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SOURCES OF RESISTANCE TO THE MAIZE WEEVIL, *SITOPHILUS ZEAMAIS* MOTS, IN 1511 CULTIVARS OF SORGHUM

by

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INTRODUCTION

It is thought that sorghum originated in east-central Africa and was probably one of the earliest plants to be domesticated. Today grain sorghum is grown extensively in Africa, India, China, Manchuria, and the United States and to a lesser extent in other areas for human and livestock consumption.

Everywhere it is attacked by insect pests in the field and in storage. Total loss of the world production of cereals due to storage insects has been estimated to be as high as 10%. Among these storage pests, the maize weevil, *Sitophilus zeamais*, is one of the most destructive.

The female weevil eats a small hole in the kernel, lays an egg in it and plugs the hole with a gelatinous secretion. A small larva hatches from this egg and develops through four instars and a pupal stage inside the kernel before emerging as an adult.

Control is usually accomplished by either chemical treatment, sanitation or physical treatment such as cooling or heating. Chemical treatment is costly and there is a risk of residual contamination. Sanitation and physical treatment involve much time and often are not effective. If varieties were available to growers that were resistant to weevil attack, a cheap and easy method of control would be provided. This would be especially valuable in developing countries where the cost of other methods of control would render them prohibitive. In developed areas such as the United States, resistant varieties would also be very worthwhile since stored grain has a low profit margin and very little money would have to be spent on pest control.

Therefore this research was undertaken as part of the Kansas Agricultural Experiment Station Project, Hatch 686 entitled "Susceptibility of Sorghum Grain in Storage to Grain Damaging Insects". The particular objective was to evaluate a worldwide collection of sorghum cultivars for resistance to the maize weevil.

LITERATURE REVIEW

Taxonomic Status of the Rice Weevil Complex

Linnaeus first described the rice weevil as *Curculio oryzae* L. in 1763. Subsequent to this description much confusion has evolved concerning the taxonomic status of certain variant populations that were originally included in the same taxon. In 1855, Motschulsky described a larger weevil from corn as *Sitophilus zea-mais* Motsch. A small weevil in Japan was named *Calandra oryzae* (L.) var. *minor* Sasaki (Sasaki, 1899) but was later renamed *Calandra sasakii* (Tak.) (Takahashi, 1928).

Richards (1944) showed that two strains of *Calandra oryzae* (L.) differed significantly in size and that hybrids of crosses between the two did not produce viable offspring. However he did not consider these strains as distinct species since there were no non-overlapping morphological differences or combination of differences between them. Birch (1944) also noted significant size differences and intersterility between two strains of *Calandra oryzae* L. and concluded that these strains could be classified as different species.

In 1946 Birch found that both strains were larger when reared on corn than when reared on wheat but one strain remained the largest regardless of rearing media. Birch (1953) reported that the innate capacity for increase was greater for the small strain when reared in wheat and greater for the large strain in corn. Furthermore in 1954 he showed that when the two strains occurred together in wheat the small strain was successful while the large strain prevailed in maize.

Floyd and Newsom (1959) substantiated intersterility between the two strains and referred to the larger as Sitophilus oryzae (L.) and the smaller as Sitophilus sasakii (Tak.). Kuschel (1961) finally clarified the taxonomic situation of the rice weevil complex when he recognized the small weevil as Sitophilus oryzae (L.) and the larger weevil as Sitophilus zeamais Mots.

General Biology

Hinds and Turner (1911), Kyle (1918), Cotton (1920), Reddy (1950 a, 1950 b, 1950 c), Howe (1952), Soderstrom (1962), Singh and Soderstrom (1963), Morrison (1964 a), Soderstrom and Wilbur (1965, 1966) and others have discussed the general biology of the rice weevil complex in detail.

Resistance in Sorghum

Ali (1950) reported that of the 15 varieties tested only Martin and Cody were suitable for reproduction of Sitophilus oryzae L. However, this high level of resistance may be attributed to a 9.6% moisture content in all varieties.

Samuel and Chatterje (1953) conducted studies on the resistance and susceptibility of 24 sorghum varieties to 6 stored-product insects including Sitophilus oryzae L. They found a non-huskable variety, JS 20, to be fully resistant to the rice weevil. They suggested that the degree of resistance might be due to a combination of factors, i. e. hardness, texture, moisture content, and husk cover.

Victoria Lieu in unpublished work done at Kansas State University in the 1950's noted that reproduction and survival of the rice weevil, granary weevil, and lesser grain borer was prohibited in two non-waxy sorghum varieties, Double Dwarf Yellow Sooner and Double Dwarf White Sooner, of 12% moisture content.

Doggett (1957) found a positive relation between the low rate of weevil damage and thick corneous outer endosperm shell. He also indicated that small grains seemed to suffer less damage than large ones. In 1958 he reported that selection for a thick corneous endosperm shell had been successful in a breeding program for weevil resistance.

Harder grained varieties, with the exception of Texioca-54, were shown to be least attractive to the maize weevil for oviposition by Russell (1962). When the varieties were mixed, the larger seeds were preferred for oviposition. Mortality of immatures was not significantly different between the two varieties.

Morrison (1964 b) compared the effect of whole, halved, and coarsely ground kernels of Atlas sorghum on the development of the maize weevil, Sitophilus zeamais Mots. Whole kernels produced the most emerged adult weevils and coarsely ground the least.

Davey (1965) concluded that a count of emerging adults was an adequate measure in comparing damage between different varieties. Higher numbers of progeny were obtained from varieties with a mealy endosperm than from those with a vitreous endosperm. Many of the parent weevils died on vitreous varieties possibly because of a slightly lower moisture content. Hardness was clearly correlated with the amount of vitreous endosperm.

In studies with 4 varieties, Russell (1965) used length of developmental period and number of first generation progeny as indicators of resistance.

He demonstrated that the reactions of *Sitophilus oryzae* L. and *Sitophilus zeamais* Mots. were analagous and due largely to the relative hardness of the varieties. Russell (1966) later found that length of adult life was shorter in harder varieties.

When comparing techniques for screening varieties of grain sorghum to the rice weevil, Stevens (1966) showed that more progeny were produced in nonchoice confined tests than in tests where the weevils were given a choice. Collier x Atlas and Double Dwarf Early Shallu were the least favorable in all tests.

Studies on Resistance of Other Grains to Stored Products Insects

Resistance in Maize

Cartwright (1930) found that longer shuck lengths were associated with resistance to field infestation of the rice weevil. Eden (1952) substantiated these findings and noted that weevil damage increased almost 1% for each increase of 1 pound per square inch pressure required for penetration of a 1/16 inch hollow steel punch. However he found no correlation of resistance to thickness of pericarp.

The rice weevil and other internal feeders were found to be capable of survival on hulled teosinite but only the Angoumois grain moth survived on unhulled grain. (Warren, 1954).

Warren (1956) reported variable responses of the Angoumois grain moth when reared on 29 strains of maize at 14% and 17% moisture content. However he did not find any significant differences in larval survival between strains at either moisture content.

A highly significant positive correlation between sugar content of kernels and field infestation and a negativo correlation between kernel hardness and rice weevil infestation were demonstrated by Singh and McCain (1963).

McCain et al (1964) designed a technique for selection of rice weevil resistance by allowing the weevils to have a choice of several varieties.

Pant et al (1964) used per cent of seeds damaged, average loss in weight of seeds and size of insect population produced as indicators of resistance to the rice weevil.

Diaz (1967) screened 139 maize collections for resistance to the maize weevil and suggested that resistant germ plasm comes from tropical lowlands or primitive corn.

Maize varieties with high amylose content adversely affected larval nutrition of the granary weevil and the rice weevil in studies by Rhine and Staples (1968). However larval survival was unproportionately high for the rice weevil on high amylose varieties while being low for the granary weevil. The authors further suggested that larval survival may have been influenced by other resistance factors since the high amylose maize was developed under a different breeding program than the varieties with normal amylose content.

Van Der Schaff (1968) screened 337 cultivars of maize for resistance to the maize weevil, Sitophilus zeamais Mots.

Resistance in Other Stored Products

Sound, mature rough rice with an intact husk appeared to be almost immune to infestation by Sitophilus sasakii (Breese, 1960). However, infestations did develop in grains with lemma and palea separated but the developing adult was often unable to emerge. Rossetto (1966) screened 1700 varieties of rough rice for resistance to Sitophilus zeamais Mots. and reported the same relationships.

Ewer (1945) noted that larger grains of wheat were preferred for oviposition by the granary weevil, Calandra granaria L.

In work with other small grains, Sinha (1969) found that hulled oats prohibited reproduction of the granary weevil and of the lesser grain borer. However most other commonly grown Canadian cereal varieties were not markedly resistant.

Podoler and Applebaum (1968) suggested that the relative resistance of varieties of broad beans was due solely to the ability of hatching larvae and emerging adults to penetrate the seed coat. They also concluded that thickness of the seed coat seemed to be the only limiting factor.

MATERIALS AND METHODS

Sorghum Collection

The sorghum collection that was screened for resistance was received from the International Germ Plasm Seed Bank (IGPSB), Chapingo, Mexico in September, 1968. It was composed of 1511 cultivars of sorghum of worldwide origin. Several hundred seeds of each cultivar were contained in paper envelopes. An abbreviated pedigree and country of origin is given in a list kept on file at the Department of Entomology, Stored-Product Insect Section, Kansas State University. A more complete pedigree may be obtained by writing the IGPSB. Cultivars that were used as resistant and susceptible checks in the screening process were Double Dwarf Early Shallu and Sugary Feterita, respectively. These two cultivars, in addition to Redlan, were also used in tests on factors influencing the level of resistance. All three of these cultivars were obtained from the Kansas Agricultural Experiment Station. Upon receipt of the grain samples, they were placed in a freezer for several days to destroy any possible insect infestation and then stored in a cold room at approximately 40° F to prevent infestation.

Source of Insects

Two strains of Sitophilus zeamais Motschulsky, the maize weevil, were employed in the screening procedures. Preliminary screening was carried out using a strain obtained from Vera Cruz, Mexico in August, 1964. The strain used in secondary screening was obtained from Stuttgart, Arkansas in 1955 and maintained in the Department of Entomology, Stored-Product Insects rearing room. In addition to these, two strains of Sitophilus oryzae (L.), the rice weevil, and one strain of Sitophilus granarius (L.), the granary weevil, were used in other experiments described in this report. One strain of the rice weevil was taken from McLain County, Kansas in 1965 while the other was obtained from the USDA Stored-Product Insects Laboratory in Atlanta, Georgia. The granary weevil was obtained from an unknown location in Kansas.

Maintenance of Insect Cultures

Cultures were maintained at a relative humidity of 70± 4% and a temperature of 80± 1° F. The room was dark except when entered. Culture media used were Redlan sorghum in the case of the Mexican strain of maize weevil and Early Triumph hard red winter wheat for all other strains and species. The grain was cleaned with a Bates Laboratory Aspirator (H. T. McGill Co., Houston, Texas) and then the moisture content was adjusted to approximately 13.5% by adding water and mixing thoroughly. The amount of water to be added was calculated by the following formula:

$$\frac{100 - \text{present \% moisture}}{100 - \text{desired \% moisture}} \times \text{Wt. of Wheat} - (\text{Wt. of Wheat})$$

The insects were reared in wide-mouth, 1 quart Mason jars with 40-mesh screen lids. A Kelthane-treated filter paper disc was inserted into each lid to prevent attack by predaceous mites, particularly *Pyemotes* sp. Further protection against these mites was provided by Kelthane-treated cloths that were placed on rearing room shelves. These cloths were replaced by freshly-treated ones every 2 to 3 wk to maintain residual miticide protection. In order to prevent escape from or entry into the cultures by insects or mites, all jars were placed on upside-down petri dishes which had been set in 34.3 cm x 24.1 cm x 1.3 cm metal pans containing paraffin oil (Plate I). About 250 gm of medium was placed in each of 3 jars and approximately 200, 2- to 4-week-old weevils were added to each jar. These were removed after a 7-day oviposition period with a No. 10 and a No. 20 hand sifter (U. S. Standard Sieve Series). Three jars were set up in this manner each wk and the same parent weevils were used for 3 wk and then replaced. Newly-emerged adult weevils were removed daily and placed in separate jars in order to determine their age, within 24 hr, and later be used in the screening process.

Sex Determination

The sex of adult weevils was determined by the snout characteristics given by Richards (1947). The weevils were examined individually under a dissecting microscope while being held with a Schuco vacuum aspirator (Schuco Scientific, New York, New York) (Plate I). During this process the insects were contained in open pans, the sides of which had been coated with Teflon to prevent the weevils from escaping.

