Screening and Breeding Maize for Resistance to *Sesamia calamistis* and *Eldana saccharina*

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Abstract

Research at the International Institute of Tropical Agriculture (IITA) on the maize stem borers Sesamia calamistis *Hmps. and* Eldana saccharina *Walker is summarized and discussed. The available evidence indicates that both* S. calamistis *and* E. saccharina *cause major economic losses and that resistant varieties would be an important part of an integrated control strategy. Our experience shows that controlled, uniform artificial infestations are needed to develop resistant varieties. The development of artificial infestation methods and the damage rating scales currently in use are described. The factors affecting efficient screening and breeding for resistance to stem borers at IITA are discussed and the methods used to identify sources of resistance explained. Future breeding plans are also discussed.*

Introduction

Lepidopterous stem borers are among the most important insect pests of maize in Africa. Four borers cause significant yield loss: the pink stalk borer, *Sesamia calamistis* Hmps. (Lepidoptera: Noctuidae); the African sugarcane borer, *Eldana saccharina* Walker (Lepidoptera: Pyralidae); the maize stalk borer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae); and the spotted stalk borer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) (Bowden 1954; Harris 1962; Appert 1970; Breniere 1971). The first three are endemic to Africa, and are present in most countries of sub-Saharan Africa, while *C. partellus* is of Asian origin and only recently introduced to eastern Africa (Appert 1970; Bordat et al. 1977; Girling 1978).

The severity and nature of stem borer damage depend upon the borer species, the plant growth stage, the number of larvae feeding on the plant, and the plant's reaction to borer feeding. Almost all plant parts—leaves, stem, tassel, and ears—are attacked. Crop losses may result from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging, and direct damage to the ears. The incidence of stalk and ear rots is increased by larval feeding and the ears of lodged plants are often rotten. Yield losses caused by maize borers in Africa have been estimated to range from 10 to 100% (Usua 1968).

Research at the International Institute of Tropical Agriculture (IITA) on stem borers has largely been confined to *S. calamistis* and *E. saccharina*, which are the predominant borer species in the forest zone of West Africa. *S. botanephaga* also occurs in West Africa (Breniere 1971), but since its behavior is similar to that of *S. calamistis*, the two will be referred to as *Sesamia* spp.

Screening and breeding maize for resistance to stem boring insects is a long-term, relatively expensive objective. Before a breeding program is initiated, the potential for economic impact should be carefully assessed. This assessment would include: 1) the economic losses attributable to insect attack; 2) the potential for cultural, biological, or other means of control; and 3) the potential for a successful breeding program. The economic importance of stem borers in the West African forest zone can only be understood in relation to their population dynamics and the agronomic constraints on maize production in the forest zone, both of which are influenced by the rainfall pattern.

West African rainfall patterns

The West African forest zone has a long, 6- to 10-month, rainy season and a shorter, 2- to 6-month, dry season in which almost no rain falls. In many regions the rainy season is interrupted by a short, unreliable, "August break." The August break divides the rainy season into two parts, the first and second rainy seasons. Maize that is planted at the beginning of the first rainy season is called first season maize, and maize that is planted after the August break is called second season maize.

The rainfall pattern affects borer populations through its effect on host plant growth. Both *S. calamistis* and *E. saccharina* are polyphagous insects that feed on maize, sugarcane, sorghum, and other grasses. Native grasses are the original hosts of both insects; maize is an introduced crop. *S. calamistis* breeds throughout the year and has no resting stage (Harris 1962). However, it is less abundant during the dry season when mature grasses (among others, *Pennisetum purpureum*, *Setaria* spp., and *Rottboellia exaltata*) are its food source. *Sesamia* spp. adults that emerge at the beginning of the cropping season are smaller and less fecund than those emerging later in the year (Bowden 1976). The combined effect of smaller numbers of less fecund adults results in lower incidence of *Sesamia* spp. in first season maize crops.

