CHINCH BUG, BLISSUS LEUCOPTERUS LEUCOPTERUS (SAY): SCREENING OF GRAIN SORGHUM GERMPLASM FOR RESISTANCE AND EVALUATION OF INSECTICIDES AT PLANTING TIME FOR CONTROL

by

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INTRODUCTION

The chinch bug, Blissus leucopterus leucopterus (Say), has been a devastating pest of grain sorghum, corn, and small grains in the Upper Mississippi Valley since the prairie was first broken into farmland over 100 years ago. Economic infestations of the insect closely parallel the westward progression of agriculture in the United States during the same period. Outbreaks of the chinch bug are sporadic, and traditionally coincide with dry growing seasons. This combination of production hazards has to a large extent been responsible for the great impact of the chinch bug on crop production in the afflicted areas.

The latest outbreak of the chinch bug began in 1976 in parts of Nebraska, Kansas, Missouri, and Oklahoma. Particularly damaging infestations have been in Eastern Kansas, where damage attributed to this pest caused losses totaling 9 million dollars in 1978 alone (Bell 1978). These infestations have stimulated much concern among growers and renewed their interest in control practices. They also have prompted researchers in these locations to develop new control techniques for the insect. Natural control by the pathogen Beauveria spp. has not been effective in suppressing populations in the recent outbreak, despite above average rainfall in 1977 and 1979.

Many of the standard chlorinated hydrocarbon insecticides formerly used as barrier treatments in the late 1950's are no longer registered for that use. Materials available for control during the most recent outbreak do not possess the residual ability necessary to control infestations during the entire migration period. This necessitates multiple applications of low-residual compounds, an expensive and time-consuming procedure. Therefore, new chemical control strategies are needed and some of the more recent systemic compounds have appeared promising in the laboratory as soil treatments (Wilde and Morgan 1978).

Plant resistance to the chinch bug in both grain sorghum and corn has long been studied and is regarded as a classic example of successful plant resistance in the United States. Workers primarily in Kansas and Oklahoma released many lines in the 1930's and 40's that were relatively more resistant than those previously utilized as sorghum germplasm. Related research also provided insight into the resistance mechanisms operating in some of these materials.

Since the last severe outbreak in the late 1950's, relatively little has been reported on chinch bug resistance in sorghum. During this span, the advent of cytoplasmic male sterility has brought about great changes in grain sorghum production practices and in the genetic make-up of sorghum. These sorghum germplasms have for the most part been developed with little regard to the chinch bug resistance levels of the parents. This has prompted renewed interest in the sources of resistance identified in the 1930's but resistance levels capable of withstanding severe seedling infestations have not been identified in this group (Painter 1951). There is presently an extensive search in the public and private sectors for higher resistance levels.

An excellent source of genetic variability in grain sorghum was developed jointly by the Texas Agricultural Experiment Station and the USDA through the sorghum conversion program (Stephens et al. 1967). In this program, exotic sorghum races and subraces were converted from photoperiod sensitive, tall genotypes to insensitive, shorter genotypes with better adapted agronomic characters. The adapted germplasm could then be used in the higher latitudes of temperate sorghum-producing states. Although the expanded gene pool has led to the discovery of resistance to various insects and diseases in the group, there has been no attempt to evaluate this germplasm for resistance to the chinch bug.

The objectives of this study were to identify improved levels of resistance to the chinch bug in grain sorghum in both Kansas and exotic sources and to investigate the efficacy of systemic soil insecticides applied at planting time for chinch bug control on seedling sorghum. Plant resistance investigations included: 1) screening various entries of the sorghum conversion program for resistance, 2) screening lines and hybrids from the Kansas sorghum breeding project at Hays, Kansas for resistance, and 3) the evaluation of available resistance levels in commercial sorghum hybrids. Insecticidal control studies involved the evaluation of various systemic compounds when applied as seed, band, and in-furrow treatments for artificial and natural seedling infestations.

REVIEW OF LITERATURE

General Control

The control of the chinch bug, Blissus leucopterus leucopterus (Say), has been a major concern of American agriculture since the first outbreak of the pest in 1785 (Webster, 1896). Walsh (1861) first suggested the use of fire to destroy the bugs in their overwintering habitat. Britcher (1903), Dean and McColloch (1913), Dean (1919), Flint (1920), Headlee (1910), and Parks (1935) also proposed burning as control. Lamp and Holtzer (1980) found that burning did not cause a significant drop in overwintering populations. Snow (1925), Flint (1935), Forbes (1912), Harris and Decker (1934), McColloch (1925), Parks (1935), Parker (1910), Severin (1923), and others suggested the use of natural and chemical barriers for the exclusion of migrating bugs from the young sorghum and corn fields. Dry furrows, coal tar, and creosote are just some of the barrier types recommended by these researchers. Thomas (1879), Osborn (1888), Burlison and Flint (1923), Davis (1922), Flint and Burlison (1920), and Henson and Drake (1934) recommended the use of alternate crops immune to chinch bugs as a control measure. Crops such as buckwheat, peas, sunflowers, and soybeans were suggested. Forbes (1883) proposed the use of an artificially grown fungal parasite of the chinch bug for their control in the field. Snow (1892), Billings and Glenn (1911), Smith (1932), and many others carried out research and reported on the method. Most results indicated that the disease was highly dependent on moisture and thus erratic as a control method. Garman (1898) summarized the various other control measures for the chinch bug. These include steam, deep plowing, and early planting.

Resistance of Sorghums to the Chinch Bug

Cottrell et al. (1900) observed that seedling kafir corn plants were destroyed by the chinch bug, but seedling corn was killed more quickly. Conner (1911) stated that Planter sorgo lodged badly under chinch bug pressure. Ball (1913) reported that Kaoliangs were less susceptible to chinch bug injury than the milos. Ball and Leidigh (1908), Cunningham and Kenney (1918), Vinall and Getty (1920), Daane and Klages (1928), Kiltz et al. (1933), Martin (1933), Stewart et al. (1934), Swanson and Laude (1934), and many others all found the milos highly susceptible to chinch bug attack. They also mention many sorghums showing promise for resistance. These included the Kafirs, Kansas Orange, Darso, Atlas, and Sumac. Borman (1914) reported that resistance to chinch bugs depended on juiciness of sorghum stalks. Hayes (1922) observed that milo crosses showing hybrid vigor were more resistant to chinch bugs. Parker (1931) observed several sorghum varieties and hybrids and found that resistance to the chinch bug was a heritable character. Vinall (1920) reported that Sudan grass was severely damaged by the chinch bug. Borman (1914) stated that sorghums possess a greater ability to recuperate from chinch bug damage than corn. Aicher (1933), and Stewart et al. (1934) reported that Wheatland, like Dwarf Yellow Milo, was very susceptible to chinch bugs. Painter (1951) stated that even the most resistant sorghums could be killed in the seedling stage with enough chinch bugs present. Snelling (1932) reported that chinch bug injury was not due to any one morphological character of the plant. He also stated that the most feasible method of chinch bug control was through plant resistance. Snelling et al. (1937)

found that many factors influence the susceptibility of a sorghum variety to the chinch bug. These include intensity of insect numbers, date of planting, plant earliness, drought resistance, and varietal adaptation to the region. Painter (1951) observed that chinch bugs appreciably reduce grain yields, even under circumstances of moderate injury to the plant. Dahms (1936), and Dahms (1948) reported that chinch bugs will feed and maintain a population on all sorghums, but some varieties are less favorable than others for these purposes. Fecundity, longevity, size, mortality, and varietal preference were examined, and significant differences in each category were noted. Painter (1928) showed that the feeding site of the chinch bug stylets was the phloem tissue of the vascular bundles. Effects of the wounds on the plant were also recorded. Snelling et al. (1937) stated that hybrids showing no heterosis were killed, and ones that had hybrid vigor usually survived. Dahms and Martin (1940) observed that in F_1 sorghum hybrids resistance expressed as reduced fecundity of the chinch bug was inherited as a dominant trait. Dahms and Fenton (1940) showed that resistance to the chinch bug in sorghum was decreased with an increase in available sodium nitrate, and was increased with an increase in available phosphates. Dahms (1947) found that the fecundity of the chinch bug increased when plants were grown in a high nitrogen, low phosphorous solution. Webster et al. (1954) found no significant chemical differences between roots of chinch bug resistant and susceptible sorghums. Benton and Flint (1938) reported that barley was the preferred host of chinch bugs over wheat and oats. Flint (1921), and Flint and Hackleman (1923) found large differences in chinch bug resistance between many open-pollinated corns grown in the Midwest.

Chemical Control of the Chinch Bug

Flint and Baldorf (1924) suggested the use of calcium cyanide dust in combination with creosote barriers to destroy migrating chinch bugs. Webster (1896), Forbes (1883), Gossard (1911), Parker (1910), and Severin (1922) reported that a soap and kerosene emulsion gave good control of chinch bugs infesting corn. Parks (1935), Severin (1922), and Forbes (1912) stated that a soap emulsion of "Black Leaf 40" gave adequate chinch bug control as a spray in infested corn and sorghum. Decker and Drake (1940), and Decker (1943) reported the 3-5-dinitro-o-cresol dust was a promising material for use against chinch bugs. These authors recommended it for dusting the bugs around the base of corn plants and as a toxic-dust barrier around fields. Kearns et al. (1949) reported that dinitro-o-cresol dusts were more toxic to chinch bugs than DDT. Richardson et al. (1937) stated that laundry soaps proved more toxic to the chinch bug in the laboratory than many other inorganic and organic insecticides. They also reported that sprays of pyrethrum and nicotene gave best control in a field situation. Luginbill and Benton (1945) observed that 5% and 10% DDT dusts gave excellent barrier control of migrating chinch bugs and complete control of bugs already infesting a field of corn. Tate and Gates (1945) reported that in the field and laboratory, highly concentrated dust and liquid formulations of sabadilla gave complete control of the chinch bug. Walton (1945) found that a 10% sabadilla dust barrier gave the best control of migrating chinch bugs in his insecticide trials. Todd (1966), and Randolph and Teetes (1971) reported that spray treatments of toxaphene, toxaphene + DDT + methyl parathion, and endosulfan + methyl parathion gave satisfactory chinch bug control two and six days after application. Granular side-dress treatments of aldicarb, phorate, and propoxur also gave control, but not until rainfall eleven days after treatment stimulated systemic activity. Bishopp (1946) reported that 20% sabadilla dust gave good control of chinch bugs in infested corn and small grains. Randolph and Newton (1959) found that liquid applications of toxaphene, endosulfan, and dieldrin provided the greatest reduction of chinch bugs in insecticide tests on sorghum. Gannon and Decker (1955a) reported that endrin, due to its high toxicity and persistance, was the insecticide best adapted for chinch bug control in sorghum. The authors also stated that toxaphene and DDT provided very poor control of the insect. Decker et al. (1953) observed that endrin and dieldrin were the two best materials for use as toxic barriers to chinch bugs, and provided the longest residual activity of those tested. Gannon and Decker (1955b) reported that aerial applications of dieldrin gave good control of chinch bugs in wheat. The authors also stated that endrin and dieldrin used as barrier sprays gave 100% control of migrating chinch bugs. Walton (1947) noted that benzene hexachloride dust afforded better control of chinch bugs in sorghum than did sabadilla or DDT dusts. Schread (1948) reported that chlordane gave good control of chinch bugs in golf greens. Schread (1963) found granular carbaryl, diazinon, and ethion provided good control of the hairy chinch bug <u>Blissus</u> <u>leucopterus</u> <u>hirtus</u> in lawns. Roberts (1963) stated that dieldrin was made more available to the chinch bug with increased soil moisture. Wilde and Morgan (1978) reported that ethyl parathion, carbaryl, carbofuran, and Penncap M ^{R} significantly reduced chinch bug numbers in sorghum. They also stated that soil applications of phorate and carbofuran successfully controlled chinch bugs in the laboratory, but were not very effective in one field trial. Parker (1969) reported effective control for 21 days from granular formulations of aldicarb, carbofuran, or phorate applied as a side dressing to young sorghum plants.

