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Maize Weevil:

A Search for Resistance in Converted Exotic Sorghum Kernels

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MAIZE WEEVIL: A SEARCH FOR RESISTANCE IN CONVERTED EXOTIC SORGHUM KERNELS

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CONTENTS

SUMMARY

Kernels of 169 converted exotic lines of sorghum, Sorghum bicolor (L.) Moench, were screened for resistance to the maize weevil, Sitophilus zeamais Motsch., utilizing free-choice and no-choice screening techniques. The criteria used for initial evaluation of samples of each line were attractiveness to maize weevil adults and the number of emerged progeny obtained. Despite considerable variability, results of this initial screening indicated that several entries possessed significant levels of resistance to maize weevil. Further tests were conducted with 25 entries, 18 of which appeared to be resistant in the initial screening. Results of this selected screening trial using several different methods to evaluate weevil resistance showed that there was congruity among different tests in identification of five converted exotic lines as exceptionally promising sources of resistance to the maize weevil. These lines were SC0226, SC0233, SC0309, SC0311, and SC0331. Additional lines which should be further investigated as sources of resistant germplasm are SC0199, SC0224, SC0227, SC0230, SC0289, and SC0333.

LABORATORY EVALUATION OF KERNELS OF CONVERTED EXOTIC SORGHUMS FOR RESISTANCE TO THE MAIZE WEEVIL*

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Perhaps one of the least exploited means of increasing available world grain supplies is to reduce post-harvest losses to insects, rodents, and other stored grain pests. Damage by insects to grain in storage by insects is a major problem, especially in the developing world. Estimates of postharvest losses of the world's grain supply due to insect damage range from 5 to 35 percent. Such losses are greater in certain tropical and subtropical countries, where estimates are as high as 30 to 40 percent (Munro 1966). However, even in the United States, where weather conditions are less favorable for insect infestation over much of the northern half of the country (Davidson and Lyon 1979) and more adequate storage facilities exist, losses are estimated to be between 300 and 600 million dollars annually (Wilbur and Mills 1978).

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*Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae)

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At the present time, mechanical, physical, and/or chemical control measures are the predominant methods used to protect stored grain from insects. Insect infestation frequently occurs after the grain is placed in storage. Consequently, control programs stress the use of clean, insect-free, and weatherproof storage facilities and the elimination of nearby sources of insect infestation. Fumigation is frequently required to control stored-grain insects. Modern technology has also encouraged conditioned-air storage, air-tight storage, and diverse drying methods, all of which can be effective in reducing insect development and damage to stored grain. Unfortunately, such control tactics are unavailable or are not used in many areas of the world, particularly in developing countries.

Chemical control of stored product pests, though widely practiced, also has serious limitations. The recent upsurge of interest in alternatives to unilateral dependence on chemical control in production agriculture is due in part to the failure or adverse side effects of some chemical pesticides, including intolerable risks to human health and the environment. Increases in pest resistance are also limiting the effectiveness of many pesticides. Worldwide, there are presently at least 305 species of insects, mites and ticks that possess strains resistant to one or more chemical pesticides (Georghiou and Taylor 1977). The increasing cost of pesticides, exacerbated by the current petroleum shortage, also encourage consideration of alternative control measures.

One such alternative which has proven its usefulness as an insect control measure in production agriculture is plant resistance to insects resulting from heritable characteristics. Plants or varieties that are inherently less injured or infested by insects than other plant varieties of the same species under comparable environmental conditions are considered resistant (Painter 1951). Resistance of grain to insects can be divided into two components, non-preference for oviposition or feeding, and antibiosis as reflected by an adverse effect on the biology of the insect. Tolerance is unlikely because grain does not have the ability to compensate for the damage done by the insects. Over 100 cultivars resistant to field insects are grown in the United States (Schmeltz 1971), but there has been less emphasis on breeding for grains resistant to stored-product insects. Particularly in countries where storage facilities are inadequate, the utilization of such resistant varieties might be used either alone or in conjunction with chemical insecticides or other control tactics to reduce or eliminate insect damage.

The susceptibility of stored sorghum and other cereals to insect attack has been studied by many workers. Samuel and Chaterji (1953) tested 25 sorghum varieties against six species of stored-grain insect pests and reported that the variety JS 20 was resistant to most of the pests. They postulated that the combination of seed hardness, endosperm texture and the presence of glumes was responsible for low levels of insect damage. After screening more than 1500 sorghum varieties from the World Collection, Rogers and Mills (1974b) recorded 50 varieties which were resistant to the maize weevil, _Sitophilus zeamais_ Motsch. Lange(1973).

selected 16 cultivars which Rogers (1970) found most resistant to the maize weevil and reported that only Redlan, CM 796, CM 2520, and CM 208 had low weevil emergence percentages. Mannechoti(1974) reported that Shallu MP-10 was the most resistant of 92 cultivars to Sitophilus oryzae, S. zeamais, Rhizopertha dominica, and R. casteneum. White (1975) found similar results using S. zeamais and R. dominica as test insects.

This work was with the maize weevil since it is one of the most destructive and widely distributed of the primary stored grain pests. It occurs in greatest abundance in the warmer, humid regions of the world, such as the southern United States. This species prefers sorghum, oats, wheat, barley, and corn. Sorghum and corn were reported to be the most frequently infested (Morrison 1963). Although several species of beetles infest grain and grain products in Texas, the maize weevil is the most prevalent within the state (Morrison 1963).

The adult maize weevil female chews a cavity in the sorghum kernel, deposits an egg and then seals the cavity with a gelatinous plug. One female can lay a total of 300 to 400 eggs. There are four larval stages which are completed in about 23 days. Morrison 1963 reported that the maize weevil completed six generations per year with an average of 39 days required for each generation. The maize weevil is a good flier (Cotton 1963), and ranks as a primary pest because of its ability to infest whole, undamaged grain. Weight loss of stored grain is caused by both adult and larval feeding, with the major damage being done by the developing larva inside the kernel. Besides grain weight loss, grain quality is reduced through contamination of the grain with insect fragments and excreta. Maize weevil damage also may result in attack by secondary grain pests that normally cannot attack whole, undamaged kernels.