As the rains progress, the new growth of the native grasses and the first season maize provide suitable hosts for insect growth, and the population of this borer increases until it peaks around August-September, when second season maize crops are being grown. As a result, *Sesamia* spp. are a very serious problem in the second season and many farmers in West Africa do not plant second season maize (Tams and Bowden 1952; IITA 1977). *E. saccharina* is also far more abundant in second season maize crops (Girling 1980).

Seasonal marketing patterns

Most of the maize grown in the West African forest zone is first season maize, and a large but undetermined portion of this crop is consumed as green maize (corn on the cob). The problems of drying and storing maize grain during the rainy season help explain why a large proportion of first season maize is harvested green and may also set limits to the expansion of first season maize production.

The price of maize grain declines sharply as the first season crop matures, and farmers who cannot dry and store their crop must sell it at discount prices. Grain prices rise during the dry season and sometimes are as much as three to four times higher than during the rainy season. Clearly, high returns would be obtained if first season maize grain could be dried and stored. But second season maize, since it matures in the dry season, is easier to dry and store and the higher quality grain attracts premium prices (Knipscheer 1980; Palada et al. 1985; IITA 1986a). Because both *S. calamistis* and *E. saccharina* limit the production and productivity of second season maize, they are of great economic importance.

Some potential for cultural and biological control of stem borers does appear to exist, but resistant varieties have been suggested as the most promising means of control (Bowden 1976; Girling 1980). At IITA, efforts have been devoted for the past several years to developing resistance to *S. calamistis* and, more recently, to *E. saccharina*. Screening for resistance to *Sesamia calamistis* was previously carried out under natural infestation, but now selection for resistance to both borers is done under artificial infestation. Based on this work, the potential for developing resistant germplasm can be assessed.

Screening and Breeding for Resistance to *S. calamistis*

S. calamistis adults lay their eggs between the leaf sheaths from the time the maize plants are about 2 weeks old until they begin to senesce (Carter 1985). Larval development takes 4 to 6 weeks, and pupation takes place within the stem or cobs. Most larvae penetrate the stem below the growing point shortly after the eggs hatch. Others penetrate the whorl, resulting in leaf, tassel, and upper stem damage. At maturity, the majority of larvae are found in the ear, but since no eggs are laid on the husk, this is clearly the result of migration. Serious yield reduction from *S. calamistis* occurs when young plants are infested and an entire cross section of the stem is consumed. This results in cessation of water flow, and the upper portion of the plant wilts and dies (dead heart).

Larvae that penetrate the stem but do not cause dead hearts will girdle the stem near a node and/or tunnel in the stem and cause increased stalk lodging later in the season.

Screening under natural infestation

IITA's search for resistance to *S. calamistis* began in 1975 with the screening of 35 materials under natural infestation at the Amakama Research Station of the National Cereals Research Institute (NCRI) near Umuahia, in southeastern Nigeria. *S. calamistis* populations have always been high in Umuahia during the second maize growing season, and this location has been used by the breeding program as a "hot spot" for much of its work on resistance to this borer. In 1976, a much wider range of materials (786 entries) was evaluated. Ears from surviving plants were selected and recombined to form the "Borer Resistant" (BR) population. The BR population was selected for agronomic characters and yield performance at Ibadan in 1977 and rescreened for borer resistance at Umuahia in 1978.

In 1979, in addition to BR lines, 724 breeding materials, which included some of the newly developed streak-resistant (SR) germplasm, were

Table 1. Selection of TZBR population for resistance to *S. calamistis* at Umuahia, Nigeria

Year	Number of families screened	Type of family	Number of families selected	Resulting population
1981	250	half-sib	12	TZBR C_1
1983	300	half-sib	15	TZBR C_2
1984	234	half-sib	43	TZBR C_3
1985	250	S_1	25	TZBR C_4

Table 2. Effect of three cycles of selection for resistance to *S. calamistis* in the TZBR population on performance under natural infestation of *S. calamistis* at Umuahia in 1985