MATERIALS AND METHODS

Plant Resistance Studies

1978 Field Tests

Four field tests were seeded in Eastern Kansas for the preliminary screening of various lines for chinch bug resistance. One test was planted on June 1, 1978 at the Agronomy Research Farm, Manhattan, Kansas. The other three tests were planted on June 18, 1978. Three were located at the Agronomy Research Farm, Manhattan, and one in a private cooperator's field near Westmoreland, Kansas. Each test was subjected to the usual dryland agronomic practices. At all locations, one row plots 25 feet in length were planted by hand at a rate of 140 seeds with an Alamco^{R} v-belt seeder. Tests were made up of 92 entries of the sorghum conversion program and eight previously-identified standard susceptible and resistant checks (Table 2). Standard checks were selected on the basis of field studies in Oklahoma from 1930 to 1936 (Snelling et al. 1937). Resistant checks were Combine Kafir 60, Atlas, and Rox Orange. Susceptible lines used as checks were Double Dwarf Yellow Milo, Early Sumac, Sooner Milo, Tx 2536, and Tx 7000. Entries were identical at all locations. Plots were thinned to 100 plants at emergence and stand counts were made before natural infestation. All locations were of a complete block, fully randomized design with only one replication. Only one replication was planted at each location due to limited amounts of seed and the need to distribute the plantings for assurance of at least one infestation. Plots at each location were planted perpendicular and immediately adjacent to wheat fields harboring a large population of chinch bug nymphs.

A visual damage rating scale of 0-10 was used at each site to evaluate chinch bug resistance. The scale was based on an estimate of the percentage of plant tissue necrosis and internode rossetting in the entire plot, with 0 = no damage and 10 = 91 to 100 percent necrosis and stunting. For example, a plot given a rating of 3 would have 21 to 30 percent of the total vegetation necrotic and stunted. A rating of 7 would indicate 61 to 70 percent had sustained damage. Damage ratings and post-infestation stand counts were made at growth stage 2, 5, and 9 (Vanderlip 1972). Growth stage 2 represents the 5-leaf stage of grain sorghum, growth stage 5 the boot stage, and growth stage 9 physiological maturity. One test at the Agronomy Research Farm was bagged for self-pollination to increase seed supplies for 1979.

1979 Field Screenings

Eight tests were planted at separate sites in Eastern Kansas to insure an infestation. A ninth test was planned at Powhatten, Kansas, but was not planted due to inadequate soil moisture. One test was located at the Rocky Ford Agronomy Farm near Manhattan, Kansas and was designated Test 1. Six tests were planted at the Agronomy Research Center, Manhattan and were designated Tests 2 through 7. The remaining field location, Test 8, was near Hesston, Kansas on the Harvey County Experiment Field. The number of entries in the tests were dependent on the availability of plot land at each site. Twenty-four converted lines representing all of the races and subraces that were available were common entries at all locations. Additional entries from both converted line and Kansas sources were common to all locations with adequate space.

The conversion program entries used were selected on the basis of low damage ratings in 1978. All tests were of a single row plot, randomized complete block design with three replications. Standard resistant and susceptible checks were used as entries at each location except Test 1. All locations had a single plot of the susceptible line Wheatland planted every 10 rows exclusive of the test entries as an indicator of infestation uniformity. The number of entries ranged from the base of 24 in Test 1 to 90 in Tests 5, 6, and 7.

As in 1978 all plots were planted perpendicular and immediately adjacent to infested small grain fields to provide the best opportunity for a uniform population distribution. Common dryland agronomic practices were conducted on all tests. Barley was used as an infestation source for Test 6 and all other tests were planted next to wheat. Test 6 plots were 25 feet in length and were planted by hand at a rate of 120 seeds with an Alamco[R] v-belt seeder. Plots of all other tests were 30 feet in length and planted with 140 seeds by a White[R] precision air planter. Plant stand counts were made ca. 8 days after planting. Tests 2, 3, 4, 6, and 7 were planted on June 11. Tests 1 and 5 were planted on June 12 and Test 8 near Hesston was planted on June 15. A complete listing of all lines evaluated for chinch bug resistance in the 1979 field trials is given in Table 1.

In 1979, the chinch bug resistance evaluation was based upon two damage rating scales. One rating was used to assess plant tissue necrosis and a separate scale was used to estimate stunting. A 0-5 system for both parameters was adopted. The necrosis scale was based on an estimate of the percentage of necrotic tissue in the total vegetation of the plot. The necrosis scale is listed as follows: 0 = no damage, 1 = 1 to 20% necrosis; 2 = 21-40% necrosis, 3 = 41-60% necrosis, 4 = 61-80% necrosis, and 5 = 81-100% necrosis. The stunting scale was based on an estimate of the percentage of plants in the plot with internodal rossetting. The stunting scale is listed as follows: 0 = no rossetting, 1 = 1-20% with rossetting, 2 = 21-40% with rossetting, 3 = 41-60% with rossetting, 4 = 61-80% with rossetting, and 5 = 81-100% with rossetting. Evaluations of all plots were made at growth stage 2, 5, and 9. Data from each test were analyzed with analysis of variance and means compared with Duncan's new multiple range test.

1979 Greenhouse Experiments

Two greenhouse experiments were conducted in the summer of 1979 to investigate the feasibility of mass screening sorghum lines under artificial conditions. An initial trial designated as Test A was planted on June 24, 1979 and included 29 entries. Twenty-four entries were the base converted lines planted at eight 1979 field locations and five entries were standard resistant and susceptible checks. The test was of a 3 replication, randomized complete block design with 1 row plots.

Wooden greenhouse flats 53 x 38 x 10 cm were partitioned into 12 rows 36 cm in length and 3 cm apart. The rows were then halved to form 24 test plots 18 cm in length. The middle 20 plots were marked and seeded with test entries at a rate of 20 seeds per plot. The outside 4 plots were seeded with Double Dwarf Yellow Milo as border rows. The seeds were covered with washed builder's sand and watered.

Ten days after planting, rectangular glass pieces held together by duct tape were placed on the inside perimeter of each flat and sanded in. The seedlings were then infested with ca. 1500 fourth and fifth instar field-collected chinch bugs by distributing them over the flat. After infesting, Plexiglas[R] tops with foam weatherstripping around their border were placed on the glass sides to complete the cage. Ventilation through the covers was provided by three cheesecloth-covered holes 7 cm in diameter.

Damage ratings were made using the 0-5 plant tissue necrosis system previously described for the field tests. Ratings were started when the susceptible checks had sustained a rating of 2.5, or an estimated 50% tissue loss. The test was then rated every two days until ca. 90% of the plants were dead. Stand counts were taken at emergence and during each rating. Data from each rating date were analyzed with analysis of variance and means were compared with Duncan's new multiple range test. The original and post-infestation plant stands were converted to a percentage ratio and analyzed by the same method.

On August 30, 1979 a second greenhouse evaluation designated as Test B was planted with 50 entries. Entries included lines from both Kansas and converted line sources which had demonstrated superior resistance qualities in the field tests. The trial used five replications and all other experimental and analytical procedures were identical to those used in the first greenhouse test.

Commercial Hybrid Yield Test

A field test using eight presently-available commercial hybrids was planted May 31, 1979 at the Agronomy Research Center, Manhattan, Kansas. The purpose of the test was to evaluate the impact of mid-season chinch bug infestations on sorghum yield and to determine relative resistance levels of commercial hybrids under such conditions. Two-row plots 24 feet in length were planted with a White [R] precision air planter at a rate of 280 seeds per plot. The experimental design was a split-plot with whole units in a randomized complete block arrangement and four replications. Two main plots were utilized. One main plot was naturally infested by a flight of second-generation chinch bugs at growth stage 5. The other main plot was kept free of the insects by liquid carbaryl treatments applied by hand sprayers with 34.5 liters of water/ha at a rate of 2.24 kg/AI/ha. A coarse spray was directed at the base of the plants to avoid drift. Plots were observed for insects after each application to judge effectiveness. A seedling greenbug infestation on all plots was controlled 10 days after planting by one foliar application of liquid disulfoton with hand sprayers at a rate of 0.56 kg/AI/ha with 34.5 liters of water/ha. At maturity, the average height and number of heads were recorded for each plot. Yield was then evaluated by harvesting grain from 20 feet of each plot with a small-plot mechanical combine. Each parameter was analyzed with the analysis of variance and means were compared by Fisher's LSD.

Commercial Hybrid Screening Test

A field trial containing 12 commercial grain sorghum hybrids and two Kansas experimental hybrids was planted on June 11, 1979 at the Agronomy Research Center, Manhattan, Kansas. Plots 30 feet in length were planted with a White[R] precision air planter at a seeding rate of

140 seeds per plot. The experimental design was a randomized complete block with one row plots and four replications. All plots were planted perpendicular and adjacent to a chinch bug infested wheat field for optimum infestation conditions. A Milo-derived hybrid check, Funk G 404, was plated every 10 rows exclusive of the test to measure infestation uniformity. Stand counts were made upon plant emergence. Evaluations of chinch bug damage were made at growth stages 2, 5, and 9 with the 0-5 rating systems for stunt and necrosis described previously for the line tests. Post-infestation stand counts were also recorded at these times. Data were analyzed using analysis of variance and means were separated by Duncan's new multiple range test.

Chemical Control Studies

1978 Chemical Tests

On June 5, 1978 15 rows of Dekalb C 46+ hybrid grain sorghum were planted at the Agronomy Research Center, Manhattan, Kansas. Rows were 30 feet in length and were planted 3 cm in depth by an Almaco^{R} v-belt seeder at a rate of 120 seeds/row. At planting, 14 rows were completely treated with one of five different insecticides applied as band, in-furrow, or seed treatments at varying rates. The remaining row was used as an untreated check.

