Reddish black	Pointed	Short	do	do	Cylindrical	do	do	Late.
Red Amber × feterita	K. B. 2513	28.5	do	do	do	do	do	Medium	do	Slightly sweet	do	do	Very large	Present	None	Creamy	Black	do	Medium	do	do	Ovate	do	do	Medium.
Pink kafir	C. I. 432	35.8	Medium	Medium	Medium	do	do	Pithy	White	Not sweet	Green	Pink	Medium	Absent	Much	White	Gray	Slender, pointed	Short	Finely pubescent	do	Cylindrical	do	do	Do.
Grohoma	C. I. 920	36.5	do	Leafy	Coarse	do	do	Medium	do	Slightly sweet	Dark green	Buff	do	Present	Some	Creamy	Reddish black	Broad, pointed	Medium	Pubescent	do	Conical	Lax	Poor	Do.
Standard Blackhull kafir	C. I. 71	37.4	do	do	Medium	do	do	do	Gray	Not sweet	Green	White	do	Absent	do	White	Black	Pointed	do	do	do	Cylindrical	Medium	Good	Do.
Kansas Orange	F. C. 9108	38.3	Tall	do	Slender	do	Some	Juicy	do	Sweet	Light green	Reddish brown	Small	Present	do	Yellow	do	Slender, pointed	do	Finely pubescent	do	do	do	do	Late.
Dawn kafir	C. I. 904	39.2	Medium	Medium	Medium	do	None	Medium	do	Slightly sweet	Green	White	Medium	Absent	do	White	do	Broad, pointed	do	Pubescent	do	do	do	do	Medium.
Milo × hegari	H. C. 282	39.4	do	Not leafy	Slender	Medium	do	do	do	Not sweet	Light green	do	do	do	Much	Creamy	do	Pointed	Short	do	do	do	Dense	Medium	Do.
Sunrise kafir	C. I. 472	39.5	Tall	Medium	do	Good	do	Juicy	do	Sweet	do	do	do	do	Some	White	do	do	do	do	do	do	Medium	Good	Do.
Sharon kafir	C. I. 813	41.5	Medium	Leafy	Medium	Medium	do	Medium	do	Not sweet	Green	do	do	do	do	do	do	do	Medium	do	do	do	do	do	Do.
White darso	K. B. 3002	42.0	do	Medium	Slender	Good	do	Juicy	do	do	do	do	do	do	do	Creamy	do	do	do	Finely pubescent	Awned	Ovate	do	do	Do
Early Sumac	F. C. 6611	42.5	Tall	Leafy	do	do	do	do	do	Sweet	Light green	Red	Small	do	do	Yellow	Reddish black	Rounded	Short	Pubescent	Awnless	Cylindrical	Dense	do	Do
Dwarf feterita × Smith milo-kafir	H. C. 302	43.5	Dwarf	do	Coarse	Medium	do	Medium	do	Not sweet	Dark green	White	Medium	do	Much	Creamy	do	Pointed	do	do	do	Conical	Medium	Medium	Do
Reed kafir	C. I. 628	45.5	Medium	Medium	Medium	Good	do	do	do	do	Green	do	do	do	None	White	Black	do	Long	Finely pubescent	do	Cylindrical	do	Good	Do
Fargo	C. I. 809	46.0	do	Leafy	Coarse	Medium	do	Pithy	Yellow	do	Dark green	Yellow	Large	do	Some	Yellow	Dark brown	do	Medium	Pubescent	Awned	Ovate	do	Medium	Late.
Juicy Pink kafir	F. C. 9091	55.0	do	Medium	Medium	do	do	Medium	Gray	do	Green	Pink	Medium	Present	Much	Creamy	Gray	Slender, pointed	Short	Finely pubescent	Awnless	Cylindrical	do	Good	Medium
Darso	C. I. 615	56.2	do	do	do	Good	do	Juicy	Yellow	Sweet	Dark green	Reddish brown	do	Absent	None	Yellow	Reddish black	Pointed	Medium	Pubescent	Awned	Ovate	do	do	Do
Wonder	C. I. 872	58.0	do	do	do	do	do	Pithy	White	Not sweet	do	White	do	Present	Some	White	Black	do	do	Heavily pubescent	Awnless	Oval	do	do	Do
Dwarf Yellow milo × Dwarf Freed	H. C. 303	59.5	Dwarf	Leafy	do	do	do	Medium	Gray	do	do	Yellow	do	Absent	do	Creamy	do	do	Short	Pubescent	Awned	Ovate	do	do	Do.