Preliminary Screening for Resistance

This stage of the screening process was carried out to reduce the number

EXPLANATION OF PLATE I

Fig. 1. Culture jars setting on upside-down petri dishes in metal pan with paraffin oil.

Fig. 2. Schuco-Vac vacuum tweezers used in handling insects.

PLATE I

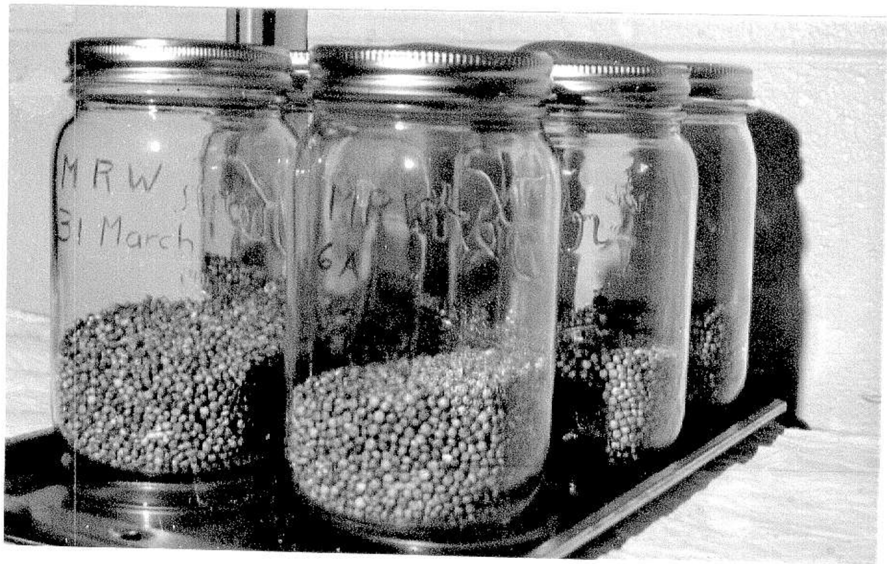


Fig. 1

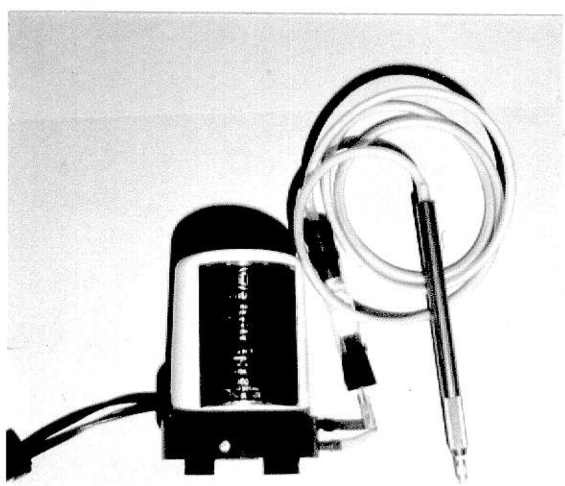


Fig. 2

of cultivars under consideration for sources of resistance and subsequently subjected to more intensive study in the second phase of screening. Methods modified from those suggested by Stevens (1966) were used. Fifty sound kernels of each cultivar were placed in 5.7 cm x 5.7 cm x 2 cm plastic test boxes (Bradley Industries, Franklin Park, Illinois). These were placed in the rearing room with lids removed and remained there for a minimum of 3 wk to allow the moisture content and temperature of the grain to equilibrate with that of the rearing room atmosphere. Measurement of the moisture content of each grain sample by electronic testers or air oven was not possible because of the small amount of grain in each sample. However an open pan of Redlan sorghum was left in the rearing room and periodic measurements of moisture content were made with the Model 919 Motomco Moisture Meter (Motomco Inc., Clark, New Jersey). Following this equilibration period, 6 female and 3 male, 11-day-old maize weevils of the Mexican strain were added to each box and removed after a 5-day oviposition period. Experimental checks consisted of a box with Double Dwarf Early Shallu (resistant) and a box with Sugary Feterita (susceptible) which were infested in the same manner as above each day that a group of tests were set up (Plate II). The resistant and susceptible qualities of these two varieties were demonstrated by Stevens (1966) and later by Hunkapillar (unpublished data). Adult progeny were counted and removed every 5 days for 30 days beginning 22 days after parent weevils were removed from the boxes. Approximately half of the cultivars were infested between the dates April 4 and April 21, 1969 (Group I) while the remainder were infested between July 7 and August 6, 1969 (Group II). The mean and standard deviation of the number of progeny per box was calculated for the resistant and susceptible checks in both groups. All cultivars that yielded as few or fewer progeny as their appropriate resistant check, within at least 2 standard deviations, were

EXPLANATION OF PLATE II

Fig. 1. Plastic boxes and lids each containing 50 seeds that were infested with 6 female and 3 male maize weevils.

Fig. 2. Sugary Feterita and Double Dwarf Early Shallu, the susceptible and resistant check varieties. The number of progeny that emerged from each sample is shown.

PLATE II

Fig. 1

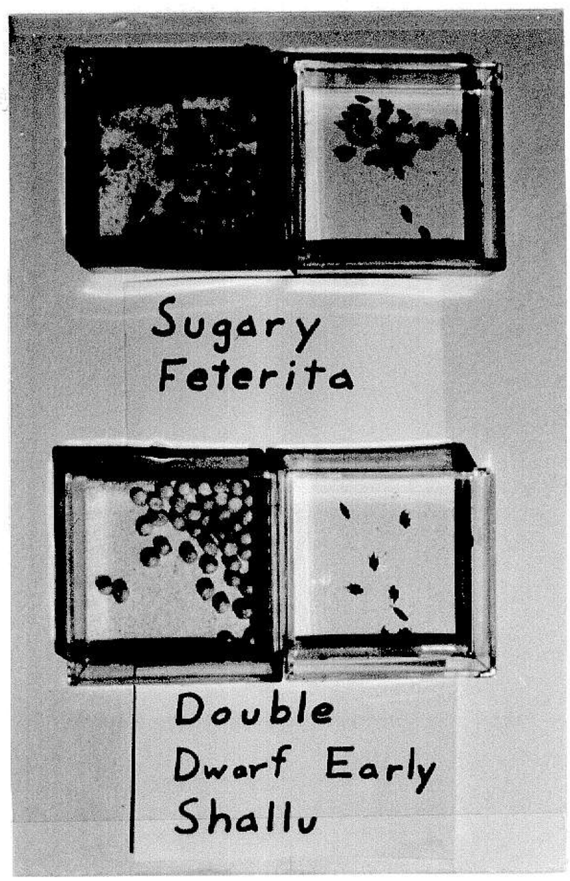


Fig. 2

selected for further screening. This included, at minimum, 95.4% of those cultivars that had a level of resistance as high as or higher than Double Dwarf Early Shallu assuming that this variety has a normal distribution as to resistance.

Secondary Screening for Resistance

Due to unreplication, the previous tests were relatively insensitive in that many of the cultivars selected were actually not as resistant as they appeared to be. This can be explained by the inherent variance present in the weevil population and in the susceptibility of the cultivars. In order to detect these, a secondary screening was carried out with those cultivars selected in the previous test. The procedure was identical to that used in preliminary screening except that 3 boxes of each cultivar were set up and the Arkansas strain of the maize weevil was used (Plate II). The mean number of progeny per box of each cultivar was compared with the mean of the resistant check by using a t test for groups with unequal numbers of samples (Snedecor, 1956).

Studies on Factors Influencing the Level of Resistance

Effect of Population Density

The objective of this test was to determine what effect increasing the number of kernels of a resistant sorghum cultivar available to a given number of test insects, in a standard plastic test box, had on the number of progeny produced by these weevils. Groups of 5 boxes each containing either 25, 50, 100, or 150 seeds per box were set up. This was done for both the Arkansas and Mexican strains of maize weevil. Six female and 3 male, 10- to 15-day-old maize weevils of the appropriate strain were added to each box and were removed after a 5-day oviposition period. Progeny counts were made in the same manner as previously described. An estimate of the direct effect of a given change in the number of seeds on the number of progeny was determined by linear regression analysis. Correlation coefficients were also computed.

Effect of Strain and Species of Weevil Used

This experiment was conducted to determine if different strains and species of stored-product weevils produced different numbers of progeny on the resistant grain sorghum, Double Dwarf Early Shallu. Five boxes each were set up for each of the following species and strains of stored-product weevils: Mexican maize weevil reared on sorghum, Mexican maize weevil on corn, Arkansas maize weevil, Kansas rice weevil, Georgia rice weevil, and a Kansas strain of the granary weevil all of which were reared on wheat. Six females and 3 males were placed in each box for a 5-day oviposition period, then removed. Progeny counts were made in the same manner as described previously. The data were analyzed with a one-way analysis of variance and Duncan's new multiple range test (Duncan, 1955).

Effect of Relative Humidity and Moisture Content

The principal objective of these tests was to determine what effect 3 relative humidities and the resulting equilibrium moisture contents of 3 varieties of sorghum had on the number of progeny produced by the Arkansas maize weevil. As a secondary objective, an attempt was made to detect differences between equilibration moisture contents of these varieties at different relative humidities. Constant humidity chambers were constructed from 31 cm x 20.5 cm x 11 cm polyethylene food containers with sealing lids

(Republic Molding Corp., Chicago, Illinois) (Plate III). The following saturated salt solutions were placed in each of 3 chambers: $SrCl_2$, NaBr, and K_2CO_3. According to Solomon (1951), these produce relative humidities of 70.83%, 57.70%, and 42.76% respectively at 25° C. The rearing room where these chambers were kept was held at 26.6± .6° C. Two-mesh hardware cloths provided a platform above the solution upon which the test boxes rested. Test boxes were the same as those used previously except they had 60-mesh screen inserts to allow ample ventilation. These inserts were installed by the method described by Swoyer (1970). In each humidity chamber, 5 boxes with 50 seeds in each were set up for Double Dwarf Early Shallu, Redlan, and Sugary Feterita. Each box was infested with 6 female and 3 male 11-day-old maize weevils of the Arkansas strain. These were removed after 5 days and progeny counts made in the manner previously described. A filled box of each variety was placed in each humidity chamber for moisture testing. A vacuum oven method of measuring moisture content of single kernels, described by Oxley (1948) and modified by Bell (unpublished data) was used about a month later. Thirty-five kernels of each variety and from each humidity were tested to determine if significant differences existed between varieties from the same humidity. A two-way analysis of variance was used to detect differences between the number of progeny produced at 3 relative humidities and in 3 varieties. This analysis was also used in detecting differences in moisture contents in these same humidities and varieties.

RESULTS AND DISCUSSION

Preliminary Screening

For convenience, the cultivars were placed in 2 groups for preliminary screening. Cultivars in Group I were infested between the dates April 4 and

EXPLANATION OF PLATE III

Fig. 1. Polyethelene containers used as constant humidity chambers.

Fig. 2. Plastic boxes with screen inserts to provide ventilation.

Fig. 3. Vacuum oven apparatus used in determining moisture content of the grain.