Treatments were evaluated for chinch bug control 8 and 21 days after planting by caging adult field-collected chinch bugs on six plants selected at 4 foot intervals in the middle 24 feet of the row and counting the surviving bugs after 48 hours. Ten and 40 chinch bugs, respectively, were caged at 10 and 21 days. Cages were made from plastic drinking cups 15 cm in height and 8 cm in diam. Two side holes 2 cm in diam. were cut in all cups and covered with organdy cloth for ventilation. Another 2 cm hole was placed in the top of each cage and stoppered with a foam plug after infestation.

An additional field trial identical to the first was planted on June 29, 1978 at the Agronomy Research Center, Manhattan, to evaluate insecticidal activity at 14 days after planting. Twenty chinch bugs were caged for the evaluation. All other aspects of the test were the same as the first experiment. Insect counts from both tests were analyzed by analysis of variance and means were separated by Duncan's new multiple range test.

1979 Chemical Test

In 1979, a single test was planted at the Agronomy Research Center, Manhattan, Kansas to further study the effectiveness of certain planting-time treatments for the control of chinch bugs. Plots 30 feet long were planted with an Alamco^{R} v-belt seeder at a depth of 3 cm. The seed treatments, and granular and liquid soil treatments were arranged in a randomized complete block design with three replications. Dekalb C 46+ hybrid grain sorghum was used, and plant stand counts were made after emergence to detect phytotoxicity. Band and in-furrow applications were placed with the v-belt seeder. Liquid applications were with a hand sprayer delivering 34 liters of water/ha.

Treatments were evaluated at 10, 20, 30, and 40 days after planting. At 10 days, control was evaluated by caging 10 adult chinch bugs on four plants in each row and making survival counts after 48 hours. A natural infestation allowed the evaluation at 20, 30, and 40 days after planting to be made by counting bugs on five plants/replicate. In addition to counts, a damage rating and plant survival were used to evaluate treatments at 30 and 40 days after planting, respectively. At maturity, plots were harvested and threshed by hand for yield assessment. The rating scale applied in the experiment was the 0-5 plant tissue necrosis system utilized in the plant resistance studies. The plant survival data were converted into percentage ratios based on original stand counts. All parameters were analyzed by analysis of variance and means were compared by Duncan's new multiple range test.

RESULTS AND DISCUSSION

Plant Resistance Studies

1978 Field Tests

Of the four identical field tests, only the June 1 planting became successfully established. The June 18 plantings were quickly destroyed by extreme hot, dry conditions after emergence, along with additional stress from moderate chinch bug populations. The surviving test was infested uniformly by a moderate to heavy population of fourth and fifth instar chinch bug nymphs beginning on June 10. A second generation remained in the test throughout the summer.

Table 2 depicts the damage evaluations made at growth stages 2, 5, and 9. Due to the single surviving replication, no statistical analysis was performed on the data. The test did provide indications of pronounced differences in chinch bug resistance within the converted lines.

Many lines exhibited a highly susceptible reaction to chinch bug feeding resembling that of the susceptible check Double Dwarf Yellow Milo. This general reaction was apparent at each rating in most Durra, Nandyal, and Cernuum entries. Milo is a subrace of the basic race Durra.

Lines in the Conspicuum, Roxburghii, Margaritiferum, and Dochna groups were generally resistant to chinch bug attack throughout the season. Many lines in these groups had damage ratings lower than those of the resistant checks Combine Kafir 60 and Rox Orange. Table 3 provides the average damage rating for each converted line work group at the evaluated growth stage.

The more resistant groups were predominantly taller lines with thick and sometimes grassy vegetation. The more susceptible groups were mostly short stocky lines with compact heads and broad erect leaves. The remaining converted line groups were quite variable, or did not have enough entries to judge general reaction trends. Stand loss was not severe enough in the test to indicate resistance levels. The superior plots did provide adequate quantities of self-pollinated seed for the 1979 tests.

1979 Field Screenings

Of the eight tests planted, Tests 3, 6, and 8 were successfully evaluated for chinch bug resistance. Test 1 at the Rocky Ford Experiment Field received only a light infestation from the wheat and no damage was apparent on the susceptible check at any time. Tests 2, 4, 5, and 7 at the Agronomy Research Center, Manhattan, received extremely heavy chinch bug populations from several adjacent wheat plantings just after plant emergence. The populations overwhelmed all cultivars in the tests before the plants were into growth stage 2. No differences between lines were detected. Infestation levels in Tests 3, 6, and 8 were not sufficient for evaluation by stand loss and stunting could not be detected in any test until stage 5.

Test 3 Manhattan. Table 4 presents the results of the Test 3 plant necrosis evaluation at the Agronomy Research Center, Manhattan, in 1979. Test 3 was the only field trial in 1979 with an adequate chronic population for evaluation of all three plant stages.

In growth stage 2, ratings showed a few lines were as susceptible to chinch bugs as the susceptible check Caprock. These lines included

SC 66 Nigricans/Guinea, SC 504 Nigricans/Feterita, SC 124 Durra/Dochna, and SC 320 Caffrorum. Other than these susceptible lines, most other entries at this point were variable in damage and not significantly different.

Through stages 5 and 9, most lines showed an increase in damage ratings from the previous stage. At stage 9, statistical analysis separated a few susceptible lines, a few resistant lines, and a large number of entries with intermediate ratings not significantly different.

The Kansas breeding line 1155 proved to be the only entry significantly more resistant than all others tested. Other entries such as KS 6 and SC 303 Margaritiferum received consistently low ratings but were not always statistically different from the intermediate lines at all three growth stages. Many lines received lower necrosis ratings than the resistant check Combine Kafir 60.

High rainfall, sometimes in the form of severe thunderstorms, reduced the second generation population markedly during the first two weeks in August by drowning the second instar nymphs. The abundant moisture also served to produce regrowth on most of the plots, causing many intermediate lines to rate less necrotic in stage 9 than in stage 5.

Table 4 also shows results obtained from the growth stage 9 stunting evaluation of Test 3. Stunting evaluations made at stage 5 were not significantly different. As with the plant necrosis evaluations, the stunt ratings identified a large number of intermediate resistance levels between very few resistant and susceptible lines. Kansas Exp. 1155 was rated as a superior line but was not significantly different than most other lines receiving low ratings. Lines with mean stunt ratings close to that of 1155 include SC 605 Margaritiferum, KS 6, SC 382 Caudatum/Kaura, and SC 17 Dochna.

Test 6 Manhattan. Test 6 at the Agronomy Research Center, Manhattan, was evaluated only at growth stage 9. The test was planted by hand and did not germinate due to an inadequate seed bed. However, chinch bug nymphs moved across the plots and germination following rains produced an adequate stand which was infested by a second-generation flight in early July. Evaluations were made after susceptible checks Spur Feterita and Wheatland were noticeably damaged.

Table 5 provides both the plant necrosis and stunting assessment of the test. Significant differences for both parameters were seen only between a small number of lines with ratings at each end of the numerical scale. Again, Kansas Exp. 1155 was rated as resistant in both cases, but was not significantly different than the ratings of SC 17 Dochna, KS 6, SC 254 Roxburghii, KS 56, or several others. Several lines were lower in damage ratings than the resistant checks Combine Kafir 60 and Blackhull Kafir. The same wet conditions which hampered the second-generation development of chinch bugs in Test 3 also affected those in Test 6. More significant delineations between lines probably would have occurred had the population developed uninhibited.

Test 8 Hesston. Chinch bug evaluations on Test 8 were made only for growth stage 2. After stage 2, the brunt of the chinch bug population moved from the wheat and totally destroyed all seedlings within two days. No significant differences in days to plant death were found.

Table 6 depicts the results of the plant necrosis evaluation of Test 8 made on June 26, 1979. Overall the damage ratings were higher at

Hesston than in Tests 3 and 6 at Manhattan, reflecting the heavier chinch bug pressure. As in the Manhattan locations, significant differences were shown only between two small groups of lines at each end of the rating scale. Lines such as SC 394 Caudatum/Kaura, SC 241 Roxburghii, SC 298 Conspicuum, and SC 291 Conspicuum received superior ratings for resistance, lower than the resistant check Combine Kafir 60.

Combined Analysis. As discussed earlier, all entries in Test 3 at Manhattan were also common to Test 6, Manhattan and Test 8 at Hesston. Where combined analysis of common entries was possible, the increase of replications did not significantly alter the individual test results.

1979 Greenhouse Experiments

The preliminary greenhouse flat screening technique used for both experiments proved to be a successful method of mass-screening sorghum seedlings for chinch bug resistance. Plant necrosis provided the best method of assessing damage. Many plants in a severely damaged plot would remain alive throughout the test, rendering percent survival counts of the plots misleading.

Test A. The results of greenhouse Test A are presented in Table 7. Analysis of the four rating dates showed each date with a significant difference among entries. Separation of the means for the July 4 and July 6 ratings demonstrated only a few entries were significantly different. As feeding continued to the July 8 evaluation, necrosis had increased in all plots and quite distinct differences were detected between resistant and susceptible lines. At this date, the resistant check Combine Kafir 60 and a majority of other lines were almost completely dead. More resistant materials significantly lower in ratings than the rest were SC 303 Margaritiferum and SC 563 Caudatum. By the July 10 rating, most lines were dead or dying except for the resistant lines mentioned previously.

Test B. Results obtained in greenhouse Test B are shown in Table 8. Fifth instar nymphs used in the test were collected prior to the normal migration period of chinch bugs to the overwintering sites. After feeding for 10 days, nymphs began molting to adults and became quite restless and disinterested in feeding. The new adults formed large aggregations in the cage corners and would feed only on the plants closest to their location. The lack of a uniform infestation forced the termination of the experiment after one rating made on September 19, 1979. Means in the test were significantly different and many entries could be classified as resistant as the resistant checks Combine Kafir 60 and Atlas. As in Test A SC 303 Margaritiferum and SC 563 Caudatum received low ratings for necrosis. Other lines rated as resistant were KS 6, 1155, SC 599 Rio, Cimmyt 1339 x KS 44, BCK 60-Tunis Grass, BH 64, and SC 66 Nigricans/Guinea.

Discussion Field and Greenhouse Screening Results

Data obtained from screening tests for chinch bug resistance showed significant differences among the entries for necrosis and stunting reaction in all cases. Few replications and more entries were necessary to best utilize the resources available for screening a maximum amount of germplasm. Thus, when the number of samples is limited, discreet levels of resistance between lines is probably not detectible and only the extremes are recognized as significantly different. This is inherent in a screening process, particularly in the first years of testing.