Dwarf feterita × Smith milo-kafir	H. C. 301	63.2	do	Medium	Coarse	do	do	do	do	do	do	White	do	do	do	do	Dark brown	do	Medium	Finely pubescent	Awnless	Oval	do	Medium	Do.
Leoti Red	F. C. 6610	67.4	Tall	do	Slender	do	Some	Juicy	Gray	Sweet	Light green	Reddish brown	Small	Present	None	Yellow	Red	Broad, rounded	Long	Pubescent on tip	Awned	Obovate	Lax	Good	Do.
Kansas Orange × Dwarf Yellow milo	Ks. 30-33	68.0	Dwarf	do	do	Medium	do	Medium	White	Not sweet	Green	Yellow	Large	Absent	do	do	Black	Pointed	Medium	Pubescent	do	Cylindrical	Medium	Medium	Do
Dwarf Freed	C. I. 971	69.5	do	Not leafy	do	Good	None	Juicy	Gray	Sweet	do	White	Medium	do	Some	Creamy	Gray	do	do	do	Heavily awned.	do	Lax	Good	Early.
Kalo	C. I. 902	77.4	do	Medium	do	Medium	do	Medium	do	Not sweet	do	Yellow	do	do	do	Yellow	Black	Rounded	do	Finely pubescent	Awned	do	Medium	do	Medium
Custer	C. I. 919	77.5	do	Leafy	Medium	do	do	do	do	do	do	Reddish yellow	do	do	do	do	do	do	Short	Pubescent	do	Ovate	do	Medium	Do.
Modoc	C. I. 905	79.0	Medium	Medium	Slender	Good	do	do	do	do	do	White	do	do	do	Creamy	do	Pointed	Medium	Heavily pubescent	Awnless	Cylindrical	do	Good	Early.
Club	C. I. 901	81.0	do	Leafy	Medium	do	do	do	do	do	Dark green	do	do	do	None	do	do	do	Long	do	do	Ovate	do	do	Medium
Pink kafir × Dwarf Yellow milo	C. I. 903; H. C. 2510	85.7	do	do	Coarse	do	do	do	Yellow	do	do	do	do	do	Some	do	Dark brown	Broad, pointed	Short	Pubescent	Awned	Conical	do	do	Late
Premo	C. I. 873	86.0	do	do	do	do	do	do	Gray	do	do	do	Very large	Present	do	White	Black	Pointed	Medium	do	Awnless	Ovate	do	Medium	Medium.
Spur feterita	C. I. 923	91.5	do	do	Medium	do	do	Pithy	White	do	Light green	do	do	do	do	Creamy	do	Broad, pointed	Short	do	do	do	do	Good	Do.
Beaver	C. I. 871	96.0	Dwarf	do	Coarse	do	do	Medium	Yellow	do	Green	Yellow	Large	Absent	None	Yellow	Dark brown	do	Medium	do	Awned	Oval	do	Medium	Do.
Wheatland	C. I. 918	97.5	do	Medium	Medium	Medium	do	do	do	do	do	do	Medium	do	Some	do	do	Pointed	do	do	Awnless	Ovate	do	do	Do.
Common feterita	C. I. 182	98.6	Medium	Not leafy	Slender	Good	Some	Pithy	White	do	Light green	White	Very large	Present	do	Creamy	Black	do	do	do	do	do	do	Good	Do.
Ajax	F. C. 6620	99.0	do	Leafy	Coarse	do	None	do	do	do	Dark green	do	Medium	do	do	do	do	do	do	do	do	do	do	do	Do.
Peirce	Ks. 24-285	99.5	do	do	do	Medium	do	do	do	do	do	do	do	Absent	do	do	do	Broad, pointed	Short	do	do	Conical	do	do	Late.
Dwarf Yellow milo	C. I. 332	99.5	do	Medium	Medium	Good	do	Medium	Yellow	do	Green	Yellow	Large	do	None	Yellow	do	do	Medium	do	Awned	Ovate	Dense	do	Medium.
Bishop	C. I. 814	99.5	do	Leafy	do	Medium	do	do	Gray	do	do	White	Medium	do	do	Creamy	do	Broad, rounded	do	do	do	Conical	Medium	do	Late.
Sooner milo	C. I. 917	99.6	Dwarf	Not leafy	Slender	Good	Some	do	Yellow	do	Light green	Yellow	Large	do	do	Yellow	Dark brown	do	Short	do	do	Oval	Dense	do	Early.
Chiltex	C. I. 874	100.0	Medium	Medium	Medium	do	None	Pithy	White	do	Green	White	Medium	Present	Some	Creamy	Black	Pointed	Medium	do	Awnless	Cylindrical	Medium	do	Medium.

