A COMPARISON OF TECHNIQUES FOR SCREENING FOR RESISTANCE TO THE CHINCH BUG, BLISSUS LEUCOPTERUS LEUCOPTERUS (SAY), IN SORGHUM

by

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TABLE OF CONTENTS

LIST OF TABLES

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INTRODUCTION

The chinch bug, Blissus leucopterus leucopterus (Say), is recognized as one of the more injurious insect pests of cereal crops in the United States. This insect is native to North America, and subsists on native prairie grasses. Continual prairie fires and resistance of the grasses to chinch bugs suppressed the insect population until settlement of territories brought about a decrease in prairie fires and an increase in small grain growing. This resulted in an increase of chinch bug numbers and consequent crop injuries (Swenk, 1925).

The first records of serious injury by this insect are found in North Carolina in 1785 (Webster, 1909), however it was not until 1840-1844 that attention was attracted to the pest in the Western States (Fitch, 1856). Serious outbreaks have been documented frequently ever since.

The chinch bug seems to become more abundant after one or more years of hot, dry summers (Polivka and Frons, 1966). Haseman (1946) noticed chinch bugs were usually found breeding on eroded hillsides when given a choice where warm, sunny and dry conditions existed.

In the midwest there are usually two generations of chinch bugs per year. As winter approaches, the adult bugs search for shelter, often within grasses, weeds, drifted leaves and litter along roadsides, edges of fields, and ravines. In the plains states dense tufts of bunch-forming prairie grasses are favorite over-wintering quarters. In the spring bugs fly or crawl to a supply of green food such as wheat and other small grains. During May bugs begin to mate and deposit eggs singly or in rows in soil surrounding the plant and on the plant behind the leaf sheath near the soil line. Eggs are about 1.7-2.0 mm long by one-third as wide, bean-shaped with one end rounded and the other flattened and bearing 3-5 small tubercles.

Eggs are dull white at first, then darken to amber to reddish as the nymphs develop within. Eggs hatch in May and June and nymphs grow through 5 instars before becoming adults. Young nymphs are reddish with a white median dorsal band. Fourth instar nymphs turn black but still have a white band, which appears as a white diamond in the fifth instar because the wingpads reaching the third abdominal segment cover the sides of the band. When small grains begin to mature and dry, the nymphs living there are forced to migrate to the nearest food source, which is usually adjacent young corn or sorghum where they cause damage. First generation adults deposit their eggs on larger plants in June, July and August. The second generation can also be damaging and matures from the middle of August through October. Cool October and November weather drives the chinch bugs back to their hibernating quarters. A diapause is induced by short day lengths (Smith et al. 1981).

Heavy May or June rains often greatly reduce the number of offspring of a large overwintering population of chinch bugs. Shelford and Flint (1943) discovered a relationship between populations of this insect and the number of sun spots, explaining that during years with high numbers of sunspots, an above average amount of precipitation occurs. Swenk (1925) reported that lower chinch bug populations during wet years is accountable to the higher incidence of the fungus Beauveria bassiana. However, we have observed that early instar nymphs, especially the first instar, have a high rate of mortality when exposed to physical factors such as tiny droplets of water. They become caught, are unable to escape and soon die.

Because of the introduction of supplemental food sources for the chinch bug and its ability to overwinter and adapt to a wide variety of grasses, the chinch bug has the potential to be a major pest for years to come. Environmental and biotic factors only keep the insect in check during

certain years. Therefore, much crop damage occurs during other years. One important way of dealing with chinch bugs is to develop resistant sorghum varieties. Resistance may be used exclusively or in conjunction with another control method. There are several reasons why a simple, reliable screening technique for sorghum resistance to chinch bugs would be welcomed. Several field studies have been conducted to evaluate sorghum lines and hybrids for chinch bug resistance. They have been characterized by a large amount of variability. In addition, during periods of low field populations, greenhouse screening with reared or collected chinch bugs might be the best alternative available.

The main objective of this research was to develop reproducible screening techniques for testing for sorghum resistance to chinch bugs in the greenhouse. Several field studies have identified the degree of resistance in some lines and hybrids. This information was used to select entries tested and comparisons were made to field acquired data. Most procedures were kept simple, inexpensive and short in time relative to field screening. Different practical techniques for caging chinch bugs on plants and storing or maintaining chinch bug colonies for further use were also explored.

Specific objectives were to (A) determine how different numbers and stages of chinch bugs damage various sorghum lines and hybrids, (B) develop a procedure for screeing sorghum lines and hybrids for chinch bug resistance under choice and no-choice conditions, (C) compare greenhouse versus growth chamber conditions while screening for chinch bug resistance in seedling sorghums, (D) study the effects of different chinch bug infestation levels during the seedling stage on subsequent plant growth and yield, and (E) investigate methods of storing or maintaining chinch bugs for future use other than in high maintenance cultures.

LITERATURE REVIEW

Controls of The Chinch Bug

One of the first successful efforts to control the chinch bug Blissus leucopterus leucopterus (Say), was reported by Walsh (1866), who fenced chinch bugs out of a field by putting boards on sides and coating the upper edge with coal tar. Dust, oil line and gas barriers, along with trap crops and destruction of bugs in their winter quarters were all variably successful methods of control during the turn of the century (Burkes, 1934). Different planting dates to minimize chinch bug injury was proposed by Osborn (1888).

Efforts were made to artifically spread the white-fungus disease as early as 1888 in Illinois and Minnesota. During the next 10-15 years several midwestern states received thousands of packages of innoculated bugs. The practice was belived to be worthwhile at first, but it became apparent that when weather and other conditions were favorable, the natural distribution of the fungus was already significant enough to make artificial distribution of the fungus impractical (Swenk, 1925).

The first successful attempt to control the chinch bug by sprays was made in 1882 when Forbes (1883) experimented with emulsions of kerosine and soap and kerosine and milk. However, by 1913 Headlee and McColloch reported that kerosine emulsions concentrated enough to kill bugs were also so injurious to corn that it could not be used practically. Luginbill and Benton (1945) determined that DDT was an effective barrier to chinch bugs between fields at a 5 percent concentration level. Gannon and Decker (1955) reported that dieldrin and endrin were effective as barrier treatments and prevented migration. Randolph and Teetes (1965) found that spray applications of toxaphene, toxaphene + DDT + methyl parathion and endosulfan + parathion

controlled chinch bugs 6 days after application. Foliar applications of ethyl parathion, carbaryl, Penn Cap E, and carbofuran significantly reduced chinch bug populations on sorghym 3 days after treatment according to Wilde and Morgan (1978), and a planting-time soil application of grandular carbofuran or phorate successfully controlled chinch bugs in laboratory tests. Mize et. al. (1980) reported that the most effective planting time treatment 20 days after sorghum was planted were granular carbofuran in-furrow, and liquid carbofuran in-furrow.

The only insect enemy of the chinch bug of considerable importance noted by Shelford and Flint (1943) is the small egg parasite Eumicrosoma benefica (Gahan). Numerous predaceous insects also attack the chinch bug, including nymphs of the gray damsel bug, Reduvioulus ferus (L.), and certain small ground beetles such as Blechrus glabratus (Lec) and B. pusio (Lec). Nymphs and adults of the bug Pagasa fusca (Stein) and Triphleps insidiosus (Say) are also important in control.

Resistant varieties as a principal control method is used most often with plant parasites with high host specificity. A chinch bug population will probably not be killed by a resistant sorghum but it may save the harvest. Insect resistance may be most commonly used as an adjunct to other control measures. We may always need to be prepared to treat young sorghum against chinch bugs, but resistant varieties may furnish a defense against second and third generations (Painter, 1944).

The effect of hosts on the biology of insects has been studied intensively for many insects. Dahms (1948) discovered that chinch bug susceptible varieties caused bugs to lay more eggs, grow larger, mature faster, and live longer than insects reared on resistant sorghums. Older plants also tend to cause bugs to lay more eggs, live longer and have a faster nymphal

development rate than younger plants, but do not significantly affect the size of the insects. According to Painter (1951), even the most resistant seedling sorghum plants may be killed by a large number of bugs.

Dahms (1948) stated that generally the milos are very susceptible, the feteritas susceptible, and the kafirs and sorgos rather resistant. The basis of these resistances was believed to be related to the condition or composition of the cell sap rather than any morphological character of the plant. Ball and Leidigh (1908), Churchill and Wright (1914), Cunningham and Kenney (1918), Hayes (1922), Daune and Klages (1928), Martin (1933), Swanson and Laude (1934), and others also noted the susceptibility of milos to chinch bugs. Dahms and Sieglinger (1954) reported that Wheatland, Westland, and Martin appeared to be moderately resistant to chinch bugs, with Midland, Plainsman, and Caprock being very susceptible. Honey and Shaller forage sorghums were also found to be quite susceptible. Wilde and Morgan (1978) found that Early Sumac was significantly more resistant to chinch bugs at the seedling stage than Honey, Redlan and Spanish Broomcorn sorghum lines. Ahmad et al. (1984) found that sublethal infestations of chinch bugs on sorghum hybrid Dekalb DK-61 seedlings reduced grain yields by as much as 68%.

MATERIALS AND METHODS FOR ALL TESTS

Insects used in all tests for this study were obtained through a stock culture maintained in the greenhouse on pearl millet. Field bugs were collected periodically and added to the culture to help minimize deleterious inbreeding affects. Insects were collected from the culture for experimentation by mouth aspirators or a similar technique using a vacuum cleaner. Desired insect populations and growthstages were obtained for tests by caging about 15 pairs of young adults on 10-15 six to eight week old pearl millet plants about 7-10 weeks prior to the experiment. The plastic culture pots were 15 cm diameter by 15 cm deep. Cages were 35-45 cm long clear plastic cylinders with mesh-covered air holes and fitted inside the pots at the soil line.

Soil for all tests and culture consisted of a one part perlite, one part vermiculite, one part sterlized clay loam and two parts peat mixture. All tests and culture plants received one or two waterings from the top as a starter, but were watered only from the bottom using large water trays thereafter.

The first part of this study involved subjecting several different sorghum hybrids and lines of known field resistance to varying amounts of chinch bugs of different instars to try to estimate the number of bugs needed to screen for plant resistance. These experiments were performed in the greenhouse and or growth chamber. Several hybrids and lines were used throughout all tests, usually including Funk G 1642 and PAG 4433 as the resistant and susceptible hybrid checks and BCK 60 1155 and Wheatland as the resistant and susceptible line checks.