When this study was undertaken, kernels of more than 150 lines not previously screened for resistance to the maize weevil were available from the Texas Sorghum Conversion Project, a joint research effort sponsored by the Texas Agricultural Experiment Station (TAES) and the United States Department of Agriculture (USDA) in Puerto Rico and Texas. In this program, exotic sorghum races and subraces were converted from photoperiod sensitive, tall genotypes, to insensitive, shorter genotypes with better adapted agronomic characters which can be used in temperate areas (Stephens et al. 1967). These converted sorghums provide diverse germplasm that can be tested for desired characters such as yield or insect resistance. The objective of the research reported here was to screen kernels of available converted sorghum lines for maize weevil resistance.

MATERIALS AND METHODS

Maintenance of Cultures

The maize weevils used in this study were obtained locally (College Station) in 1976 and reared on either heterowaxy (AT x 378 x NSA 965, ATx 374 x NSA 954) or a commercial sorghum hybrid in an incubator. One pint, wide mouth Mason® jars with caps fitted with brass screens were used to hold the grain on which weevil cultures were maintained. Approximately 200 gm of sorghum grain in jars were moisture-equilibrated in an incubator for seven days before infesting with 150 unsexed weevils.

To obtain test insects of a known age, these weevils were allowed to oviposit for seven days, after which they were removed from the grain using a No. 10 U.S. Standard Sieve and discarded. The infested grain was maintained in the incubator, and the emerging adults were removed beginning 32 days post-oviposition. For the next seven days, all newly emerged adults were removed and placed in separate jars with cultured grain. The adult weevils reared and collected by this method were approximately 10 ± 3.5 days old.

Initial Screening

A total of 169 converted exotic sorghum lines chosen for the study were received from plant breeders at the Texas Agricultural Experiment Station at Lubbock. Entries were identified by their sorghum conversion (SC) number. Corresponding world collection (IS) numbers for these varieties have been published by Schuering and Miller (1978). Shallu MP-10 and Kafir 60, two lines previously reported as resistant and susceptible, respectively, to the maize weevil by both Lange (1973) and Mannechoti (1974), were obtained from Kansas State University. They were used as standard checks in both free-choice and no-choice tests.

Free-choice test. This method was used to determine the preference of maize weevil to kernels of 169 different sorghum lines. Plastic strips 5.2 cm wide were used to rim each of eight plywood circular trays 34 cm in diameter. Each tray had 25 separate seed compartments 2.6 cm in diameter which were equidistant from the tray center. Each compartment was also equidistant from adjacent ones. A 25-kernel sample of each of 22 randomly selected sorghum lines was placed in each compartment. Resistant (Shallu MP-10) and susceptible (Kafir 60) varieties, as well as the variety used as the rearing medium for the maize weevil cultures, served as controls in each chamber. Test seeds were equilibrated for two weeks at 27°C and 60 ± 3 percent RH. A group of 225 unsexed weevils 10 ± 3.5 days old were then placed in the center of the tray and allowed to move freely to the seeds confined in different compartments. Each tray was covered with fine mesh cloth to confine the weevils and maintained in the incubator for seven days, after which the number of weevils present in each compartment was recorded. The experiment was replicated four times.

No-choice test. Fifty undamaged kernels of each line were placed in small vials (2.2 cm in diameter and 2.5 cm in height) and equilibrated in the test chamber for two weeks. Maize weevils were sexed using snout characteristics described by Reddy (1951), after which six female and three male weevils 10 ± 3.5 days old were added to each vial. Vials were then covered with fine mesh cloth and maintained in the test chamber for a seven-day oviposition period, after which the adult weevils were removed. The vials remained in the test chamber for the next 55 days, during which time the number of emerging progeny was recorded. This experiment was replicated six times. Two replications of these trials were conducted in one incubator, in which the relative humidity ranged from 40-80 percent at 27°C. Four replications were conducted in an environmental chamber at 60 ± 3 percent RH and 27°C. Initially, two chambers were used to determine relative humidity effects.

Data from the free-choice and no-choice tests were statistically analyzed using analysis of variance procedures to determine significant differences among tested lines in the number of adults present and the number of emerged progeny. Duncan's multiple range test (DMRT) was used to test for statistical differences between individual means at the .05 probability level. Correlation analysis was also performed to determine whether a relationship existed between the two methods.

Selected Screening

Eighteen of the most resistant lines identified in the above tests were then compared to seven susceptible lines in a selected screening test. The former were lines in which the fewest adults had been found in the free-choice test and from which the fewest weevil progeny had emerged in the no-choice test. In the selected screening test, the same methods (free-choice and no-choice tests) were used to evaluate the selected lines, but in both tests additional evaluation criteria were used. In the free-choice test, data were collected not only on the number of adults present in each sample but also on the number of kernels damaged, egg plugs, and emerged progeny for each sample. In the no-choice test, in addition to the number of emerged progeny obtained, parent mortality after a seven-day oviposition period was also recorded. All tests were conducted in an environmental chamber set at 27°C and 70 ± 3 percent RH. Data were transformed using the square root transformation procedures previously described.

RESULTS AND DISCUSSION

Initial Screening

Free-choice test. Numbers of adult maize weevils recovered from kernels of each sorghum line in a free-choice test after a seven-day exposure period are presented in Table 1. Data were transformed using the square root transformation procedure prior to statistical analysis to generate a normal distribution. Analysis of variance showed significant differences in the number of adults present among lines. The F-test value of 2.75 (significant at the .05 level) indicated that the difference among sorghum lines in the number of adults present was slightly greater than the difference in adult numbers among replications of the same line.

Duncan's multiple range test revealed overlapping groups. SC0289, SC0186, SC0528, SC0427, and SC0165 were among the most susceptible entries. SC0254, SC0215, SC0303, SC0079, and SC0331 were among the most resistant entries based upon the number of adults in the free-choice test. Standard checks (Shallu MP-10 and Kafir 60) which were used as resistant and susceptible lines, respectively, could not be separated as resistant or susceptible in the free-choice test. Mannechoti (1974) and Lange (1973) reported these as resistant and susceptible, respectively, based on the number of progeny obtained.