[1] The peduncles of each variety were straight except those of Dwarf Yellow milo, which had a tendency to gooseneck.

is incidental and due to the fact that in these experiments the dwarf varieties were largely milo and milo hybrids, which are susceptible to chinch bug injury.

The sweet-stalk varieties tend to be resistant, while the nonsweet group shows a wide range in injury and includes both resistant types such as kafir and the highly susceptible milos. A few varieties of sorgo tested at Lawton and Manhattan in 1934 proved highly susceptible to chinch bugs, in sharp contrast to such resistant varieties as Kansas Orange and Atlas. More sorgos should be tested before any definite conclusions are drawn regarding the relationship between sweetness of stalk and chinch bug resistance.

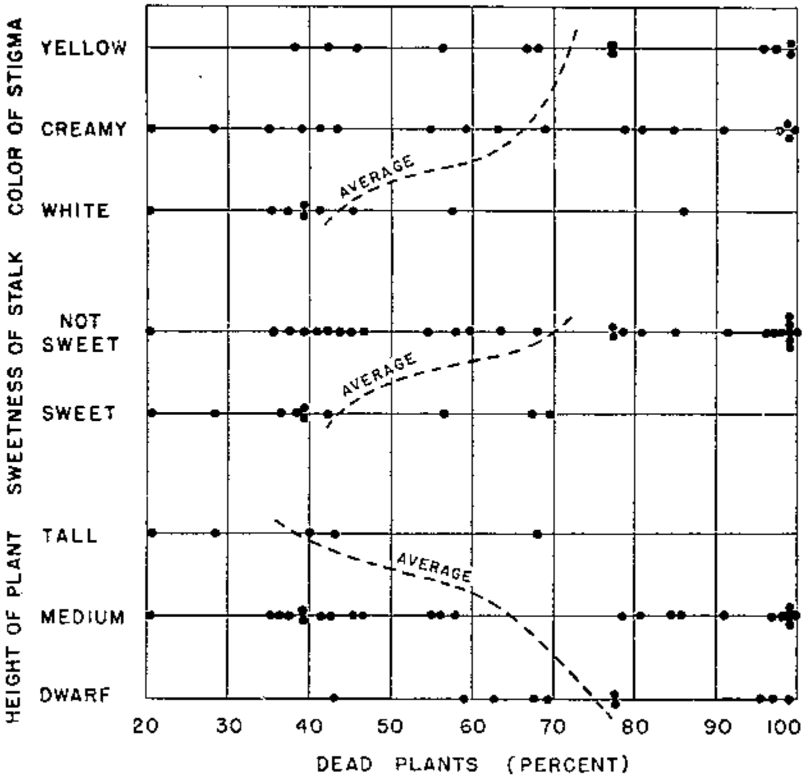


FIGURE 14.—Relation of height, sweetness of stalk, and color of stigma to percentage of dead plants. Each dot represents a sorghum variety.

There seems to be a slight relationship between chinch bug reaction and color of stigma. The varieties were classed as yellow, creamy, and white for color of stigma. The varieties with yellow stigma were generally more susceptible than the white-stigma varieties, which were rather resistant, with two exceptions. Wonder, a white-stigma variety, was injured 58 percent and Premo was injured 86 percent. The creamy class, which was intermediate in color between the yellow and the white stigma groups, included varieties that ranged from the most resistant to the most susceptible. Although there were indications that color of stigma might be correlated with chinch bug injury, more varieties of the yellow- and the white-stigma types should be tested in order to learn more about this apparent correlation. The milos and many of the milo derivatives have yellow stigmas and are very susceptible.