PLATE III

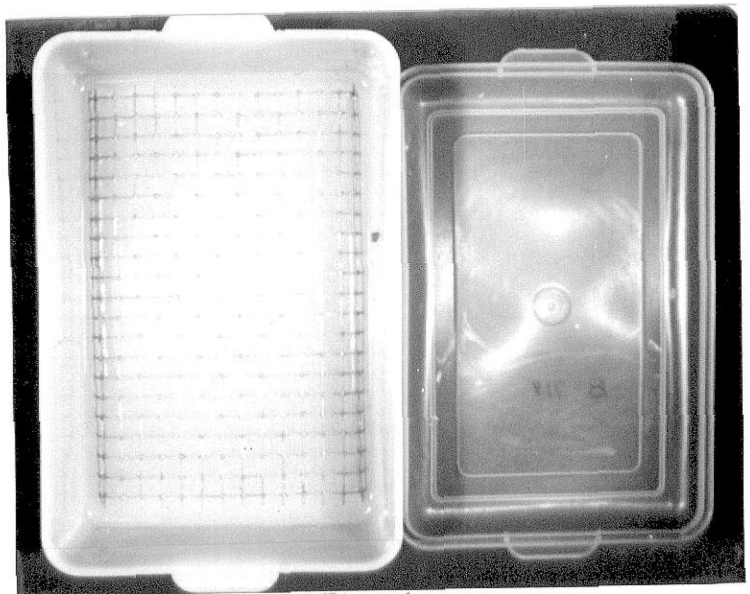


Fig. 1

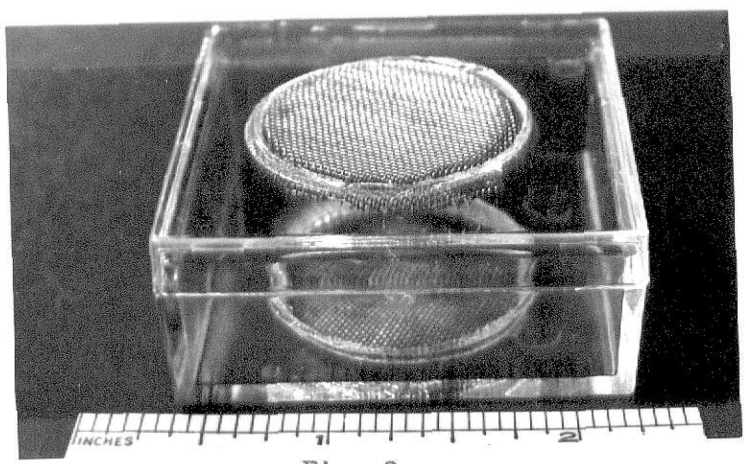


Fig. 2

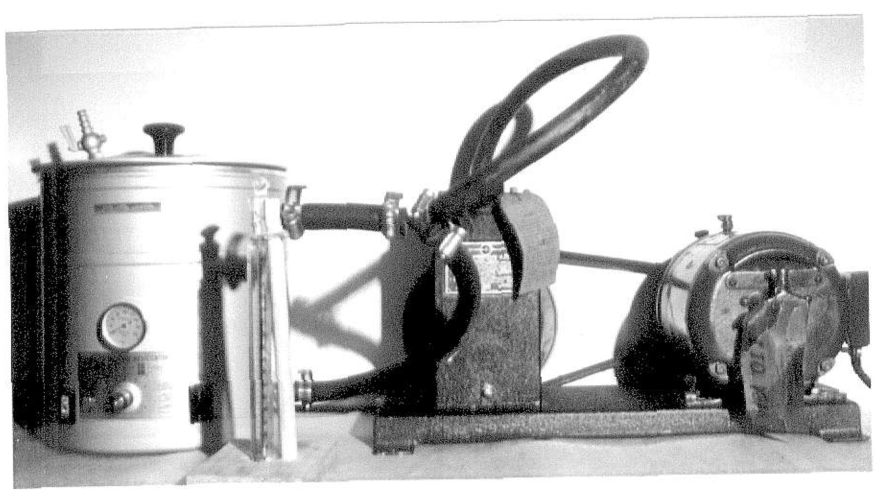


Fig. 3

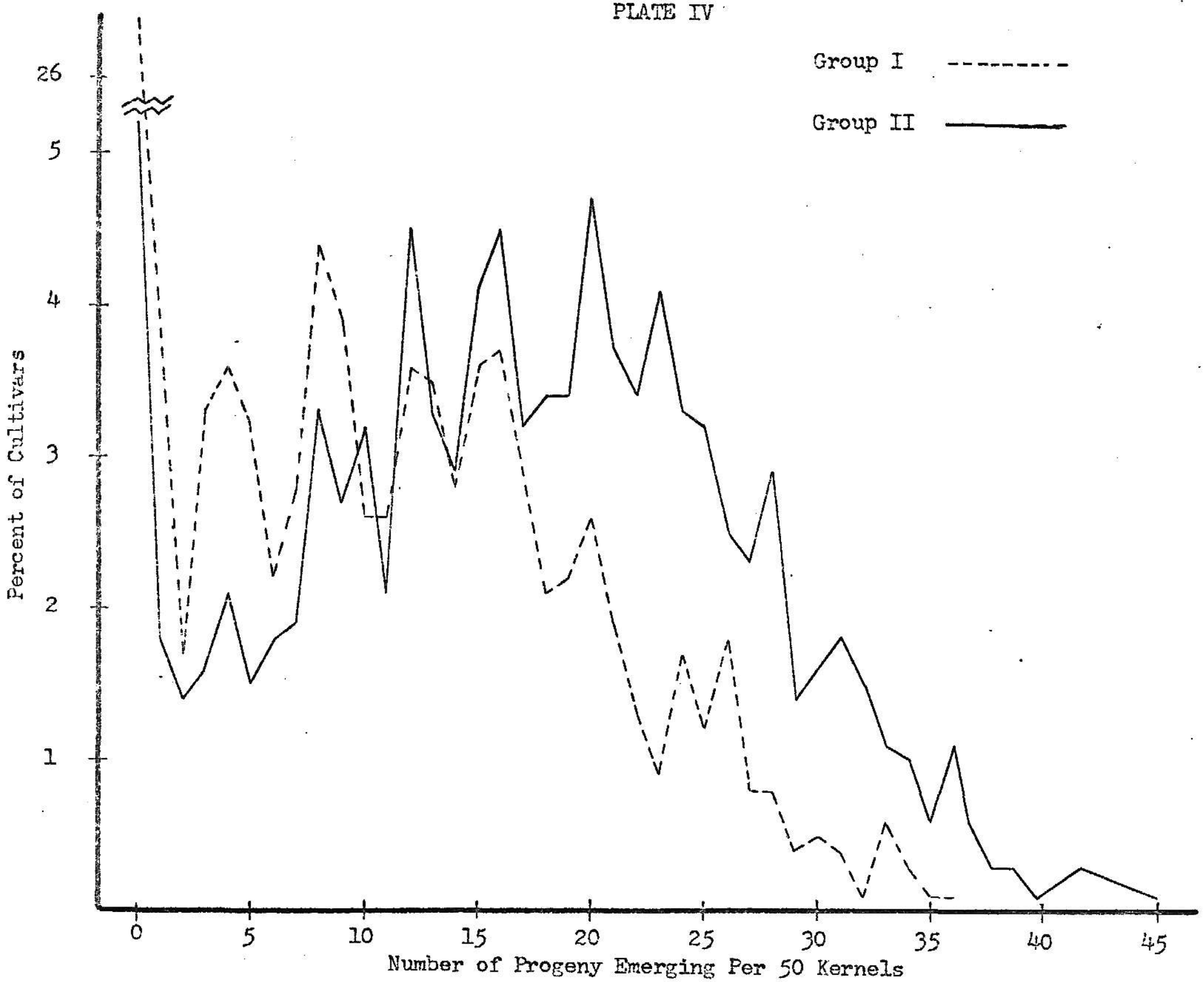
April 21, 1969 and the cultivars in Group II were infested between July 7 and August 6, 1969. Of the 1511 cultivars tested in Groups I and II, 497 were selected for secondary screening. This number consisted of those cultivars in both groups that produced as few progeny as the mean number of progeny from their respective resistant checks within at least two standard deviations. In Group I, 318 or 40.8% of the 780 cultivars tested were selected. This number included all varieties that yielded 5 or less progeny. The mean number of progeny per replicate produced by the resistant check variety was 0.3 with a standard deviation of 0.7. Of 731 cultivars in Group II, 179 or 24.5% were selected for further study. This included all cultivars that had 10 or less progeny. The resistant checks for this group produced a mean of 3.2 progeny with a standard deviation of 3.2.

When comparing the percentage of cultivars at varying levels of progeny emergence (Plate IV), more cultivars in Group I produced a small number of progeny than in Group II. This is especially noticeable with the number of cultivars producing no progeny. Of the cultivars in Group I, 26.4% produced no progeny, but only 5.2% of the cultivars in Group II fell in this category. The differences are not as distinct at other levels but Group I consistently had a larger percentage of cultivars at low levels of progeny emergence and a smaller percentage at high levels. Furthermore a t test comparing the means of the number of progeny emerging from the resistant checks of each group showed that the check for Group II had significantly more progeny than the check for Group I at the 0.05 significance level. However, there were no significant differences between susceptible checks. The mean number of progeny from the susceptible checks in Group I was 33.2 with a standard deviation of 3.8 while for Group II the mean was 35.5 with a standard deviation of 6.1.

EXPLANATION OF PLATE IV

A comparison of the percentage of cultivars in each group at various levels of progeny emergence.

PLATE IV


Group I
Group II
26
5
4
3
2
1
Percent of Cultivars
0
5
10
15
20
25
30
35
40
45
Number of Progeny Emerging Per 50 Kernels

The larger percentage of cultivars demonstrating resistance in Group I than in Group II could be due simply to the fact that there are more resistant cultivars in that group or it could be due in part to some other factor that differed between the two groups. The fact that the resistant checks produced more progeny when tested with Group II seems to support the latter explanation. Upon close examination of experimental conditions in both groups, the only apparent variable was the number of generations the test weevils had been reared on sorghum after being removed from maize. Most of the test insects used in Group I had been reared on sorghum for only 1 to 2 generations while the insects used in Group II had been on sorghum for up to 5 generations. Unknown variables, however, could also have been responsible for the differences between the two groups.

Secondary Screening

Results from this phase of screening are summarized in Table 1. Nineteen replicates of the resistant check produced a mean of 9.2 progeny with a standard deviation of 3.6 while the same number of susceptible checks produced a mean of 42.4 progeny with a standard deviation of 4.0. A t test comparing the mean number of progeny from the resistant check with the mean of each cultivar tested showed that 336 or 67.74% of the 497 cultivars had significantly more progeny than the resistant check at the 0.15 level of probability. This relatively low level of significance was chosen because of the small number of replicates of each cultivar.

Due to the fact that the Arkansas strain of maize weevil was used in secondary screening instead of the Mexican strain which was used in preliminary screening, many more progeny resulted in the second phase both in the checks and in the cultivars being screened. A t test comparing the number of

Table 1. Number of progeny resulting when 6 female and 3 male maize weevils were confined for 5 days with 50 seeds of each sorghum cultivar; calculated t when mean number of progeny per replicate for each cultivar was compared to the mean number of progeny per replicate for the resistant check. ($t_{0.15}$ = 1.066).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny				Calculated t
			Rep. 1	Rep. 2	Rep. 3	Mean	
336	*BE 13	Nigeria	0	0	0	0	
337	*BE 14	Nigeria	0	0	0	0	
694	*KB 23	Nigeria	0	0	0	0	
914	*AS 4269 Red Irungo	India	0	0	0	0	
980	*MN 735	U.S.A.	0	0	0	0	
1122	*SA 364 Combine Kafir	U.S.A.	0	0	0	0	
1207	*AS 5202 Amer. Early Red	Australia	0	0	0	0	
1442	*Balasiyor	India	0	0	0	0	
1932	*SA 9849 Big Seed Yel. End.	U.S.A.	0	0	0	0	
2257	*Sorghum 23	Nigeria	0	0	0	0	
2436	*Kanke No. 2	India	0	0	0	0	
3399	*FC 16156 Planter	Mexico	0	0	0	0	
3680	*Purdue No. 8116 - 1 DKS Indiana	U.S.A.	0	0	0	0	
3585	*No. 61 Waliso	Ethiopia	0	0	0	0	
54	*Keshwal	India	0	0	1	0.3	-1.484
1493	*MN 753	U.S.A.	0	0	1	0.3	-1.484
1663	*KO 41	Nigeria	0	0	1	0.3	-1.484
3741	*<u>S. verticilliflorum</u> MN 1650 PI 156112	U.S.A.	0	1	0	0.3	-1.484
996	*Kala Gangai Kumarhaga	India	2	0	2	1.3	-1.314
1494	*MN 864	U.S.A.	2	2	0	1.3	-1.314
1441	AS 4055	N. Rhodesia	1	2	2	1.7	-1.257
1972	IN 58	Nigeria	3	1	2	2.0	-1.201
3388	*MN 904	U.S.A.	2	1	4	2.3	-1.143
3733	EC 21406 MAC 4	India	5	4	0	3.0	-1.026

*Cultivars with glumes completely surrounding seed.