Number of adults present in a free-choice test is one measurement of sorghum resistance to the maize weevil and is a convenient method of eliminating obviously susceptible entries. Its chief advantage over the no-choice test is that it eliminates the time-consuming task of sexing the weevils when a large number of varieties are to be evaluated.

Lines selected from this preliminary screening trial were subjected to the Selected Screening test described in succeeding paragraphs. The additional test was conducted to further study the weevil's behavior (oviposition, etc.), the extent of feeding on the grain, and the extent of progeny production.

<u>No-choice test</u>. Data from the no-choice test, based on the number of emerged progeny from kernels of each sorghum line, are given in Table

2. Data were transformed using the square root transformation procedure prior to statistical analysis. Analysis of variance showed significant differences among sorghum lines in the number of progeny which emerged. A greater F-test value was obtained in this test (9.25) in comparison to that obtained in the free-choice test (2.75), indicating that more variation was detected among the test lines by comparing numbers of progeny numbers.

Comparisons of the mean number of progeny obtained from different lines using DMRT indicated several overlapping groups of sorghum lines, particularly the intermediate lines. Significantly greater numbers of weevils (32 weevils/replicate) were obtained from the most susceptible line, SCO165, in comparison to the most resistant lines, SCO226, SCO230, and SCO233, which averaged only 0.17 weevils/replicate.

When seed quantity is limited, comparison of the number of emerged progeny obtained from different lines is considered a reliable method for determining weevil resistance in cereals, especially corn, wheat, rice, and sorghum (Davey 1965, Stevens and Mills 1973). Russell (1962) and Mills (1976) found that there was no significant difference among the sorghum lines they tested in regard to developmental period from egg to adult, or progeny weights. Windstrom et al. (1972) studied six methods (grain loss, number of emerged progeny per sample, percent damaged kernels, percent progeny mortality, and progeny weight) in corn kernels resistant to maize weevil and concluded that the total number of emerged progeny per sample was a better indicator of resistance than the other five methods. The no-choice test is a suitable measurement for selecting resistant lines because it simulates conditions in a grain bin. However, Mills (1976) reported that Shallu MP-10 was apparently more resistant to the maize weevil when tested in small quantities than when samples of 50 grams or more were tested.

Correlation analysis of the number of adults present in the free-choice test and the number of emerged progeny in the no-choice test showed significant positive correlation (r=0.324) at the .05 level. The results indicated that the number of adults present in the free-choice test had some value in the identification of the obviously susceptible lines. McCain et al. (1964) developed the "cafeteria method" for selecting for rice weevil resistance in corn and reported a high correlation (r = 0.65) between this method and a progeny test in the ranking of 10 corn hybrids. Stevens and Mills (1972) conducted similar studies in which they modified the free-choice test by separating it into a random distribution and a uniform distribution test. They found that when sorghum varieties were ranked according to resistance to the rice weevil, the results of all three types of test were nearly equal. In our study, however, relatively small correlation coefficients were obtained, indicating that neither of the distribution tests was as reliable as the no-choice test in detecting resistance of sorghums to the maize weevil. Our results were probably due to the fact that each line in the initial free-choice test was not tested against all other lines in the same test tray, since each tray could accommodate a maximum of only 25 lines.

The no-choice test showed that the response of some converted sorghum lines to maize weevil infestation was influenced by relative humidity. Although highly susceptible lines consistently produced relatively large numbers of progeny throughout the range of humidity occurring in this study, the resistance of some other lines to maize weevil was reduced when exposed to higher relative humidity.

Selected Screening

Free-choice test. Analysis of variance showed significant differences among the different entries in the numbers of adults present (Table 3). Of the converted lines tested, SC0193, SC0006, SC0331, SC0215, SC0224, SC0228, and SC0233 attracted fewer adult weevils (3.5-5.75/replicate) than did SC0366, SC0278, SC0333, SC0165, SC0227, SC0186, and SC0425 (10-23.5/replicate). Weevils were most numerous in the SC0425 and the SC0186 samples.

The acid fuchsin staining method (Frankenfeld 1948) was used to facilitate counting of egg plugs. The acid fuchsin stained the gelatinous plug a deep cherry red and the feeding punctures a light pink color. The number of egg plugs varied from one to more than six per kernel. The oviposition site was frequently found in the endosperm close to the base of the kernel. Results of the staining procedure indicated that SC0425 was the most susceptible to oviposition (53.50 plugs/ replicate), whereas SC0233 was the most resistant (4.25 plugs/replicate) (Table 4).

The number of kernels damaged by the adult weevils was determined using a biocular microscope to observe feeding damage. Kernels in which weevils had oviposited were separated before damaged kernels were counted. The number of damaged kernels ranged from 2.75/replicate in SC0193 to 12.25/replicate in SC0186 (Table 4). The number of emerged progeny obtained from different lines in the test ranged from 2.5/

replicate for SC0233 to 20.5/replicate for SC0425. Some progeny died following emergence from kernels of SC0233 or SC0331.

Correlation analysis among variables measured in the free-choice test showed that in general, the numbers of adults present were positively correlated with the number of egg plugs and number of emerged progeny; that is, as the number of adults attracted to each line increased, the number of egg plugs and emerged progeny also increased. However, an exception to this typical result occurred in the case of Kafir 60, the susceptible check. Although only 3.25 weevils/replicate were recovered from this line after the seven-day exposure period, an average of 31.75 egg plugs and 12.5 progeny per replicate were recorded. One explanation for such an exception might be the observation by Cogburn (1974) who stated that some lines either apparently attract more females than males, or females move to other lines after oviposition. The highest correlation coefficient (0.84) was found between the number of egg plugs and the number of emerged progeny, indicating that the probability of progeny survival to the adult stage after hatch was good. However, normally only one adult developed from a kernel in which two or more eggs had been laid. Sharifi and Mills (1971) found that small larvae were killed by larger ones. Such cannibalism occurred during several stadia but was most prevalent during the second. Schoonhoven et al. (1975) made a similar observation while screening 10 corn varieties against the maize weevil, concluding that resistance was primarily expressed as a reduction in oviposition. If an egg was laid in a kernel of either a resistant or a susceptible line, probability of progeny survival to the adult stage after hatch was good. However, Dobie (1974) experimented with 25 maize varieties from Malawi and found that there was no evidence of a relationship between the number of eggs laid and susceptibility. He concluded that the susceptibility of these varieties was determined by post-oviposition factors. In our study, there was no high correlation between the number of adults present and the number of damaged kernels.