A. How different numbers and stages of chinch bugs damage various sorghum lines and hybrids.

Materials and Methods

Single Plant No-Choice Test A1. The first test consisted of infesting 2 hybrids with 9 different nymph infestation treatments listed with the results in Table A1. There were 4 replications. Seeds were planted in 3.8 cm diameter by 20 cm deep white plastic Supercells® placed in 36 by 72 cm holding racks. Soil was lightly tamped within 3-4 cm from the top of each cell. Three to five seeds were placed at that level and then covered with approximately 2 cm of soil. Seedlings were kept in the sunny areas of the greenhouse to aid in emergence and growth. As seedlings developed to 3 cm, all except the most vigorous plant were pulled from each cell. The entire seedling, including the seed had to be pulled to prevent regrowth. Plants were in the 2 leaf stage, or approximately 13-15 cm from the soil line to the tip of the tallest leaf with the collar of the third leaf not showing yet when infested. Two and one-half by 30 cm clear plastic tubes were used as cages and fitted snugly into the supercell to prevent bug escape. Three air holes about 3 cm in diameter were cut out on all sides in the middle half of the cage and covered with fine cloth to allow for ventilation. Liquid teflon was painted inside the top 2-5 cm of the cages to help prevent the insects from escaping. Foam stoppers were fitted snugly into the tops to prevent bugs from emigrating or immigrating. Approximately 1 cm of fine sand was placed around each plant prior to infestation to help simplify bug recovery with the mouth aspirator. Treatments were evaluated by counting the number of days after infestation until total plant necrosis. Bugs were recounted immediately after plant death to estimate an approximate escape

percentage. If recovery was less than 75% the data for that cell was not used in the analysis. Data for all tests in this section were analyzed with analysis of variance and means were compared using Duncan's new multiple range test, (Duncan, 1955) at a significance level of 5%.

Single Plant No-Choice Test A2. The design of this test was the same as the preceding except 3 sorghum lines were infested with 6 different treatments at 4 replications each as described in Table A2 with the results.

Multiplant No-Choice Test A3. Sorghum hybrids Funk G 499 and NC+ 271 were infested with several different numbers of adult chinch bugs per plant at different numbers of plants per pot as explained in Table A3 with the results. There were 4 replications. Seeds were planted in the usual soil mixture in a scattered distribution in 15 by 15 cm pots and watered as ususal in the greenhouse. Plants were infested 15-16 days after planting at the 3 leaf stage with the third collar showing. Adult chinch bugs were sexed the day prior to infestation by using a magnifying glass and a cold plate to slow the insect's movements. All males and all females were caged on separate millet culture plants to avoid remixing. The pots were sanded and caged before infestation. Plant mortality counts were taken each day, and the test was terminated when all treatments reached approximately 75% plant mortality. The number of adults and their progeny were recorded at the termination of each pot.

Results and Discussion

Single Plant No-Choice Test A1. A summary of the results of the first test appear in Table A1. A significant difference in days until necrosis occurred between infestation levels, but not between the two hybrids at the same infestation level. The largest difference between hybrids at the same infestation level was with 10 fourth instar nymphs, with Funk G 550 mean

days until necrosis being 18.50 versus Funk G 499 at 13.25 days. The results show that the more insects per plant, the fewer days until necrosis, but there was little difference between third, fourth, and fifth instar nymphs in causing plant mortality.

Single Plant No-Choice Test A2. Results of the nymph line test with differing infestation levels are listed in Table A2. Fewer bugs were used on lines than on hybrids because of the lack of vigor found in lines. Treatment KS 72 with 5 thirds was deleted because of poor germination. Treatment KS 72 with 10 fifths was killed significantly later than KS 71 or TX 7078 at the same infestation rate, and TX 7078 with 10 fourths was significantly more susceptible than KS 71 and KS 72 at the same infestation level. However, these differences were not manifested at the other treatment levels.

Multiplant No-Choice Test A3. When all infestation levels were combined for analysis, hybrid Funk G 499 had significantly more dead plants than NC+ 271 on all 4 days data were analyzed. The average date of termination was also significantly less with G 499 than NC+ 271 over all infestation levels, but there was no significant difference in the number of bugs recovered (Table A3). In the individual infestation comparisons, G 499 was significantly more susceptible than NC+ 271 at the 7 pair 5 plant and 10 pair 8 plant infestation levels (Table A4). There was no significant difference in bug numbers between hybrids within any treatments.

Conclusions

It was decided that third, fourth or young fifth instar nymphs were best suited for no-choice plant studies that were to be done later. Using older fifth instar nymphs posed the problem of their molting to the adult stage and then feeding less than nymphs which resulted in less plant damage.

Results of these and other tests indicated that a desired infestation level that results in plant mortality within 2 weeks but still allows some exhibition of the mechanisms of resistance is approximately 1.4 third, fourth or early fifth instar nymphs per cm of seedling growth of sorghum hybrids and 1.0 third, fourth or early fifth instar nymphs per cm of seedling growth for lines. The test using hybrids suggested that infesting with 1-2 pair of adults per 3 leaf plant is a good infestation level for tests involving adults and their progeny over a 30-40 day period.

B. Developing a procedure for screening sorghum lines and hybrids for chinch bug resistance under choice and no-choice conditions.

Materials and Methods

Nymphal Choice Test B1. Five commercial sorghum hybrids, Funk G 1642, O's Gold GS 712, Pioneer X 5563, Pioneer X 3082, and PAG 4433 were tested to determine susceptibility under choice conditions to chinch bug nymphs. Five replications each containing the 5 hybrids were planted in standard black plastic 20 cm diameter by 20 cm deep pots in the greenhouse. Ten seeds of each hybrid were planted in a straight line within 2-3 cm around the perimeter of the pot to 2-3 cm from the center, each equidistant from the other to form a five-spoked wagon wheel pattern. Seedlings were thinned to the 5 most vigorous plants in each hybrid. Twenty cm diameter by 50 cm tall clear plastic cages which fit snugly inside of the pots were used to retain 250 fourth instar chinch bugs per pot (10 bugs per plant) when plants were 12-14 cm tall. Fine sand was added to the pots prior to infestation to assure minimal bug escape and aid in bug recovery. Cages had three 7 cm air holes covered with fine cloth to reduce moisture condensation and temperature buildup, and had the inside top 5-8 cm painted with liquid teflon to

retain crawling bugs. "No-see-um" netting was rubberbanded over the top of the cages to prevent escape of flying bugs. Treated pots were kept shaded in the green house under canopies of white bedsheets draped over wooden frames which housed fluorescent and incandescent lamps set for 16 hour photoperiods. The number of dead plants of each hybrid in each pot was recorded each day until all plants were killed. All data in this section were analyzed with analysis of variance and means were compared using Duncan's new multiple range test (Duncan, 1955) at a significance level of 5%.

Nymphal Single Plant No-Choice Test B2. The 6 hybrids tested in B1 were evaluated in a no-choice test. Six replications of each hybrid were planted at 3 seeds each and later thinned to the most vigorous seedling per supercell. The most vigorous 5 replications of each hybrid were sanded and caged in the usual manner and infested with 20 fourth instar nymphs per plant at 10-14 cm height (2 leaf stage). Days until plant death after infestation was recorded.

Nymphal Choice Test B3. The same procedure discussed in Test B1 was performed with 5 sorghum lines, BCK 60, BCK 60 1155, KS 71, KS 72 and Wheatland. Four replications were infested with 250 bugs (1/2 third and 1/2 fourth instar nymphs) at a seedling height of 12-14 cm. The objective was to study the chinch bug susceptibility of lines in a choice situation.

Nymphal Single Plant No-Choice Test B4. The same procedure discussed in Test B2 was performed with the same lines in Test B3, except 15 fourth instar nymphs were used. The objective was to compare seedling susecptibility in a no-choice situation.

Adult Choice Test B5. Two groups of 3 seeds of each hybrid Pioneer X 3082, X 5563, Funk G 1642, PAG 4433 and O's Gold GS 712 were randomly planted around the perimeter of 15 cm pots. Plants were thinned to the 2

most vigorous seedlings of each entry and infested with 20 pair of young adult chinch bugs at the 3 leaf stage (20 cm). There were 5 replications, with 2 observations per entry (10 observations per pot or rep.). Plants were rated on a 1-9 scale (1 = normal growth, 9 = dead) at 19, 23 and 28 days after infestation.

Adult Choice Test B6. Sorghum lines BCK 60 1155, KS 72, KS71, BCK 60 and Wheatland were tested in the same manner as B5 except 15 pair of new adults were caged per pot at the 3 leaf stage (16 cm). There were 5 replications, with 2 observations per replication.

Nymphal Multiplant No-Choice Test B7. Five 15 cm pots of each hybrid PAG 4433, Funk G 499 and Dekalb DK 58 were planted with 20 seeds and thinned to 8 seedlings each upon emergence. Plants were sanded and caged at 12-14 cm and infested with 120 fifth instar nymphs per pot. The number of totally necrosed plants were counted for each pot every day, and the test was terminated when all plants were necrosed. The number of bugs recovered after necrosis of all plants in each pot was recorded to assure plants did not survive longer because of insect escape.

Adult Multiplant No-Choice Test B8. Four replications of hybrids Funk G 404 and Dekalb DK 61 were planted and grown in 15 cm pots. Plants were thinned to the 10 most vigorous seedlings and infested with 10 pair of adults per pot at 20-24 cm (3 leaf stage). A daily record was kept of permanently wilted (totally necrosed) plants. The number of adults and progeny recovered and days until termination (80% plants dead in that pot) were recorded.

Adult Mulitplant No-Choice Test B9. Three replications of twenty seeds were planted of 8 hybrids per 15 cm pot, later thinned to the 10 most vigorous seedlings, and infested with 10 pair of adult chinch bugs at 15-20 cm height (3 leaf stage). Leaves were cut off several cm below the top of

the cage to prevent plant "congestion" on plants that grew that tall, as in Test B6. A daily record of totally necrosed plants was kept, and the test was terminated when 80% of all plants were dead. The number of adults and their progeny were recorded at the termination of each pot.

Adult Mulitplant No-Choice Test B10. Twenty seeds of hybrids PAG 4433, NK 2778, Funk G 1642 and NC+ 271 were planted in 15 cm pots, and later thinned to the 10 most vigorous seedlings. When plants reached the 3 leaf stage, 4 replications of pots were sanded, caged, and each infested with 15 pair of new adults. Plant mortality was recorded each day and number of adults and progeny were recorded when 80% of all plants in a pot were dead.

Nymphal Single Plant No-Choice Test B11. Sorghum hybrids O's Gold GS 712 and Funk G 1642 were planted at 3 seeds per supercell with 7 replications per hybrid. Seedlings were thinned to the most vigorous seedling, sanded, caged and infested at the 2 leaf stage (13-18 cm) with 15 third and 10 fourth instar nymphs. The number of days until total plant death and number of bugs present at plant death were recorded.