Height of plant, sweetness of stalk, and color of stigma were the only plant characters that showed any degree of correlation with chinch bug resistance or susceptibility.

The manner in which the leaf sheath fits around the stalk may be related to chinch bug injury. The leaf sheath closely surrounds the stalk of a number of resistant varieties, while it fits loosely around the stalk of certain susceptible varieties, especially milo. Chinch bugs are gregarious and feed in the protected location inside the sheath when possible, and this may result in concentrated injury to the plants. This feeding habit is indicated by the greater number of punctures (pl. 1, *D*) on the inside of the leaf sheath of varieties in which the sheath fits loosely around the stalk. These observations indicate the possibility of a relationship between the manner in which the leaf sheath fits around the stalk and the degree of chinch bug resistance of sorghum varieties.

Whitehead [7] studied the relation of several characters to chinch bug resistance in selections from Kansas Orange sorgo (resistant) × Dwarf Yellow milo (susceptible). He found that light injury from chinch bugs in the F_4 hybrid lines was associated with (1) slight firing of leaves, (2) light aphid infestation, and (3) small amount of dry pith in the stalks, as viewed in stained cross sections. He found very slight or no correlation of chinch bug resistance with seedling vigor as expressed in height of uninjured plants. In the case of correlation of firing and aphid infestation of plants with chinch bug infestation, the resistant and susceptible hybrids tended to resemble the respective parents. The Kansas Orange parent is characterized by juicy stalks (small amount of dry pith) and the Dwarf Yellow milo by less juice. Hybrids with juicy stalks showed a tendency to give the same chinch bug reaction as the resistant parent. The reverse was also true.

PREFERENCE OF BUGS FOR CERTAIN VARIETIES

Varietal preference, as it may apply to resistance, has been partially explored in two ways: (1) By a study of the olfactory responses of the chinch bugs, and (2) by counts and observations of the number of bugs on varieties of contrasting reaction.

The distribution of chinch bugs in fields and plots of sorghums presents many irregularities. Some of the factors which influence the distribution are: Distance from small grains; difference in size, age, and vigor of the plants; presence of crabgrass or other species of food plants; density of growth of food plants; and soil heterogeneity. It is difficult to determine whether a preference for certain varieties is a factor in this distribution of bugs and in resistance under field conditions.

There have been occasions at Manhattan when the bugs appeared to show a preference for certain varieties under field conditions. When the spring migration of the bugs from hibernating quarters was delayed, and the sorghums were planted early, the few migrating bugs flying into the sorghum field showed a distinct tendency to concentrate on milo. The winged adults of the first generation sometimes

[7] WHITEHEAD, F. E. See footnote 6.

showed this same preference. These occasions, contrary to the apparent habits of the bugs when present in large numbers, may be the result of stimulus for oviposition rather than for feed, or of olfactory sensations quickened by hunger or some other physiological state.

An unsatisfactory attempt was made to study the olfactory responses of the bugs by means of the McIndoo olfactometer (*50*). The bugs congregated in various parts of the instrument and gave only erratic responses.

Later, a field olfactometer (fig. 15, *B*) was designed that appeared to give more reliable results.[8] This instrument consisted of a wooden box with the ends closed by screen wire and the top closed by two sliding pieces of glass which opened in the middle. A large cardboard box covered the growing plants at each end of the wooden box and confined the bugs near the screen wire ends. By means of suction a slight current of air was drawn equally through the two ends of the wooden box. Chinch bugs were placed in the center of this box. After about 1 hour, a glass partition was inserted in the center of the box and the insects in each end were counted.

The instrument was tested on adults of the Colorado potato beetle (*Leptinotarsa decemlineata* (Say)), an insect known to have strong olfactory responses. The results of these tests compared to those using chinch bugs in the olfactometer are given in table 16. Adult chinch bugs and those in the last two nymphal instars were used. No attempt was made to separate the different stages. A new group of insects was used in each experiment.