Entry	Percent plant survival	Percent borer incidence	Damage rating[a]
TZBR C_0	52.2	75.6	7.90
TZBR C_1	62.8	68.4	7.49
TZBR C_2	56.4	69.3	7.79
TZBR C_3	55.1	68.9	7.77
Checks			
TZSR-Y-1	57.5	68.5	7.78
8338-1	55.0	74.1	7.82
Prob. of F value	0.59	0.22	0.48

a *Sesamia* damage rating scale where 1 = escape; 2 = minor leaf feeding damage; 9 = dead heart (IITA 1985). The numbers shown are the mean rating of non-escapes.

screened at Umuahia. Those with less borer damage were selected and recombined to form the "Borer Resistant Streak Resistant" (BRSR) population. In 1980, BR lines were evaluated under induced infestation in a screenhouse at Ibadan. The best lines were selected, recombined, and again tested at Umuahia. In addition, 127 BRSR families were tested, and superior ones from both populations were selected. The BR and BRSR populations were crossed, and from then on the population was referred to as TZBR (Tropical Zea Borer Resistant).

Selection efforts for the improvement of TZBR concentrated primarily on young plant resistance to dead hearts under natural infestation at Umuahia. TZBR Cycle 0 was screened in 1981 using 250 half-sib families. Remnant seed of the 12 families that showed the highest percent survival 3 weeks after flowering were recombined to form TZBR Cycle 1 (Table 1). This process, with slight modifications, continued for three cycles in an attempt to increase the frequency of genes for resistance to *S. calamistis*. The fourth cycle of selection was conducted using S_1 instead of half-sib families.

In 1984, TZBR Cycle 2 was compared to Cycle 0 in a trial with ten replications in Umuahia. No response to selection was evident. In 1985 the products of three cycles of selection were compared to the original TZBR population and two improved check varieties that had not been selected for resistance to *S. calamistis*. Resistance levels were assessed using percent survival and a 1 to 9 scale to rate the severity of borer damage (IITA 1985). No significant differences were found among the treatments for either percent survival or severity rating, and there was no trend indicating that improvement might have been made (Table 2). The TZBR population was no better than the checks.

The lack of progress in selection for *S. calamistis* resistance at Umuahia might be explained by inadequate experimental precision and/or the difficulties associated with screening based on natural infestations. The problem of soil variability was serious at Umuahia and was only partially solved in some years by applications of fertilizer, micro-nutrients, and lime. Each year differences in plant vigor were noted that apparently were caused by variation in soil fertility. The areas of the field with more vigorous plant growth showed higher plant stand and lower severity of *S. calamistis* damage.

The apparent explanation for this is that feeding by *S. calamistis* larvae is more likely to kill a weak, slow growing maize plant than a vigorous one. Less vigorous maize plants are in a growth stage that is susceptible to dead heart damage for a longer period of time. In addition, there may be decreased larval establishment on more vigorous plants. Studies with artificial infestation have clearly shown that the ability of *S. calamistis* to cause dead hearts is a function of plant growth stage. Highly significant differences on the establishment of *S. calamistis* larvae on maize plants of different ages (12 vs 21 days after emergence) were observed in tests conducted at Ibadan, Nigeria. Our work with inbreds and hybrids confirmed the effect of plant vigor on larval establishment (IITA 1986b; N. Bosque-Perez, unpublished).

Insufficient genetic variation among half-sib families for resistance contributed to the difficulty of detecting significant differences; for this and other reasons, S_1 families were screened in 1985. Added to these difficulties are those of selection under non-uniform natural infestations. If evaluations are based on survival, the problem of escapes will limit efficient selection. Plants are growing under continuous egg laying by *S. calamistis*, (Carter 1985) and might be infested at different times. Thus, it is practically impossible to determine whether minor feeding damage is the result of late infestation or genetic resistance.