In most tests, many lines from Kansas and conversion sources were damaged less than resistant checks such as Combine Kafir 60. Therefore, these lines possibly represent chinch bug resistance levels higher than those of the previous resistance sources. Lines such as KS 6, SC 303 Margaritiferum, SC 291 Conspicuum, SC 563 Caudatum, and Kansas Exp. 1155 are examples of the more resistant lines.

Further testing is needed for an evaluation of resistance levels and the identification of resistance mechanisms. If more than one mechanism is identified, they might be combined to increase resistance levels. Combinations of parents resistant to the chinch bug, greenbug, and MDMV could possibly lead to the development of sorghum hybrids with multiple-pest resistance.

The more resistant sorghums found in the conversion program lines do tend to fall into one and possibly two races of cultivated sorghums. Several lines from the Margaritiferum, Roxburghii, and Conspicuum work groups, all of which belong to the basic race Guinea, were consistently resistant to chinch bug damage. Members of the basic race Bicolor were also resistant in most cases, but were not as consistent in reaction as those of the Guinea race. However, since the converted lines are a diverse source of genetic variation both between and within the classification groups, wide variations between members of the same work group were common in the experiments.

In our studies even the most resistant sorghums were killed if the plants were small and chinch bug populations were extremely high. If the plants are four to five weeks old before migration, the additional stress tolerance afforded by the larger size would make plant resistance effective as a control measure, particularly when coupled with less frequent chemical applications. If resistance is to be a key factor in reducing early season seedling chinch bug problems, the importance of early planting should be emphasized.

Commercial Hybrid Yield Test

Results of the yield evaluation are given in Table 9. A distinct yield differential between protected and non-protected plots indicates the importance of heavy and chronic mid-season infestations on grain sorghum yield. Variation between the hybrids involving significant yield differences demonstrate the presence of important relative resistance levels in the hybrids tested.

Funk HW 2124 is an experimental hybrid with Kafir in its parentage. It's small yield loss definitely points out the advantage of such a background over hybrids derived from Milo parents, such as Funk G 404. The data suggest that growers in the chinch bug areas may have been unknowingly suffering significant yield losses from second-generation flights and that resistance levels are commercially available to partially protect against such losses. Higher resistance levels from new sources may reduce economic losses substantially.

Commercial Hybrid Screening Test

Table 10 gives the results of the plant necrosis evaluation of the 14 hybrids throughout the season. Significant differences were shown at growth stages 2 and 9. Heavy rains produced abundant regrowth after stage 2 and no significant differences between hybrids were found at growth stage 5. Damage after stage 5 was largely due to second-generation feeding.

In stages 2 and 9, the 2 hybrids derived from KS lines had less plant necrosis than most other entries, but differences were not significant. The female used in the Kansas hybrids, H 64, was a line which showed good resistance qualities in the greenhouse line evaluations. As in the yield test, Funk HW 2124, along with Prairie Valley 708 and 599, exhibited some resistance. Pioneer 8324 showed a higher resistance level in this test than in the split-plot yield test, possibly due to the differing infestation types. Funk G 642 is a full-season hybrid utilizing Kaura in its make-up. Its resistance in this test may reflect the capabilities of some of the more resistant Caudatum/Kauras in the line tests.

Table 10 also shows the stunting evaluations for stages 5 and 9 of the hybrid test. Hybrids which were found resistant by the plant necrosis ratings also appeared resistant to stunting. However, some hybrids had mean necrosis ratings substantially lower than their mean stunt ratings. Hybrids Funk G 404 and PAG 4488 are examples of such differences. In the case of Pioneer 8585, the growth stage 9 mean necrosis rating was much more severe than the stage 9 mean stunt rating. The different reactions for the two parameters demonstrate the importance of using both as a damage index.

Chemical Control Studies

1978 Chemical Tests

Results of the Test 1 and Test 2 soil chemical control studies in 1978 are given in Table 11. At eight days after planting no band treatment gave effective control of chinch bugs. Seed and in-furrow applications of carbofuran and terbufos were significantly more effective than the other treatments. At 21 days carbofuran seed treatments, carbofuran in-furrow at 0.28 kg/AI/ha, and disulfoton or phorate bands gave no control. Terbufos gave some control in-furrow but not as a band. Carbofuran at 1.12 kg/AI/ha gave some control in both in-furrow and band placements but left bugs surviving on all plants.

In the 14 day evaluation (Test 2), all in-furrow and band treatments except disulfoton significantly reduced chinch bug numbers. The effectiveness of band treatments in the test probably was due to a 3 cm rain 11 days after planting. The disulfoton band and carbofuran seed treatments did not differ significantly from untreated plots.

1979 Chemical Test

As shown in Table 12, the superior treatments in 1979 10 days after planting were the carbofuran seed treatments and in-furrow treatments of carbofuran, terbufos, bendiocarb, and acephate. All band treatments were significantly less effective. At 20 days some bugs survived on all plots, but the granular carbofuran in-furrow and band, granular terbufos and bendiocarb in-furrow, and liquid carbofuran in-furrow treatments were the most effective. A 4 cm rain between the

10 and 20 day evaluations probably accounted for the increased effectiveness of the carbofuran band treatments. The 30 and 40 day chinch bug counts in treated plots did not differ significantly from the untreated check. Plant damage ratings on day 30 and plant survival counts on day 40 reflect the cumulative protection provided by the granular in-furrow treatment of carbofuran, and the band treatment of granular carbofuran. The yield data express the same trend, with liquid carbofuran in-furrow giving the highest yield. No phytotoxicity was indicated by stand counts.

Chinch Bug Chemical Tests Discussions

In 1978 and 1979, the data prove the advantage of in-furrow treatments over band treatments for desired chinch bug control immediately after plant emergence. Band treatments were not effective unless activated by a rain. The data also demonstrate how insecticides react differently in the soil. Granular carbofuran was effective both in-furrow and as a band, but terbufos was systemically active only in-furrow.

SUMMARY AND CONCLUSIONS

Flint (1935) stated that the chinch bug has probably caused more damage in the last 100 year period than any other insect with the possible exception of the grasshopper and the cotton boll weevil. The most recent outbreak of the chinch bug in the Midwest has shown how severe damage can be when extremely heavy populations develop and effective control measures are not available. Growers were unprepared for the problem and an anticipated decline in damaging infestations from natural controls did not materialize, despite wet growing conditions. The threat of prolonged crop losses brought about the need for long term solutions, as well as immediate remedies for the situation at hand.

Results of several screening tests have shown that levels of chinch bug resistance do exist in many sources of sorghum genetic variability previously unavailable for resistance evaluations. Lines showing good resistance capabilities were consistent over different locations, infestation conditions, and testing procedures. Greenhouse screening techniques developed for the experiment provide a viable means of resistance evaluations under controlled conditions. The broad screening tests did not detect definitive levels of resistance between most of the entries, but damage ratings of many lines were consistently lower than those of formerly-identified resistance sources. More quantitative testing procedures should be carried out with the new sources to provide a more empirical evaluation of resistance levels and identify resistance mechanisms. Should these qualities be practical, hybrid combinations that could withstand common chinch bug infestations are a realistic possibility in the near future. Higher levels of resistance could also serve to increase the economic injury level of the insect, thereby reducing the number and urgency of insecticidal applications.

In the evaluation of chinch bug resistance in commercial sorghums, relative resistance levels were detected which could provide immediate assistance to growers through non-chemical means. Quantitative and qualitative evidence suggested that many hybrids now available could provide some protection from crop losses. Kafir-based hybrids were advantageous over many hybrids derived from Milo sources. Second-generation mid-season infestations by flight were shown in the yield evaluation to be an important source of yield loss in the more susceptible hybrids. Such infestations from mid-season flights have previously not been reported as a cause of great economic loss in sorghum.

Chemical control of the chinch bug during the most recent outbreak was severely limited by bans on many chlorinated hydrocarbon materials previously used as residual controls. Results from soil chemical tests in 1978 and 1979 present many practical alternatives for immediate utilization.

In 1978 and 1979, carbofuran provided effective control under artificial infestation conditions and also gave superior protection from a natural infestation. Carbofuran and terbufos were the most effective compounds at 21 days after planting in 1978 and again gave control for 20 to 30 days in 1979. Bendiocarb was also effective in 1979. In both years, residual control did not exceed 30 days. Therefore, if chinch bug migration occurred more than 30 days after planting, treatment at planting would be ineffective. Data from these experiments provided necessary information for the emergency registration of carbofuran in Kansas, Nebraska, and Missouri for seedling chinch bug control.

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Table 1. Entries screened for chinch bug resistance at locations in Eastern Kansas, 1979.

Designation [a/]	Variety, Group, or Derivation [b/]	Race [b/]	Test 3 [c/]	Test 6 [c/]	Test 8 [d/]
SC 418	Caudatum/Kafir	Caudatum	X	X	X
SC 504	Nigricans/Feterita	Caudatum	X	X	X
SC 331	Nigricans/Durra	Durra	X	X	X
SC 63	Caudatum/Nigricans	Caudatum	X	X	X
SC 319	Dochna/Nigricans	Caudatum	X	X	X
SC 237	Dobbs	Caudatum	X	X	X
SC 405	Caudatum/Guinea	Bicolor	X	X	X
SC 303	Margaritiferum	Guinea	X	X	X
SC 244	Roxburghii	Guinea	X	X	X
SC 317	Dochna/Roxburghii	Guinea-caudatum	X	X	X
SC 578	Caudatum/Durra	Caudatum	X	X	X
SC 320	Caffrorum	Kafir-caudatum	X	X	X
SC 563	Caudatum	Durra	X	X	X
SC 372	Caudatum/Kaura	Durra-caudatum	X	X	X

Table 1. Continued

Designation [a]	Variety, Group, or Derivation [b]	Race [b]	Test 3 [c]	Test 6 [c]	Test 8 [d]
SC 6	Subglabrescens	Durra-bicolor	X	X	X
SC 16	Dochna/Amber	Bicolor	X	X	X
SC 66	Nigricans/Guinea	Guinea-caudatum	X	X	X
SC 124	Durra/Dochna	Durra-bicolor	X	X	X
SC 170	Zerazera	Caudatum	X	X	X
KS 56	-	-	X	X	X
KS 6	-	-	X	X	X
SC 256	Conspicuum	Guinea	X	X	X
SC 17	Dochna	Bicolor	X	X	X
SC 252	Roxburghii	Guinea	X	X	X
SC 337	Caudatum	Durra	X	X	X
TAM 428	-	-	X	X	X
SC 358	Caudatum/Kaura	Durra-caudatum	X	X	X
TX 430	-	-	X	X	X

Table 1. Continued

Designation a/	Variety, Group, or Derivation b/	Race b/	Test 3 c/	Test 6 c/	Test 8 d/
Combine Kafir 60 e/	-	Kafir	X	X	X
TX 7000	Caprock	-	X	X	X
SC 58	Caudatum	Durra	X	X	X
SC 367	Caudatum/Kaura	Durra-caudatum	X	X	X
SC 241	Roxburghii	Guinea	X	X	X
SC 261	Conspicuum	Guinea	X	X	X
SC 108	Zerazera	Caudatum	X	X	X
SC 605	Margaritiferum	Guinea	X	X	X
SC 508	Subglabrescens	Durra-bicolor	X	X	X
SC 514	Roxburghii	Guinea	X	X	X
SC 173	Zerazera	Caudatum	X	X	X
SC 382	Caudatum/Kaura	Durra-caudatum	X	X	X
SC 215	Durra	Durra	X	X	X
SC 291	Conspicuum	Guinea	X	X	X
SC 307	Dochna	Bicolor	X	X	X

Table 1. Continued.