No-choice test. Percent parental mortality was determined after weevils had been confined to seeds of each sorghum line for seven days. Such mortality ranged from 0-100 percent and was highest in SC0226, SC0233, SC0311, SC0309, and SC0227. Parental mortality did not occur in the checks and was low for SC0165 and SC0425. Rogers and Mills (1974a) found that the resistant variety "Double Dwarf Early Shallu" exhibited an antibiotic effect at 43 percent relative humidity causing an average of 85 percent parental mortality after a five-day oviposition period.

Duncan's multiple range test revealed distinctive groups of sorghum lines based on the number of emerged progeny (Table 4). The most resistant group consisted of SC0233, SC0226, and SC0311. These three lines averaged less than one progeny/replicate. The most susceptible lines - SC0165, SC0186, SC0103, SC0278, and SC0425 - averaged more than 25 weevils/replicate.

Correlation analysis between the number of progeny and percent parental mortality was negatively correlated (r=-0.89) and highly significant at the .05 level. In other words, the higher the parental mortality, the smaller the number of progeny obtained. Windstrom et al. (1972) concluded that the ranking of 25 selected lines in relation to maize weevil resistance was nearly the same when either percent parental mortality or number of emerged progeny was used as the criterion.

Correlation between the number of emerged progeny in the no-choice and the free-choice test was positive (r=0.89) and significant at the .05 level. The ranking of lines in order of resistance was similar for both tests. Sorghum lines such as SC0006, SC0193, SC0233, SC0311, and SC0331 were identified as resistant; of these, SC0233 and SC0311 were the most resistant. Kernels of these two lines consistently received less oviposition and yielded fewer emerged progeny in free-choice and the no-choice tests.

CONCLUSIONS

Based on the results of this study, the following conclusions may be drawn:

1. Preliminary screening of 169 converted exotic sorghum lines for resistance to the maize weevil using free-choice and no-choice methods revealed significant differences among lines in weevil aggregation tendencies and numbers of emerged progeny, thus indicating that some of the lines tested were resistant to the pest.
2. Results of selected screening trials indicated that there was congruity among different criteria used to detect resistance to maize weevil in converted exotic lines. Based on the results of this more detailed screening of 25 selected converted lines, five lines consistently displayed exceptional promise as sources of germplasm resistant to the maize weevil. These were SC0226, SC0233, SC0309, SC0311, and SC0331. Additional lines which should be further investigated as possible sources of resistant germplasm are SC0199, SC0224, SC0227, SC0230, SC0289, and SC0333.

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Table 1. Number of adults present among kernels of 169 converted exotic sorghums, standard checks and culture medium after a seven-day exposure period in free-choice test

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0289*	44	22	19	14	24.75	a
SC0186*	34	16	13	15	19.50	ab
SC0528	17	32	13	10	18.00	a-c
SC0427	36	13	13	10	18.00	a-d
SC0165*	30	16	13	10	17.25	a-e
SC0126	22	22	8	12	16.00	a-f
SC0425	8	12	19	24	15.75	a-g
SC0344	24	7	16	15	15.50	a-h
SC0103*	10	23	17	10	15.00	a-i
SC0055	19	17	22	4	15.50	a-j
SC0368	26	10	23	4	15.75	a-k
SC0144	8	27	15	10	15.00	a-l
SC0354	28	8	13	11	15.00	a-l
SC0402	25	13	9	11	14.50	b-m
SC0291	27	21	8	5	15.25	b-n
SC0362	19	18	12	7	14.00	b-o
SC0380	22	15	11	8	14.00	b-o
SC0048	39	11	5	7	15.50	b-o
SC0337	19	13	6	16	13.50	b-q
SC0278	13	12	12	15	13.00	b-q

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0389	16	16	12	8	13.00	b-r
SC0417	12	19	6	16	13.25	b-r
SC0285	33	9	11	4	14.25	b-s
SC0398	25	5	14	8	13.00	b-t
SC0367	17	9	11	11	12.00	b-u
SC0063	13	14	7	14	12.00	b-v
SC0399	13	12	7	16	12.00	b-v
Culture medium	5	6	26	14	12.75	b-w
SC0358	15	18	10	5	12.00	b-x
SC0356	10	11	8	17	11.50	b-y
SC0396	10	19	5	13	11.75	b-y
SC0370	6	15	15	10	11.50	b-y
SC0120	23	11	3	12	12.25	b-y
SC0267	17	11	7	10	11.25	b-y
SC0282	8	16	9	10	10.75	b-y
SC0329	17	5	10	11	10.75	b-y
SC0353	6	17	13	7	10.75	b-y
SC0271	10	12	12	9	10.75	b-y
SC0293	9	6	12	15	10.50	b-y
SC0394	16	18	9	2	11.25	b-y
SC0335	15	20	5	4	11.00	c-z
SC0315	12	6	9	13	10.00	c-z

Table 1. (Continued)