Artificial infestation methods

We believe it is possible to develop germplasm with resistance to *S. calamistis*; however, our experience at Umuahia showed that controlled, uniform artificial infestations are needed to achieve this goal. Research on artificial infestations with this borer has included a study of the factors that affect larval establishment and a comparison of artificial infestation methods. Factors found to affect establishment include the source of insects (wild vs. laboratory-reared), the presence of predatory ants, and plant age. Wild *S. calamistis* were found to be more aggressive than laboratory-reared ones (IITA 1986b), possibly because the latter were reared on artificial diet for a long time, suffered from inbreeding, and/or were affected by diseases. Our stem borer colonies at IITA are now replaced periodically to avoid this problem. Ants are known to be important predators of stem borer eggs and young larvae (Girling 1980), and in some instances it is necessary to control them with insecticides to get good establishment of borer larvae.

At present, infestations are being done with egg masses at the black-head stage (one day before hatching) by placing them within the leaf sheaths at the base of the plant with forceps 21 days after plant emergence. Infestations with a larval dispenser (bazooka) have resulted in decreased larval establishment. The larvae appear to be injured by the dispenser and the frequency of escapes (plants which show no establishment of larvae) is higher.

Inbred lines are infested with ca. 40 eggs per plant in the screenhouse and ca. 75 eggs per plant in the field. Although we still are in the process of refining the rating scale, evaluation of plants is done with a 1 to 9 scale based on overall plant damage at the time of tasseling (Table 3, modified from Guthrie et al. 1960). The main difficulty in developing a rating scale for *S. calamistis* is the large variability in types of feeding damage that occur.

Leaf damage might or might not occur and signs of borer activity might take up to 3 weeks after infestation to become readily apparent. However, using this scale (Table 3) we have been able to screen various breeding materials and have found consistent and significant differences in reaction to this insect (Table 4). The susceptible (TZi 19) and the intermediately resistant (TZi 4) inbred lines will be used to examine different methods of infestation and will form the basis of a resistance breeding program.

Role of maize streak virus
Several factors needed to be taken into consideration when a breeding program for resistance to *S. calamistis* under artificial infestation was planned at IITA in Ibadan. Since the borer rearing facility is small, the germplasm to be screened needs to be planted sequentially throughout the year so that the available insects are fully utilized. The presence of maize streak virus disease does not allow screening of streak susceptible germplasm throughout the year. Unadapted or inbred germplasm is also likely to show reduced vigor, and this has been shown to increase susceptibility to *S. calamistis*. Therefore, unadapted germplasm is intensively screened for resistance to *S. calamistis* as testcrosses (topcrosses) to an adapted streak-resistant tester line.

Genetic theory and practical experience have shown that an inbred tester that has a low frequency of favorable genes is the most efficient tester (Hallauer and Miranda 1981). Therefore, introduced germplasm will be crossed to the susceptible inbred, TZi 19, and thoroughly evaluated as testcrosses before introductions are selected for a *S. calamistis* resistance breeding pool. This breeding pool will utilize TZi 4 as a source of streak resistance, tropical adaptation, and resistance to *S. calamistis*. In addition, locally adapted improved germplasm will be more intensively screened for reaction to infestations with this borer.

Screening and Breeding for Resistance to *E. Saccharina*

In contrast to *S. calamistis*, *E. saccharina* begin to infest maize plants after flowering. Females lay their eggs on the plant or on debris on the soil (Atkinson 1980). Larvae migrate to the stem and enter it through the nodes. Eventually some larvae move to the ears. Tunneling of the stem commonly results in stalk breakage later in the season. Larval development takes 3 to 5 weeks and the pupae, which are covered by a cocoon made of silk and plant debris, can be found in the stems or ears. Rapid population buildups of this borer are common and, as a result, crops can suffer serious damage before they are ready for harvest (Girling 1980). *E. saccharina* is the dominant stem borer during maize harvest at many locations in southern Nigeria (IITA 1986b; N. Bosque-Perez, unpublished) and in southern Cameroon (R. Arroga, Insitut de la Recherche Agronomique, personal communication). At the IITA campus in Ibadan, *E. saccharina* has been a serious pest of second season maize nurseries.