Nymphal Single Plant Stunting Test B12. Funk G 404, Funk G 1642 and O's Gold GS 712 sorghum hybrids were tested in this stunting experiment. Five replications of 3 seeds per supercell were planted and thinned to the most vigorous seedling when height permitted. Plants were sanded, caged and infested with 10 fourth and 10 fifth instar chinch bugs when 20-22 cm tall (fourth leaf, collar showing). Bugs were left on for 3 and 5 days for each hybrid. Controls were also caged to correspond with the treatments. The hybrids were compared by calculating the plant height difference between each treated plant and its' control initially, 5 and 10 days after insect removal (Table 12). Plants were measured at the original soil line, grown in the greenhouse and watered from the bottom as usual.

Nymphal Multiplant No-Choice Test B13. Sorghum lines TX 7078, KS 71

and KS 72 were planted at 15 seeds per 15 cm pot, and later thinned to the 5 most vigorous seedling per pot at 2-4 replications each. Thirty-five fourth instar nymphs were placed in each pot (7 fourths per plant) when plants were 14-18 cm in height. Plant mortality in each pot was recorded daily and a count of all bugs retained was made at the conclusion of the experiment.

Adult Multiplant No-Choice Test B14. Three replications of lines KS 71 and KS 72 were infested with 12 pair of adults per 8 seedlings in 15 cm pots. Plants were in the 3 leaf stage (20 cm) when infested. Plant mortality was recorded each day after infestation and observations were terminated on individual pots when 80% of the plants were dead. The number of days to this point was recorded for each pot. Leaves were clipped just through the midrib several centimeters below the top of the cages to minimize bug escape and to keep all plant material alive. Adult and progeny counts were recorded at termination.

Nymphal Single Plant No-Choice Test B15. Three seeds of BCK 60, BCK 60 1155, KS 71 and Wheatland were planted in a supercell and all seedlings were thinned except the most vigorous. Plants were sanded, caged and 4-6 replications were infested with 5 third and 10 fourth instar nymphs at an average plant height of 15 cm (2 leaf stage). Number of bugs retained and days until plant mortality were recorded, with mortality in this test being all leaves or all but one being permanently wilted.

Adult Multiplant No-Choice Test B16. Four replications of lines BCK 60, KS 71 and Wheatland were planted at 20 seeds per 15 cm pot. The 10 most vigorous seedlings were infested with 13 pair of new adults when the third leaf collar appeared. Prior to the experiment, fifth instar nymphs were separated from the rearing culture and adults from these pots were used. Plants were infested when the third leaf collar appeared. Heights of the

lines varied at the third collar stage: BCK 60 18-21 cm, KS 71 15-17 cm, and Wheatland at 19-23 cm. The number of plants dead in each pot was recorded daily until approximately 80% of all plants were killed. The number of bugs found in each pot was then recorded.

Results and Discussion

Nymphal Choice Test B1 and Single Plant No-Choice Test B2. Plant mortality was significantly greater with PAG 4433 than several of the other hybrids exposed to chinch bug nymphs in the seedling stage at 8, 10, 12, and 14 days after infestation in a choice situation (Table B1-B2). O's Gold GS 712 had consistently fewer and significantly less dead plants than PAG 4433 at the above dates in the choice test. These results agree with those obtained in a field test conducted by Wilde et al. (1982) where they found PAG 4433 the most susceptible entry in their tests. Hybrid Funk G 1642 was significantly less damaged than O's Gold GS 712 when infested with an equal amount of nymphs in a no-choice situation. There was no significant difference among other entries. The results indicate that differences in damage that occur in a choice situation may not occur in a no-choice situation with grain sorghum hybrid seedlings.

Nymphal Choice Test B3 and Single Plant No-Choice Test B4. Significantly more Wheatland and KS 71 plants were dead 4-12 days after infestation with chinch bug nymphs than BCK 60 1155 in the choice test (Table B3-B4). However, no significant differences in damage were observed between lines BCK 60 1155, BCK 60, KS 71, KS 72 and Wheatland at an infestation level of 15 fourth instar nymphs per plant at the 2 leaf stage in a no-choice test (plants 12-14 cm in height). Since all lines possessed about the same level of damage in the no-choice situation, it appears that Wheatland and KS 71 are more preferred for feeding. Again, as with the

hybrids, the amount of damage on a particular entry and differences between entries may differ depending if the test is a choice or no-choice test.

Adult Choice Test B5. Hybrids PAG 4433 and O's Gold GS 712 were significantly more damaged by adults in a choice test than Funk G 1642 at all dates analyzed (Table B5). Pioneer X 5563 and X 3082 were variable and between the extremes in their damage. O's Gold GS 712 did not differ from PAG 4433 in this choice test using adults as it did in the nymph choice test. Otherwise, results were similar to the nymph choice test and were very similar to that obtained in ther previously reported field test (Wilde et al. 1982).

Adult Choice Test B6. Wheatland had a significantly higher necrosis rating than KS 72, BCK 60 1155 and BCK 60 for all 3 dates analyzed. KS 71 also suffered significantly more damage than KS 72, BCK 60 1155 and BCK 60 at the first 2 dates and more than BCK 60 1155 and BCK 60 at the last date (Table B6). In general, the results of this adult choice test were similar to the nymphal choice test in that Wheatland and KS 71 were the most susceptible and BCK 60 1155, BCK 60 and KS 72 were the most resistant.

Nymphal Multiplant No-Choice Test B7. Although DK 58 had somewhat lower plant mortality, no significant differences were observed in the number of dead plants at any date between PAG 4433, Funk G 499 and DK 58 when groups of 8 seedlings were subjected to 120 fifth instar nymphs in a no-choice multiplant test (Table B7). Earlier studies have shown 4433 to be extremely susceptible in a choice situation.

Adult Multiplant No-Choice Test B8. Results obtained in this hybrid test agreed with those obtained by Wilde et al. (1982) in that Funk G 404 was significantly more susceptible at 35 days after infestation than Dekalb DK 61 and 80% plant mortality occurred significantly earlier with G 404

than with DK 61. Hybrid G 404 also produced significantly more bugs than DK 61. The results are summarized in Table B8.

Adult Multiplant No-Choice Test B9. Ten days after infestation Dekalb DK 61 had significantly more dead plants than Cargill 55, NC+ 271 and Funk G 1642 (Table B9). At 15 days Northrup-King 2778 had significantly more dead plants than C 55, NC+ 271 and G 1642 and at 35 days after infestation DK 61 had significantly more dead plants than NC+ 271. There were no significant differences in the number of bugs between hybrids. These results in a no-choice situation differ somewhat from those in a field choice test involving a number of the hybrids involved in this experiment (Wilde et al. 1982) in that large differences between some entries were not discerned in this test.

Adult Multiplant No-Choice Test B10. The first significant difference in plant mortality between the hybrids occurred at 45 days after the initial infestation of adult chinch bugs (Table B10). At 45, 50 and 54 day counts PAG 4433 had significantly more dead plants than NC+ 271, which corresponds with field test results by Wilde et al. (1982). There were no significant differences in the number of bugs reared on the plants.

Nymphal Single Plant No-Choice Test B11. No significant differences in the average days to plant death after infestation of 15 third and 10 fourth instar chinch bug nymphs were recorded between hybrids O's Gold GS 712 and Funk G 1642 (Table B11). No differences occurred between the same 2 hybrids in the Nymph Choice Test B1 but did occur in the No-Choice Test B2. Differences in field resistances between 712 and 1642 were found by Wilde et al. (1982).

Nymphal Single Plant Stunting Test B12. Significant differences in stunting were observed between Funk G 404 and hybrids O's Gold GS 712 and Funk G 1642 initially and 5 days after insect removal at both the 3 and 5 day infestation periods (Table B12). A significant difference between 712

and 1642 also occurred initially at the 3 day infestation. By 10 days all hybrids had recovered enough to be insignificantly different for both infestation periods.

Nymphal Multiplant No-Choice Test B13. TX 7078 had significantly more dead plants than both KS 71 and KS 72 14 days after infestation (Table B13). The number of bugs recovered from each line was not significantly different.

Adult Multiplant No-Choice Test B14. KS 72 showed significantly more susceptibility than KS 71 from 20 days after infestation until termination of the line at about 40 days (Table B14). There was a significant difference in the number of days to 80% plant mortality between KS 71 (28.6 days) and KS 72 (52.6 days).

Nymphal Single Plant No-Choice Test B15. BCK 60, KS 71 and Wheatland plants died significantly later than BCK 60 1155 at an infestation rate of 5 third and 10 fourth instar nymphs per 15 cm seedling as seen in Table B15. These results do not correspond with those of Test B4 in which there were no significant differences between the same lines when plants were infested with 15 fourth instar nymphs at the same seedling height.

Adult Multiplant No-Choice Test B16. Wheatland had significantly higher plant mortality at 30-45 days after the infestation of 1 3 pair of adult chinch bugs at the 3 leaf stage than either KS 71 or BCK 60 (Table B16). There were also significantly fewer days until 80% plant necrosis with Wheatland compared to KS 71 and BCK 60. There were no significant differences in the number of bugs present between any of the lines at termination.

Conclusions

Differences in results were obtained when lines or hybrids were subjected to nymphs in choice as compared to no-choice situations (Tests B1,

B2, B3 and B4). A line or hybrid which had significantly higher plant mortality in a choice nymph test was not significantly different when compared to the same entries in a no-choice test. This suggested that antixenosis may be an important mechanism of resistance in some instances and should be kept in mind by those conducting resistance studies.

The Adult Choice Tests B5 and B6 with the same lines and hybrids as in Tests B1-B4 resulted in similiar differences as the nymphal choice tests.

Inconsistent results were obtained in No-Choice Single Plant Tests B2, B4, B11 and B15 which involved nymphs. A line or hybrid would be significantly less damaged than another in one test and not significantly different in another test.

There was a trend for previously identified resistant lines and hybrids to exhibit less damage under no-choice multiplant tests involving nymphs (B7 and B13), but differences were not significant in the hybrid test.

Hybrids and lines tested in the no-choice multiplant tests (B8, B9, B10, B14 and B16) reacted to chinch bugs much in the manner previously reported in field tests. Lines and hybrids which were classified as susceptible in the field were usually damaged the most in these tests. However, all entries were damaged to some extent.

Stunting Test B12 showed no differences between hybrids in plant height 10 days after bug removal with the 3 and 5 day infestation periods, even though differences were significant initially and 5 days after insect removal. This indicated an equal ability of the seedling entries to recover after sublethal infestations.