Designation a/	Variety, Group or Derivation b/	Race b/	Test 3 c/	Test 6 c/	Test 8 d/
SC 322	Nigricans	Caudatum	X	X	X
SC 450	Durra	Durra		X	X
SC 424	Caudatum/Nigricans	Caudatum		X	X
SC 566	Caudatum	Durra		X	X
SC 394	Caudatum/Kaura	Durra-caudatum		X	X
SC 298	Conspicuum	Guinea		X	X
SC 202	Durra	Durra		X	X
SC 308	Dochna	Bicolor		X	X
SC 56	Caudatum/Nigricans	Caudatum		X	X
SC 501	Caudatum/Durra	Caudatum		X	X
SC 387	Caudatum/Kaura	Durra-caudatum		X	X
SC 206	Durra	Durra		X	X
SC 499	Nandyal	Durra		X	X
SC 530	Conspicuum	Guinea		X	X

Table 1. Continued.

Designation a/	Variety, Group or Derivation b/	Race b/	Test 3 c/	Test 6 c/	Test 8 d/
SC 257	Conspicuum	Guinea		X	X
SC 417	Conspicuum	Guinea		X	X
SC 389	Caudatum/Kaura	Durra-caudatum		X	X
Spur Feterita f/	-	-		X	X
SC 216	Cernuum	Durra		X	X
SC 285	Conspicuum	Guinea		X	X
SC 254	Roxburghii	Guinea		X	X
SC 346	Caudatum	Durra		X	X
Blackhull Kafir e/	-	Kafir		X	X
SC 399	Caudatum/Kaura	Durra-caudatum		X	X
SC 482	Nandyal	Durra		X	
SC 248	Roxburghii	Guinea		X	
SC 207	Durra	Durra		X	
SC 290	Conspicuum	Guinea		X	

Table 1. Continued.

Designation a/	Variety, Group, or Derivation b/	Race b/	Test 3 c/	Test 6 c/	Test 8 d/
SC 369	Caudatum/Kaura	Durra-caudatum		X	
SC 227	Durra	Durra		X	
SC 396	Caudatum/Kaura	Durra-caudatum		X	
SC 368	Caudatum/Kaura	Durra-caudatum		X	
SC 403	Caudatum/Kaura	Durra-caudatum		X	
SC 431	Durra	Durra		X	
SC 242	Roxburghii	Guinea		X	
SC 243	Roxburghii	Guinea		X	
SC 254	Roxburghii	Guinea		X	
SC 388	Caudatum/Kaura	Durra-caudatum		X	
SC 203	Durra	Durra		X	
SC 205	Durra	Durra		X	
White Kafir e/	-	Kafir		X	
Early Kalo	-	-		X	

Table 1. Continued

Designation a/	Variety, Group, or Derivation b/	Race b/	Test 3 c/	Test 6 c/	Test 8 d/
1155	-	-		X	
RKS 6	-	-		X	
Combine Kafir B-140	-	Kafir		X	
Wheatland f/	-	-		X	
BH 64	-	-		X	

a/ "SC" indicates member of sorghum conversion program, Stephens et al., 1967.
b/ Work groups and races as defined by Harlan and deWet, 1972.
c/ Manhattan, Kansas.
d/ Hesston, Kansas.
e/ Resistant check.
f/ Susceptible check.

Table 2. 1978 converted line chinch bug screening test. Damage evaluation for growth stage 2, 5, and 9. Manhattan, Kansas.

Designation [a]	Work Group [b]	Damage Rating by Growth Stage [c] [d]		
		2	5	9
SC 256	Conspicuum	0.5	0.5	1.5
SC 372	Caudatum/Kaura	0.5	0.5	1.5
SC 291	Conspicuum	0.5	0.5	1.5
SC 17	Dochna	0.5	1.5	1.5
SC 303	Margaritiferum	0.5	1.0	2.0
SC 549	Conspicuum	1.5	1.5	2.0
SC 242	Roxburghii	1.0	1.0	2.0
SC 267	Caudatum/Kaura	0.5	1.5	2.0
SC 394	Caudatum/Kaura	0.5	1.0	2.0
SC 309	Dochna	1.5	2.5	2.5
SC 307	Dochna	1.0	1.0	2.5
SC 227	Durra	1.5	1.5	2.5
SC 319	Dochna/Nigricans	1.0	1.5	2.5
SC 267	Conspicuum	1.0	1.0	2.5
SC 261	Conspicuum	1.0	2.0	2.5
SC 244	Roxburghii	1.0	1.5	2.5
SC 358	Caudatum/Kaura	1.0	1.0	2.5
SC 399	Caudatum/Kaura	1.0	1.5	2.5
SC 387	Caudatum/Kaura	1.5	2.0	2.5
SC 530	Conspicuum	2.0	2.5	2.5
SC 389	Caudatum/Kaura	1.0	1.0	2.5
Combine Kafir 60	-	2.0	2.5	2.5

Table 2. Continued.

Designation a/	Work Group b/	Damage Rating by Growth Stage c/ d/		
		2	5	9
SC 243	Roxburghii	1.5	2.0	3.0
SC 252	Roxburghii	1.5	2.0	3.0
SC 248	Roxburghii	1.0	1.5	3.0
SC 285	Conspicuum	1.0	2.5	3.0
SC 337	Caudatum	1.0	1.5	3.0
SC 368	Caudatum/Kaura	1.0	2.0	3.0
SC 290	Conspicuum	1.0	1.5	3.0
SC 298	Conspicuum	0.5	1.5	3.0
SC 403	Caudatum/Kaura	0.5	2.0	3.0
SC 6	Subglabrescens	0.5	1.0	3.0
Atlas	-	1.5	2.0	3.0
SC 257	Conspicuum	2.0	2.5	3.0
SC 322	Nigricans	2.5	2.5	3.5
SC 226	Durra	2.0	2.5	3.5
SC 237	Dobbs	2.5	3.0	3.5
SC 501	Caudatum/Durra	2.0	2.5	3.5
SC 417	Caudatum/Kafir	1.5	2.0	3.5
SC 369	Caudatum/Kaura	1.0	2.5	3.5
SC 563	Caudatum	1.0	2.0	3.5
SC 396	Caudatum/Kaura	1.0	1.5	3.5
SC 56	Caudatum/Nigricans	1.0	2.5	3.5
SC 58	Caudatum	2.5	3.5	3.5
SC 63	Caudatum/Nigricans	1.5	2.5	3.5

Table 2. Continued.

Designation [a]	Work Group [b]	Damage Rating by Growth Stage [c] [d]		
		2	5	9
SC 90	Conspicuum	1.0	1.5	3.5
Rox Orange	-	2.0	2.5	3.5
SC 207	Durra	3.5	3.5	4.0
SC 241	Roxburghii	2.0	2.5	4.0
SC 431	Durra	2.0	2.5	4.0
SC 499	Nandyal	3.5	3.5	4.0
SC 388	Caudatum/Kaura	1.0	2.5	4.0
SC 424	Caudatum/Nigricans	1.0	2.0	4.0
SC 418	Caudatum/Kafir	2.5	3.0	4.5
SC 566	Caudatum	3.0	4.0	4.5
SC 206	Durra	4.0	4.5	6.0
SC 209	Cernuum	4.5	5.0	6.0
SC 331	Nigricans/Durra	4.5	4.0	6.0
SC 405	Caudatum/Guinea	3.0	4.5	6.0
SC 254	Roxburghii	2.0	3.0	6.0
SC 320	Caffrorum	2.5	4.0	6.0
SC 283	Conspicuum	2.5	4.5	6.0
SC 578	Caudatum/Durra	3.0	4.5	6.5
SC 48	Zerazera	2.5	4.5	6.5
SC 124	Durra/Dochna	3.0	4.5	6.5
Early Sumac	-	3.5	4.0	6.5
SC 215	Durra	5.0	5.5	7.0

Table 2. Continued

Designation a/	Work group b/	Damage Rating by Growth Stage c/ d/		
		2	5	9
SC 52	Nigricans/Feterita	4.0	5.5	7.0
SC 504	Nigricans/Feterita	3.5	5.0	7.0
SC 346	Caudatum	3.0	4.5	7.0
SC 482	Nandyal	5.0	5.0	7.5
SC 459	Durra	3.5	4.5	8.0
SC 426	Caudatum/Durra	3.5	5.0	8.0
SC 450	Durra	3.0	5.5	8.5
SC 112	Zerazera	3.5	7.0	8.5
SC 202	Durra	4.0	7.0	9.0
SC 414	Caudatum/Kafir	5.0	7.5	9.0
SC 114	Caudatum/Nigricans	4.5	8.0	9.0
SC 79	Caudatum/Caffrorum	3.5	8.0	9.0
SC 199	Nandyal	6.5	7.0	9.5
SC 203	Durra	4.5	7.0	9.5
SC 216	Cernuum	5.5	8.5	9.5
SC 239	Zerazera	6.0	8.0	9.5
SC 29	Durra	4.5	6.0	9.5
SC 31	Durra	3.5	5.5	9.5
SC 205	Durra	5.0	7.0	10.0
SC 208	Durra	6.5	8.0	10.0
SC 489	Nandyal	5.0	6.5	10.0
SC 36	Durra	5.0	7.0	10.0
SC 44	Dochna/Amber	6.5	8.0	10.0

Table 2. Continued.

Designation [a]	Work Group [b]	Damage Rating by Growth Stage [c] [d]		
		2	5	9
SC 78	Caudatum/Caffrorum	4.5	7.5	10.0
SC 144	Durra/Caudatum	4.5	7.5	10.0
Tx 7000	-	8.0	9.5	10.0
Tx 2536	-	7.5	8.5	10.0
SC 315	Dochna/Roxburghii	--	--	--
SC 335	Caudatum	--	--	--
SC 401	Caudatum/Kaura	--	--	--
SC 66	Nigricans/Guinea	--	--	--
DD Yellow Milo	-	10.0	--	--
Sooner Milo	-	10.0	--	--

a/ "SC indicates member of sorghum conversion program, Stephens et al., 1967.
b/ Work groups as defined by Harlan and deWet, 1972.
c/ 0 = no damage, 10 = 91 to 100% necrosis and stunting.
d/ Vanderlip 1972.