Artificial infestation
Methods of artificial infestation with *E. saccharina* were studied in 1985 and 1986. Since this borer is a post-anthesis pest, all artificial infestations were done within 1 week after silking. Larval establishment was found to be higher when egg masses were placed behind the leaf sheaths at the base of the plant, compared to placing them on the ground at the base of the plant. A later test showed infestations with larvae by means of a larval dispenser (bazooka) not to be effective. *E.*

Table 3. Rating scale for *S. calamistis* based on overall plant damage

Class	Description
1	No visible leaf injury or small number of pin holes on one or two leaves.
2	Small amount of shot-hole type lesions on two or three leaves.
3	Shot hole injury on four or more leaves and elongated lesions (2.5 cm) on two or three leaves.
4	Four to five leaves with elongated lesions (2.5 cm or more).
5	Broken midribs, elongated lesions on six or more leaves, some tassel damage.
6	Severe leaf damage and/or broken tassel and plant slightly stunted.
7	Stunted plant, top portion of the plant dead, or drying up, or stalk broken above the ear.
8	Plant broken midway between the ear and the ground or plant severely stunted and drying.
9	Dead heart or plant.

Table 4. Damage rating of maize inbred lines artificially infested with *S. calamistis*, Ibadan, 1986

Inbred line	Pedigree	*S. calamistis* damage rating Field test	Screenhouse test
Tzi 19	Across 7635 x TZSR	7.2	6.8
Tzi 4	Guanacaste 7729 x TZSR	3.9	3.5
L.S.D., 5%		1.9	2.4
Prob. of F value		0.01	0.01

Damage rated on a 1-9 scale where; 1 = no injury or small number of pin holes and 9 = dead heart (Table 3).

saccharina larvae produce abundant silk, which clogs the bazooka and interferes with the flow of the larvae/corn grits mixture. Methods to reduce the clumping of larvae in order to avoid this problem will be studied in the future.

Further experiments conducted in 1986 on the efficiency of artificial infestations showed that placing the eggs behind the leaf sheaths at the node below the ear was adequate for larval establishment and faster than placing egg masses close to the base of the plants (N. Bosque-Perez, unpublished). Less larval establishment when the egg masses are placed close to the base of the plants might be due to the combined effect of greater numbers of larvae being killed by ants and more larval migration to the other plants. At present, plants are infested with ca. 80 black-head-stage eggs each.

At harvest, the infested maize stalks are split open, and the following assessments made: 1) an estimate of the percentage of the stalk below the ear that shows tunneling; 2) the number of nodes below the ear that show borer damage; and 3) an estimate of the percentage of grain consumed or damaged by borers using a 1 to 5 rating scale (scale: 1 = 0 to 5%, 2 = 6 to 25%, 3 = 26 to 50%, 4 = 51 to 75%, and 5 = 76 to 100% kernel damage). In addition, notes on standard agronomic characters and levels of stalk rot are made. The estimate of the percentage of the stalk that has been tunneled is considered better than measuring the length of the tunnels, because it eliminates the problem of different plant heights and the difficulties of measuring lesions of irregular shape, and is much faster.

The breeding program

The factors affecting any attempt to breed for *E. saccharina* resistance at the IITA campus in Ibadan are similar to those that affect breeding for resistance to *S. calamistis*. These factors include a small facility for rearing the borers for artificial infestation and the streak virus epidemics that kill susceptible maize germplasm if planted at any time other than the beginning of the rainy season. Therefore, germplasm must have some level of resistance to maize streak virus if we are to fully utilize the available facilities. Streak susceptible germplasm that holds potential as a source of resistance to *E. saccharina* is evaluated as a testcross to a tropically adapted, streak-resistant tester.