These experiments indicated that chinch bugs were attracted less by milo than the potato beetle was to its host. Under the duress of starvation chinch bugs show only a relatively weak olfactory response. In order to determine whether the chinch bug can distinguish between varieties, without tasting them, more delicate tests must be devised

TABLE 16.—*Comparison of strength of olfactory responses of Colorado potato beetles and chinch bugs determined with a field olfactometer*

Insect	Tests	Period of starvation	Period of exposure	Insects at end of box near host [1]	Insects at end of box near soil	Approximate ratio
	Number	*Hours*	*Minutes*	*Number*	*Number*	
Colorado potato beetle	4	96 to 109	70 to 90	268	39	7:1
Chinch bug	7	160 to 238	55 to 100	1,320	703	>2:1

[1] The hosts were potatoes and Dwarf Yellow milo, respectively, the plants growing normally in the field

The other method of approaching the problem of chinch bug preference is by counts of the number of bugs on plants. Accurate counts are difficult to secure, because the bugs leave the plant quickly when it is disturbed. In spite of this difficulty two series of counts have been made on Kansas Orange and Dwarf Yellow milo.

The first of these counts as recorded by Hayes and Parker [9] is summarized in table 17. The counts were made in the field when the plants were subjected to a moderate infestation.

[8] PETERSON, A. A MANUAL OF ENTOMOLOGICAL EQUIPMENT AND METHODS. pt. 1, illus. Ann Arbor, Mich., 1934. [Mimeographed.]

[9] HAYES, W. P., and PARKER, J. H. See footnote 5.

FIGURE 15.—*A*, Young plants of susceptible Dwarf Yellow milo (left) and resistant Kansas Orange (right), showing characteristic reaction to chinch bugs, Lawton, Okla., 1930; *B*, field olfactometer used in the study of reaction of chinch bugs to sorghum at Manhattan, Kans.

TABLE 17.—*Number of chinch bugs on 25 plants in adjacent rows of sorghums, Manhattan, Kans., July 20, 1922*

Variety	Total	Average per plant	Range per plant (number)
	Number	*Number*	
Dwarf Yellow milo	579	23±2.1	2 to 65.
Kansas Orange sorgo	652	26±3.1	0 to 121.

At Lawton, a count of bugs on Kansas Orange sorgo and Dwarf Yellow milo was made in 1930. The plants of these two varieties were grown side by side in rows spaced 6 inches apart (fig. 15, *A*). No attempt was made to control infestation artificially, but equal chances for infestation on the two varieties were obtained by growing them close together.

Counts were made on preserved plants collected when about 6 inches high and growing under a heavy infestation. The roots were cut below the crown, when the bugs were feeding intensely, either in the early morning or late afternoon. Under these conditions the plants could be removed from the soil and placed in a cloth bag without greatly disturbing the bugs. The number of bugs present, determined later in the laboratory, ranged from 2 to 282 to the plant for each variety. A summary of these counts is given in table 18. Rows 67, 68, and 69 were planted about a week earlier than the others. The total number of bugs on the 30 Dwarf Yellow milo plants was 2,148, or an average of 71.6 to the plant. The total on Kansas Orange sorgo was 3,024, or an average of 100.8 bugs to the plant. In each paired group of five plants there were only two in which the number of bugs on Dwarf Yellow milo exceeded the number on Kansas Orange.

TABLE 18.—*Number of chinch bugs on adjacent pairs of plants of Dwarf Yellow milo (susceptible) and Kansas Orange sorgo (resistant) at Lawton, Okla., in 1930*

Row no.	Total on 5 plants		Average per plant	
	Dwarf Yellow milo	Kansas Orange sorgo	Dwarf Yellow milo	Kansas Orange sorgo
	Number	*Number*	*Number*	*Number*
67	879	804	175.8	160.8
68	599	911	119.8	182.2
69	143	370	28.6	74.0
267	297	691	59.4	138.2
268	113	174	22.6	34.8
269	117	74	23.4	14.8
Total	2,148	3,024	71.6	100.8

These counts do not appear to support a theory of preference by the bugs for a susceptible variety under conditions of this experiment. There was a wide variation in the number of bugs present on plants of the same variety. This type of distribution on individual plants of the same variety agreed with field observations made at that time. The factors which influence the number of chinch bugs present on individual plants and on varieties under different conditions require further investigation.

FEEDING HABITS IN RELATION TO RESISTANCE

When the mouth parts of a hemipterous insect are inserted in plant tissue there is formed about them a stylet sheath (pl. 1) that takes a definite staining reaction. Studies by Fife (*20*) and by Smith (*62*) have shown that the sheath deposited by leafhoppers is largely of insect origin and may contain chitin. Studies of the feeding habit of the chinch bugs have been concerned with these stylet sheaths which mark the location and extent of the places of feeding. Observations regarding the feeding habits of chinch bugs as they occur on corn have been published by Painter (*56*).