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
916	*AS 4532 Arisi Cholam	India	4	0	7	3.7	-0.910
30	Vellai Cholam	India	7	6	0	4.3	-0.797
169	*FC 16153 Mayo Amber	thru Mexico	4	9	2	5.0	-0.685
3706	*Purdue No. 81397 - 2 x J MScK 60 x Wise	U.S.A.	8	6	4	6.0	-0.520
38	Muttin Guti Jola	India	9	10	0	6.3	-0.460
1428	NS 10 Kapire	Nyasaland	10	1	8	6.3	-0.461
95	Konda Jonna Kuddapali	India	2	11	9	7.3	-0.299
208	S 52 Blanc de Sandiniere	Senegal	7	8	7	7.3	-0.302
979	MN 733	U.S.A.	4	7	12	7.7	-0.245
15	Disease Resistant Variety	Thailand	6	6	12	8.0	-0.192
177	Double Dwarf Early Shallu 6657-25-3-1	thru Mexico	5	9	10	8.0	-0.193
180	DDET 6660-2-1-1	thru Mexico	13	6	5	8.0	-0.192
3689	Purdue No. 81244-1 x Beltsu. Sel. Indiana	U.S.A.	8	8	8	8.0	-0.192
1313	194 Kano	Kenya	9	9	7	8.3	-0.141
1781	Achigo 629	Sudan	7	3	16	8.7	-0.085
18	Unknown	Unknown	6	9	12	9.0	-0.033
35	Vellai Cholam	India	11	3	13	9.0	-0.034
104	Nala Janzarala Unstapura	India	6	13	8	9.0	-0.035
130	Jendhri	India	10	2	15	9.0	-0.034
3457	Jola Nondyal	India	12	5	10	9.0	-0.034
2511	a-34	Japan	14	9	5	9.3	0.017
34	Kaka Cholam	India	13	8	9	10.0	0.120
934	M 439	U.S.A.	12	7	11	10.0	0.120
65	Bajri Duhrar	India	8	10	13	10.3	0.170
152	AS 7745 Alangara Cholam	India	10	11	10	10.3	0.170
1000	Irungu Cholam	India	16	3	12	10.3	0.166
1944	KA 13	Nigeria	10	15	6	10.3	0.168
2368	AS 4290 Alangara Cholam	India	9	13	9	10.3	0.170

*Cultivars with glumes completely surrounding seed.

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
2377	a-27	Japan	9	12	10	10.3	0.170
2791	Mungari Jola	India	11	11	9	10.3	0.170
172	Dwarf Shallu 5463-15-5-4	thru Mexico	10	10	12	10.7	0.221
692	KB 12	Nigeria	7	11	14	10.7	0.220
2289	305 Feterita Suki II	Sudan	8	12	12	10.7	0.221
3075	Jogpura	India	10	13	9	10.7	0.220
3443	Jola Mandyal	India	12	6	14	10.7	0.228
2140	EC 21419, SB 26	India	13	9	11	11.0	0.270
2385	Velai Cholam	India	15	7	11	11.0	0.268
2520	6358 Nebraska	U.S.A.	13	10	10	11.0	0.270
191-D	Yellow Endosperm Shallu SA 8009-5-7-4-8-2 Texas	U.S.A.	15	13	7	11.7	0.365
2239	279 Feterita Kadugli	Sudan	7	18	10	11.7	0.363
3446	Jola Nandyal	India	13	9	13	11.7	0.366
3423	Shenali 4-5	India	11	11	13	11.7	0.367
29	Silku Jonnalo	India	14	16	6	12.0	0.410
75	AS 4876	India	15	10	11	12.0	0.414
119	Ginora	India	13	14	9	12.0	0.414
1102	AS 1451 Dull midrib Irungu	India	14	12	10	12.0	0.414
1466	PI 229838-P3734 Q2/5/42	U.S.A.	14	15	7	12.0	0.412
2116	EC 21350 G17	India	13	10	13	12.0	0.415
2382	Chinnathadagam	India	14	14	8	12.0	0.413
2801	Ginigeri Jola	India	8	10	18	12.0	0.410
3238	Popa type Masma	India	12	12	12	12.0	0.415
90	Jonna Madanapolli	India	9	8	20	12.3	0.453
111	Samba Cholam	India	21	8	8	12.3	0.451
140	Bajri Jullhine	India	13	9	15	12.3	0.460
1285	6327 Nebraska	U.S.A.	14	9	14	12.3	0.460
236	TAB Farako	W. Volta	13	13	12	12.7	0.510
795	Kangar chari	India	15	18	5	12.7	0.500
1622-A	144 Dinder wawi 2	Sudan	13	12	13	12.7	0.510
2001	Unchamba	India	13	11	14	12.7	0.509

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
100	Jonna Bandupalla	India	15	12	12	13.0	0.555
113	Alluna Jola Kindgal	India	11	17	11	13.0	0.552
155	Sathammazada Jonna	India	10	11	18	13.0	0.551
1977	Chicken Corn SA 1951	U.S.A.	8	16	15	13.0	0.551
3063	Sohela	India	13	11	15	13.0	0.554
3583	No. 25 Didesse Valley	Ethiopia	17	10	12	13.0	0.552
133	Kurucholu	India	12	18	10	13.3	0.596
961	MN 721	U.S.A.	11	13	16	13.3	0.599
2414	AS 4632	Tanganyika	19	17	4	13.3	0.584
3001	IC 6159 Big Jowar	India	15	14	11	13.3	0.599
3124	Nambai	India	13	18	9	13.3	0.595
3205	Gugheri Kinchiabad	India	14	15	11	13.3	0.599
115	Alluna Jola Bailwad	India	13	12	16	13.7	0.645
1116	HC 6028	Japan	17	12	12	13.7	0.644
1954	NG 26	Nigeria	16	14	11	13.7	0.645
3064	Sahela	India	13	18	10	13.7	0.642
1	LGV 89-3 Yellow Grain African	thru Mexico	11	11	20	14.0	0.682
2325	Local Nature type 48/52 Matopos	S. Rhodesia	13	12	17	14.0	0.688
2798	Kempus Alluna	India	10	18	14	14.0	0.685
3208	Wagadi Tramba	India	17	11	14	14.0	0.687
28	Muthu Cholam	India	13	16	14	14.3	0.733
1249	PI 229859 Fort Cox II Q2/5/67	U.S.A.	17	16	10	14.3	0.729
2489	MN 808	U.S.A.	20	8	15	14.3	0.722
2754	Yerra Jona	India	12	13	18	14.3	0.730
3091	Bhawrasa	India	15	16	12	14.3	0.732
3505	Jowar Shenoli 4-5	India	8	15	20	14.3	0.722
123	Navadi Santhal	India	13	17	14	14.7	0.776
231	EC 21343 C13	India	15	14	15	14.7	0.777

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
227	Tiryo Kalagnigue	Mali	13	16	20	16.3	0.978
1405	EC 21379, J 70	India	17	8	24	16.3	0.959
3319	Magi Jonna	India	15	21	13	16.3	0.976
84	Motichura Pannar	India	15	21	14	16.7	1.018
141	Bardhona Big Rajpur	India	12	19	19	16.7	1.017
156	Jonna Malikpadi	India	23	15	12	16.7	1.011
161	Roxi Barikel	India	19	16	15	16.7	1.022
1185	AS 6525 Tiller, headless tall	India	10	24	16	16.7	1.005
2207	SA 8339-1 (D) Texas	U.S.A.	19	18	13	16.7	1.019
76	TPT 2	India	15	18	18	17.0	1.061
110	Kakacholam Pudor	India	11	21	19	17.0	1.051
134	Choranga	India	23	11	17	17.0	1.048
235	No. 4 Hadoui	W. Volta	19	19	13	17.0	1.057
1093	Selo Junello	India	17	15	19	17.0	1.064
1204	5639 SA 1740 Edwards Combine White Kafir	U.S.A.	16	19	16	17.0	1.061
1372	62-9821 38 Day Milo	U.S.A.	15	18	18	17.0	1.061
1395	Sorghum Coll. Karamajos	Uganda	6	27	18	17.0	1.020
2064	a-80-1	Japan	20	13	18	17.0	1.057
83	Jhallar	India	22	11	19	17.3	1.087
186	KFYE 1-3-2	thru Mexico	9	21	22	17.3	1.079
1462	428 El Savra	Sudan	19	14	19	17.3	1.096
96	Ishimurta Tahoor Jonna	India	15	21	17	17.7	1.135
132	Khera	India	19	11	23	17.7	1.123
171-A	Dwarf Shallu 5462-37-3-3	thru Mexico	15	22	16	17.7	1.132
1242	Ntuli Red DL/60/135 - ex Swaziland	S. Africa	13	20	20	17.7	1.132
2349	Tabroro White 481 Tozi	Sudan	23	16	14	17.7	1.129
7	EC 18103	Nepal	18	22	14	18.0	1.168
1380	AS 4163 Kanchebela	N. Rhodesia	27	14	13	18.0	1.150
1385	AS 4625 Mygasa - Maswadt	Tanganyika	17	16	21	18.0	1.172

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
3218	Kaljanpur	India	11	19	24	18.0	1.157
3432	Jola Mandyal	India	18	16	20	18.0	1.173
32	Erra Jonnalu	India	19	21	15	18.3	1.207
470-D	ZA 24	Nigeria	22	11	22	18.3	1.194
1111	AS 4136 Masaka Luwemba	N. Rhodesia	15	27	13	18.3	1.187
1318	Tseta Local Nature Type 27/51 Bulawayo	S. Rhodesia	16	23	16	18.3	1.204
1908	397 Liposa	Sudan	14	19	22	18.3	1.204
2201	SA 8010-1	thru Mexico	16	15	24	18.3	1.201
2476	AS 4854 T 12 x AS 60	India	10	25	20	18.3	1.186
2748	Bili Kesari	India	20	14	21	18.3	1.205
3504	Jawar Kalgundi	India	20	16	19	18.3	1.209
52	Gundi Jesa	India	21	18	17	18.7	1.246
89	Motichura Chirodi	India	29	10	17	18.7	1.209
99	Khed Jonna	India	16	19	21	18.7	1.245
658	SP 28	Mali	16	23	17	18.7	1.242
1268	Ntuli Swaziland AW/58/197 DL/59/1533	S. Africa	12	18	26	18.7	1.227
1391	T 15	Uganda	17	21	18	18.7	1.246
2431	J-31	India	18	17	21	18.7	1.246
31	Erra Jonnalu	India	20	19	18	19.0	1.283
682	BO 5	Nigeria	21	18	18	19.0	1.282
798	428 PI 282668	U.S.A.	21	16	20	19.0	1.280
1263	Radar 226/56, ex S. Africa Bulawayo	S. Rhodesia	13	26	18	19.0	1.264
1274	Radar	S. Africa	13	23	21	19.0	1.271
2445	AS 5033 Upp. Vellai Cholam	India	19	16	22	19.0	1.279
2518	AS 4294 Konda Jonna	India	18	21	18	19.0	1.282
3398	SO 43	India	19	19	19	19.0	1.283
9	EC 18322	Nepal	21	18	19	19.3	1.317
64	Bajri Hathi Bari	India	26	16	16	19.3	1.303
74	AS 1055 Talaivirichan Cholam	India	24	17	17	19.3	1.310

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
6-A	SV 193	India	14	15	15	14.7	0.777
183-A	DDET 6662-7-1 R	thru Mexico	15	17	13	15.0	0.818
1340	EC 21421 SB 37	India	20	9	16	15.0	0.809
1434	J-27	Uganda	18	17	10	15.0	0.813
1491	MN 590	U.S.A.	17	14	14	15.0	0.818
1909	MN 749	U.S.A.	16	15	14	15.0	0.819
67	Bajri Onda	India	15	10	21	15.3	0.850
86	Dukri Higna	India	24	14	8	15.3	0.839
163	Bujra Bhinkanda	India	12	9	25	15.3	0.837
375	PL 23	Nigeria	19	15	12	15.3	0.857
659	SP 40	Mali	18	14	14	15.3	0.859
1305	TS 45 Pink Kafir	thru Mexico	18	14	14	15.3	0.859
1338	a-83	Japan	23	14	9	15.3	0.844
2032	KO 23	Nigeria	18	19	9	15.3	0.850
2378	Karurethu Cholom Vedapatti	India	16	11	19	15.3	0.855
2752	Kogar Jola	India	18	15	13	15.3	0.859
3073	Ramsur	India	20	12	14	15.3	0.855
3083	Bundi	India	16	15	15	15.3	0.861
102	Jonsola Pandikamal	India	9	18	20	15.7	0.891
142	Bajra Udaipur	W. Bengal	16	15	19	15.7	0.885
150	AS 4730 Jonna Sukkunda	India	16	10	21	15.7	0.892
325-A	BA 37	Nigeria	21	7	19	15.7	0.883
1665	KO 56	Nigeria	9	18	20	15.7	0.891
2369	AS 2700 Pallaku Jolam	India	15	18	14	15.7	0.902
3451	Jola Nandyal	India	16	16	15	15.7	0.903
3465	Jowar Kagundi	India	16	15	16	15.7	0.903
39	Bili Jola Kador Jola	India	12	18	18	16.0	0.939
170	SB 256	Uganda	19	14	15	16.0	0.940
1918	Dawa VAR Bwasar	U.A.R.	16	13	19	16.0	0.940
51	Havnar	India	17	15	17	16.3	0.983
154	Joudra Kharif Taked Budhur	India	13	19	17	16.3	0.980