Entry**	No. of adults present/replicate 1	2	3	4	Mean	DMRT[a]
SC0296	18	5	12	15	10.50	c-z
SC0298	9	6	12	15	10.50	c-z
Kafir 60	9	8	13	9	9.75	c-z
SC0372	14	13	13	2	10.50	c-z
SC0228*	7	5	23	7	10.50	c-z
SC0053	6	7	11	14	9.50	c-z
SC0450	11	11	4	12	9.50	c-z
SC0188	9	9	3	18	9.75	c-z
SC0050	3	8	12	16	9.75	c-z
SC0229	11	17	6	4	9.50	c-z
SC0403	14	3	10	10	9.25	d-a'
SC0426	12	15	4	6	9.25	d-a'
Culture medium	11	12	4	9	9.00	d-a'
SC0387	7	7	11	10	8.75	d-a'
SC0299	8	24	4	4	10.00	d-a'
Kafir 60	6	8	8	13	8.75	d-a'
Culture medium	6	8	8	13	8.75	d-a'
SC0256	10	12	11	3	9.00	d-a'
SC0408	10	7	4	15	9.00	d-a'
SC0578	5	9	7	14	8.75	e-b'
SC0205	5	5	11	14	8.75	f-c'
SC0064	7	7	6	14	8.50	f-c'

Table 1. (Continued)

Entry**	No. of adults present/replicate 1	2	3	4	Mean	DMRT[a]
Culture medium	3	7	12	13	8.75	f-c'
SC0284	6	9	10	8	8.25	f-c'
SC0226*	6	3	11	14	8.50	f-c'
SC0108	5	6	10	11	8.00	f-c'
Kafir 60	6	9	2	18	8.75	f-c'
SC0369	4	11	8	9	8.00	f-c'
SC0534	4	15	9	5	8.25	f-c'
SC0309*	7	10	8	6	7.75	f-c'
SC0257	8	3	11	10	8.00	f-c'
SC0405	3	10	11	8	8.00	f-c'
SC0173	12	5	7	7	7.75	f-c'
SC0418	20	4	5	5	8.50	f-c'
SC0407	3	9	9	10	7.75	g-d'
SC0216	7	10	11	3	7.75	g-d'
SC0230*	1	12	11	9	8.25	g-d'
SC0112	2	8	14	8	8.00	g-d'
SC0374	8	6	10	9	8.00	h-e'
SC0239	7	11	7	5	7.50	h-e'
SC0118	6	11	5	8	7.50	h-e'
SC0036	6	6	12	6	7.50	h-e'
SC0029	6	4	8	12	7.50	h-e'
SC0097	3	11	8	8	7.50	h-e'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0549	6	10	6	7	7.25	i-f'
SC0424	6	9	9	5	7.25	i-f'
SC0220	4	4	3	23	8.50	i-f'
SC0308	8	12	8	2	7.50	i-f'
SC0261	9	8	5	6	7.00	j-f'
Kafir 60	4	9	3	14	7.50	j-f'
SC0268	5	3	10	11	7.25	k-g'
SC0290	5	5	11	7	7.00	k-g'
SC0221	9	10	3	6	7.00	l-g'
SC0124	5	9	1	16	7.75	m-g'
SC0066	10	8	1	10	7.25	m-g'
SC0333*	5	5	9	11	7.50	n-g'
SC0241	11	7	3	6	6.75	n-g'
SC0058	4	2	9	13	7.00	o-g'
Shallu MP-10	7	4	13	3	6.75	o-g'
Kafir 60	2	6	7	12	6.50	o-g'
SC0563	5	6	8	6	6.25	p-g'
Culture medium	3	7	5	11	6.50	p-g'
SC0392	5	13	7	2	6.75	p-g'
SC0250	4	3	11	8	6.50	p-g'
SC0212	3	4	3	19	7.25	p-g'
SC0056	1	8	12	6	6.75	p-g'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0258	9	8	5	3	6.25	p-g'
Culture medium	6	7	5	6	6.00	p-g'
SC0388	7	7	5	5	6.00	q-g'
SC0414	13	6	5	2	6.50	q-g'
SC0272	6	4	7	7	6.00	q-g'
SC0199*	4	8	5	7	6.00	q-g'
Culture medium	2	9	5	9	6.25	r-g'
Culture medium	5	5	10	4	6.00	r-g'
SC0501	8	4	3	9	6.00	r-g'
SC0031	1	8	8	8	6.25	s-g'
SC0057	5	5	8	5	5.75	s-g'
SC0193*	5	7	4	7	5.75	s-g'
SC0166	4	4	8	8	6.00	s-g'
Shallu MP-10	4	5	5	9	5.75	s-g'
SC0489	5	4	3	12	6.00	s-g'
Shallu MP-10	9	3	6	5	5.75	s-h'
Kafir 60	10	4	3	6	5.75	t-h'
SC0214	1	4	7	13	6.25	t-h'
SC0265	4	4	4	11	5.75	t-i'
SC0317	3	7	5	7	5.50	t-i'
SC0504	4	3	7	8	5.50	t-i'
Kafir 60	5	5	3	9	5.50	t-i'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
Culture medium	5	5	9	3	5.50	t-i'
SC0319	3	3	5	12	5.75	t-j'
SC0110	8	5	7	2	5.50	t-j'
SC0566	2	5	8	7	5.50	t-j'
SC0346	7	4	4	6	5.25	u-j'
SC0052	4	4	8	5	5.25	u-j'
SC0307	4	5	8	4	5.25	u-j'
SC0202	6	3	4	8	5.25	v-j'
SC0281	8	3	2	9	5.50	v-j'
SC0493	5	8	6	2	5.25	w-j'
Shallu MP-10	9	5	1	7	5.50	w-j'
SC0499	9	8	4	1	5.50	w-j'
SC0206	6	9	2	4	5.25	w-j'
SC0530	2	4	9	6	5.25	x-j'
SC0182	4	0	11	9	6.00	x-j'
SC0209	4	5	10	2	5.25	x-j'
SC0203	5	3	4	8	5.00	x-j'
SC0253	9	4	4	3	5.00	y-j'
SC0208	5	3	2	11	5.25	y-j'
Shallu MP-10	7	2	3	8	5.00	z-j'
SC0271*	5	5	4	6	4.75	z-j'
SC0233*	6	4	3	6	4.75	z-j'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0195	3	5	4	7	4.75	z-j'
SC0243	3	5	8	3	4.75	z-j'
SC0224*	4	7	6	2	4.75	z-j'
SC0093	6	5	3	4	4.50	z-j'
Culture medium	3	7	4	4	4.50	z-j'
Culture medium	6	6	3	3	4.50	z-j'
SC0340	6	5	3	5	4.50	z-j'
Culture medium	8	4	3	3	4.50	z-j'
SC0411	3	7	2	6	4.50	z-j'
SC0311*	5	4	3	5	4.25	z-j'
SC0292	9	4	3	2	4.50	z-j'
Culture medium	4	5	6	2	4.25	z-j'
SC0114	1	8	6	3	4.50	z-j'
SC0090	1	1	4	15	4.25	z-j'
Shallu MP-10	1	5	7	4	4.25	z-j'
SC0237	2	8	5	2	4.25	z-j'
SC0017	3	3	4	6	4.00	z-j'
SC0322	3	6	1	6	4.00	z-j'
Shallu MP-10	4	3	13	0	5.00	z-j'
SC0109	2	7	5	2	4.00	a'-j'
SC0240	4	5	6	1	4.00	a'-j'
SC0223	2	9	1	5	4.25	a'-j'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0227*	2	5	4	4	3.75	a'-j'
SC0366*	2	3	5	5	3.75	a'-j'
SC0423	2	5	3	5	3.75	a'-j'
SC0078	2	4	3	6	3.75	a'-j'
SC0283	2	3	5	5	3.75	a'-j'
SC0006*	0	5	5	5	3.75	a'-j'
SC0459	1	4	5	5	3.75	a'-j'
Kafir 60	4	1	4	6	3.75	a'-j'
Culture medium	3	6	3	2	3.50	a'-j'
SC0252	2	2	6	4	3.50	a'-j'
SC0044	2	1	3	9	3.75	a'-j'
SC0175	1	5	6	2	3.50	a'-j'
Culture medium	2	3	3	5	3.25	a'-j'
SC0431	2	1	5	5	3.25	b'-j'
SC0217	2	1	4	6	3.25	b'-j'
SC0248	2	5	2	3	3.00	c'-j'
SC0244	4	1	1	5	2.75	d'-j'
SC0207	1	4	7	0	3.00	d'-j'
SC0457	0	3	2	6	2.75	d'-j'
Shallu MP-10	3	5	1	1	2.50	e'-j'
SC0019	1	3	0	7	2.75	f'-j'
SC0331*	4	0	2	4	2.50	f'-j'
SC0079	0	3	2	4	2.25	g'-j'