Table 3. 1978 converted line chinch bug screening test. Mean damage ratings by work group.

Work Group [a]	n	Mean Damage Rating by Growth Stage [b] [c]		
		2	5	9
Margaritiferum	1	0.50	1.00	2.00
Dochna	3	1.00	1.66	2.16
Dochna/Nigricans	1	1.00	1.50	2.50
Caudatum/Kaura	13	0.87	1.58	2.70
Conspicuum	12	1.12	1.91	2.87
Subglabrescens	1	0.50	1.00	3.00
Roxburghii	7	1.42	1.92	3.35
Dobbs	1	2.50	3.00	3.50
Nigricans	1	2.50	2.50	3.50
Caudatum	6	2.10	3.10	4.30
Caudatum/Nigricans	4	2.00	3.75	5.00
Caudatum/Kafir	3	3.00	4.66	5.66
Caffrorum	1	2.50	4.00	6.00
Caudatum/Durra	3	2.83	4.00	6.00
Caudatum/Guinea	1	3.00	4.50	6.00
Nigricans/Durra	1	4.50	5.00	6.00
Nandyal	4	5.00	5.75	6.37
Durra/Dochna	1	3.00	4.50	6.50
Nigricans/Feterita	2	2.83	5.25	7.00
Durra	15	3.83	5.16	7.40
Zerazera	3	4.00	6.50	7.50
Cernuum	2	5.00	6.75	7.75

Table 3. Continued.

Work Group a/	n	Mean Damage Rating by Growth Stage b/ c/		
		2	5	9
Caudatum/Caffrorum	2	4.00	7.75	9.50
Durra/Caudatum	1	4.50	7.50	10.00
Dochna/Amber	1	6.50	8.00	10.00
Nigricans/Guinea	1	-	-	-
Dochna/Roxburghii	1	-	-	-

a/ Work groups as defined by Harlan and deWet, 1972.
b/ 0 = no damage, 10 = 91 to 100% necrosis and stunting.
c/ Vanderlip 1972.

Table 4. Growth stage 2, 5, and 9 necrosis evaluation and growth stage 9 stunting evaluation Test 3. Manhattan, Kansas, 1979.

Designation [a]	Mean Necrosis Rating [b] [e] Growth Stage [d]			Mean Stunt Rating [c] [e]
	2	5	9	
SC 66	4.33 a	4.83 a	4.33 a	4.66 a
SC 504	3.50 ab	3.50 abcde	3.83 a	3.50 abcd
SC 124	3.50 ab	4.33 ab	2.33 defg	4.00 ab
SC 320	3.33 ab	4.16 abc	2.30 defg	3.66 abc
SC 215	2.83 bc	3.00 bcdefgh	3.33 bcde	3.00 abcdefg
Tx 7000	2.83 bc	2.83 cdefghi	2.66 bcdefg	2.50 bcdefgh
SC 256	2.66 bcd	2.50 defghij	2.00 efg	2.33 bcdefgh
SC 173	2.66 bcd	3.83 abcd	2.50 cdefg	3.00 abcdefg
SC 291	2.50 bcde	2.83 cdefghi	2.33 defg	3.16 abcdef
SC 405	2.00 cdef	2.16 efghij	3.66 ab	2.66 bcdefgh
SC 317	2.00 cdef	3.50 abcde	2.66 bcdefg	3.33 abcde
SC 319	1.66 cdefg	1.83 fghij	2.66 bcdefg	2.66 bcdefgh
SC 16	1.66 cdefg	2.33 defghij	2.50 cdefg	2.00 bcdefgh

Table 4. Continued.

Designation a/	Mean Necrosis Rating b/ e/ Growth Stage d/			Mean Stunt c/ e/ Rating
	2	5	9	
TAM 428	1.66 cdefg	2.83 cdefghi	2.66 bcdefg	2.33 bcdefgh
Tx 430	1.66 cdefg	2.66 cdefghij	3.00 abcde	2.83 abcdefg
SC 261	1.66 cdefg	2.33 defghij	2.50 cdefg	2.33 bcdefgh
SC 322	1.50 defg	2.50 defghij	3.00 abcde	2.66 bcdefgh
SC 418	1.50 defg	2.33 defghij	3.50 abc	1.50 defgh
SC 237	1.50 defg	2.33 defghij	3.33 abcd	2.50 bcdefgh
SC 303	1.50 defg	1.50 hij	1.83 fg	2.00 bcdefgh
SC 244	1.50 defg	2.66 cdefghij	2.66 bcdefg	2.50 bcdefgh
KS 56	1.50 defg	1.83 fghij	2.16 efg	1.33 efgh
SC 17	1.50 defg	2.33 defghij	2.83 abcdef	1.16 fgh
SC 358	1.50 defg	2.00 efghij	2.83 abcdef	1.66 cdefgh
SC 367	1.50 defg	2.00 efghij	2.83 abcdef	2.00 bcdefgh
SC 216	1.33 efg	3.33 bcdef	2.83 abcdef	2.66 bcdefgh

Table 4. Continued

Designation [a]	Mean Necrosis Rating [b] [e] Growth Stage [d]			Mean Stunt [c] [e] Rating
	2	5	9	
SC 307	1.33 efg	2.16 efghij	2.83 abcdef	2.16 bcdefgh
SC 331	1.33 efg	2.66 cdefghij	3.50 abc	2.33 bcdefgh
SC 578	1.33 efg	2.50 defghij	2.50 cdefg	2.50 bcdefgh
SC 252	1.33 efg	1.33 ij	3.33 abcd	1.50 defgh
SC 337	1.33 efg	2.00 efghij	3.33 abcd	2.16 bcdefgh
SC 241	1.33 efg	3.16 bcdefg	2.66 bcdefg	2.66 bcdefgh
SC 108	1.33 efg	2.66 cdefghij	3.66 ab	2.83 abcdefg
SC 508	1.33 efg	2.33 defghij	2.83 abcdef	2.50 bcdefgh
SC 63	1.16 fg	2.00 efghij	2.16 efg	2.33 bcdefgh
SC 372	1.16 fg	1.66 ghij	2.16 efg	1.16 fgh
SC 170	1.16 fg	1.83 fghij	3.00 abcde	1.66 cdefgh
SC 58	1.16 fg	1.33 ij	2.83 abcdef	1.33 efgh
SC 605	1.16 fg	1.16 j	2.16 efg	1.00 gh

Table 4. Continued.

Designation a/	Mean Necrosis Rating b/ e/ Growth Stage d/			Mean Stunt c/ e/ Rating
	2	5	9	
SC 514	1.16 fg	2.50 defghij	2.16 efg	1.66 cdefgh
SC 563	1.00 fg	1.83 fghij	3.00 abcde	1.16 fgh
SC 6	1.00 fg	1.50 hij	2.50 cdefg	1.16 fgh
SC 382	1.00 fg	1.66 ghij	2.83 abcdef	1.00 gh
KS 6	0.83 fg	1.16 j	1.66 g	1.00 gh
Combine Kafir 60	0.83 fg	2.33 defghij	2.33 defg	1.83 cdefgh
1155	0.66 g	1.50 hij	0.66 h	0.67 h

a/ "SC" indicates member of sorghum coversion program, Stephens et al., 1967.
b/ 0 = no damage, 5 = 81-100% necrosis.
c/ 0 = no plants with rossetting, 5 = 81-100% with rossetting.
d/ Vanderlip, 1972.
e/ Means with same letter in vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

Table 5. Growth stage 9 stunting and necrosis evaluation Test 6. Manhattan, Kansas, 1979.

Designation [a]	Mean Stunt [b] [d] Rating	Mean Necrosis [c] [d] Rating
SC 417	4.66 a	4.83 ab
SC 173	4.66 a	5.00 a
SC 108	4.33 ab	4.66 abc
SC 205	4.16 abc	4.00 abcdefg
SC 216	4.00 abcd	4.00 abcdefg
SC 482	4.00 abcd	4.50 abcd
SC 389	3.83 abcde	4.00 abcdefg
SC 399	3.83 abcde	4.88 abcde
SC 368	3.83 abcde	4.16 abcdef
SC 203	3.83 abcde	3.83 abcdefgh
SC 63	3.83 abcde	3.66 abcdefghi
SC 227	3.66 abcdef	4.33 abcde
SC 405	3.66 abcdef	4.00 abcdef
SC 66	3.66 abcdef	3.83 abcdefgh
SC 202	3.50 abcdefg	4.00 abcdefg
Spur Feterita	3.50 abcdefg	4.00 abcdef
SC 207	3.50 abcdefg	4.16 abcdef
SC 290	3.50 abcdefg	3.50 abcdefghij
SC 388	3.50 abcdefg	3.83 abcdefgh
SC 346	3.33 abcdefgh	4.00 abcdefg
SC 369	3.33 abcdefgh	3.83 abcdefgh
SC 215	3.33 abcdefgh	3.83 abcdefgh
SC 124	3.33 abcdefgh	4.16 abcdef

Table 5. Continued.

Designation [a]	Mean Stunt [b] [d] Rating	Mean Necrosis [c] [d] Rating
SC 170	3.33 abcdefgh	3.16 bcdefghijkl
SC 256	3.33 abcdefgh	3.83 abcdefgh
SC 499	3.16 abcdefghi	3.16 bcdefghijkl
Early Kalo	3.16 abcdefghi	4.16 abcdef
SC 307	3.16 abcdefghi	3.83 abcdefgh
SC 322	3.16 abcdefghi	3.66 abcdefghi
SC 418	3.16 abcdefghi	3.50 abcdefghij
SC 331	3.16 abcdefghi	3.50 abcdefghij
SC 382	3.16 abcdefghi	2.66 efghijkl
SC 501	3.00 abcdefghij	2.83 defghijkl
SC 530	3.00 abcdefghij	2.66 efghijklm
SC 396	3.00 abcdefghij	2.83 defghijkl
SC 243	3.00 abcdefghij	3.83 abcdefgh
SC 358	3.00 abcdefghij	3.33 abcdefghijk
Tx 430	3.00 abcdefghij	3.83 abcdefgh
SC 514	3.00 abcdefghij	3.00 cdefghijkl
SC 206	2.83 abcdefghijk	3.50 abcdefghij
SC 504	2.83 abcdefghijk	3.66 abcdefghi
SC 6	2.83 abcdefghijk	3.16 bcdefghijkl
SC 424	2.83 abcdefghijk	3.16 bcdefghijkl
SC 58	2.66 bcdefghijkl	3.16 bcdefghijkl
SC 394	2.50 bcdefghijkl	3.16 bcdefghijkl

Table 5. Continued.