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
101	Jhanjharala	India	16	25	17	19.3	1.307
131	Lal Bedra Seja	India	14	28	26	19.3	1.210
1390	N 1	Uganda	24	15	19	19.3	1.308
1444	EC 21370 H 8	India	17	20	21	19.3	1.316
1806	129 Adol	Sudan	19	25	14	19.3	1.304
2102	Rahmatalla 241	Sudan	23	17	18	19.3	1.313
3459	Jola Nandyal	India	20	17	21	19.3	1.316
1237	Matilda 60/50 Ex Australia Bulawayo	S. Rhodesia	23	19	17	19.7	1.348
1381	AS 4185 Ncseheja	N. Rhodesia	22	18	19	19.7	1.351
1457	Unknown	Unknown	19	23	17	19.7	1.348
2413	LGV 93-3	thru Mexico	16	17	26	19.7	1.339
2974	MN 945	U.S.A.	23	20	16	19.7	1.347
148	Nauhatta	India	21	17	22	20.0	1.383
663	EC 21339, C 15	India	23	18	19	20.0	1.383
733		Nigeria	20	24	16	20.0	1.379
877	FC 13498	thru Mexico	14	27	19	20.0	1.366
2580	Tombad Fundi	India	18	19	23	20.0	1.383
3506	Jowar Shenoli 4-5	India	20	20	20	20.0	1.386
120	Janera Judhen	India	22	20	19	20.3	1.418
1151	Stiff Stalk Kafir SA 8060-7-3-1	U.S.A.	22	17	22	20.3	1.415
1155	FC 6608 Red Kafir	thru Mexico	20	24	17	20.3	1.413
1261	Birdproof 196/51	S. Africa	19	25	17	20.3	1.411
1685	Andro Pagam	Nigeria	19	19	23	20.3	1.416
2430	A - 5	India	25	15	21	20.3	1.407
3027	SG 12 Bulk	Uganda	25	19	17	20.3	1.411
3084	Khadkar	India	20	20	21	20.3	1.419
202	AS 4176 Namudzi	N. Rhodesia	21	24	17	20.7	1.447
1145	Wd. No. 44-41-14 Dwarf Kafir	thru Mexico	25	20	17	20.7	1.445

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
1289	6336 Nebraska	U.S.A.	25	10	27	20.7	1.413
1345	C. Bh. Kafir SA 6939-19-4-3-3-1 Texas	U.S.A.	17	22	23	20.7	1.447
2242	482 5/30/26/1 Feterita Maatuk	Sudan	22	16	24	20.7	1.444
2475	KS 152 Cholam	India	18	20	24	20.7	1.448
3005	G.M. 2-3-1	India	22	22	18	20.7	1.450
85	Jeepri Type Karijot	India	24	23	16	21.0	1.475
312	401 Malwal Red	Sudan	21	17	25	21.0	1.476
532	IN 19	Nigeria	23	23	17	21.0	1.478
652	tl-101	Mali	17	16	30	21.0	1.456
758	105 Nazonglaila	E. Volta	17	27	19	21.0	1.471
965	AS 6189 Nambeu	Nyasaland	19	21	23	21.0	1.482
1278	G 301 Nebraska	U.S.A.	24	18	21	21.0	1.480
1805	Maluk 145	Sudan	16	28	19	21.0	1.466
2403	Sangatti Jola	India	17	23	23	21.0	1.478
3447	Jola Nandyal	India	21	22	20	21.0	1.483
112	Bili Alluna Jola Yamauur	India	23	12	29	21.3	1.480
525	IN 7	Nigeria	21	22	21	21.3	1.515
1465	PI 229836 - P 3731 Q2/5/39	U.S.A.	22	20	22	21.3	1.515
2965	Kabha Trana	India	19	21	24	21.3	1.512
17	Olanbar Jonna	India	28	18	19	21.7	1.533
50	Bhawra Jandra Marvi	India	29	16	20	21.7	1.526
79	SV 34	India	25	24	16	21.7	1.535
1458	Feterita Wad Husein	Sudan	21	21	23	21.7	1.547
3509	Jowar Shenoli 4-2	India	18	24	23	21.7	1.541
166	Kasa Gangai	India	26	23	17	22.0	1.567
284	336 Hambomain II	W. Volta	23	19	24	22.0	1.574
777	Flattie - ba Kassinsso	Mali	23	21	22	22.0	
810	FPI 63923 White Kaoling Waxy	thru Mexico	25	25	16	22.0	1.564

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
1095	Chanan Singoo	India	24	18	24	22.0	1.572
1484	EC 21380 J 75	India	20	24	22	22.9	1.575
107	Gangai	India	20	24	23	22.3	1.605
128	Jhumra Gheva	India	23	19	25	22.3	1.602
295	365 Drama Ba. II	W. Volta	19	22	26	22.3	1.601
373	PL 21	Nigeria	26	24	17	22.3	1.596
1365	7078 Nebraska	U.S.A.	28	17	22	22.3	1.592
1490	MN 404	U.S.A.	17	29	21	22.3	1.589
3401-A	No. 68 N.W. Nedjo	Ethiopia	25	17	25	22.3	1.597
8	EC 18256	Nepal	23	25	20	22.7	1.634
402	NG 25	Nigeria	20	28	20	22.7	1.627
472	ZA 28	Nigeria	16	24	28	22.7	1.619
970	MN 904	U.S.A.	17	29	22	22.7	1.620
1426	466 US 9	Uganda	22	20	26	22.7	1.633
1503	EC 21394 L 20	India	20	25	23	22.7	1.634
1784	Nyan Bau	Sudan	25	20	23	22.7	1.634
2422	IC Delhi Local	India	22	20	26	22.7	1.633
1302	MN 936	U.S.A.	19	26	24	23.0	1.660
1468	MN 428	U.S.A.	27	22	20	23.0	1.660
2411	Karad Local	India	20	23	26	23.0	
239	30 Dazoumbissi Sanna	E. Volta	27	21	22	23.3	1.689
241	32 Beloka Nonogo	E. Volta	17	24	29	23.3	1.676
522	IN 3	Nigeria	28	22	20	23.3	1.686
1096	SA 8478-3 (D.D.) Texas	U.S.A.	22	22	26	23.3	1.692
2647	Patch	India	22	26	22	23.3	1.692
103	Gangai Telku	India	19	29	23	23.7	1.711
272	212 Baniga	E. Volta	27	20	24	23.7	1.717
370	PL 18	Nigeria	27	19	25	23.7	1.715
1892	KO 16	Nigeria	28	22	21	23.7	1.716
2444	AS 3898 Br. Baluchistan	India	21	22	28	23.7	1.716
60	Junhari White Chapan	India	27	22	23	24.0	1.747

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
61	Bari 598	Sudan	17	23	30	24.0	1.674
106	Gangai	India	25	25	22	24.0	1.750
262	164 Baninga Zouhagodo	E. Volta	27	17	28	24.0	1.732
804	S. Simembronaccum, 720 PI 282869	U.S.A.	21	27	24	24.0	2.746
1482	EC 21376 J 55	India	25	16	31	24.0	1.723
2018	KO 22	Nigeria	28	22	22	24.0	1.745
240	31 Banindinga	E. Volta	25	28	20	24.3	1.769
397	NG 17	Nigeria	26	22	25	24.3	1.775
669	210 Bera Sablaga	E. Volta	28	27	18	24.3	1.762
745	5076	Mali	26	21	26	24.3	1.773
1461	420 Kalatilansa	Sudan	27	24	22	24.3	1.774
1650	BA 5	Nigeria	27	25	21	24.3	1.773
1920	M 4	Nigeria	23	22	28	24.3	1.772
1947	KO 43	Nigeria	25	29	19	24.3	1.765
2499	G.M. 1-3-1 Bailhongal	India	26	25	22	24.3	1.775
2632	Yellow Cholam (Kharif)	India	21	25	27	24.3	1.775
2639	Jonna Samear	India	27	26	20	24.3	1.770
2672	Kinda Jonna	India	24	18	31	24.3	1.756
3512	Shenoli Local	India	23	29	21	24.3	1.769
44	Siswa	India	24	22	28	24.7	1.800
268	195 Drama - BA	W. Volta	22	23	29	24.7	1.798
527	IN 10	Nigeria	30	16	28	24.7	1.777
668	209 Banidego	E. Volta	25	22	27	24.7	1.802
1417	a-15	Japan	22	24	28	24.7	1.800
1481	a-101	Japan	26	20	28	24.7	1.796
1887	KA - 8	Nigeria	27	21	26	24.7	1.800
2020	KO 45	Nigeria	24	24	26	24.7	1.804
33	Vilunthakal Lattini	India	23	28	24	25.0	1.827
944	Adhuk Wong Wut	Sudan	28	28	19	25.0	1.817
907	MN 402	U.S.A.	23	26	26	25.0	1.829

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
1368	Plainsman	U.S.A.	16	30	29	25.0	1.801
1411	EC 21404 M 4	India	25	24	26	25.0	1.830
1473	Sorgo Niska 549/0	Belgian Congo	27	24	24	25.0	1.829
1965	ZA 19	Nigeria	22	34	19	25.0	1.800
2715	Karurethucholam	India	23	28	25	25.3	1.853
2806	Bili Gund	India	25	27	24	25.3	1.855
55	Bhapura	India	20	29	28	25.7	1.870
259	153 AB Farako - BA	W. Volta	24	25	28	25.7	1.880
514	ZA 119	Nigeria	34	24	19	25.7	1.854
919	A 5773 Karu Irungu	India	25	26	26	25.7	1.882
1694	YL 248	Nigeria	27	27	23	25.7	1.880
1713	Barking 119	Sudan	26	23	28	25.7	1.879
1729	PI 217890 Feterita Abu Dircana Q2/3/37	U.S.A.	29	27	21	25.7	1.874
1907	Matindi Grey 99	Sudan	30	25	22	25.7	1.874
184	Guad. Selection 6662-5-2-1	thru Mexico	29	24	25	26.0	1.903
520	IN - 1	Nigeria	26	27	25	26.0	1.906
627	B.C. 85 U.T.	Gambia	30	20	28	26.0	1.893
1157	SPI 19492 Red Kafir TS 46	thru Mexico	23	25	30	26.0	1.900
1915	ZA 75	Nigeria	29	20	29	26.0	1.893
1942	BA 29	Nigeria	27	22	29	26.0	1.900
206	MN 762	U.S.A.	27	26	26	26.3	1.913
301	390	E. Volta	22	27	30	26.3	1.923
1138	F.C. 5894 Blackhull Kafir	thru Mexico	27	25	27	26.3	1.930
1255	PI 229872 Red x Maferking Q2/5/79	U.S.A.	21	30	28	26.3	1.920
1840	479 Farhoda	Sudan	30	23	26	26.3	1.925
63	Bardhona Khejura	India	23	29	28	26.7	1.951
105	Gangai	India	28	28	24	26.7	1.953
283	PL 35	Nigeria	28	33	19	26.7	1.931
800	<u>Sorghum mellitum</u> 1114 PI 282864	U.S.A.	27	25	28	26.7	1.955

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
959	IC Jowar Pohran	India	23	28	29	26.7	1.951
1420	Sorghum Coll. Karamajos	Uganda	25	25	30	26.7	1.952
1877	BO 29	Nigeria	23	30	27	26.7	1.950
473	ZA 30	Nigeria	32	20	29	27.0	1.960
495	ZA 77	Nigeria	25	31	25	27.0	1.973
1348	Redbine 655	thru Mexico	23	27	31	27.0	1.971
1394	Sorghum Soroti	Uganda	32	26	23	37.0	1.969
1480	a-95	Japan	29	27	25	27.0	1.977
2463	AS 5053 Sen Cholam	India	27	22	32	27.0	1.967
126	Panchrishi	India	25	34	23	27.3	1.985
183	DDET 6662-7-1R	thru Mexico	27	28	27	27.3	2.002
465	NG 162	Nigeria	22	32	28	27.3	1.990
515-A	ZA 120	Nigeria	30	18	34	27.3	1.969
672	ADI	Nigeria	21	30	31	27.3	1.987
938	MN 724	U.S.A.	28	31	23	27.3	1.994
1297	6353 Nebraska	U.S.A.	26	25	31	27.3	1.997
1975	Farar Kaura	Nigeria	26	27	29	27.3	2.001
2112	Wit Bultfontein DL/59/1538	S. Africa	26	28	28	27.3	2.002
2141	EC 21420, SB 36	India	26	29	27	27.3	2.001
2534	Mehra Mundra Khurd	India	35	25	22	27.3	1.980
2544	Ram Nivas Etawah	India	27	29	26	27.3	2.001
2967	Jowar Fategarh	India	28	27	27	27.3	2.002
114	Allina Jola Bailwade	India	29	30	24	27.7	2.021
506	ZA 106	Nigeria	26	34	23	27.7	2.010
778	ZA 7	Nigeria	30	25	28	27.7	2.023
889	African Millet	thru Mexico	30	25	28	27.7	2.023
1337	SA 8769-27-5912 Midland x Sooner Milo x Big Seed Yel. End. 4-Dw Texas	U.S.A.	21	27	35	27.7	2.002
1803	Culum Abgash 29	Sudan	25	30	28	27.7	2.023
2209	PI 217729 Wad Akr. 2Q/2/81	U.S.A.	29	27	27	27.7	2.025
2598	Karnatak Gidgap	India	26	30	27	27.7	2.024