Later studies of both fresh and preserved tissue of sorghum plants and of insect punctures have served to confirm most of the points discussed by Painter. Chemical tests and stains other than iron haematoxylin have failed to differentiate the presence of a two-layer sheath and have not shown any relationship between tannin and resistance. No further evidence of the dissolving action of the salivary fluid is available.

The fresh punctures were studied in freehand sections, or in sections cut with a freezing microtome from parts of plants known to contain punctures. In these sections the sheath material could be identified without staining, by its appearance and its refractive properties. Sections containing sheaths were then subjected to microchemical tests.

Some investigators have considered these stylet sheaths to be largely or entirely of insect origin. Many of the observations in the present investigations point in the same direction. There is also some evidence that following their deposition in the plant tissue the stylet sheaths change by addition of pigment from the plant. In plants of most sorghum varieties a reddish pigment forms about any mechanical injury which eventually is laid down in the cell walls. This pigment forms in abundance about the places of puncture by hemipterous insects, and it appears in the stylet sheaths of chinch bugs in these areas (pl. 1, *E*).

The composition of the sheath would be of importance if it could be shown to differ in resistant and susceptible varieties or to change in composition after deposition. In investigating this question various microchemical tests, largely those described by Eckerson [10] and Campbell (*10*), were used. Callose, pectic substances, and chitin have been reported to be present in stylet sheaths formed by various Hemiptera and Homoptera. Staining reactions or solubility tests or both failed to indicate the presence of these substances. Stylet sheaths treated with either hot or cold concentrated potassium hydroxide dissolved when transferred to 90-percent alcohol. Delicate fragments of insect exoskeleton did not dissolve when treated in the same manner. Since the treatment with hot concentrated potassium hydroxide followed by alcohol and iodine-potassium iodide solution constitutes the chitosan test for chitin it appears that this substance is not present in the stylet sheaths of the chinch bugs.

The stylet sheaths gave a positive protein reaction with Millon's reagent, turning red almost as soon as the reagent was applied. This agrees with tests made by Smith (*62*) on the stylet sheaths of certain leafhoppers.

[10] ECKERSON, S. H. MICROCHEMISTRY. Chicago Univ. Bot. Dept. 30 pp. [Mimeographed.]

In solubility and staining tests there appear minor differences in the effect of chemicals on different stylet sheaths, which in some cases are correlated with the age of the sheaths. Few differences of this kind were found that might be attributed to the variety in which the sheath was deposited.

Plant material containing chinch bug punctures preserved at Lawton, in 4-percent formalin, was studied at Manhattan. In some cases bugs with their stylets in the plant tissue were etherized and preserved with the plants in formalin (pl. 1, *B*, *D*). Sections of this preserved material stained with analin blue, saurefuchsin, and safranin gave good differentiation of the sheath material. Methylene blue, methyl green, and neutral red gave a fair differentiation, while Biebrich scarlet, orange G, light green, and gentian violet did not stain the sheath or failed to differentiate it from the surrounding tissue. The stains were dissolved in water or in 50-percent alcohol at concentrations of 1 percent or less. These sheaths persisted in the plant tissue for at least 4 days in both susceptible Dwarf Yellow milo and resistant Kansas Orange. There was evidence that sheaths remain permanently in the plant tissue.

The location and number of punctures on the Dwarf Yellow milo and Kansas Orange varieties were studied by bleaching the whole preserved plants in chlorine produced by treating potassium chlorate with hydrochloric acid and staining overnight with 0.025-percent analin blue solution (pl. 1, *D*, *F*). The plants were washed in running water to remove excess stain and each leaf was examined under a binocular. Counts were made of the number of punctures on each leaf blade and leaf sheath (table 19). The plants used in making these counts came from Lawton and from the same series of rows as those used in making the count of the number of chinch bugs to the plant. The number of bugs present at that time on the two varieties was about equal (table 18).