Designation [a]	Mean Stunt [b] [d] Rating	Mean Necrosis [c] [d] Rating
SC 298	2.50 bcdefghijklm	3.00 cdefghijkl
SC 403	2.50 bcdefghijklm	4.16 abcdef
SC 431	2.50 bcdefghijklm	2.50 fghijklm
White Kafir	2.50 bcdefghijklm	3.33 abcdefghijk
SC 578	2.50 bcdefghijklm	2.66 efghijkl
SC 320	2.50 bcdefghijklm	3.33 abcdefghijk
SC 241	2.50 bcdefghijklm	2.33 ghijklmn
SC 566	2.33 cdefghijklmn	1.83 jklm
SC 248	2.33 cdefghijklmn	3.00 cdefghijkl
SC 563	2.33 cdefghijklmn	3.00 cdefghijkl
SC 16	2.33 cdefghijklmn	2.00 ijklmn
Combine Kafir 60	2.33 cdefghijklmn	3.50 abcdefghi
Tx 7000	2.33 cdefghijklmn	3.50 abcdefghi
SC 56	2.16 defghijklmn	2.50 fghijklm
SC 319	2.16 defghijklmn	2.33 ghijklmn
SC 367	2.16 defghijklmn	3.16 bcdefghijkl
SC 261	2.00 efghijklmn	3.16 bcdefghijkl
SC 508	2.00 efghijklmn	2.66 efghijklm
SC 285	1.83 fghijklmn	3.00 cdefghijkl
SC 303	1.83 fghijklmn	3.66 abcdefghi
SC 244	1.83 fghijklmn	2.83 defghij
SC 387	1.66 ghijklmn	2.00 ijklmn
Blackhull Kafir	1.66 ghijklmn	2.16 ijklmn

Table 5. Continued.

Designation [a]	Mean Stunt Rating [b] [d]	Mean Necrosis Rating [c] [d]
SC 252	1.66 ghijklmn	2.33 ghijklmn
SC 450	1.66 ghijklmn	1.66 klmn
SC 257	1.50 hijklmn	2.33 ghijklmn
SC 237	1.50 hijklmn	2.50 fghijklmn
SC 308	1.33 ijklmn	2.15 ijklmn
SC 254	1.33 ijklmn	1.66 klmn
SC 372	1.33 ijklmn	2.00 ijklmn
SC 337	1.33 ijklmn	2.50 fghijklmn
TAM 428	1.33 ijklmn	2.33 ghijklmn
Combine Kafir 60 B-140	1.16 jklmn	2.33 ghijklmn
SC 242	1.00 klmn	1.50 lmn
SC 291	1.00 klmn	1.83 jklm
SC 317	1.00 klmn	1.66 klmn
KS 56	0.83 lmn	3.00 cdefghijkl
KS 6	0.83 lmn	1.50 lmn
SC 17	0.83 lmn	2.50 fghijklmn
SC 254	0.66 mn	1.66 klmn
1155	0.50 n	0.83 n

a/ "SC" indicates member of sorghum conversion program, Stephens et al., 1967.
b/ 0 = no plants with rossetting, 5 = 81-100% with rossetting.
c/ 0 = no damage, 5 = 81-100% necrosis.
d/ Means with same letter in vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

TABLE 6. Growth stage 2 necrosis evaluation Test 8. Hesston, Kansas, 1979.

Designation [a]	Mean Necrosis Rating [b] [c]
Spur Feterita	4.50 a
SC 66	4.33 ab
SC 173	4.33 ab
SC 206	4.33 ab
SC 322	4.16 abc
SC 170	4.16 abc
SC 337	4.16 abc
SC 508	4.16 abc
SC 389	4.16 abc
SC 331	4.00 abcd
SC 124	4.00 abcd
SC 417	4.00 abcd
SC 346	4.00 abcd
SC 307	3.83 abcde
SC 319	3.83 abcde
SC 256	3.83 abcde
Tx 7000	3.83 abcde
SC 254	3.83 abcde
SC 504	3.66 abcdef
SC 63	3.66 abcdef
SC 405	3.66 abcdef
SC 548	3.66 abcdef
SC 16	3.66 abcdef

Table 6. Continued.

Designation [a]	Mean Necrosis Rating [b] [c]
SC 252	3.66 abcdef
SC 261	3.66 abcdef
SC 501	3.66 abcdef
SC 215	3.50 abcdefg
SC 418	3.50 abcdefg
SC 320	3.50 abcdefg
KS 56	3.50 abcedfg
SC 424	3.50 abcdefg
SC 566	3.50 abcdefg
SC 308	3.50 abcdefg
SC 257	3.50 abcdefg
SC 399	3.50 abcdefg
SC 216	3.33 abcdefgh
SC 303	3.33 abcdefgh
SC 392	3.33 abcdefgh
SC 6	3.33 abcdefgh
SC 17	3.33 abcdefgh
SC 108	3.33 abcdefgh
SC 283	3.33 abcdefgh
SC 450	3.33 abcdefgh
SC 31	3.33 abcdefgh
SC 233	3.16 bcdefgh
SC 563	3.16 bcdefgh

Table 6. Continued

Designation [a]	Mean Necrosis Rating [b] [c]
SC 58	3.16 bcdefgh
SC 216	3.16 bcdefgh
SC 244	3.00 cdefgh
KS 6	3.00 cdefgh
SC 367	3.00 cdefgh
SC 202	3.00 cdefgh
SC 387	3.00 cdefgh
SC 530	3.00 cdefgh
1155	3.00 cdefgh
Blackhull Kafir	3.00 cdefgh
SC 285	2.83 defgh
SC 605	2.66 efgh
SC 514	2.66 efgh
SC 499	2.66 efgh
TAM 428	2.50 fgh
Combine Kafir 60	2.50 fgh
SC 56	2.50 fgh
SC 358	2.33 gh
SC 291	2.16 h
SC 241	2.16 h

Table 6. Continued.

Designation[a/]	Mean Necrosis Rating[b/] [c/]
SC 394	2.16 h
SC 298	2.16 h

a/ "SC" indicates member of sorghum conversion program, Stephens et al., 1967.
b/ 0 = no damage, 5 = 81-100% necrosis.
c/ Means followed by the same letter do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

Table 7. Greenhouse flat screening necrosis evaluation Test A. Manhattan, Kansas, 1979.

Designation [a]	Mean Necrosis Rating by Date [b] [c]			
	July 4	July 6	July 8	July 10
SC 63	5.00 a	5.00 a	5.00 a	5.00 a
Wheatland	5.00 a	5.00 a	5.00 a	5.00 a
DD Yellow Milo	5.00 a	5.00 a	5.00 a	5.00 a
SC 321	4.66 ab	5.00 a	5.00 a	5.00 a
SC 578	4.66 ab	5.00 a	5.00 a	5.00 a
SC 48	4.66 ab	4.83 ab	5.00 a	5.00 a
SC 237	4.00 abc	5.00 a	5.00 a	5.00 a
SC 320	3.82 abcd	4.33 abcd	4.66 a	5.00 a
SC 319	3.75 abcd	4.00 abcde	4.50 ab	5.00 a
SC 215	3.66 abcd	4.16 abcd	4.66 a	5.00 a
Combine Kafir 60	3.66 abcd	3.66 abcdef	4.50 ab	4.66 a
SC 216	3.16 abcd	3.33 abcdef	4.83 a	4.83 a
SC 418	3.00 abcd	4.50 abc	4.50 ab	4.50 a
SC 317	2.83 abcd	2.83 bcdef	4.50 ab	5.00 a
SC 291	2.66 abcd	3.33 abcdef	4.66 a	5.00 a
SC 372	2.66 abcd	3.66 abcdef	4.16 abc	5.00 a
SC 244	2.33 bcd	2.33 def	4.16 abc	4.66 a
SC 6	2.33 bcd	3.16 abcdef	4.16 abc	4.66 a
Redlan	2.33 bcd	3.00 abcdef	4.00 abc	4.00 ab
SC 405	2.25 bcd	3.66 abcdef	4.00 abc	4.16 ab
SC 124	2.16 bcd	2.66 cdef	3.83 abc	5.00 a

Table 7. Continued.

Designation [a/]	Mean Necrosis Rating by Date [b/] [c/]			
	July 4	July 6	July 8	July 10
Redbine 60	2.16 bcd	2.66 cdef	4.00 abc	4.33 ab
SC 307	2.00 bcd	2.33 def	3.83 abc	4.33 a
SC 322	2.00 bcd	3.33 abcdef	4.50 ab	4.66 a
SC 303	1.75 bcd	1.83 f	1.83 d	3.66 ab
SC 563	1.75 bcd	1.83 f	2.66 cd	3.00 b
SC 504	1.50 cd	2.33 def	4.16 abc	5.00 a
SC 66	1.25 cd	2.00 ef	3.00 bcd	3.00 b
SC 44	1.00 d	2.00 ef	3.66 abc	4.00 ab

a/ "SC" indicates member of sorghum conversion program, Stephens et al., 1967.
b/ 0 = no damage, 5 = 81-100% necrosis.
c/ Means with the same letter in vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

Table 8. Greenhouse flat screening necrosis evaluation Test B. Manhattan, Kansas, 1979.

Designation a/	Mean Necrosis Rating b/ c/
DD Yellow Milo	4.50 a
SC 285	4.20 ab
SC 63	4.20 ab
Wheatland	3.80 abc
SC 319	3.80 abc
SC 173	3.70 abcd
SC 372	3.60 abcde
SC 17	3.50 abcdef
SC 58	3.50 abcdef
78-20-55	3.50 abcdef
KS 65	3.30 abcdefg
SC 237	3.30 abcdefg
1-70	3.20 abcdefgh
SC 16	3.20 abcdefgh
SC 170	3.20 abcdefgh
SC 337	3.20 abcdefgh
Wiru	2.10 abcdefgh
Martin	3.00 bcdefgh
SC 358	2.90 bcdefghi
SC 33	2.80 bcdefghij
SC 605	2.70 cdefghijk

Table 8. Continued.

Designation [a]	Mean Necrosis Rating [b] [c]
SC 418	2.50 cdefghijkl
SC 6	2.50 cdefghijkl
SC 307	2.30 defghijklm
Redlan	2.20 efghijklmn
SC 326	2.20 efghijklmn
TAM 428	2.20 efghijklmn
Combine Kafir 60	2.10 fghijklmno
SC 291	2.10 fghijklmno
SC 320	2.00 ghijklmno
SC 241	2.00 ghijklmno
SC 504	1.90 ghijklmno
BH 64	1.80 hijklmno
SC 66	1.50 ijklmno
Redbine 60	1.50 ijklmno
SC 317	1.50 ijklmno
SC 599	1.40 jklmno
SC 563	1.40 jklmno
1155	1.30 klmno
SC 175	1.30 klmno
Cimmyt 1339 x KS 44	1.30 klmno
Atlas	1.20 klmno
BCK 60 - Tunis Grass	1.20 lmno

Table 8. Continued.