During the second season of 1985, 102 introductions from the USA, CIMMYT (Mexico), the International Centre of Insect Physiology and Ecology (Kenya), and local germplasm were screened for resistance to *E. saccharina* under natural infestation supplemented with artificial infestation at Ibadan. All the introductions have shown resistance to other stem boring insects. The introductions were screened as testcrosses with the hybrid 8338-1 (TZi 9 x TZi 10), which is a streak resistant, single-cross hybrid with good root lodging resistance and stalk quality. Plants were infested at tasseling with ca. 50 eggs each. Egg masses at the black-head stage were cut to the appropriate size, and placed behind the leaf sheaths near the base of the plants. Assessments of borer damage were made at harvest.

Table 5. *E. saccharina* damage assessments and agronomic trait ratings for selected testcrosses of 102 introductions grown under artificial infestation, Ibadan, Nigeria, 1985

Entry	Percent of stalk tunneled	Number of nodes bored	Husk cover rating[a]	Percent grain loss[b]
Testcrosses				
PRM02 C6 88-3-3	7	2.0	3.0	15
Mp 496	8	2.6	1.5	2
Mp 704	9	2.5	2.5	5
Pop. 47	37	3.5	4.0	30
Mean (102 introductions)	20	3.1	2.7	15
Controls				
Tester (8338-1)	16	2.9	2.4	5
TZSR-Y-1	23	3.6	2.8	8
TZSR C3	24	3.4	2.8	12
Prob. of F value	0.01	ns	0.04	0.01
L.S.D.	17.1	ns	1.98	18.6

Entries were screened as testcrosses with the single-cross hybrid 8338-1

a Rating scale of 1 - 5 where 1 = tight and complete husk cover and 5 = very loose husk cover and exposed ear tips.

b Visual estimate.

Significant differences were found for most agronomic traits and assessments of *E. saccharina* damage (Table 5, IITA 1986b). The mean percent stalk tunneling for the testcrosses was similar to that of the tester (testcrosses 20% vs. tester 16%). This suggests that germplasm that shows resistance to another borer species does not necessarily carry resistance to *E. saccharina*. However, estimates of percent stalk tunneling for the testcrosses ranged between 7.2 and 37.0 (L.S.D. 5% = 17.1), indicating that some of the introductions may be very useful. Cycle 3 of TZBR, which was selected for resistance to *S. calamistis* under natural infestation, did not show any sign of resistance to *E. saccharina*. The correlation between percent stalk tunneling and stalk rot was highly significant, indicating that increasing levels of stem borer tunneling are associated with higher levels of stalk rot. Ears with poorer husk cover showed greater grain loss due to borers. The effects of length and tightness of husk cover and number and thickness of the husk leaves on ear damage due to *E. saccharina* will be studied in the near future.

Based on the initial screening results of 1985, the six best and the four worst testcrosses were re-evaluated during the first rainy season of 1986 to confirm their reaction to *E . saccharina* (Table 6). Comparisons between the best six and the worst four showed that the best six had a significantly lower percentage of nodes bored by *E. saccharina*. Differences for percent stalk tunneled and percent stalk lodging indicated gains in the expected direction, but were not significant.

The best 50 of the original 102 testcrosses were re-screened in the 1986 second season. Ten plants per row (2 replications) were infested at tasseling with ca. 80 black-head-stage eggs each, by placing the eggs behind the leaf sheaths at the node below the ear. Measurements taken at harvest were similar to those described above. Differences in percentage of the stalk tunneled were found (range 21.1 to 54.4), but were not significant at the 5% level. Differences in the percentage of nodes bored were also not significant.

Twenty-one superior testcrosses were selected and individually backcrossed to their respective original introduction. The resulting backcrosses are being evaluated now (early 1987). If selection among the introductions can be made with a high level of confidence, then the best backcrosses will be recombined to form an *E. saccharina* resistance breeding pool. These introductions and any new introduction must clearly show reduced borer damage before they are crossed into the pool. In addition, it would be desirable to look at the available improved streak resistant germplasm in Africa for potential sources of resistance to this insect.