C. Comparing greenhouse versus growth chamber conditions while screening for chinch bug resistance in seedling sorghums.

Once an approximation of the number of bugs needed to obtain plant death within about 15 days after infestation of single seedling plants was established, several no-choice experiments were performed to determine if differences between greenhouse (GH) and growth chamber (GC) growing conditions occur.

Nymphal Single Plant No-Choice GH-GC Test C1. Sorghum hybrids Funk G 404, Funk G 1642 and O's Gold GS 712 were planted at 3-4 seeds per supercell and later thinned to the most vigorous seedling. There were 5 replications in the greenhouse and 5 in the growth chamber. Plants were sanded, caged and infested at 12-14 cm with 8 fourth and 8 fifth instar nymphs. Plant height was measured from the soil line to the tip of the tallest leaf and the number of bugs retained along with days until necrosis after infestation were recorded at the termination of each observation. Temperature and photoperiod records were kept for both environments in all tests (16 hr days, 21-32 ^{o}C average in the GH and 16 hr days at 24-30 ^{o}C in the GC). Plant mortality was rated as all or all but one leaf permanently wilted. All data in this section were analyzed by analysis of variance and means were compared using Duncan's new multiple range test (Duncan, 1955) at a significance level of 5%.

Nymphal Single Plant No-Choice GH-GC Test C2. Sorghum hybrids Funk G 1642, O's Gold GS 712, Pioneer X 3082, Pioneer X 5563 and PAG 4433 were planted in supercells and thinned to 1 plant per cell in the greenhouse and growth chamber. An infestation rate of 10 fourth and 10 fifth instar nymphs per plant was used at a seedling height of 14-17 cm. There were 5 replications. Days until plant death and height at that time were recorded.

Nymphal Single Plant No-Choice GH-GC Test C3. Individual plants of sorghum hybrids PAG 4433, Funk G 1642, Northrup-King 2778 and NC+ 271 were grown in supercells in the greenhouse and growth chamber and infested at 11-14 cm with 18 small to medium sized fifth instar nymphs. There were 7 replications. The same data were recorded as in previous C tests.

Nymphal Single Plant No-Choice GH-GC Test C4. Individual plants in 5 supercells of O's Gold GS 712 and Funk G 1642 were infested with 10 third and 10 fourth instar nymphs in both the greenhouse and growth chamber when plants were 16-19 cm in height. Days to plant death and height at plant death were recorded.

Nymphal Single Plant No-Choice GH-GC Test C5. Lines Double Dwarf Yellow Milo, BCK 60, BCK 60 1155, SC 303 and Atlas Sorgo were grown as described in Test C1 and infested with 15 fifth instar nymphs at 13-15 cm in height. Days until total necrosis, plant height and the number of bugs retained were again recorded. There were 3 replications.

Nymphal Single Plant No-Choice GH-GC Test C6. Five replications of lines KS 71, BCK 60, BCK 60 1155 and Wheatland were grown in 5 supercells in both greenhouse and growth chamber environments and treated with 13 fourth instar nymphs when 15 cm tall. The same data were recorded as in previous C tests.

Results and Discussion

Nymphal Single Plant No-Choice GH-GC Test C1. When greenhouse and growth chamber data were combined, Funk G 404 and O's Gold GS 712 had significantly fewer days to plant mortality than Funk G 1642 (Table C1). G 404 was dead significantly earlier in the greenhouse than 712 or 1642, and both 404 and 712 were dead significantly sooner in the growth chamber than 1642. There were no difference in days to plant death within hybrids

between the greenhouse and growth chamber environments. Heights at plant death for each hybrid were not significantly different in either the greenhouse or growth chamber environments.

Nymphal Single Plant No-Choice GH-GC Test C2. There were no significant differences between the five hybrids tested in days to plant death in the growth chamber (Table C2). Hybrid X 3082 was significantly more resistant than GS 712 in the greenhouse and G 1642 and X 3082 more resistant than GS 712 when greenhouse and growth chamber data were combined. Plants generally died earlier in the growth chamber as compared to the greenhouse but differences were not significant. There were no significant differences between growing conditions within hybrids in plant height at death.

Nymphal Single Plant No-Choice GH-GC Test C3. Hybrids did not differ significantly in days to plant death in the growth chamber, greenhouse or when greenhouse and growth chamber data were combined (Table C3). There was no difference in plant heights within hybrids between growing conditions.

Nymphal Single Plant No-Choice GH-GC Test C4. Hybrids Funk G 1642 and O's Gold GS 712 were not significantly different in any parameter measured (Table C4). The results differ from those obtained in Tests C1 and C2 where G 1642 and GS 712 did differ in some comparisons.

Nymphal Single Plant No-Choice GH-GC Test C5. Significant differences in days to plant death were present between lines BCK 60 1155 and SC 303, with the latter having fewer days to plant death when greenhouse and growth chamber data were combined (Table C5). However, only growth chamber conditions yielded differences between these same 2 lines. Greenhouse seedlings were dead consistently earlier than growth chamber seedlings, which differed from results with hybrids in Test C2, but none were significantly different. Again, there were no significant differences in days to plant death between

the greenhouse and growth chamber. There were no significant differences in height at plant death between the greenhouse and growth chamber for any line.

Nymphal Single Plant No-Choice GH-GC Test C6. When greenhouse and growth chamber observations were combined, KS 71 took significantly more days to die than Wheatland and BCK 60 (Table C6). The same was true in the greenhouse but not the growth chamber when interaction effects were measured. There were no significant differences in days until death within lines between the greenhouse and growth chamber. There were also no significant differences between greenhouse and growth chamber heights at plant death within lines.

Conclusions

Generally differences between hybrids or lines in days until death were the same in the greenhouse and growth chamber. Occasionally one hybrid would be significantly different from another in the growth chamber and not in the greenhouse and vice versa but there did not seem to be a trend for one environment to show differences and the other not. This would suggest that screening of the type described could be done either in the greenhouse or growth chamber under the temperature and photoperiods used.

D. Effects of different chinch bug infestation levels during the seedling stage on subsequent plant growth and yield.

Materials and Methods

Relationship of Greenhouse Seedling Damage to Yield Test D1. Sorghum lines Wheatland, BCK 60, BCK 60 1155, KS 71, KS 72 and TX 430 were planted in 7.6 cm diameter peat pots in the regular soil mixture at 3-4 seeds per pot. Pots were watered from the top to establish germination and then from

the bottom. Seedlings were thinned to 1 per pot, sanded, caged and infested with 0, 3 or 6 young adults when 12-15 cm tall. Adults were caged for 7 days and seedling heights were measured immediately after bug removal. Twenty-four days after planting the pots were transplanted into the field using a 7.6 cm diameter soil probe to dig holes every 15.2 cm (35,000 plants per acre or 86,485 per hectare at rows 76.2 cm apart). A randomized complete block design was used with 7 observations per infestaion level for each of the 4 replications per sorghum line. The outer 2 observations for each infestation level per replication were deleted from the analysis, and used as border plants to help minimize advantages or disadvantages that bordering plants may have received from the environment. Plant height was measured at 39, 54 and 70 days after planting and blooming dates along with the number of heads per plant were recorded. Blooming dates were recorded when flowering had occurred on about the bottom 5 cm of the head. During the seed filling stages plants were protected with a bird netting canopy. Heads were harvested by hand, threshed with a small individual head thresher, sacked per plant and put into a large drying oven for 7 days at 66 ^{o}C. Seed moisture percentages and two 100 seed weights per plant (yield components) were recorded for all plants before recording total seed weights per plant. Analysis of all parameters measured in all D tests were made on the differences of the infested plants from their respective controls (uninfested plants). Tests in this section were analyzed using the SAS GLM procedure for analysis of variance (SAS Institute Inc.) and means were compared using t-tests (Least Significant Difference) at a significance level of 5%.

Relationship of Greenhouse Seedling Damage to Yield Test D2. The same procedure as Test D1 was used with hybrids Funk G 1642, Northrup-King 2778,

PAG 4433 and O's Gold GS 712. Infestation levels were 0, 4 and 8 adults per seedling for 7 days when plants reached 12-15 cm. Seedlings were transplanted to the field using the same methodology and data were recorded similarly.

Relationship of Field Seedling Damage to Yield Test D3. Sorghum lines KS 71, KS 72, BCK 60 and BCK 60 1155 were each planted in approximately 35 meter rows in the field at about 15.2 cm seed spacing and 76.2 cm row spacing (35,000 seeds per acre or 86,485 per hectare). When plants were 12-20 cm tall or at the 4-5 leaf stage, 8 groups of 7 plants equidistant from each other were sanded and caged with 5 cm diameter by 25.4 cm tall clear plastic cages with three 2.5 cm meshed air holes. Foam stoppers or plastic caps were used as lids. The 7 plants in the 4 replications per line were infested with 10 adult chinch bugs each and the other 4 noninfested replications served as controls. The controls were caged to equalize any greenhouse effect between the infested and control plants. Cages were removed after 6 days (21 days after planting) and all plants were immediately treated with 1 lb. per acre granular Thimet to kill remaining bugs. Another application of the insecticide was made 23 days later to kill any natural infestation or progeny of the caged bugs. Average heights were recorded just prior to infestation, and individual heights recorded when the cages were removed and at 39 and 52 days after planting. Measurements were taken only on the middle 5 plants. The outer plant on each side of the replication served to help eliminate border effects. Bloom dates and the number of heads per plant were also recorded. Heads were harvested by hand and threshed with a small head thresher. Total seed weight per plant and two 100 seed weights were recorded after seeds were dried for 7 days at 66 °C.

Relationship of Field Seedling Damage to Yield Test D4. Sorghum hybrids PAG 4433, Northrup-King 2778, Funk G 1642 and Funk G 499 were tested

with the same experimental design as discussed in Test D3. Fifteen adult bugs were caged per seedling for 7 days. There were 4 replications of infested and noninfested plants.