Table 1. (Continued)

Entry**	No. of adults present/replicate				Mean	DMRT[a]
	1	2	3	4		
SC0303	1	1	2	2	1.50	h'-j'
SC0215*	0	3	0	3	1.50	i'-j'
SC02154	0	0	0	4	1.00	j'

[a] Means followed by a common letter are not significanlty different at the .05 level according to Duncan's multiple range test (DMRT).

* Selected for further testing.

** IS numbers of entries can be obtained from TAES MP-1367, 1978.

Table 2. Number of emerged progeny from kernels of 169 converted exotic sorghums, 2 standard checks and culture medium 55 days post oviposition in no-choice test.

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0165*	34	50	28	22	32	26	32.00	a
SC0186	45	47	24	27	12	37	32.00	ab
Kafir 60*	42	47	19	20	32	26	31.00	a-c
SC0050	29	40	3	-	36	42	30.00	a-d
SC0278*	20	47	20	15	21	40	27.17	a-e
SC0103	29	48	5	22	30	32	27.67	a-f
SC0501	29	42	13	17	31	26	26.33	a-g
SC0108	31	46	18	15	26	20	26.00	a-g
SC0267	25	40	20	15	36	18	25.67	a-g
SC0056	14	43	13	21	31	33	25.83	a-h
SC0118	36	41	12	15	24	26	25.67	a-h
SC0578	35	47	17	20	25	11	25.83	a-h
SC0528	35	22	12	12	40	31	25.33	a-i
SC0126	24	25	17	18	35	27	24.17	a-j
SC0389	19	36	9	32	21	30	24.50	a-k
SC0388	24	38	11	18	25	24	23.33	a-l
SC0402	23	25	15	16	24	35	23.00	a-m
SC0048	8	47	11	13	34	31	24.00	a-n
SC0405	12	43	7	23	25	30	23.33	a-n

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0530	35	46	3	14	19	28	24.17	a-o
SC0315	22	38	19	14	20	19	22.00	a-o
SC0387	28	32	15	15	19	22	21.83	a-p
SC0120	26	40	16	10	24	18	22.33	a-p
SC0052	5	41	21	23	23	25	22.67	a-q
SC0398	30	38	13	11	16	25	22.17	a-r
SC0344	27	33	18	4	24	29	22.50	a-s
SC0358	22	27	9	22	28	21	21.50	a-s
SC0329	26	20	12	27	13	30	21.33	a-t
SC0282	25	41	7	15	24	20	22.00	a-t
SC0258	14	34	14	18	26	20	21.00	a-u
SC0399	12	36	17	19	25	17	21.00	a-v
SC0112	13	43	14	14	23	21	21.33	a-v
SC0293	18	39	13	11	24	20	20.83	a-v
SC0250	9	39	10	18	25	26	21.17	a-v
SC0093	28	45	12	4	23	19	21.83	a-v
SC0173	32	30	7	13	18	23	20.50	a-w
SC0166	31	45	25	3	22	7	22.17	a-w
SC0253	13	38	16	13	14	26	20.00	a-w
SC0418	34	44	1	3	33	25	23.33	a-w
SC0319	29	39	10	10	12	22	20.33	a-w