An average of 444 ± 39 punctures to the plant was recorded for Dwarf Yellow milo, as compared with an average of 387 ± 35 for Kansas Orange. This difference of 57 ± 52 punctures to the plant on milo, as compared with Kansas Orange, is not significant. Although only a small number of plants were studied, the data seem to indicate that the chinch bugs probably feed about equally on these two varieties, namely, one resistant and the other susceptible. However, a larger number of plants must be studied before drawing definite conclusions. There appears to be a significant difference in the location of the chinch bug punctures in the plants of the two varieties. On the plants of Kansas Orange the punctures were distributed fairly equally in both the leaf blade and leaf sheath. On the plants of milo there were more than three times as many punctures on the leaf sheaths as on the leaf blades. This varietal difference in the location of the chinch bug punctures may be explained on the basis of the morphology of the plants.

TABLE 19.—*Number of chinch bug stylet sheaths in Kansas Orange and Dwarf Yellow milo plants grown at Lawton, Okla., 1930*

Leaf no.	Kansas Orange plants [1]			Dwarf Yellow milo plants [2]		
	Leaf-blade punctures	Leaf-sheath punctures	Total	Leaf-blade punctures	Leaf-sheath punctures	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
1 (basal)	109	505	614	135	532	667
2	195	446	641	132	514	646
3	235	311	546	105	655	760
4	481	440	921	114	942	1,056
5	508	219	727	238	409	647
6	256	33	289	213	8	221
7 (upper)	128	0	128	3	0	3
Total	1,912	1,954	3,866	940	3,060	4,000
Average per plant	191±25	195±29	387±35	104±12	340±42	444±30

[1] Average of 20 plants.
[2] Average of 19 plants.

The leaf sheaths on the Kansas Orange plants grow rather closely around the stalk while those on the Dwarf Yellow milo plants are more open (p. 44). This fact may account for the approximately equal total numbers of chinch bug punctures in the leaf sheaths and the leaf blades of the Kansas Orange plants, and for the wide difference in total numbers of punctures on the leaf sheaths and the leaf blades in Dwarf Yellow milo. Injury to the plant owing to disruption of the transport system in the xylem and phloem would be greater as a result of the feeding on the leaf sheath where the vascular bundles are fewer than in the leaf blade. This appears to be one of the factors in the difference in the resistance of these two varieties.

Since the counts mentioned above were made it has been found that analin blue stains recently deposited sheaths better than those which have been deposited for a longer period of time, and also that stylet sheaths in Kansas Orange sorgo are more easily stained than those in milo. However, unstained or lightly stained sheaths are easily visible under the microscope, and it is believed that relatively few were overlooked. Safranin and saurefuchsin are now known to give more uniform stains and should be used in future studies of this kind. It should be pointed out that these counts give information concerning the location and number of feeding places, but do not indicate the amount of fluid withdrawn from the plants or the length of time occupied by the feeding.

SUMMARY

The biological control of insects by means of host resistance is a relatively new field of study in which recent development has been rapid. The data presented in this bulletin were gathered at Manhattan, Kans., at intervals during a period of more than 15 years and during a period of 5 years at Lawton, Okla. They deal with the possibility of reducing chinch bug injury to sorghums by utilizing host resistance.

The chinch bug reaction of most of the important and standard varieties of sorghum has been determined. In general, the milos are very susceptible, the feteritas susceptible, and the kafirs and sorgos

rather resistant to chinch bug injury. Most of the sorgos are slightly more resistant than the kafirs, but others are susceptible.

Atlas sorgo is highly resistant to chinch bugs. This is an important factor in its adaptation to eastern Kansas and Oklahoma, where it is increasing in acreage and popularity. Chiltex and Ajax are limited to some extent in southwestern Oklahoma, because of their susceptibility to chinch bugs. Beaver, Wheatland, and most other milo derivatives tested are very susceptible. Hegari is more susceptible to chinch bugs than most of the kafirs. Darso is moderately resistant and produces good yields of grain even in unfavorable seasons. Certain varieties such as feterita, Sooner milo, Greeley, and Cheyenne are susceptible but under some conditions evade serious injury because of their early maturity.

The range in average percentage of plants killed in 30 varieties tested at Lawton for 4 years was from 7, for a highly resistant selection of Kansas Orange sorgo × Dwarf Yellow milo, to 100, for the very susceptible Dwarf Yellow milo. The average percentage of plants killed by chinch bugs in 22 varieties tested at both Manhattan and Lawton ranged from 10 percent in a very resistant selection of Red Amber sorgo × feterita to 85 percent for the highly susceptible Dwarf Yellow milo.