Results and Discussion

Relationship of Greenhouse Seedling Damage to Yield Test D1. Lines BCK 60 1155 and BCK 60 were both significantly more stunted than TX 430 immediately after bug removal (Table D1) at the 6 bug infestation level. KS 71 was stunted as much as the other lines immediately after bug removal, but recovered earlier since it was significantly less stunted with 6 bugs at the 39 day rating than Wheatland, BCK 60 1155 and BCK 60. Line KS 71 was still significantly less stunted than BCK 60 at the 6 bug infestation 54 days after planting, and significantly less than BCK 60 1155 at 70 days after planting. There were no significant differences in the number of heads produced per plant or bloom dates between the lines, even though noninfested plants consistently had more heads and bloomed earlier than plants infested with 3 or 6 bugs. BCK 60 had nearly significantly more seed mass per plant at the 6 bug infestation level than Wheatland, KS 72, KS 71 and TX 430, but no significant differences in total seed weight per plant were present. There were several significant differences in both 100 seed weights between lines at the 6 bug infestation level. Line TX 430 produced significantly larger seeds than Wheatland, BCK 60 1155 and BCK 60. KS 71 and KS 72 also had significantly larger seeds than BCK 60 in both seed counts at the 6 bug infestation level. Wheatland had significantly larger seeds than BCK 60 in one 100 seed count at both 3 and 6 bug levels. BCK 60 1155 also had larger seed mass than BCK 60 at the 6 bug level at one 100 seed count. Most lines at both infestation levels were reduced in yield but no significant differences were recorded in yield between the lines.

Relationship of Greenhouse Seedling Damage to Yield Test D2. There were no significant differences in plant stunting between the hybrids immediately after bug removal, 39 days and 70 days after planting for either the 4 or 8 bug infestation levels (Table D2). However, all hybrids at both infestation levels were significantly more stunted than their respective controls at the initial measuring date. Fifty-four days after planting GS 712 was significantly more stunted in height than both G 1642 and PAG 4433 at the 8 insect infestation level when compared to their respective controls. Evaluation of the 4 dates of plant height suggest some hybrids are more capable of recovery from chinch bug stress than others, such as NK 2778 being nearly significantly more stunted that G 1642 at 39 days, but being nearly equal in height and vigor at the latter 2 dates, compared to the significant or nearly significant differences between G 1642 and GS 712 throughout the entire plant growth period. There were no significant differences between the number of heads produced by the hybrids, but most of the infested plants had fewer heads than their respective controls. NK 2778 bloomed significantly later than 4433 at the 8 bugs per plant infestation level. Both infestation levels of 4433 bloomed within 1 day of their control, opposed to the 8 bugs per plant infestation level of 2778 which bloomed 4.25 days later than its control. No significant differences were recorded between hybrids in total seed weight (yield) per plant. GS 712 had significantly greater seed weight in both 100 seed counts at the 4 bugs per plant infestation level than NK 2778.

Relationship of Field Seedling Damage to Yield Test D3. No significant differences occurred between the heights of any lines immediately after cage removal (21 days after planting) and 39 or 52 days after planting (Table D3). All infested plants had fewer heads than their controls but there were

no significant differences between lines in the number of heads produced because of chinch bug stress. KS 72 produced significantly more grain per plant than BCK 60 and KS 71, however yield in kg/ha could not be calculated because of variable plant spacing. There were no significant differences in seed size (100 seed counts) between the lines, so the cause of KS 72 having greater yields than KS 71 and BCK 60 can be attributed to a larger head size with more seeds.

Relationship of Field Seedling Damage to Yield Test D4. No significant differences occurred between hybrids Funk G 499, G 1642, Northrup-King 2778 or PAG 4433 for the 3 plant heights, total and two 100 seed count weights, and head number (Table D4). The largest difference in total seed mass was between G 1642 and G 499, with G 1642 suffering the least damage, out-yielding its control by 6.28 g/plt., opposed to G 499 which produced 17.31 g/plt. less seed than its control.

Conclusions

None of the greenhouse infested tests resulted in significant yield reductions due to the chinch bug treatments. Good growing conditions at and immediately after the infestations allowed all lines and hybrids to recover from what appeared to be heavily damaged seedlings. All entries were more stunted than their controls immediately after cage removal, but none were significantly different from each other within tests. Some significant differences in height occurred later as the plants recovered. Generally the more heavily infested plants bloomed later and had fewer heads than the less infested plants. Infested plants consistently bloomed up to 4 days later than the noninfested plants. The only test to produce significant differences in yield was Test D3. Line KS 72 produced significantly more grain

per plant than BCK 60 and KS 71 in the Field Test D3 when infested in the field at 12-20 cm with 10 adult chinch bugs per plant for 6 days. BCK 60 suffered the largest yield reduction from its control (36.4%, not significantly different from the others) in Test D1. These results differ from those obtained by Ahmad et al. (1984) in Nebraska where they found infestation levels of 5 and 10 bugs per plant for 7 days caused a 28 and 68% respective yield reduction in hybrid Dekalb DK 61.

Discussion of Cold Storage Practices

Several methods of storing chinch bugs for future use besides maintaining the usual culture colonies were investigated but no experimental designs were incorporated or statistical analyses made.

Adult bugs of mixed ages were placed on 5 caged 15 cm pots of 10-15 pearl millet plants and 2 pots of hybrid Pioneer X 3183 corn. All plants were 4-7 weeks old. Pots were caged with 400-900 bugs each and left in a large walk-in refigerator maintained at 5-6 ^{o}C with a constant 24 hr scotoperiod. Pots were moistened approximately every 2 weeks. Bugs on the corn pots were recounted after 30 days of storage because of the necrosed corn plants. About 24% of the bugs survived. The millet pots were removed 70 days after being put into storage and bugs counted. Less than 1% of all bugs survived. Plant material had been dead for nearly 30 days.

Bugs were also stored in a home refrigerator at 5-6 ^{o}C and a 24 hr scotoperiod under 3 different conditions. Fifteen cm diameter by two and one-half cm deep clear plastic lidded petri dishes were used. Three dishes had 10 Johnson and Johnson^{R} dental swabs soaked in water and placed in a group on a paper towel. Two dishes had 10 dental swabs soaked in a granulated white sugar water solution (2 pts water, 1 pt sugar) situated as before. Three dishes had 10 cm sections of young corn stalks (not wider

than 2 cm diameter). The sheaths were removed, and groups of 5 were waxed together by dipping the ends of the bundles into a flask of hot wax. This also sealed the stalk ends to help prevent moisture loss.

A survival rate of 90% was observed after 10 days, 30% after 30 days, 10% after 60 days and 3-4% after 75 days of storage with adult bugs in the plain water dishes. About 15% of the bugs were alive at 30 days and 4% at 70 days in the sugar water dishes. Each dish of corn stalks had a different life stage of chinch bug. Seventy percent of the adults survived after 2 days, but none after 15 days. About 70% of the fifth instar nymphs survived after 2 days, but all were dead after 15 days. About 75% of the third and fourth instar nymphs were alive after 2 days, but again all were dead within 15 days. Chinch bug adults and progeny survived long periods of time on unrefrigerated stalk sections but did poorly on the refrigerated stalks. Water and sugar water proved to be the most efficient for short-term (10 days) storage. Most nymphs that were with the adults in these dishes survived also, suggesting this may be a method of maintaining nymphs at a desired life stage for short time periods.

The most promising method of long-term cold storage investigated was the use of clumps of little bluestem prairie grass Andropogon scoparius Michx., stored in one gallon white cardboard ice cream containers. Water was added to clumps at 2 week intervals to insure green plant material for bugs to feed. Several hundred adults or near adult chinch bugs were placed in several containers and recovered throughout the storage period when nymphs would be needed at a later date. Approximately 50% of the adults would commonly survive after 3 months of storage. Plant material of this type was also easiest to maintain (remained adequate for food longer). A long-term tolerance test was conducted to compare adults from cold storage and direct

from the culture. There was no significant differences at the 5% level between the 2 in the length of time to egg laying and the number of progeny produced when bugs were removed from the refrigerator one week before test time.

SUMMARY

Third, fourth and fifth instar chinch bug nymphs and adults were the most convenient and effective to use for screening for resistance in seedling sorghums. Resistance levels varied between tests. For example BCK 60 1155 and Funk G 1642 were less damaged than other entries in choice tests, yet when evaluated in a no-choice situation, they were as susceptible as the others tested in some instances. Differences between greenhouse and growth chamber conditions were generally insignificant, and inconsistent when significant. Field tests exhibited few significant differences between entries. Sublethal seedling infestations in the greenhouse caused no significant yield reductions, and since higher infestations would have resulted in seedling death, the greenhouse-field transplant tests were considered impractical for large scale use. A major problem throughout all tests was escaping bugs due to small leaks in the various cages. Observations that had more than 30% of the infested bugs missing or dead at infestation termination were not analyzed with the data. This problem was responsible for the exclusion of some tests from this study. Thrips were also a major problem for some of the longer termed tests in the greenhouse and resulted in some deletions of observations. Storing insects other than in high maintenance cultures was most successful on clumps of little bluestem Andropogon scoparius Michx., at 5-6 ^{o}C under a constant scotoperiod.

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Table A1. Effect of different nymphal infestation levels on single sorghum hybrid seedlings.

Hybrid	Infestation[a]	Ave. No. Days to Necrosis[b]
Funk G 550	10 seconds	17.00 bcd
Funk G 499	10 seconds	18.00 bc
Funk G 550	10 thirds	16.75 bcde
Funk G 499	10 thirds	12.25 defg
Funk G 550	10 fourths	18.50 bc
Funk G 499	10 fourths	13.25 cdefg
Funk G 550	10 fifths	16.25 bcde
Funk G 499	10 fifths	15.00 cdef
Funk G 550	15 seconds	23.75 a
Funk G 499	15 seconds	20.75 ab
Funk G 550	15 thirds	9.25 g
Funk G 499	15 thirds	11.25 efg
Funk G 550	15 fourths	10.50 fg
Funk G 499	15 fourths	13.00 cdefg
Funk G 550	15 fifths	14.00 cdefg
Funk G 499	15 fifths	12.25 defg
Funk G 550	5 fourths	18.00 bc
Funk G 499	5 fourths	18.00 bc

[a] Number of chinch bugs and nymphal instar, 4 reps., infested at 13-15 cm.

[b] Means with same letter not significantly different at 5%. Duncan's new multiple range test.

Table A2. Effect of different nymphal infestation levels on single sorghum line seedlings.

Line	Infestation[a]	Ave. No. Days to Necrosis[b]
TX 7078	5 thirds	19.00 ab
KS 71	5 thirds	19.00 ab
KS 72	5 thirds	-
TX 7078	5 fourths	18.00 abc
KS 71	5 fourths	18.50 ab
KS 72	5 fourths	16.25 abc
TX 7078	5 fifths	21.00 a
KS 71	5 fifths	17.50 abc
KS 72	5 fifths	17.50 abc
TX 7078	10 thirds	13.50 cd
KS 71	10 thirds	14.25 bc
KS 72	10 thirds	15.75 bc
TX 7078	10 fourths	7.75 e
KS 71	10 fourths	14.25 bc
KS 72	10 fourths	18.75 ab
TX 7078	10 fifths	6.75 e
KS 71	10 fifths	9.33 de
KS 72	10 fifths	15.50 bc

[a] Number of chinch bugs and nymphal instar, 4 reps., infested at 13-15 cm.