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0403	20	39	4	18	23	18	20.33	a-w
SC0499	17	30	10	17	23	18	19.17	a-x
Shallu MP-10	28	47	10	12	8	17	20.50	a-x
SC0427	15	17	19	11	22	27	18.50	a-x
SC0396	27	40	6	13	29	5	20.00	a-x
SC0063	21	41	5	6	24	18	19.17	a-x
SC0057	26	45	0	13	20	19	20.50	a-x
SC0504	25	34	10	17	8	15	18.17	a-x
SC0450	5	27	18	12	23	21	17.67	a-x
SC0110	22	44	17	4	12	12	18.50	a-x
SC0257	16	36	6	6	19	26	18.17	a-x
SC0291	2	26	12	23	22	21	17.67	b-y
SC0175	19	46	6	11	2	31	19.17	b-y
SC0354	11	20	12	19	18	17	16.17	b-y
SC0372	9	26	13	13	19	18	16.33	c-z
SC0353	17	32	7	14	9	18	16.17	d-a'
SC0417	31	29	11	19	11	2	17.17	d-a'
SC0356	29	31	6	7	10	17	16.67	d-a'
SC0368	9	37	13	11	16	11	16.17	d-a'
SC0114	20	46	5	10	13	8	17.00	d-a'
SC0237	30	37	7	3	13	10	16.67	d-a'

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0563	14	19	15	9	10	21	14.17	d-a'
SC0109	25	40	14	1	17	4	16.83	d-a'
SC0292	24	40	2	0	13	23	17.00	d-a'
SC0090	8	25	10	8	10	20	13.50	d-a'
SC0044	0	24	17	15	11	21	14.67	e-b'
Culture medium	27	29	6	9	8	5	14.17	e-b'
SC0394	23	18	3	4	21	15	14.00	e-b'
SC0424	26	29	0	13	11	10	14.83	f-c'
SC0566	4	32	9	11	13	12	13.50	g-c'
SC0261	20	23	9	0	22	12	14.33	g-c'
SC0144	20	32	6	6	12	4	13.33	h-d'
SC0369	21	37	2	7	8	7	13.67	i-e'
SC0207	24	33	4	1	9	11	13.67	i-f'
SC0493	7	34	2	14	7	14	13.00	j-f'
SC0337	23	10	9	7	10	11	11.67	j-f'
SC0411	16	24	2	14	7	9	12.00	k-g'
SC0265	15	31	8	1	9	11	12.50	l-g'
SC0392	11	29	5	0	19	14	13.00	l-g'
SC0053	0	21	1	-	22	28	14.40	l-h'
SC0209	18	26	6	8	12	1	11.83	l-h'
SC0457	12	34	0	6	8	16	12.67	m-h'

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0549	22	15	3	2	12	14	11.33	n-h'
SC0459	30	33	1	0	14	5	13.83	n-h'
SC0284	20	42	0	0	7	17	14.33	n-h'
SC0426	35	24	0	1	15	6	13.50	n-h'
SC0296	12	24	3	0	19	12	11.67	o-i'
SC0214	16	34	0	7	11	4	12.00	p-j'
SC0124	18	22	7	4	6	5	10.33	q-k'
SC0335	19	15	9	9	4	4	10.00	r-k'
SC0097	15	22	0	-	13	6	11.20	r-l'
SC0346	5	24	6	11	8	6	10.00	s-l'
SC0340	13	33	0	5	3	17	11.83	t-l'
SC0380	14	15	11	7	14	0	10.17	u-l'
SC0272	13	30	9	4	6	13	11.00	v-l'
SC0182	10	20	0	1	14	17	10.33	w-m'
SC0017	14	21	3	5	0	14	9.50	x-n'
SC0362	20	7	0	4	15	7	8.83	y-o'
SC0205	24	12	1	2	6	6	8.50	y-p'
SC0239	20	21	2	2	3	3	8.50	y-q'
SC0244	1	37	0	3	6	10	9.50	y-r'
SC0079	12	17	2	0	7	8	7.67	y-s'
SC0283	20	32	0	0	0	10	10.33	y-t'

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0221	9	11	0	0	21	8	8.17	y-t'
SC0066	15	2	5	11	2	6	6.83	y-t'
SC0256	17	14	0	2	9	3	7.50	z-u'
SC0078	4	25	0	4	12	2	7.83	z-v'
SC0208	24	18	0	0	3	6	8.50	a'-v'
SC0220	10	13	6	0	5	6	6.67	a'-v'
SC0031	14	21	0	9	2	1	7.83	a'-v'
SC0212	1	13	8	5	4	6	6.17	a'-v'
SC0489	7	24	0	2	2	9	7.33	a'-w'
SC0243	6	25	0	3	7	2	7.17	b'-x'
SC0420	5	16	0	0	6	14	6.83	b'-y'
SC0408	4	9	4	5	6	3	5.17	b'-y'
SC0055	2	4	0	3	16	11	6.00	b'-y'
SC0423	8	24	1	0	0	9	7.00	b'-y'
SC0285	20	10	0	1	9	0	6.67	b'-y'
SC0298	19	7	4	1	1	2	5.67	b'-y'
SC0425*	12	22	3	1	0	1	6.50	b'-y'
SC0254	7	23	0	0	0	12	7.00	b'-y'
SC0019	5	27	1	1	2	2	6.33	b'-y'
SC0281	9	20	0	0	2	4	5.83	b'-y'
SC0414	12	3	0	6	4	0	4.67	b'-y'

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0534	20	3	1	0	1	9	5.67	b'-y'
SC0036	5	31	0	0	0	6	7.00	b'-y'
SC0370	15	4	0	2	3	5	4.83	c'-z'
SC0248	10	16	0	0	3	3	5.33	c'-z'
SC0217	5	6	0	6	1	6	4.00	d'-z'
SC0252	1	33	0	0	0	7	6.83	d'-z'
SC0223	14	16	0	0	0	3	5.50	d'-z'
SC0188	3	4	1	1	4	10	3.83	d'-z'
SC0240	19	1	0	1	2	6	4.83	e'-z'
SC0203	7	4	1	1	3	5	3.50	f'-z'
SC0374	5	10	1	4	1	1	3.67	f'-z'
SC0367	1	11	0	6	2	3	3.83	g'-z'
SC0431	7	15	0	0	2	2	4.33	g'-z'
SC0290	3	11	0	1	4	3	3.67	g'-z'
SC0308	7	2	2	5	3	0	3.17	h'-z'
SC0064	0	3	0	0	1	29	5.50	h'-z'
SC0058	4	10	2	1	2	0	3.17	h'-z'
SC0407	16	5	0	0	0	2	3.83	i'-z'
SC0322	3	3	2	4	1	1	3.22	i'-z'
SC0029	10	6	0	0	0	3	3.17	j'-z'
SC0303	2	19	0	0	9	2	3.83	k'-z'