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
3310	Patcha Vidisilark	India	31	25	27	27.7	2.021
416	NG 56	Nigeria	29	27	28	28.0	2.048
828	AS 5236 Ting	thru India	26	26	32	28.0	2.042
1228	AS 5108 Natal light red	S. Africa	28	31	25	28.0	2.044
1800	III Gbangi	Sudan	32	26	26	28.0	2.042
1815	186 Nagad Blus	Sudan	23	29	32	28.0	2.038
2241	Query 6-624	Sudan	27	31	26	28.0	2.045
2572	Jhingri Kolumbi	India	28	29	29	28.0	2.048
2652	Patcha Jonna	India	26	28	30	28.0	2.046
40	Allina Jola Hire Bajewade	India	29	27	29	28.0	2.070
1180	C. Blackhull Kafir SA 7176-2-3-1-1	U.S.A.	32	28	25	28.3	2.064
1291	6344 Nebraska	U.S.A.	30	26	29	28.3	
1470	J - 56	Uganda	27	23	35	28.3	2.052
326	BA 42	Nigeria	30	27	29	28.7	2.092
408	NG 39	Nigeria	32	24	30	28.7	2.084
499	ZA 88	Nigeria	33	28	25	28.7	2.085
1521	EC 21464 STR 5/2	India	30	28	28	28.7	2.092
1535	PI 221662	U.S.A.	33	26	27	28.7	2.086
2651	Bombay Jonna	India	27	29	30	28.7	2.092
5	S 51 Kinto Blanc	Senegal	29	28	30	29.0	2.113
220	Karigowla Kala Faula	Mali	29	24	34	29.0	2.102
255	135 AB Farako - BA	W. Volta	24	30	33	29.0	2.104
528	IN 11	Nigeria	32	29	26	29.0	2.109
611	SO 86	Nigeria	29	30	28	29.0	2.113
1299	6363 Nebraska	U.S.A.	30	34	23	29.0	2.099
507	ZA 108	Nigeria	26	36	26	29.3	2.118
1280	6310 Nebraska	U.S.A.	33	29	26	29.3	2.129
1875	BO 26	Nigeria	31	23	34	29.3	2.119
1460	Bari 598	Sudan	29	29	31	29.7	2.155
464	NG 151	Nigeria	27	35	28	30.0	2.167
592	SO 51	Nigeria	29	31	30	30.0	2.176

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
752	a-35-2	Japan	33	32	25	30.0	2.167
1229	PI 229867 Pictersburg Q2/5/75 Baker	U.S.A.	30	29	31	20.0	2.176
1788	Oarfuri Wateni 2	Sudan	33	31	26	30.0	2.170
62	Bajri Mori Poldi	India	28	32	31	30.3	2.194
1456	IN 80	Nigeria	28	21	32	30.3	2.194
1727	PI 217765 Shemshem Wh. tall Sel. Q2/2/90	U.S.A.	34	34	23	30.3	2.177
372	PL 20	Nigeria	38	27	27	30.7	2.220
441	NG 110	Nigeria	36	31	25	30.7	2.202
1552	MN 881	U.S.A.	37	21	34	30.7	2.182
1611	87 Bassa	Sudan	31	30	31	30.7	2.216
1917	SO 28	Nigeria	31	28	33	30.7	2.213
108	Zanzala Jodida	India	28	31	34	31.0	2.231
462	NG 148	Nigeria	35	28	30	31.0	2.229
1733	MN 764	U.S.A.	29	32	32	31.0	2.234
2508	Fulgar Yellow	India	32	35	26	31.0	2.225
512	ZA 116	Nigeria	25	37	32	31.3	2.237
581	SO 27	Nigeria	27	33	34	31.3	2.247
662	a-74-1	Japan	35	32	27	31.3	2.246
1869	BO 2	Nigeria	33	29	32	31.3	2.252
237	9 Widga	E. Volta	28	34	33	31.7	2.269
380	PL 37	Nigeria	40	29	26	31.7	2.248
386	PL 44	Nigeria	31	32	32	31.7	2.274
648-A	Karan Ja Dio Kofiague	Mali	36	32	27	31.7	2.264
827	AS 5224	thru India	31	29	35	31.7	2.269
1200	58H H 37 CK-60 x 56H 5268 Kybrid	U.S.A.	25	37	33	31.7	2.256
1703	C 25	Uganda	35	28	32	31.7	2.268
1903	273 Umm Bayud	Sudan	32	31	32	31.7	2.274
367	PL 12	Nigeria	27	39	30	32.0	2.274
478	ZA 39	Nigeria	32	31	33	32.0	2.291

Table 1 (cont'd).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny Rep. 1	Rep. 2	Rep. 3	Mean	Calculated t
533	IN 20	Nigeria	33	36	28	32.3	2.302
539	IN 28	Nigeria	25	43	29	32.3	2.269
1644	AD 37	Nigeria	34	34	29	32.3	2.306
303	392	E. Volta	30	34	34	32.7	2.326
760	BO 7	Nigeria	33	31	34	32.7	3.327
1592	Double Dwarf White Feterita SA 5-883-3	thru Mexico	31	31	36	32.7	2.324
479	ZA 43	Nigeria	28	38	32	32.7	2.316
368	PL 13	Nigeria	36	27	36	33.0	2.333
651	50 - 97	Mali	36	33	30	33.0	2.341
729	SO 97	Nigeria	29	31	30	33.0	2.333
214	Gountina Kafoulo	Mali	36	30	24	33.3	2.355
490	ZA 63	Nigeria	33	36	31	33.3	2.360
593	SO 52	Nigeria	31	34	35	33.3	2.361
927	T/20 or J-20 Sirsa	India	33	33	34	33.3	2.362
1218	EC 21434 SB 77	India	31	36	33	33.3	2.360
448	NG 123	Nigeria	30	33	28	33.7	2.540
468	ZA 12	Nigeria	35	33	33	33.7	2.380
769	M 592	Nigeria	36	29	36	33.7	2.373
783	SO 80	Nigeria	34	34	33	33.7	2.380
2022-A	NG 68	Nigeria	27	38	36	33.7	2.365
316	AD 12	Nigeria	36	33	33	34.0	2.395
387	NG 2	Nigeria	34	33	35	34.0	2.396
390	NG 7	Nigeria	35	33	34	34.0	2.396
985	Lahi	India	41	31	30	34.0	2.380
409	NG 41	Nigeria	36	35	32	34.3	2.411
675	AD 9	Nigeria	32	35	36	34.3	2.411
715-A	ZA 101	Nigeria	35	37	32	34.7	2.427
2217	Vagadi Bedi	India	33	40	31	34.7	2.420
173	Dwarf Shallu 5527-19-1	thru Mexico	35	33	37	35.0	2.444
356	KB 7	Nigeria	33	33	39	35.0	2.440

Table 1 (concluded).

World collection number	Abbreviated pedigree	Country of origin	Number of progeny				Calculated t
			Rep. 1	Rep. 2	Rep. 3	Mean	
771	EC 21363 G 37	India	31	37	37	35.0	2.440
1740	MN 872	U.S.A.	34	37	34	35.0	2.444
364	PL 9	Nigeria	33	33	40	35.3	2.454
1485	EC 21474 T 11	India	35	28	43	35.3	2.436
363-A	PL 7	Nigeria	37	31	39	35.7	2.469
511	ZA 115	Nigeria	35	37	35	35.7	2.476
710	ZA 18	Nigeria	39	36	32	35.7	2.471
215	Gountina Kalawago	Mali	37	37	34	36.0	2.491
1400	a - 38	Japan	39	37	33	36.3	2.502
323	BA 30	Nigeria	40	35	35	36.7	2.518
1688	461 Makoi	Sudan	37	36	36	36.7	2.538
666	EC 21422 SB 40	India	37	38	36	37.0	2.536
1612	96 Bahana 2	Sudan	37	35	39	37.0	2.534
412	NG 46	Nigeria	35	38	40	37.7	2.562
926	221539	U.S.A.	38	38	38	38.0	2.578
2481	SA 8334 (D.D.) Texas	U.S.A.	34	39	41	38.0	2.573
1878	BO 31	Nigeria	40	33	43	38.7	2.595
1487	EC 21480 U 6	India	40	37	40	39.0	2.618
1726	AS 5468 Idutubira	Tanganyika	40	42	35	39.0	2.613
1771	PI 217838 Fayoumi Q2/3/26	U.S.A.	32	46	39	39.0	2.599
1796	EC 21425 SB 53	India	35	46	36	39.0	2.604
378	PL 28	Nigeria	42	38	39	39.7	2.643
1600	PL 45 Farinkawa	Nigeria	38	39	43	40.0	2.655
501	ZA 92	Nigeria	43	40	38	40.3	2.667
1880	BO 41	Nigeria	41	43	39	41.0	2.693
1881	BO 42	Nigeria	42	39	46	42.3	2.736

progeny emerging from the resistant and susceptible checks in secondary screening with the number emerging from the checks in preliminary screening revealed that significantly more progeny were obtained in secondary screening for both resistant and susceptible checks. In secondary screening, cultivars carried over from Group I produced an average of 21.4 more progeny than they did in preliminary screening while cultivars from Group II produced an average of 14.1 more. The higher levels of infestation that occurred in secondary screening were most apparent at the lower levels of progeny emergence. For example, only 6.7% of the cultivars in secondary testing had an average of less than 8 progeny as compared with 46.9% and 17.3% in Group I and Group II, respectively, of preliminary screening. A more detailed study of the differential effects of various strains and species of grain infesting weevils upon the level of resistance will be discussed in a later section.

Cultivars showing the highest degree of resistance were those with glumes completely enclosing the seed. As indicated in Table 1, all cultivars that resulted in a mean of 1.3 or less progeny exhibited this character and the 4 remaining cultivars with this character had only slightly higher infestations. This near immunity is probably due to the glumes acting as a barrier to oviposition and not to the seed itself since cultivars with glumes that did not completely surround the seed showed no such marked resistance. The protective characteristics of glumes and hulls against weevils and other stored grain insects has also been demonstrated in other small grains. Breese (1960) and Rossetto (1966) found rough rice with an intact husk to be almost immune to <u>Sitophilus sasakii</u> (rice weevil) and <u>Sitophilus zeamais</u> Mots respectively. Hulled oats were shown to be highly resistant to the granary weevil and lesser grain borer (Sinha, 1969). However, since sorghum cultivars that have their seeds completely enclosed by glumes are not usually grown for grain they would not be especially useful in a program for breeding varieties resistant to grain-infesting insects.

Of the 776 cultivars from African countries only 30 or about 3.9% were found to be as resistant as the resistant check while 82 or 18.8% of the 437 cultivars from the Indian subcontinent were in this category. Most of the diversity in sorghum is located in these 2 areas. This is interesting because nearly all grain sorghum grown in the United States is of African origin with the notable exception of the shallus which were first introduced from India about 1890 (Martin, 1936). The shallus and cultivars that have the characteristic appearance of shallu seem to be relatively resistant to the maize weevil.