[b] Means with same letter not significantly different at 5%. Duncan's new multiple range test.

Table A3. Combined adult infestation levels on multiplant sorghum hybrid seedlings.

Hybrid	Mean % dead plts., days after infestation[a] 25 days	30 days	35 days	40 days	Ave. No. Days to Term.[b]	Ave. No. Bugs[c]
Funk G 499	0.216 a	0.426 a	0.625 a	0.720 a	37.47 b	488.53 a
NC+ 271	0.086 b	0.188 b	0.320 b	0.571 b	43.65 a	620.55 a

[a] Mean % of dead plants, 19-20 reps., infested at
[b] Days after infestation until 80% plant mortality in a pot.
[c] Number of adults and progeny recovered at termination.
[d] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table A4. Effect of different adult infestation levels on multiplant sorghum hybrid seedlings.

Hybrid	Infestation	Ave. No. Days to Term.[a,b]	Ave. No. Bugs[c,d]
NC+ 271	10pr 5pl	38.75 cde	684.75 ab
Funk G 499	10pr 5pl	34.75 de	463.00 ab
NC+ 271	10pr 7pl	41.00 cd	733.50 ab
Funk G 499	10pr 7pl	36.67 cde	414.00 ab
NC+ 271	10pr 8pl	49.50 ab	813.75 a
Funk G 499	10pr 8pl	39.75 cde	729.00 ab
NC+ 271	8pr 4pl	35.75 de	470.50 ab
Funk G 499	8pr 4pl	31.25 e	447.00 ab
NC+ 271	7pr 5pl	53.25 a	400.25 ab
Funk G 499	7pr 5pl	44.75 bc	371.00 b

[a] Number of sexed adult chinch bugs and plants per pot, 4 reps., infested at 18-20 cm.
[b] Days after infestation until 80% plant mortality in a pot
[c] Number of adults and progeny recovered at termination.
[d] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table B1-B2. Plant mortality in a nymphal choice and no-choice test on selected sorghum hybrids.

Hybrid	Ave. no. dead plants, days after infestation, choice test[ac] 6days	8days	10days	12days	14days	No-choice[bc] Ave. No. Days to Plt. Death
PAG 4433	1.0 a	2.4 a	3.4 a	3.6 a	3.8 a	8.6 ab
Pioneer X 5563	.6 a	1.6 ab	1.8 ab	2.2 ab	2.4 ab	8.0 ab
Pioneer X 3082	.2 a	.8 ab	1.2 a	1.4 b	1.8 b	9.4 ab
Funk G 1642	.2 a	.4 b	1.4 b	2.0 ab	2.0 b	9.8 a
O's Gold GS 712	.2 a	.4 b	.8 b	1.0 b	1.8 b	7.6 b

a Test B1, mean number dead plants of 5 total, 5 reps., each with 25 plants infested at 12-14 cm with 250 fourth instar chinch bugs.
b Test B2, days after chinch bug infestation, 5 reps., individual 10-14 cm seedlings infested with 20 fourth instar bugs.
c Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B3-B4. Plant mortality in a nymphal choice and no-choice test on selected sorghum lines.

Line	Ave. no. dead plants, days after infestation, choice test[ac] 4days	6days	10days	12days	No-choice[bc] Ave. No. Days to Plt. Death
Wheatland	1.25 a	2.75 a	4.00 a	5.00 a	6.6 a
KS 71	1.50 a	2.75 a	4.00 a	5.00 a	6.0 a
BCK 60	0.25 b	1.50 ab	3.75 a	4.50 a	7.4 a
KS 72	0.25 b	0.75 ab	1.75 b	3.00 b	7.6 a
BCK 60 1155	0.00 b	0.25 b	1.25 b	2.75 b	8.0 a

e Test B3, mean number dead plants of 5 total, 4 reps., each with 25 plants infested at 12-14 cm with 250 chinch bugs (1/2 third & 1/2 fourth instar)
b Test B4, days after chinch bug infestation, 5 reps., individual 10-14 cm seedlings infested with 20 fourth instar bugs.
c Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B5. Rating of plant mortality in an adult choice test on selected sorghum hybrids.

Hybrid	Mean necrosis rating, days after infestation[abc]		
	19days	23days	28days
PAG 4433	6.5 a	8.1 a	9.0 a
O's Gold GS 712	5.6 a	7.0 ab	8.1 ab
Pioneer X 5563	5.5 a	6.6 bc	7.7 ab
Pioneer X 3082	4.8 ab	6.5 bc	6.8 bc
Funk G 1642	3.0 b	5.4 c	6.1 c

[a] Ten (2 obs. per hybrid) 20 cm seedlings infested with 20 pair of adult chinch bugs, 5 reps.
b 0 = no damage, 9 = 100% necrosis.
c Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B6. Rating of plant mortality in an adult choice test on selected sorghum lines.

Line	Mean necrosis rating, days after infestation[abc]		
	19days	23days	28days
Wheatland	7.90 a	8.50 a	8.80 a
KS 71	6.22 a	7.67 a	8.44 ab
KS 72	3.80 b	5.78 b	7.00 bc
BCK 60 1155	3.78 b	5.50 b	6.10 c
BCK 60	4.20 b	5.20 b	6.00 c

[a] Ten (2 obs. per hybrid) 16 cm seedlings infested with 15 pair of adult chinch bugs, 5 reps.
b 0 = no damage, 9 = 100% necrosis.
c Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B7. Plant mortality in a no-choice multiplant nymphal hybrid test.

Hybrid	Ave. no. dead plants, days after infestation[ab] 3days	8days	13days
PAG 4433	0.4 a	4.4 a	7.8 a
Funk G 499	0.8 a	3.6 a	7.0 a
DK 58	0.4 a	3.2 a	5.8 a

[a] Mean number of dead plants of 8 total, 5 reps., infested at 12-14 cm with 120 fifth instar nymphs.
[b] Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B8. Plant mortality and chinch bug reproduction in a no-choice multiplant hybrid test.

Hybrid	Ave. no. dead plants, days after infestation[ad] 20days	25days	30days	35days	Ave. No. Days to Term.[b]	Bugs[c]
Funk G 404	1.75 a	3.00 a	5.25 a	8.50 a	33.75 b	812.50 a
Dekalb DK 61	.75 a	1.75 a	4.50 a	6.50 b	37.75 a	560.25 b

[a] Mean number of dead plants of 10 total, 4 reps., infested at 20-24 cm with 10 pair adult chinch bugs.
[b] Days after infestation until 80% plant mortality in a pot.
[c] Number of adults and progeny recovered at termination.
[d] Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B9. Plant mortality and chinch bug reproduction in a no-choice multiplant hybrid test.

Hybrids	Ave. no. of dead plants, days after infestation[ac]									Ave. No. Bugs[bc]
	10days	15days	20days	25days	30days	35days	40days	45days	50days	
Northrup-King 2778	0.33 ab	1.67 a	2.00 a	2.67 a	3.00 a	3.33 ab	4.67 a	6.00 a	7.00 a	400.33 a
Dekalb DK 61	1.50 a	1.50 ab	2.50 a	2.50 a	3.00 a	5.00 a	7.00 a	7.50 a	8.00 a	647.50 a
Growers GSA 1310A	1.00 ab	1.00 ab	1.33 a	2.33 a	3.00 a	3.33 ab	3.67 a	4.33 a	5.00 a	576.00 a
Prairie Valley 734	0.50 ab	1.00 ab	1.00 a	1.25 a	2.00 a	3.50 ab	5.25 a	6.00 a	6.75 a	482.25 a
O's Gold GS 712	0.33 ab	0.33 ab	0.33 a	1.33 a	2.33 a	3.67 ab	6.67 a	7.33 a	7.67 a	448.00 a
Cargill 55	0.00 b	0.00 b	0.67 a	0.67 a	1.00 a	1.33 ab	3.33 a	3.33 a	4.00 a	395.33 a
NC+ 271	0.00 b	0.00 b	0.33 a	0.33 a	1.00 a	1.00 b	3.00 a	4.33 a	5.00 a	496.00 a
Funk G 1642	0.00 b	0.00 b	0.33 a	0.67 a	2.00 a	3.67 ab	6.00 a	6.33 a	6.33 a	436.00 a

a Number of dead plants of 10 total, 3 reps., infested at 15-20 cm with 10 pair of adult chinch bugs.
b Number of adults and progeny at test termination.
c Means with same letter in vertical column not significantly different at 5%: Duncan's new multiple range test.

Table B10. Plant mortality and chinch bug reproduction in a no-choice multiplant hybrid test.

Hybrids	Ave. no. of dead plants, days after infestation[ac]							Ave. No. Bugs[bc]
	10days	20days	30days	40days	45days	50days	54days	
PAG 4433	0.50 a	0.50 a	1.50 a	3.00 a	4.75 a	6.50 a	7.00 a	330.75 a
NK 2778	0.50 a	0.75 a	1.00 a	2.50 a	2.75 ab	4.25 ab	5.25 a	472.75 a
Funk G 1642	0.50 a	0.75 a	1.50 a	2.50 a	2.75 ab	3.50 b	4.25 ab	577.00 a
NC+ 271	1.25 a	1.50 a	1.75 a	1.75 a	1.75 b	2.00 b	2.00 b	477.50 a

[a] Number of dead plants of 10 total, 4 reps., infested at 20-24 cm with 15 pair of adult chinch bugs.
[b] Number of adults and progeny at test termination.
[c] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table B11. Days to plant death in a nymphal no-choice single plant hybrid test.

Hybrid	Ave. No. Days to Plant Death[ab]
Funk G 1642	12.67 a
O's Gold GS 712	11.29 a

[a] After chinch bug infestation, 6-7 reps., infested at 13-18 cm with 15 third and 10 fourth instar chinch bug nymphs.

[b] Means with same letter not significantly different at 5% level. Duncan's new multiple range test.

Table B12. Plant stunting in a no-choice nymphal single plant hybrid test.

	3 day infestation			5 day infestation		
	ad	bd	cd	ad	bd	cd
Hybrid	Initial	5days	10days	Initial	5days	10days
Funk G 404	16.00 a	28.00 a	36.80 a	16.40 a	29.00 a	35.40 a
O's Gold GS 712	7.20 c	21.80 b	29.80 a	9.60 b	23.40 b	29.00 a
Funk G 1642	11.60 b	25.60 a	32.40 a	9.40 b	25.20 b	38.20 a

[a] Differences between control and infested plant heights in cm immediately after insect removal, 5 reps., infested at 20-22 cm with 10 fourth and 10 fifth instar chinch bug nymphs.