Table 2. (Continued)

Entry**	No. of progeny/replicate 1[a]	2[a]	3[b]	4[b]	5[b]	6[b]	Mean	DMRT[c]
SC0195	17	2	0	0	0	2	3.50	l'-z'
SC0299	4	5	0	5	1	0	2.50	l'-z'
SC0241	8	9	0	1	0	0	3.00	l'-z'
SC0216	1	3	0	0	2	9	2.50	l'-z'
SC0268	10	6	0	1	0	0	2.83	l'-z'
SC0202	1	17	0	0	0	2	3.33	l'-z'
SC0006*	1	1	1	2	0	7	2.00	m'-z'
SC0289*	0	3	1	2	2	2	1.67	m'-z'
SC0206	2	6	0	0	1	1	1.67	n'-z'
SC0333*	0	11	1	0	1	0	2.17	o'-z'
SC0331*	0	12	2	0	0	0	2.33	o'-z'
SC0311*	3	9	0	0	0	0	2.00	o'-z'
SC0317	2	6	0	1	0	0	1.50	p'-z'
SC0307	1	5	0	0	1	1	1.33	p'-z'
SC0228*	2	6	0	0	0	0	1.33	q'-z'
SC0215*	3	4	0	0	0	0	1.17	r'-z'
SC0224*	1	4	0	1	0	0	1.00	r'-z'
SC0229	1	2	0	0	0	2	0.83	s'-z'
SC0271*	0	5	0	0	0	1	1.00	t'-z'
SC0227*	3	2	0	0	0	0	0.83	u'-z'
SC0193*	2	2	0	0	0	0	0.67	v'-z'

Table 2. (Continued)

Entry**	No. of progeny/replicate						Mean	DMRT[c]
	1[a]	2[a]	3[b]	4[b]	5[b]	6[b]		
SC0199*	0	2	0	0	0	1	0.50	w'-z'
SC0366*	3	0	0	0	0	0	0.50	x'-z'
SC0309*	0	1	0	0	1	0	0.33	y'-z'
SC0226*	1	0	0	0	0	0	0.17	z'
SC0230*	0	1	0	0	0	0	0.17	z'
SC0233*	0	1	0	0	0	0	0.17	z'

[a] Samples maintained in an incubator at 27°C and 40-80% RH.

[b] Samples maintained in an environmental chamber at 27°C and 60 ± 3% RH.

[c] Means followed by a common letter are not significantly different at the .05 level according to Duncan's multiple range test (DMRT).

* Selected for further testing.

** IS numbers of entries can be obtained from TAES MP-1367, 1978.

Table 3. Mean number of adults present, eggs plugs, damaged kernels, and emerged progeny in free-choice tests, and percent parent mortality and number of emerged progeny in no-choice tests

	Free choice[a]				No-choice[a]	
Entry	No. of adults present	No. of egg plugs	No. of damaged kernels	No. of emerged progeny	Percent parent mortality	No. of emerged progeny
SC0425	23.50a	53.50a	5.50c-h	20.50a	5.56f	37.50a
SC0186	21.00a	22.7e-h	12.25a	11.75c-i	13.89e	27.13a
SC0227	15.25b	13.00ij	9.50a-c	10.00e-j	83.34b	2.88g
SC0165	14.75b	30.50b-f	8.00a-f	15.50a-d	1.39ef	32.13a
SC0333	12.75bc	35.75bc	5.75b-h	14.50a-e	54.17cd	17.00b-d
SC0278	12.50bc	25.00d-g	10.25ab	16.00a-c	5.56ef	31.63a
SC0366	10.00cd	33.25b-d	6.25b-g	15.50a-d	51.39d	19.88bc
SC0230	9.25c-e	26.50c-f	6.25b-g	14.50a-e	51.39d	17.63b-e
SC0103	9.50c-e	28.50c-f	9.00a-e	13.75b-f	12.50ef	28.00a
SC0309	9.00c-e	16.50hi	8.25a-f	11.75c-i	94.45ab	3.13g
SC0226	7.50d-f	15.50hi	7.25a-f	7.50ij	100.00a	0.00h
SC0199	6.50d-g	14.50ij	8.00a-f	8.75g-j	59.33cd	12.00c-f
SC0311	6.00d-g	17.25g-i	5.25c-h	4.50k-l	97.22a	0.50gh
SC0271	6.00d-g	17.00hi	8.00a-f	10.50d-j	50.00d	17.88b-d
SC0289	6.00d-g	40.75b	4.00e-h	19.75ab	54.17cd	20.75b
SC0233	5.75e-g	4.25k	7.50a-f	2.50l	100.00a	0.00h
SC0228	5.50e-g	21.25f-h	8.00a-f	13.75c-g	51.39d	17.63b-e
SC0224	4.50fg	13.25ij	9.50a-d	9.25f-j	68.06c	9.13f
SC0215	4.50fg	30.00b-f	4.00gh	9.25f-j	55.56cd	11.00ef
SC0331	4.00g	7.75jk	7.00b-f	3.25l	66.67c	2.75g
SC0006	3.75g	14.75hi	5.00d-h	7.75ij	55.56cd	8.50ef
SC0193	3.50g	14.25hi	2.75h	8.50h-j	50.00d	11.25d-f
Shallu MP-10	3.25g	15.50hi	6.75b-f	6.75jk	0.00f	13.75c-f
Kafir 60	3.25g	31.75b-e	5.25e-h	12.50c-h	0.00f	28.00a

[a] Means followed by a common letter are not significantly different at the .05 level according to Duncan's Multiple Range Test.

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