<u>Studies on Factors Influencing the Level of Resistance</u>

Effect of Population Density

Plate V illustrates that the number of progeny produced by a given number of female maize weevils in the resistant sorghum, Double Dwarf Early Shallu, is highly dependent upon the number of kernels that are available for oviposition. Correlation coefficients also show a strong relationship between these two variables. Coefficients for the Arkansas and Mexican strains were 0.9746 and 0.9509 respectively. Both of these values are significant at the 0.01 level of probability. Although the Arkansas strain produced consistently more progeny than the Mexican strain, the increase in progeny per unit increase in the number of kernels is nearly the same for both strains. Therefore the slopes of the lines and regression coefficients are very similar. The coefficient for the Arkansas strain was 0.0994 and for the Mexican strain was 0.0856. Even though a nearly linear relationship appears to exist within this range of numbers of kernels, if larger numbers of kernels were used the curve would

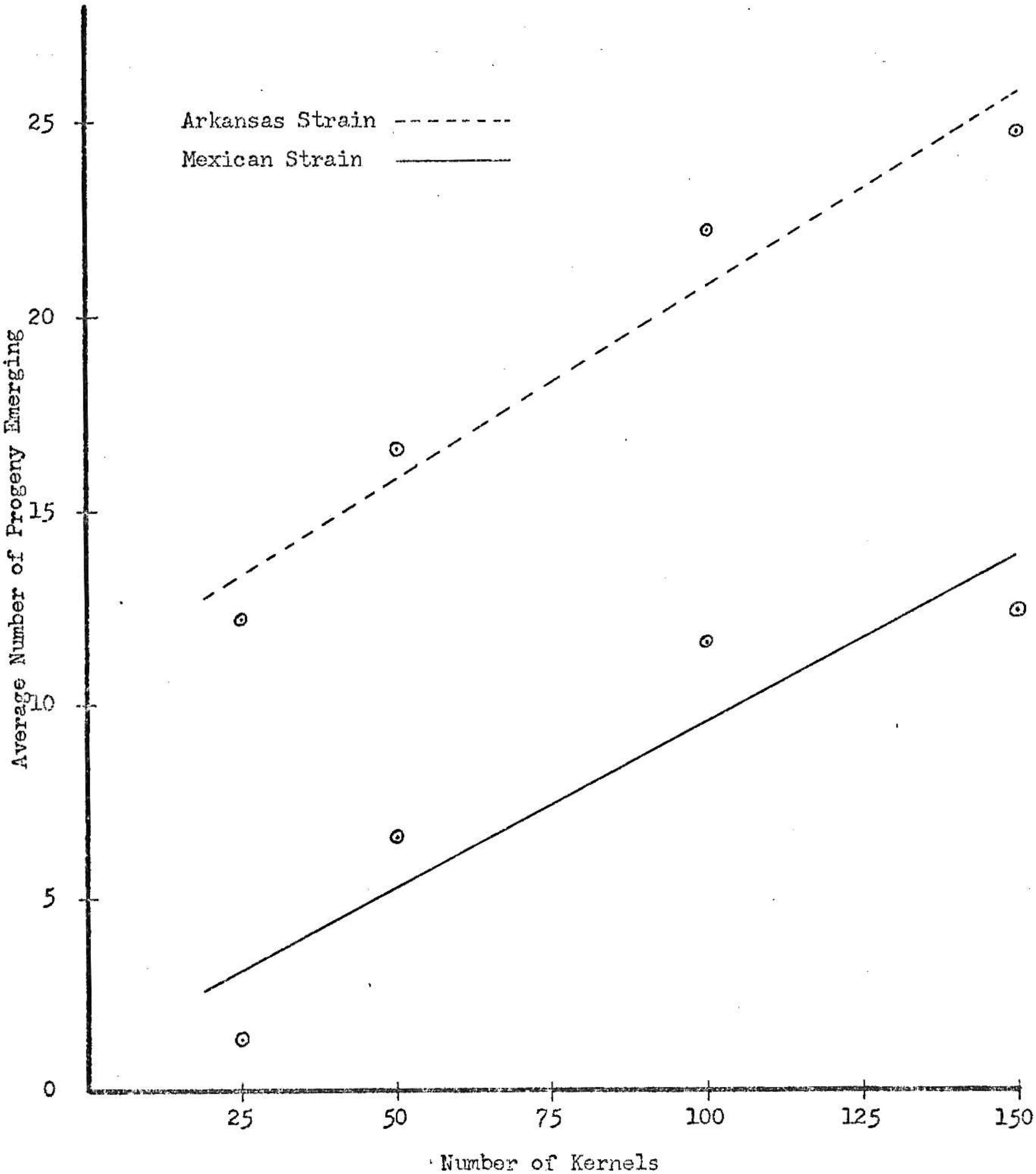
EXPLANATION OF PLATE V

Number of progeny emerging when 6 female and 3 male maize weevils of two strains were confined on varying numbers of seeds of Double Dwarf Early Shallu. Lines were fitted by the following linear regression equations:

$Y = 10.87 + 0.0994\ (X_i)$ for the Arkansas strain

$Y = 1.09 + 0.0856\ (X_i)$ for the Mexican strain

PLATE V



Arkansas Strain
Mexican Strain
Average Number of Progeny Emerging
0
5
10
15
20
25
25
50
75
100
125
150
Number of Kernels

probably become distinctly curvilinear, flattening out as the weevils reached their upper limits of fecundity. Richards (1947) found a direct straight line relationship between the number of grains of wheat and the number of eggs laid per female rice weevil per day and indicated that about 50 grains per female are necessary for maximum oviposition. The maximum number of kernels per female in the tests reported here was 25. Therefore if Richards' observations are correct and are analagous to the maize weevil in sorghum maximum oviposition was not reached. He submitted 2 explanations for the reduction of oviposition with increased population density: (1) grains already containing eggs are avoided somewhat and (2) the weevils interfere with each other. These two explanations are very tenable but another also seems applicable when a resistant cultivar is involved. This being that if a larger number of seeds is presented to the insect, and individual seeds vary as to susceptibility or attractiveness within the cultivar, there will be a larger number of more susceptible or attractive seeds available. This would result in higher oviposition and progeny emergence.

Effect of Strain and Species

Table 2 summarizes the results of an analysis of variance carried out on this data and points out that significant differences exist in the ability of different strains and species of grain infesting weevils to reproduce on a resistant sorghum. The number of progeny produced by the different species and strains are listed in Table 3. Significant differences between these are also noted. Plave VI illustrates these differences graphically. From the data it seems apparent that the strain of Sitophilus granarius used in this experiment had great difficulty in reproducing on this resistant sorghum. It is also interesting to note that the two Mexican strains of Sitophilus zeamais

Table 2. Analysis of variance for data from the experiment investigating the fecundity of several species and strains of grain infesting weevils on a resistant grain sorghum.

Source of Variation	d.f.	Sum of Squares	Mean Square	F
Among Strains	5	1,041.1	208.2	18.8**
Within Strains	24	265.6	11.1	
Total	29	1,306.7		

** - Significant at the 0.01 level of probability

Table 3. Number of progeny resulting when 6 female and 3 male weevils of various species were confined on 50 kernels of Double Dwarf Shallu, a resistant sorghum, for a 5-day oviposition period.

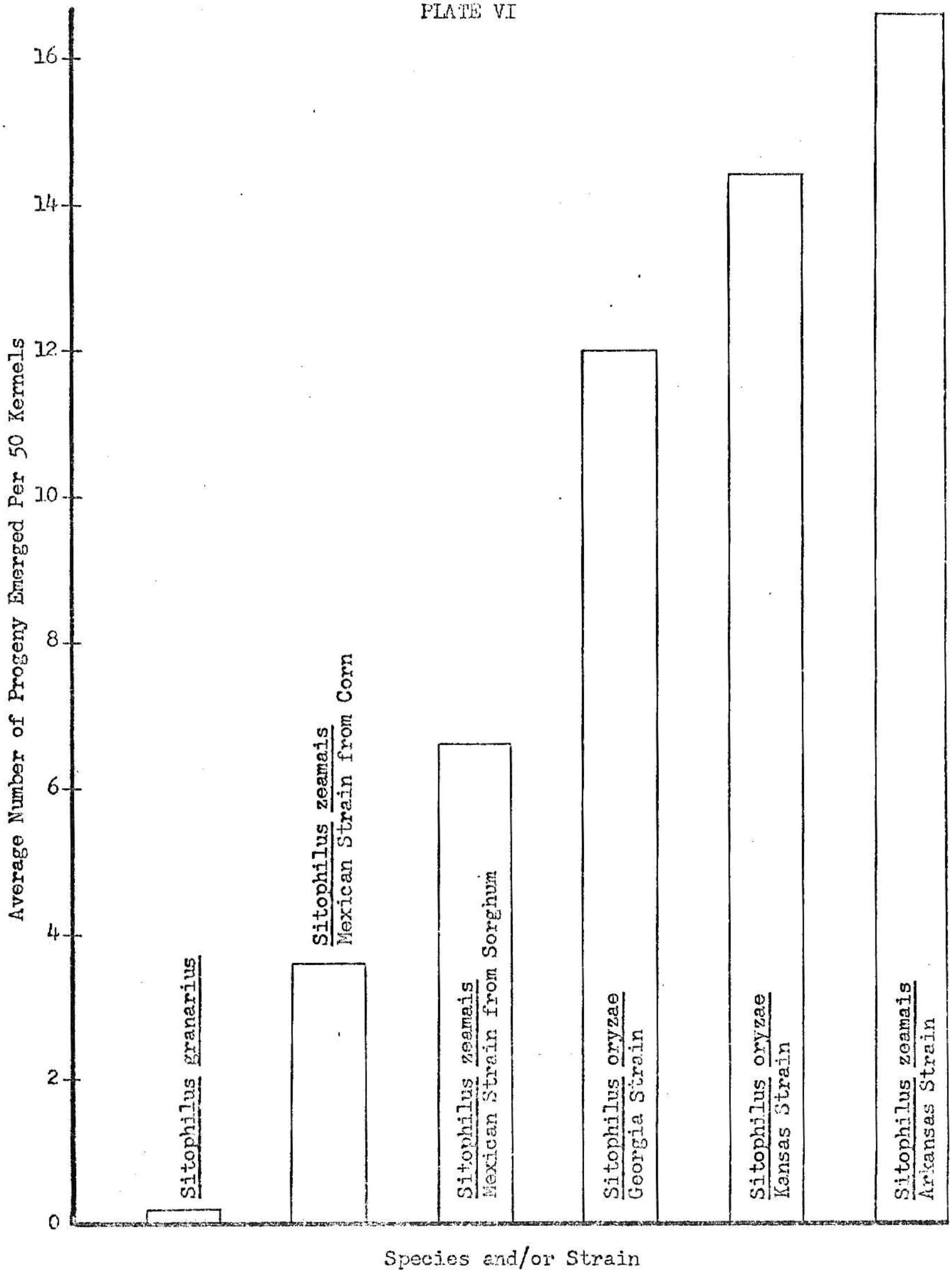
	Number of Progeny					
	Replicate					
Species and Strain	I	II	III	IV	V	Mean
Sitophilus granarius	0	0	0	0	1	0.2 a
Sitophilus zeamais						
Mexican Strain (Corn)	4	1	0	13	0	3.6 ab
Mexican Strain (Sorghum)	3	8	9	10	3	6.6 b
Arkansas Strain	13	13	19	16	22	16.6 d
Sitophilus oryzae						
Georgia Strain	13	13	10	13	11	12.0 c
Kansas Strain	11	14	16	18	13	14.4 cd

Means followed by the same letter are not significantly different at the 5% level of probability according to Duncan's New Multiple Range Test.

EXPLANATION OF PLATE VI

Average number of progeny per replicate (5 replicates) when 6 female and 3 male grain-infesting weevils of various species and strains were confined on 50 kernels of Double Dwarf Early Shallu for a 5-day oviposition period.

PLATE VI


Average Number of Progeny Emerged Per 50 Kernels
16
14
12
10
8
6
4
2
0
Sitophilus granarius
Sitophilus zeamais Mexican Strain from Corn
Sitophilus zeamais Mexican Strain from Sorghum
Sitophilus oryzae Georgia Strain
Sitophilus oryzae Kansas Strain
Sitophilus zeamais Arkansas Strain
Species and/or Strain

produced significantly fewer progeny than either of the *Sitophilus oryzae* strains while the Arkansas strain of *Sitophilus zeamais* produced more progeny than any strain of species tested. This is important for 2 reasons. The first being that in screening cultivars for resistance a strain capable of maximum productivity is desired to avoid a large number of cultivars which appear to be resistant but are actually only escaping infestation such as occurred in preliminary screening. This is why the Arkansas strain was used for secondary screening. The second reason is that these data indicate that the ability to reproduce on a resistant cultivar may be more closely related to the individual population than to the particular species when closely related species are involved. Soderstrom and Wilbur (1966) compared productivity of an Arkansas strain of maize weevil with that of a Kansas and a Louisiana strain of rice weevil. These, with the exception of the Louisiana strain of rice weevil, were the same populations as those discussed in this report. They found that the Arkansas strain of maize weevil produced more progeny than the 2 rice weevils on 3 varieties of grain sorghum. The findings of this report substantiate their work.