[b] Differences 5 days after bug removal.

[c] Differences 10 days after bug removal.

[d] Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B13. Plant mortality in sorghum lines in a nymphal no-choice multiplant test.

Line	Ave. No. Dead Plants, Days after infestation[ac] 4days	9days	14days	Ave. No. Bugs Recovered[bc]
TX 7078	1.25 a	2.25 a	4.50 b	38.00 a
KS 72	1.00 a	2.00 a	2.50 a	34.00 a
KS 71	.33 a	1.00 a	1.33 a	34.67 a

[a] Mean number of necrosed plants of 5 total, 2-4 reps., infested at 14-18 cm with 35 fourth instar chinch bug nymphs.
[b] Number of bugs recovered at termination of test.
[c] Means with same letter in vertical column not significantly different at 5% level. Duncan's new multiple range test.

Table B14. Plant mortality and chinch bug reproduction in a no-choice multiplant line test.

Line	Ave. no. of dead plants, days after infestation[ad] 15days	20days	25days	30days	35days	Ave. No. Days to Term.[bd]	Ave. No. Bugs[cd]
KS 72	0.33 a	2.00 a	5.00 a	6.33 a	7.00 a	28.67 b	566.67 a
KS 71	0.33 a	0.67 b	1.00 b	1.00 b	1.67 b	52.67 a	828.33 a

[a] Number of dead plants of 8 total, 3 reps., infested at 20 cm with 12 pair of adult chinch bugs.
[b] Days after infestation until 80% plant mortality in a pot.
[c] Number of adults and progeny recovered at termination.
[d] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table B15. Days to plant death in a nymphal no-choice single plant line test.

Line	Ave. No. Days to Plant Death[ab]
BCK 60	14.40 a
KS 71	12.50 a
Wheatland	12.20 a
BCK 60 1155	7.50 b

[a] After chinch bug infestation, 4-6 reps., infested at 15 cm with 5 third and 10 fourth instar cninch bug nymphs.

[b] Means with same letter not significantly different at 5% level. Duncan's new multiple range test.

Table B16. Plant mortality and chinch bug reproduction in a no-choice multiplant line test.

Line	Ave. no. of dead plants, days after infestation[ad]						Ave. No. Days to Term.[bd]	Ave. No. Bugs[cd]
	20days	25days	30days	35days	40days	45days		
Wheatland	1.00 a	2.25 a	5.50 a	7.25 a	7.75 a	8.50 a	33.50 b	286.50 a
KS 71	0.25 a	0.25 a	1.50 b	3.00 b	4.25 b	5.75 b	44.25 ab	378.50 a
BCK 60	0.67 a	1.00 a	2.00 b	3.00 b	4.00 b	4.33 b	51.00 a	265.67 a

[a] Number of dead plants of 10 total, 4 reps., infested at 16-22 cm with 13 pair of adult chinch bugs.
[b] Days after infestation until 80% plant mortality in a pot.
[c] Number of adults and progeny recovered at termination.
[d] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table C1. Nymphal greenhouse-growth chamber hybrid test C1.

Combined GH-GC data[abg]		Interaction effects[cg]		
Hybrid	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
Funk G 1642	14.22 a	GH	14.25 a	14.37 a
		GC	14.20 a	15.50 a
Funk G 404	6.11 b	GH	5.00 c	15.10 a
		GC	7.50 bc	15.50 a
O's Gold GS 712	9.56 b	GH	12.00 ab	15.67 a
		GC	7.60 bc	13.70 a

a GH = greenhouse, GC = growth chamber.
b 12-14 cm plants infested with 8 fourth and 8 fifth instar chinch bug nymphs, 5 reps. in GH and GC.
c Comparisons between environments and hybrids.
d GH and GC data combined, days until plant death after infestation.
e Days until plant death after infestation.
f Height of plants at death. Must compare within hybrids between GH and GC, not between hybrids.
g Means with same letter in verical columns not significantly different at 5%. Duncan's new multiple range test.

Table C2. Nymphal greenhouse-growth chamber hybrid test C2.

Combined GH-GC data[abg]		Interaction effects[cg]		
Hybrid	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
Funk G 1642	7.60 a	GH	7.80 ab	14.90 bc
		GC	7.40 ab	15.20 bc
Pioneer X 3082	7.60 a	GH	8.00 a	15.10 bc
		GC	7.20 ab	16.60 ab
Pioneer X 5563	6.70 ab	GH	7.20 ab	17.40 a
		GC	6.20 ab	17.60 a
PAG 4433	6.56 ab	GH	6.75 ab	16.75 ab
		GC	6.40 ab	15.60 ab
O's Gold GS 712	6.00 b	GH	5.80 b	14.70 bc
		GC	6.20 ab	13.20 c

[a] GH = greenhouse, GC = growth chamber.
[b] Plants infested at 14-17 cm with 10 fourth and 10 fifth instar chinch bug nymphs, 5 reps. in GH and GC.
[c] Comparisons between environments and hybrids.
[d] GH and GC data combined, days until plant death after infestation.
[e] Days until plant death after infestation.
[f] Height of plants at death. Must compare within hybrids between GH and GC, not between hybrids.
[g] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table C3. Nymphal greenhouse-growth chamber hybrid test C3.

Combined GH-GC data[abg]		Interaction effects[cg]		
Hybrid	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
NC+ 271	10.33 a	GH	10.00 a	13.17 a
		GC	10.67 a	13.33 a
Funk G 1642	10.14 a	GH	11.25 a	13.25 a
		GC	8.67 a	13.33 a
Northrup-King 2778	9.31 a	GH	10.00 a	12.57 a
		GC	8.50 a	14.00 a
PAG 4433	9.15 a	GH	10.00 a	13.57 a
		GC	8.17 a	13.50 a

a GH = greenhouse, GC = growth chamber.
b Plants infested at 11-14 cm with 18 fifth instar chinch bug nymphs, 4-7 reps. in GH and GC.
c Comparisons between environments and hybrids.
d GH and GC data combined, days until plant death after infestation.
e Days until plant death after infestation.
f Height of plants at death. Must compare within hybrids between GH and GC, not between hybrids.
g Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table C4. Nymphal greenhouse-growth chamber hybrid test C4.

Combined GH-GC data[a,b,c]		Interaction effects[c,g]		
Hybrid	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
Funk G 1642	13.90 a	GH	14.40 a	19.20 a
		GC	13.40 a	18.20 a
O's Gold GS 712	13.56 a	GH	15.25 a	17.50 a
		GC	12.20 a	17.20 a

a GH = greenhouse, GC = growth chamber.
b Plants infested at 16-19 cm with 10 third and 10 fourth instar chinch bug nymphs, 5 reps. in GH and GC.
c Comparisions between environments and hybrids.
d GH and GC data combined, days until plant death after infestation.
e Days until plant death after infestation.
f Height of plants at death. Must compare within hybrids between GH and GC, not between hybrids.
g Means with same letter in vertical columns not significantly different at 5%. Duncan's new multiple range test.

Table C5. Nymphal greenhouse-growth chamber line test C5.

Combined GH-GC data[abg]		Interaction effects[cg]		
Line	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
BCK 60 1155	8.00 a	GH	7.00 ab	16.33 a
		GC	9.50 a	16.00 a
BCK 60	7.17 ab	GH	7.00 ab	16.00 a
		GC	7.33 ab	16.00 a
Atlas	6.83 ab	GH	6.67 ab	15.00 a
		GC	7.00 ab	15.67 a
DDYM	5.80 ab	GH	4.00 b	13.00 a
		GC	7.00 ab	14.67 a
SC 303	4.83 b	GH	4.67 b	14.33 a
		GC	5.00 b	14.00 a

[a] GH = greenhouse, GC = growth chamber.
[b] Plants infested at 13-15 cm with 15 fifth instar chinch bug nymphs, 3 reps. in GH and GC.
[c] Comparisons between environments and lines.
[d] GH and GC data combined, days until plant death after infestation.
[e] Days until plant death after infestation.
[f] Height of plants at death. Must compare within lines between GH and GC, not between lines.
[g] Means with same letter in vertical column not significantly different at 5%. Duncan's new multiple range test.

Table C6. Nymphal greenhouse-growth chamber line test C6.

Combined GH-GC data[abg]		Interaction effects[cg]		
Line	Ave. No. Days to Plt. Death[d]	Env't	Ave. No. Days to Plt. Death[e]	Ht(cm)[f]
KS 71	13.00 a	GH	14.80 a	14.80 b
		GC	11.20 ab	15.80 ab
BCK 60	9.90 b	GH	10.40 ab	15.80 ab
		GC	9.40 b	16.60 ab
BCK 60 1155	10.30 ab	GH	11.60 ab	18.00 a
		GC	9.00 b	17.20 a
Wheatland	8.90 b	GH	8.80 b	16.60 ab
		GC	9.00 b	17.20 a

[a] GH = greenhouse, GC = growth chamber.
[b] Plants infested at 15 cm with 13 fourth instar chinch bug nymphs, 5 reps. in GH and GC.
[c] Comparisons between environments and lines.
[d] GH and GC data combined, days until plant death after infestation.
[e] Days until plant death after infestation.
[f] Height of plants at death. Must compare within lines between GH and GC, not between lines.
[g] Means followed by same letter in vertical column not not significantly different at 5%. Duncan's new multiple range test.

Table D1. Relationship of sublethal greenhouse seedling damage to yield in selected sorghum lines.