Early planting is one of the most important cultural practices in limiting chinch bug injury in the vicinity of Lawton, Okla. Chinch bugs will attack sorghums during any part of the vegetative period of the plant, but older plants are better able to withstand the attacks. The plants in the earlier plantings at Lawton have been larger at the time when the chinch bugs migrated into the sorghum nurseries and consequently showed the least injury and produced the highest yields.

Results obtained suggest that resistance may be dominant or partially dominant in the crosses studied, although the continued manifestation of heterosis in the F_2 generation of these crosses may have increased the average resistance of the population. There is a close relationship between heterosis and chinch bug resistance of some F_1 sorghum hybrids.

In 100 F_3 lines of the cross Sharon kafir (resistant) × Dwarf Yellow milo (susceptible), observed figures give a very close fit to a calculated 3:1 ratio and might be taken to indicate that one main factor pair governs chinch bug reaction in this cross. However, there is evidence that the inheritance of chinch bug resistance is more complex and is influenced not only by other genes directly affecting chinch bug reaction but by genetic factors controlling such plant characters as earliness, vigor of early growth, character of sheath, and others.

The occurrence of several lines apparently homozygous for intermediate reaction to chinch bugs is not in agreement with a single factor hypothesis.

Data obtained on hybrids show that resistance to chinch bug injury in sorghums is inherited, but the genetic factors involved have not been determined. Several hybrid selections are more resistant than the resistant parent, showing transgressive segregation.

Heterozygosity of varieties with respect to resistance factors is responsible for some inconsistent reactions to chinch bugs in different seasons. This is revealed when seed is saved year after year from varieties grown under severe infestations of chinch bugs.

Selections from Chiltex, kafir × milo, Kansas 27-317, and darso made at Lawton are much more resistant to chinch bug injury than the parent varieties.

Experiments and observations indicate that chinch bug injury to sorghums results from a combination of one or more of at least four factors: (1) The direct withdrawal of plant fluids from cells and especially from the xylem and phloem tubes; (2) the exudation of plant fluids from punctures left open after the feeding of the insects, with the attendant possible interference with root pressure and translocation; (3) a clogging of the plant conductive tissue with stylet sheath material deposited by the bugs; (4) and openings in the plant tissue are provided through which fungi and bacteria can enter.

Resistance to chinch bug injury is not closely associated with any of the observed morphological or physiological plant characters. Height of plant, sweetness of stalk, and color of stigma were the only characters that showed even slight association with chinch bug reaction. This apparent correlation is incidental and relates to the characters of the particular varieties in these experiments. The manner in which the leaf sheath fits around the stalk may be related to chinch bug injury.

Limited counts of bugs did not indicate preference for the more susceptible varieties, but observations in years of light infestation at Manhattan have shown a higher concentration of bugs on susceptible varieties. Olfactometer studies with the chinch bug indicated that the olfactory sense in this insect is not so strongly developed as in the Colorado potato beetle.

The feeding habits of chinch bugs have been studied by examination of the stylet sheaths which are left in the plant tissue at the site of the insertion of the mouth parts. Counts of punctures (or stylet sheaths) in plants of Kansas Orange sorgo (resistant) and Dwarf Yellow milo (susceptible) indicate that the bugs feed about equally on the two varieties. Approximately equal numbers of punctures were found on the leaf sheaths and blades of Kansas Orange sorgo plants, while on Dwarf Yellow milo there were more than three times as many punctures on the leaf sheaths as on the leaf blades. Injury to the plant owing to disruption of the transport system in the xylem and phloem would be greater as a result of the feeding on the leaf sheath, where the vascular bundles are fewer than in the leaf blade.

Certain susceptible varieties mature early enough to evade chinch bug injury to some extent.

Experiments and observations indicate that resistance may consist of physiological characters involving at least in part the ability of a variety to grow or recover in spite of the feeding of the chinch bugs.

Studies regarding the cause of resistance from a number of aspects have given mostly negative results. They have indicated, however, the improbability of a number of possible causes. Even though the exact mechanism of resistance remains obscure, this has not prevented distinct progress in the production of resistant varieties through selection and hybridization.

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