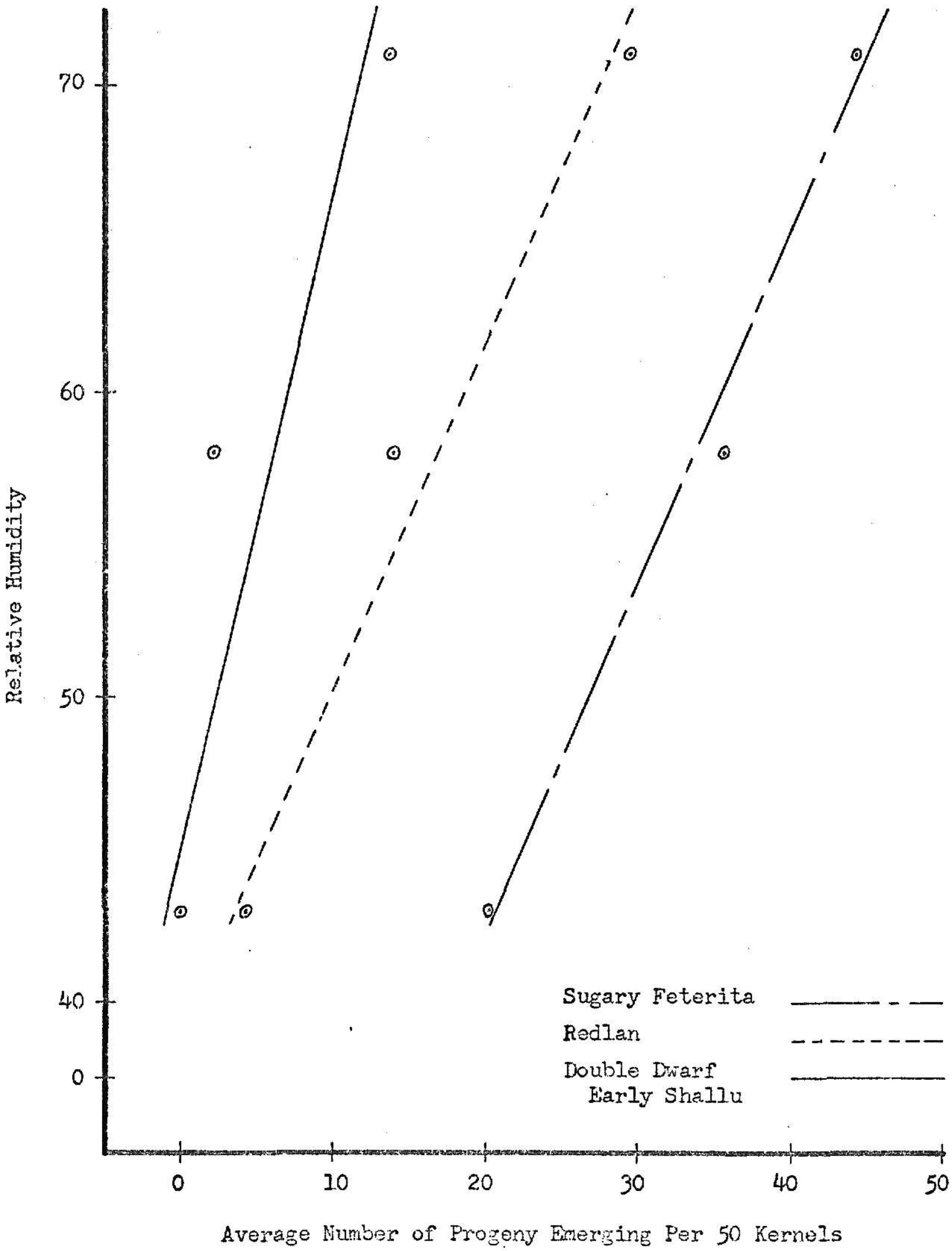
Effect of Relative Humidity and Moisture Content

Plate VII shows graphically the relationship between relative humidity and the average number of progeny per 50 kernels produced in 3 varieties of sorghum by 6 female and 3 male maize weevils given a 5-day oviposition period. The linear regression coefficients for the regression of number of progeny on relative humidity were calculated and found to be 0.0484, 0.8907, and 0.8615 for Double Dwarf Early Shallu, Redlan, and Sugary Feterita, respectively. A t test comparing the homogeneity of these coefficients indicated that the regression coefficient for Double Dwarf Early Shallu was significantly different from the other 2.

EXPLANATION OF PLATE VII

Average number of progeny per replicate (5 replicates) resulting when 6 female and 3 male maize weevils were confined on 50 kernels of 3 varieties of sorghum at 3 relative humidities for a 5-day oviposition period. Lines are eye fitted.

PLATE VII


70
60
50
40
0
Relative Humidity
0
10
20
30
40
50
Average Number of Progeny Emerging Per 50 Kernels
Sugary Feterita
Redlan
Double Dwarf
Early Shallu

This evidence would support the hypothesis that at least this resistant variety has a smaller increase in progeny per unit increase in relative humidity than more susceptible varieties. It is interesting to note that at 43% relative humidity no progeny emerged from Double Dwarf Early Shallu, the resistant variety. This was probably partly due to the high mortality of parent weevils in this variety and relative humidity during the 5-day oviposition period. An average of 7.6 of the 9 parent weevils per replicate were found to be dead after the oviposition period. Mortality of parent weevils did not occur at any other combination of variety and relative humidity. One possible explanation is that an interaction of the variety and relative humidity resulted in a condition of the seeds such that the weevils could not penetrate and feed, thus starvation ensued. In support of this conclusion, Singh (1966) reported total mortality of 15-day-old mated pairs of the Arkansas strain of maize weevil in 2 to 7 days when held at 80° F without food. This was the identical strain used in this report. Two way analysis of variance (Table 4) revealed significant differences between the number of progeny produced at different relative humidities and highly significant differences between varieties. However, the term for interaction between relative humidity and variety was not significant indicating that the varying humidities had similar effects on all 3 varieties. Table 5 gives the mean number of progeny emerging from each variety at each relative humidity and the collective means for each variety and relative humidity. Significant differences between the collective means are indicated. It is important to note that no significant differences appear between 43% and 58% relative humidity. Real differences probably exist in the population but would be expected to be smaller than between 58% and 71%. The analysis of variance in Table 6 shows that the mean equilibration moisture contents of the 3 varieties are significantly different

Table 4. Analysis of variance for data obtained from the experiment investigating the number of progeny produced by 6 female and 3 male maize weevils in 3 varieties, each at 3 relative humidities.

Source of Variation	d.f.	Sum of Squares	Mean Square	F
Variety	2	5,991.111	2,995.555	29.896**
Relative Humidity	2	3,328.045	1,664.022	16.697*
Relative Humidity x Variety	4	317.822	79.456	N.S.
Experimental Error	4	400.800	100.200	
Total	44	10,037.778		

* - Significant at the 0.05 level of probability
** - Significant at the 0.01 level of probability

Table 5. Mean number of progeny emerging from 50 sorghum kernels within 53 days after 6 female and 3 male maize weevils were removed following a 5-day oviposition period.

Variety	Relative Humidity 43%	58%	71%	Mean
Double Dwarf Early Shallu	0.00	2.20	13.80	5.33
Redlan	4.40	14.00	29.60	16.00
Sugary Feterita	20.20	35.60	44.20	33.00
Mean	8.20	17.27	29.20	

Least significant difference between relative humidity means or between variety means equals 10.13 at the 5% level of probability.

Table 6. Analysis of variance for data obtained from the experiment investigating the equilibration moisture content of whole kernels of 3 varieties of sorghum, each at 3 relative humidities.

Source of Variation	d.f.	Sum of Squares	Mean Square	F
Relative Humidity	2	513.2100	256.6050	48.036**
Variety	2	17.2895	8.6447	N.S.
Relative Humidity x Variety	4	6.1171	1.5293	N.S.
Experimental Error	4	21.3675	5.3419	
Total	314	561.9814		

** - Significant at the 0.01 level of probability

Table 7. Mean percent moisture in 35 whole kernels of 3 varieties of sorghum, each at 3 relative humidities.

Variety	Relative Humidity 43%	58%	71%	Mean
Double Dwarf Early Shallu	11.497	13.417	15.037	13.317
Redlan	11.830	13.094	14.759	13.228
Sugary Feterita	11.370	12.695	14.279	12.781
Mean	11.566	13.069	1 .692	

Least significant difference between relative humidity means equals 2.340 at the 5% level of probability.

between relative humidities but not within one relative humidity. Table 7 shows the mean equilibration moisture contents of each variety at each relative humidity and the collective means for each variety and relative humidity. If resistant varieties equilibrated at lower moisture contents than susceptible ones this would help explain their resistance. However, the data presented here indicate no differences between the resistant variety and two susceptible varieties.

SUMMARY

This study was conducted primarily to search for germ plasm resistant to the maize weevil among 1511 cultivars of sorghum of worldwide origin obtained from the International Germ Plasm Seed Bank in Chapingo, Mexico. A 2-phase screening process was employed. In unreplicated preliminary screening, 6 female and 3 male maize weevils were confined for a 5-day oviposition period on 50 kernels of each cultivar, after which they were removed and emerging progeny counted every 5 days beginning 22 days after removal of the parents and ending 30 days after the first count. At the conclusion of this phase of screening, 497 of the most resistant cultivars were screened more intensively using 3 replicates of each cultivar tested. The Arkansas strain of maize weevil, a more productive population than the Mexican strain used in preliminary screening, was used to reduce the number of kernels that escaped infestation. Two cultivars previously shown to be resistant and susceptible were tested concurrently with both phases of screening to provide a comparison for the cultivars being screened and a check on experimental procedure.

As a result of screening procedures, 160 of the original 1511 cultivars were found to produce significantly as few as or fewer progeny than the resistant check at the 0.15 level of probability. Cultivars with glumes completely

enclosing the kernel were nearly immune but this type usually is not grown for grain. Many of the cultivars from India showed greater resistance to the maize weevil than cultivars from other areas. Possibly this is due to the large amount of shallu-like sorghum grown there, which seems to have a higher degree of resistance to the maize weevil.

Tests were also conducted to determine what effect population density, species and strain of weevil, and relative humidity had on the level of resistance.

Evidence was secured which indicated that an approximately linear positive relationship exists between the number of progeny produced by a given number of maize weevils and the number of kernels of a resistant cultivar available for oviposition. This relationship was almost identical for both the Mexican and Arkansas strains.

The species and strain of weevil used to infest a resistant cultivar, Double Dwarf Early Shallu, also had a large effect on the number of progeny produced. Sitophilus granarius produced only 1 progeny from 5 replicates of 50 seeds, each infested with 6 female and 3 male weevils. It was followed by two Mexican strains of Sitophilus zeamais which produced an average of 3.6 and 6.6 progeny per replicate. Two strains of Sitophilus oryzae yielding an average of 12.0 and 14.4 progeny per replicate and the Arkansas strain of Sitophilus zeamais which produced 16.6 progeny, were the most productive.

An increase in relative humidity led to an expected increase in the number of progeny emerging from resistant, intermediate and susceptible varieties of sorghum. However, the increases in progeny in the resistant variety were much smaller with a given increase in relative humidity. This would tend to make the resistant variety more resistant, relative to the susceptible variety, at higher relative humidities than at lower levels. It was also shown that there were no significant differences between the equilibration moisture contents of the 3 varieties.

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SOURCES OF RESISTANCE TO THE MAIZE WEEVIL, *SITOPHILUS ZEAMAIS* MOTS, IN 1511 CULTIVARS OF SORGHUM

by

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The principal objective of this work was to search for germ plasm resistant to the maize weevil, *Sitophilus zeamais* Mots. among 1511 cultivars of sorghum obtained from the International Germ Plasm Seed Bank, Chapingo, Mexico. A two-phase screening process was employed. In preliminary screening, one replicate of 50 seeds of each cultivar was subjected to a 5-day oviposition and feeding period by 6 female and 3 male maize weevils. The resulting progeny were counted and this was used as a measure of resistance. The 497 cultivars that produced the least progeny were carried into secondary screening where 3 replicates of each cultivar were tested and the more productive Arkansas strain of maize weevil used to increase the level of infestation. Results from secondary screening indicated that 161 cultivars produced as few as or fewer progeny than the resistant check at the 0.15 level of probability. All cultivars that produced no progeny had glumes tightly surrounding the seed but sorghums possessing this feature are rarely grown for grain.

Related studies illustrated that the number of progeny produced in the resistant sorghum, Double Dwarf Early Shallu, by 6 female and 3 male maize weevils is positively correlated to the number of kernels available. While the Arkansas strain produced consistently more progeny than the Mexican strain, the increase in progeny resulting from a given increase in the number of kernels was nearly the same for both strains.

The level of resistance of Double Dwarf Early Shallu varied when 50 kernels were subjected to a 5-day oviposition period by 6 female and 3 male grain weevils of various species and strains. It was found to be almost immune to the granary weevil. The other weevils ranked from lowest to highest number of progeny produced were: Mexican maize weevil from corn, Mexican maize weevil from sorghum, Georgia rice weevil, Kansas rice weevil, and Arkansas maize weevil.

An increase in relative humidity was found to lead to an expected increase in the number of progeny produced by 1 resistant and 2 susceptible varieties of sorghum. However, the increase in the number of progeny produced due to a given increase in relative humidity was much smaller for the resistant variety than for the susceptible ones. No significant differences were found between the equilibration moisture contents of the 3 varieties.

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