Lines	[c] Ht.(cm) at Bug Removal	Ht.(cm) at 29 Days	Ht.(cm) at 54 Days	Ht.(cm) at 72 Days	No. Heads /Plt.	[d] Bloom Date	[e] Tot. Seed (g/Plt.)	100 Seed wt.(g)	100 Seed wt.(g)	Yield Diff. (kg/ha)	[f] Yield Change (%)
					3 bug infestation level						
Wheatland	-8.30 a	-3.79 a	0.60 a	1.93 a	-0.05 a	1.15 a	-8.19 a	0.19 b	0.09 a	-708.81 a	-11.64
BCK 60 1155	-11.15 a	-2.90 a	2.20 a	-2.75 a	-0.50 a	1.25 a	-11.89 a	0.03 ab	-0.07 a	-1028.68 a	-13.04
KS 72	-8.80 a	-1.05 a	0.50 a	2.35 a	-0.35 a	0.75 a	-7.28 a	0.03 ab	0.05 a	-629.65 a	-10.05
BCK 60	-9.35 a	-2.15 a	-2.70 a	1.55 a	-0.25 a	0.75 a	-10.17 a	-0.04 a	-0.08 a	-879.28 a	-15.24
KS 71	-9.90 a	2.40 a	3.95 a	4.35 a	-0.15 a	1.75 a	-1.58 a	0.06 ab	0.11 a	-2.44 a	-1.97
					6 bug infestation level						
Wheatland	-10.25 ab	-6.90 a	-2.70 ab	3.46 ab	-0.19 a	2.50 a	0.19 a	0.04 b	0.01 ab	65.43 a	0.27
BCK 60 1155	-13.25 a	-6.80 a	-0.35 ab	-4.95 a	-0.55 a	3.25 a	-9.66 a	-0.00 b	-0.04 ab	-835.69 a	-10.59
KS 72	-10.65 ab	-3.45 ab	-3.85 ab	2.00 ab	-0.55 a	1.75 a	-4.27 a	0.10 c	0.05 bc	-369.59 a	-5.90

Table D1. Continued.[abg]

Lines	Ht.(cm) at Bug Removal[c]	Ht.(cm) at 29 Days	Ht.(cm) at 54 Days	Ht.(cm) at 72 Days	No. Heads /Plt.	Bloom Date[d]	Tot. Seed (g/Plt.)[e]	100 Seed wt.(g)	100 Seed wt.(g)	Yield Diff. (kg/ha)	Yield Change (%)[f]
BCK 60	-12.55 a	-6.75 a	-6.95 a	-2.60 ab	-0.70 a	3.00 a	-24.30 a	-0.22 a	-0.18 a	-2101.30 a	-36.90
TX 430	-8.79 b	-5.87 ab	-1.27 ab	2.07 ab	-0.39 a	3.07 a	-4.29 a	0.21 c	0.25 c	-370.96 a	-4.67
KS 71	-10.30 ab	0.51 b	3.68 b	4.94 b	-0.05 a	3.25 a	4.99 a	0.06 bc	0.07 bc	432.08 a	6.25

[a] Means of differences between infested from noninfested plants.
b - numbers = less or earlier than controls, + numbers = more or later than controls.
c Plant height, days after planting, 4 reps., 5 obs. per rep., plants infested at 12-15 cm with 0, 3 or 6 adult chinch bugs for 7 days in the greenhouse.
d Days from noninfested plants.
e After all seed dried to approximately 6% moisture.
f Percent yield change compared to noninfested plants.
g Means with same letter in vertical column not significantly different at 5%. T tests (Least Significant Difference).

Table D2. Relationship of sublethal greenhouse seedling damage to yield in selected sorghum hybrids.[abg]

Hybrids	Ht.(cm) at Bug Removal[c]	Ht.(cm) at 29 Days	Ht.(cm) at 54 Days	Ht.(cm) at 70 Days	No. Heads /Plt.	Bloom Date[d]	Tot. Seed (g/Plt.)[e]	100 Seed wt.(g)	100 Seed wt.(g)	Yield Diff. (kg/ha)	Yield Change (%)[f]
					4 bug infestation level						
O's Gold GS 712	-14.85 a	-4.55 a	-1.75 a	5.00 a	0.30 a	2.50 a	1.66 a	0.27 b	0.23 b	143.00 a	1.56
PAG 4433	-14.15 a	-3.55 a	-0.55 a	2.20 a	-0.30 a	0.00 a	2.39 a	0.12 ab	0.10 ab	206.70 a	2.95
Northrup-King 2778	-11.75 a	-9.23 a	-0.59 a	1.06 a	0.00 a	1.25 a	8.20 a	-0.07 a	-0.01 a	790.50 a	9.40
Funk G 1642	-11.55 a	-3.00 a	-3.00 a	0.70 a	-0.15 a	0.75 a	-1.41 a	0.06 ab	0.03 ab	-121.80 a	-1.60
					8 Bug infestation level						
O's Gold GS 712	-16.85 a	-14.90 a	-14.15 a	3.10 a	0.10 a	3.75 ab	5.57 a	0.21 a	0.21 a	481.00 a	5.26
PAG 4433	-15.55 a	-10.70 a	-2.40 b	6.15 a	-0.35 a	1.00 a	-7.65 a	0.02 a	0.01 a	-661.60 a	-9.47

Table D2. Continued.[abg]

Hybrids	Ht.(cm) at Bug Removal[c]	Ht.(cm) at 29 Days[c]	Ht.(cm) at 54 Days[c]	Ht.(cm) at 70 Days[c]	No. Heads /Plt.[c]	Bloom Date[d]	Tot. Seed (g/Plt.)[e]	100 Seed wt.(g)[e]	100 Seed wt.(g)	Yield Diff. (kg/ha)[f]	Yield Change (%)[f]
Northrup-King 2778	-13.80 a	-19.45 a	-5.95 ab	0.95 a	-0.40 a	4.25 b	-13.09 a	0.04 a	0.08 a	-1132.40 a	-15.13
Funk G 1642	-13.75 a	-7.70 a	-2.60 b	3.25 a	-0.35 a	2.25 ab	-6.33 a	0.16 a	0.12 a	-547.20 a	-7.30

[a] Means of differences between infested from noninfested plants.
[b] - numbers = less or earlier than controls, + numbers = more or later than controls.
[c] Plant height, days after planting, 4 reps., 5 obs. per rep., plants infested at 12-15 cm with 0, 4 or 8 adult chinch bugs for 7 days in the greenhouse.
[d] Days from noninfested plants.
[e] After seed dried to approximately 6% moisture.
[f] Percent yield change compared to noninfested plants.
[g] Means with same letter in vertical columns not significantly different at 5%. T tests (LSD).

Table D3. Relationship of sublethal field seedling damage to yield in selected sorghum lines.[abc]

Line	Ht.(cm) at 21 days[d]	Ht.(cm) at 39 days[d]	Ht.(cm) at 52 days[d]	No. heads /plt.[d]	Tot. seed (g/plt.)[e]	100 seed wt.(g)[e]	100 seed wt.(g)[e]
KS 71	-12.2 a	-10.36 a	-6.39 a	-0.35 a	-4.74 a	0.014 a	0.073 a
KS 72	-9.2 a	-9.47 a	-8.56 a	-0.15 a	14.84 b	-0.049 a	-0.063 a
BCK 60	-12.9 a	-8.53 a	-11.58 a	-0.05 a	-10.82 a	0.011 a	-0.051 a
BCK 60 1155	-12.6 a	-6.76 a	-4.88 a	-0.05 a	-0.33 ab	0.097 a	0.104 a

[a] Means of differences between infested from control plants.

[b] Means with same letter in vertical column not significantly different at 5%. T tests (LSD).

[c] - numbers = less or earlier than controls, + numbers = more or later than controls.

[d] Plant height, days after planting, 4 reps., 5 obs. per rep., infested at 12-20 cm with 10 adult chinch bugs for 6 days in the field.

[e] After all seed dried to ca. 6% moisture.

Table D4. Relationship of sublethal field seedling damage to yield in selected sorghum hybrids.[abc]

Hybrid	Ht.(cm) at 21 days[d]	Ht.(cm) at 39 days[d]	Ht.(cm) at 52 days[d]	No. heads /plt.[d]	Tot. seed (g/plt.)[e]	100 seed wt.(g)	100 seed wt.(g)
PAG 4433	-14.90 a	-9.90 a	-5.10 a	-0.35 a	-7.62 a	-0.006 a	0.048 a
NK 2778	-14.25 a	-16.74 a	-8.89 a	-0.30 a	-13.20 a	0.455 a	0.386 a
Funk G 1642	-14.90 a	-13.19 a	-8.75 a	-0.55 a	6.28 a	0.211 a	0.159 a
Funk G 499	-13.90 a	-9.32 a	0.05 a	-0.20 a	-17.31 a	0.070 a	0.118 a

[a] Means of differences between infested from control plants.
[b] Means with same letter in verical column not significantly different at 5%. T tests (LSD).
[c] - numbers = less or earlier than controls, + numbers = more or later than controls.
[d] Plant height, days after planting, 4 reps., 5 obs. per rep., infested at 12-20 cm with 15 adult chinch bugs for 6 days in the field.
[e] After all seed dried to ca. 6% moisture.

Table D5. Precipitation during 1984 field tests D1-D4.[abc]

Week	Feb.	Mar.	Apr.	May.	June	Jul.	Aug.	Sept.	Oct.	Nov.
1st-7th	0.00	1.14	3.07	1.09	7.42	1.14	0.00	1.63	2.21	0.79
8th-14th	0.00	0.43	0.61	1.91	11.51	0.00	0.46	9.17	0.31	0.00
15th-21st	2.21	4.70	1.22	4.75	4.62	2.21	1.78	0.46	6.83	0.00
22nd-28th	0.03	0.58	1.57	3.38	2.84	0.00	0.00	1.32	1.60	0.00
29th-	0.00	1.02	3.05	0.00	0.00	0.00	0.00	0.00	0.69	0.00

[a] Measured in cm.
[b] North Manhattan, Ks. Kansas State University Ag. Research Farm.
[c] Test D1 transplanted to field June 18, 1984; Test D2 transplanted to field June 14, 1984; Tests D3 and D4 planted in field June 4, 1984.

A COMPARISON OF TECHNIQUES FOR SCREENING FOR RESISTANCE TO THE CHINCH BUG, BLISSUS LEUCOPTERUS LEUCOPTERUS (SAY), IN SORGHUM

by

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B. S., Kansas State University, 1982

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The primary objective of this study was to develop reproducible techniques for screening sorghum for resistance to chinch bugs in the seedling stage. Tests were conducted under greenhouse, growth chamber and field conditions. Several hybrids and lines were used, including Funk G 1642 and PAG 4433 as the resistant and susceptible hybrid checks, and BCK 60 1155 and Wheatland as the resistant and susceptible line checks. Third, fourth and fifth instar chinch bug nymphs and adults were the most convenient and effective to use for screening for resistance in seedling sorghum. Resistance levels varied between tests. For example BCK 60 1155 and Funk G 1642 were less damaged than other entries in choice tests, yet when evaluated in a no-choice situation, they were as susceptible as the others in some instances. Differences between greenhouse and growth chamber conditions were generally insignificant and inconsistent when significant. This suggests that screening of the types described could be done either in the greenhouse or growth chamber. There were no significant yield reductions between lines or hybrids in the sublethally infested greenhouse seedlings transplanted to the field. Line KS 72 produced significantly more grain than KS 71 and BCK 60 when infested in the field at 12-20 cm with 10 adult chinch bugs for 6 days. Storing chinch bugs other than in high maintenance cultures was most successful on clumps of little bluestem Andropogon scoparius Michx., at 5-6 ^{o}C with a constant scotoperiod.