Evaluating the Methodology

In order to more efficiently utilize the available mass-reared borers and the labor required to split maize stalks and evaluate the damage, and to be more likely to find significant differences among the germplasm screened, the sources of experimental error in our infestation experiments were studied. Estimates of the plant-to-plant and the plot-to-plot error for percent of the stalk tunneled were obtained and used to predict the least significant difference (LSD) under different numbers of plants per plot and replications (Figure 1). The estimated LSD decreases rapidly as the number of plants screened increases, up to about 40 plants, and thereafter an increase of the number of plants screened results in minimal reduction in the estimated LSD. As the number of plants screened is distributed among increasing numbers of replications, the LSD is likewise reduced.

Table 6. Results of initial screening and confirmation trial of ten testcrosses for assessments of damage by artificially infested *Eldana saccharina*, Ibadan, Nigeria, 1985 and 1986.

	–1985 screening–		—1986 confirmation trial—		
Entry[a]	Number of nodes bored	Percent of stalk tunneled	Percent of nodes bored	Percent of stalk tunneled	Percent stalk lodging
Best six testcrosses					
PRM02 x PRM0SQB 87-4	3.1	9.0	32.6	10.3	27
PRM02(S1)C6 88-8	2.6	7.6	30.7	14.7	33
PRM02(S1)C6 88-3-3	2.0	7.2	30.4	11.8	53
PRM02(S1)C6 752-1	2.4	8.1	41.3	16.8	16.8
Mp 496	2.6	8.3	35.5	17.6	20
Mp 704	2.5	9.3	20.8	14.2	0
Worst four testcrosses					
PRM02(S1)C6 88-6	3.9	36.5	44.0	18.1	73
PRM02(S1)C6 88-3-1	4.0	36.5	39.3	11.5	47
PRM02(S1)C6 88-3-2	3.5	36.0	39.8	13.9	47
Pop. 47	3.5	37.0	47.3	20.7	67
Check					
Tester (8338-1)	2.9	16.1	40.6	19.3	33
Mean of best six	2.5	8.3	31.8	14.2	24
Mean of worst four	3.7	36.5	42.6	16.2	59
Orthhogonal comparison[b]	-	-	.01	ns	.10
LSD(5%)	ns	17.1	12.2	ns	ns

[a] Entries were screened as testcrosses with the single-cross hybrid 8338-1.

[b] The probability of obtaining the observed F value for planned F tests comparing the best six entries from the screening trial with the worst four.

The number of plants and replications required to achieve a given estimated LSD would be expected to change depending upon the genetic uniformity of the materials screened and the efficiency of the infestation technique. In future experiments, we intend to infest 40 plants per entry, using 10 plants per plot in four replications. This will allow us to divide our infestation and evaluation periods into manageable units and give reasonable experimental precision. Given our borer rearing capabilities, we can screen 75 to 100 entries per season during the three growing seasons per year. The results of our trials are encouraging, and we believe that germplasm with resistance to *E. saccharina* can be rapidly and efficiently developed.

References

Appert, J. 1970. Insects harmful to maize in Africa and Madagascar. Madagascar Institute of Agronomic Research, Antananarivo, Madagascar.

Atkinson, P.R. 1980. On the biology, distribution and natural host-plants of *Eldana saccharina* Walker (Lepidoptera: Pyralidae). Journal of the Entomological Society of South Africa 43:171-194.

Bordat, D., J. Breniere and J. Coquard. 1977. Foreurs de graminees africaines: parasitisme et techniques d'elevage. L'Agronomie Tropicale 32:391-399.

Bowden, J. 1954. The stem-borer problem in tropical cereal crops. Report 6th Commonwealth Entomological Conference.

Bowden, J. 1976. Stem-borer ecology and strategy for control. Annals of Applied Biology 84:107-134.

Breniere, J. 1971. Les problemes des lepidopteres foreurs des graminees en Afrique de l'ouest. Annals Zoologie-Ecologie Animal 3:287-296.

Carter, A.O. 1985. An evaluation of the importance of stem borers and their control on maize grown in south eastern Nigeria. M.Sc. thesis, Reading University, England.