Designation [a/]	Mean Necrosis Rating [b/] [c/]
SC 124	1.00 mno
KS 6	0.80 no
SC 303	0.70 o

a/ "SC" indicates member of sorghum conversion program, Stephens et al., 1967.
b/ 0 = no damage, 5 = 81-100% necrosis.
c/ Means followed by the same letter do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

Table 9. Mean grain yields for chinch bug protected and unprotected plots. Manhattan, Kansas, 1979.

		Grain Yield bu/acre a/		Yield Loss bu/acre
Company	Hybrid	Insecticide	No Insecticide	
Pioneer	8324	161.7 a	125.4 bcde	36.3
Funk	G 623	130.9 bcde	121.0 cdef	9.9
Funk	G 522	134.0 bcde	105.1 f	28.9
Funk	G 404	119.5 def	67.7 g	51.8
Funk	HW 2124 Exp.	135.4 bcd	127.4 bcde	8.0
Dekalb	DK 61	136.0 bcd	115.3 ef	20.7
Funk	HW 2194 Exp.	141.6 b	122.1 bcdef	19.5
NC+	170	140.9 bc	124.3 bcdef	16.6

a/ Means followed by the same letter are not significantly different at the 5% level. LSD = 20.05.

Table 10. Hybrid screening test growth stage 2 and 9 necrosis evaluation and growth stage 5 and 9 stunting evaluation. Manhattan, Kansas, 1979.

Company	Hybrid	Mean Necrosis Rating a/ d/ Growth Stage c/		Mean Stunt Rating b/ d/ Growth Stage c/	
		2	9	5	9
Funk	HW 2124 Exp.	1.75 abcd	2.87 def	1.00 e	2.00 d
Funk	G 642	2.00 abcd	2.75 def	1.50 cde	2.00 d
	AH 64 x RKS 6	2.00 abcd	2.75 def	1.50 cde	2.12 d
	AH 64 x RKS 53	2.50 abcd	2.50 f	2.00 cde	2.12 d
Prairie Valley	599	1.50 bcd	2.62 ef	1.25 de	2.12 d
Pioneer	8324	1.50 bcd	2.87 def	1.50 cde	2.25 d
Pioneer	8585	1.12 d	4.62 a	2.75 abcd	2.87 cd
Prairie Valley	708	1.00 d	2.75 def	2.25 bcde	3.00 cd
Prairie Valley	530	2.87 abc	3.00 cdef	3.12 abc	3.37 bc
Funk	HW 2194 Exp.	3.00 ab	3.25 bcde	3.00 abc	4.00 ab
NC+	170	1.62 abcd	3.63 bc	4.00 a	4.12 ab
DeKalb	DK 61	2.25 abcd	3.63 bc	3.75 ab	4.37 a
Funk	G 404	3.25 a	3.62 bc	3.87 ab	4.62 a
PAG	4488	2.37 abcd	3.87 b	3.87 ab	4.75 a

a/ 0 = no damage, 5 = 81-100% necrosis.
b/ 0 = no plants with rossetting, 5 = 81-100% with rossetting.
c/ Vanderlip, 1972.
d/ Means with same letter in vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

Table 11. Chinch bug control on sorghum with seed and soil treatments at planting. Manhattan, Kansas, 1978.

Treatment	Form.	kg/AI/ha	Placement	Avg. no. live chinch bugs/caged plant c/		
				Test 1		Test 2
				8 days a/	21 days b/	14 days d/
Disulfoton	15G	1.12	Band	7.1 a	13.0 cd	8.8 b
Carbofuran	10G	0.56	Band	7.1 a	9.6 de	0.0 e
Untreated				6.6 ab	20.5 abc	10.8 b
Terbufos	15G	1.12	Band	6.6 ab	16.8 bcd	0.5 e
Phorate	15G	1.12	Band	6.3 abc	24.5 a	5.0 c
Carbofuran	10G	1.12	Band	5.1 bc	5.3 ef	0.0 e
Carbofuran	10G	0.84	Band	4.7 c	13.5 cd	0.0 e
Carbofuran	10G	0.28	Furrow	1.3 d	18.3 abc	4.3 cd
Carbofuran	10G	0.56	Furrow	0.7 d	5.3 ef	2.1 cde
Carbofuran	10G	0.84	Furrow	0.3 d	4.6 ef	1.3 de
Carbofuran	Seed treat.	1.12 kg/112 kg	Seed	0.2 d	23.6 ab	15.5 a
Carbofuran	10G	1.12	Furrow	0.0 d	4.6 ef	1.5 de
Terbufos	15G	1.12	Furrow	0.0 d	1.8 f	1.3 de
Carbofuran	Seed treat.	2.24 kg/112 kg	Seed	0.0 d	18.6 abc	9.0 b
Carbofuran	Seed treat.	4.48 kg/112 kg	Seed	0.0 d	14.8 cd	10.0 b

a/ Ten adult chinch bugs per plant caged on 8 plants.
b/ Forty chinch bug nymphs per plant caged on 6 plants.
c/ Means with the same letter in the vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.
d/ Twenty adult chinch bugs per plant caged on 6 plants.

Table 12. *Chinch* bug control and yield of sorghum with seed and soil treatments at planting. Manhattan, Kansas, 1979.

				Mean		Mean		Mean		Mean
				Chinch bugs a/e/	Chinch bugs b/e/	Chinch bugs b/e/	Plant damage d/e/	Chinch bugs d/e/	Plant survival c/e/	Yield e/ bu/A
Treatment	Form.	AI/ha	Placement	10 days	20 days	30 days		40 days		
Untreated				6.3 a	46.1 a	39.0 abc	4.4 a	15.2 ab	15.0 e	6.2 ef
Terbufos	15GC	1.12	Band	5.2 ab	41.0 ab	48.2 ab	4.3 a	18.4 ab	10.5 e	1.4 f
Terbufos	15G	1.12	Band	5.0 ab	33.2 bc	32.6 bc	4.5 a	26.2 a	22.3 e	4.9 ef
Phorate	15G	1.12	Band	5.0 ab	42.0 ab	56.4 ab	4.3 a	21.4 a	8.6 e	1.4 f
Carbofuran	10G	1.12	Band	3.8 bc	10.9 ef	31.3 bc	1.8 ghi	10.1 ab	90.6 ab	64.3 b
Disulfoton	15G	1.12	Band	3.8 bc	38.6 ab	73.1 a	4.1 ab	19.2 ab	14.6 e	3.1 f
Carbofuran	10G	0.86	Furrow	2.2 cd	20.9 de	50.4 ab	2.6 ef	13.2 ab	57.0 c	53.6 b
Acephate	5G	1.12	Furrow	1.5 d	41.6 ab	31.5 bc	4.3 a	11.8 b	19.3 e	7.3 ef
Bendiocarb	10G	1.12	Furrow	1.4 d	20.0 de	23.6 bc	1.6 hi	14.6 ab	86.0 ab	66.4 b
Terbufos	15G	0.86	Furrow	1.1 d	22.6 cde	35.8 bc	2.5 fg	12.8 b	65.0 abc	25.2 cd
Terbufos	15GC	1.12	Furrow	1.1 d	22.6 cde	59.2 a	3.0 def	24.5 a	55.0 cd	12.5 cdef
Carbofuran	seed treat.	1.12kg/112 kg		1.1 d	40.8 ab	47.2 abc	4.5 a	20.2 ab	15.6 e	3.8 f
Carbofuran	seed treat.	2.24kg/112 kg		1.1 d	31.6 bcd	72.5 a	3.5 bcd	10.8 b	30.0 de	10.1 def
Terbufos	15G	1.12	Furrow	1.0 d	17.4 ef	34.8 bc	3.3 cde	16.8 ab	62.0 bc	20.4 cde
Carbofuran	10G	1.12	Furrow	0.9 d	14.7 ef	29.0 bc	2.3 fgh	21.4 ab	92.3 a	53.6 b
Carbofuran	seed treat.	1.78kg/112 kg		0.9 d	34.7 ab	68.5 a	3.8 abc	18.1 ab	29.0 de	16.9 cdef
Carbofuran	4F	1.12	Furrow	0.8 d	7.0 ef	14.6 c	1.1 i	16.4 ab	91.0 a	88.9 a

a/ Avg. no. chinch bugs surviving per plant after 10 adult bugs were confined on a single plant for 2 days. Four plants caged per replicate.
b/ Avg. no. chinch bugs/plant. Five plants counted per replication.
c/ Avg. of three replications
d/ Scale of 0-5, 0 = no damage, 5 = 81-100% necrosis. Rating based on visual analysis of entire replication.
e/ *Means with same* letter in vertical column do not differ significantly ($P < 0.05$). Duncan's new multiple range test.

CHINCH BUG, BLISSUS LEUCOPTERUS LEUCOPTERUS (SAY):

SCREENING OF GRAIN SORGHUM GERMPLASM FOR RESISTANCE

AND EVALUATION OF INSECTICIDES AT PLANTING TIME FOR CONTROL

by

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B. S., Texas Tech University, 1978

AN ABSTRACT OF A MASTER'S THESIS

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Several studies were carried out in 1978 and 1979 to investigate public and commercial sorghum germplasm for existing levels of chinch bug resistance, and to evaluate the efficacy of planting-time treatments for controlling chinch bugs with six systemic insecticides. Lines and hybrids from many sources were planted at various field locations in Eastern Kansas exposed to chinch bug infestations differing in intensity and type. Respective evaluations for plant stunting, plant necrosis, and grain yield gave statistically significant differences in all tests which received a uniform, non-lethal initial population of chinch bugs on all replications. Certain lines of both converted line and Kansas origin were consistently lower in damage ratings over the variable testing environments, and generally less damaged than the previously identified resistant lines used as checks. Greenhouse techniques developed for the resistance studies proved to be a successful method of screening seedlings with artificial infestations. Overall most of the consistent superior lines were not statistically different from a large segment of the materials tested due to the necessary rationing of experimental units. Chinch bug resistance levels which could reduce damage caused by adult infestations in mid-July were found in some commercial and public hybrids. Hybrids of Kafir origin were usually more resistant to such infestations than those of Milo parentage. Planting-time applications of insecticides at variable rates, formulations, and placements were evaluated in three tests for chinch bug control with artificial and natural infestations. Significant differences were noted among treatments for chinch bug mortality, plant necrosis, and grain yield. Each parameter reflected the residual activity of the treatments. In-furrow carbofuran, terbufos, bendiocarb, or acephate and seed treatments of carbofuran gave good initial control. Band treatments were ineffective without rainfall. In-furrow and banded carbofuran and in-furrow bendiocarb provided the longest residual control, up to 30 days after planting.