Girling, D.J. 1978. The distribution and biology of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) and its relationship to other stem borers in Uganda. Bulletin of Entomological Research 68:471-488.

Girling, D.J. 1980. *Eldana saccharina* as a crop pest in Ghana. Tropical Pest Management 26:152-156.

Guthrie, W.D., F.F. Dicke and C.R. Neiswander. 1960. Leaf and sheath feeding resistance to the European corn borer in eight inbred lines of dent corn. Ohio Agricultural Experiment Station (Wooster) Research Bulletin No. 860.

Hallauer, A.R. and J.B. Miranda. 1981. Quantitative genetics in maize breeding. Iowa State University Press; Ames, Iowa. Pp. 269-274.

Harris, K.M. 1962. Lepidopterous stem borers of cereals in Nigeria. Bulletin of Entomological Research 53:139-171.

IITA. 1977. Cereal improvement program in-house report for 1976. International Institute of Tropical Agriculture. Ibadan, Nigeria.

IITA. 1985. Annual Report 1984. International Institute of Tropical Agriculture. Ibadan, Nigeria.

IITA. 1986a. Farming systems program annual report 1985. International Institute of Tropical Agriculture. Ibadan, Nigeria.

IITA. 1986b. Maize research program annual report 1985. International Institute of Tropical Agriculture. Ibadan, Nigeria.

Knipscheer, H.C. 1980. Prices of major food crops in Togo. International Institute of Tropical Agriculture. Ibadan, Nigeria. Agricultural Economics Information Bulletin No. 5.

Palada, M.C., W.O. Vogel and H.J.W. Mutsaers. 1985. Report on exploratory survey of Ijaiye-Imini pilot research area, Oyo State, Nigeria. International Institute of Tropical Agriculture. Ibadan, Nigeria. On-farm Research Bulletin No. 2.

Tams, W.H.T. and J. Bowden. 1952. A revision of the African species of *Sesamia* Guenee and related genera (Agrotidae - Lepidoptera). Bulletin of Entomological Research 43:645-678.

Usua, E.J. 1986. Effect of varying populations of *Busseola fusca* larvae on the growth and yield of maize. Journal of Economic Entomology 61:375-376.

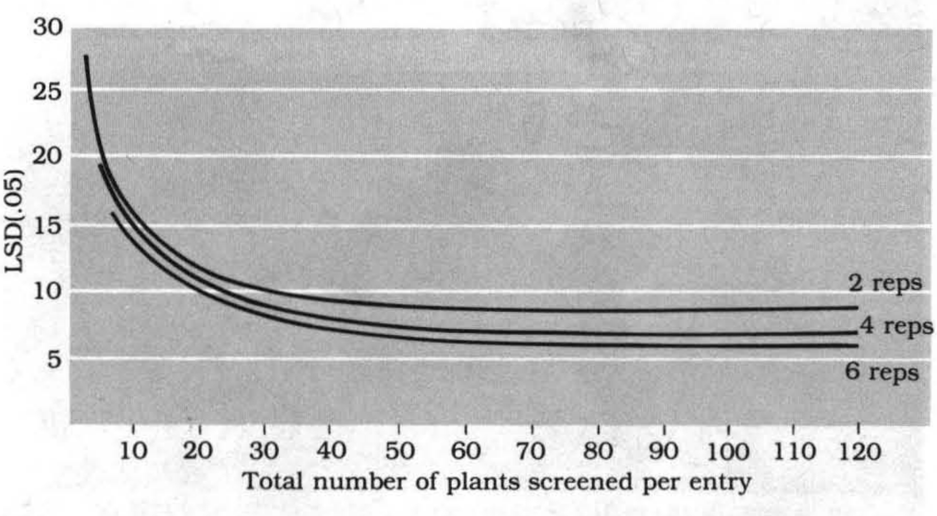

Figure 1. Effect of replication and total number of plants screened on the LSD for percent stalk tunneled by artificially infested *E. saccharina* larvae, assuming 50-entry trial.