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PROGRESS IN BREEDING FOR RESISTANCE TO MAIZE STEM BORERS *SESAMIA CALAMISTIS* AND *ELDANA SACCHARINA* IN WEST AND CENTRAL AFRICA.

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ABSTRACT

The pink stem borer (*Sesamia calamistis* Walker (Pyralidae)) and the sugarcane borer (*Eldana saccharina* Hampson (Noctuidae)) are among the most damaging pests of maize in West and Central Africa, a region where IITA invests considerable effort in improving productivity of maize-based systems. The use of host plant resistance (HPR) is central to any Integrated Pest Management (IPM) programme; therefore, development and use of maize varieties with resistance to *Sesamia* and/or *Eldana* are integral to IPM activities in the region. Early research efforts resulted in the establishment of mass rearing facilities and screening procedures for both insect species, and the development of maize genotypes with resistance to *Sesamia* and/or *Eldana*. S1 selection has been used successfully to improve levels of resistance. New genotypes with resistance to both borer species have been developed by either broadening the genetic base of existing genotypes or by classifying the developed genotypes into heterotic groups and pooling each group to form a reciprocal pool for further improvement. Artificial infestation has identified levels of cross resistance in a number of genotypes. Inbred lines with resistance to either of the borer species have been isolated and tested. Stem borer resistant varieties are currently being grown on-farm in Nigeria, Ghana and Cameroon. There is, however, the need to correctly classify the mechanism of resistance in the identified genotypes to improve efficiency of selection and to combine different mechanisms of resistance into different genotypes.

INTRODUCTION

Stem borers are among the most important insect pests of maize in Africa. Three species of stem borers, *Sesamia calamistis*, *Eldana saccharina* and *Busseola fusca*, are of economic importance to maize in West and Central Africa. A few other species including *Sesamia poephaga* damage maize but are not of economic importance (Schulthess and Ajala, 1999). Both the pink stem borer (*Sesamia calamistis*) and the sugarcane borer (*Eldana saccharina*) attack maize especially in the lowland regions while the African stem borer (*Busseola fusca*) is found commonly in the Cameroon mid-altitude region. Both *Sesamia calamistis* and *Busseola fusca* attack maize early in the life of the plant while *Eldana saccharina* is a later infesting borer. In the lowland region of West and Central Africa, stem borer population build-up would generally reach very high damaging levels in the second season. Scientists at IITA have been conducting research on the integrated control of stem borers especially in the lowland regions of West and Central Africa where *Sesamia* and *Eldana* predominate, and host plant resistance has been a major component of this effort.

The pink stem borer (*Sesamia calamistis*) lays its eggs between the leaf sheaths of young plants at about three weeks after emergence. When the larvae hatch, they penetrate either the whorl or the stem resulting in leaf or stem damage and also deadheart formation. The sugarcane borer, *Eldana saccharina* lays its eggs on dry leaves and debris on the soil but also on the hairy margins of the leaves. *Eldana* larvae usually attack maize at the flowering stage resulting in stalk tunnelling, breakage and cob damage. The overall effect of stem borer infestation is reduction in yield ranging from 20-70% depending on severity. Total crop failure had been reported in a few instances (Usua, 1968a and b; Bosque-Perez and Mareck, 1991; Gounou *et al*. 1994; Schulthess and Ajala, 1999).

Kling *et al*. (1994) reported early progress made at IITA to screen and breed for resistance to both *Sesamia* and *Eldana*. These efforts included the development and use of controlled and uniform artificial infestation which in turn was made possible by the development of mass rearing techniques for both insect species and the formation of stem borer resistant populations (Bosque-Perez *et al*., 1989). Since then, significant progress has been made in improving and developing better performing maize genotypes with resistance to stem borer attack.

PROGRESS IN BREEDING STEM BORER RESISTANT GENOTYPES

Three populations, each with resistance to *Sesamia* and *Eldana,* were developed in the late 1980s. These were named TZBR (Tropical Zea Borer Resistant) Sesamia or Eldana 1, 2 and 3. Both TZBR Sesamia 2 and TZBR Eldana 2 were eventually discontinued due to low levels of resistance to their respective pests. TZBR Sesamia 1 was obtained by crossing five inbred lines from various sources with Tzi 4. While TZBR Sesamia 3 was also formed by crossing 29 lines mostly from CIMMYT with Tzi 4. Tzi 4 is a tropically adapted maize inbred line with resistance to both *Sesamia* (IITA, Maize Research Program Annual Report, 1986) and ECB2 (Kim *et al*., 1988). TZBR Eldana 1 was formed from 14 selected backcrosses obtained by screening 102 accessions mostly from CIMMYT with resistance to various stem borers. The accessions were screened as testcrosses and the selected testcrosses were backcrossed to their original accessions. Selecting and recombining superior S1 lines from DMRLSR-W, La Posta and TZSR-W resulted in the formation of TZBR Eldana 3. Because TZBR Eldana 3 was developed from elite adapted populations, it quickly proved its worth as a high yielding stem borer resistant material in multilocational trials at NARS testing sites within the region.

Table 1. Evaluation of progress from selection in TZBR Eldana-1 estimated from field trial at Ibadan in 1999.

Genotypes	% Stem Tunnelling	Cob damage (1-9)*	Grain yield (kg/ha)	
			Infested	Un-infested
TZBR Eld -1 C0	2.1	4.8	3096	3192
TZBR Eld -1 C1	3.6	4.3	2078	2711
TZBR Eld -1 C2	3.2	5.0	3013	2913
TZBR Eld -1 C4	5.3	4.0	3146	3227
TZBR Eld -1 C5	4.3	4.3	3356	3598
TZBR Eld -1 C7	1.6	3.8	3913	4194
Mean	4.6	4.0	3731	3798
SED	2.7	0.5	519	498
CV (%)	84	16	20	18

*1 = resistant, 9 = susceptible

Improvement of stem borer resistant populations:

The developed populations are being improved through S1 family testing. For this method, between 250 and 500 progenies are generated per population. Progenies are usually evaluated under artificial infestation with *Sesamia* and/or *Eldana* under non-infested conditions at Ibadan and in two additional locations at Ikenne and Egbema, all in Nigeria. Ibadan and Ikenne are in the south-western part of Nigeria and are separated from one another by approximately 90 km. Ikenne is used in our breeding programme for screening against foliar disease including lowland blight, *Curvularia* leaf spot, rust and ear rot. Egbema is approximately 700 km east of Ibadan and it is a stem borer hotspot location in south-eastern Nigeria. Ratings and measurements of stem borer resistant parameters are made on leaves, stem, cob and grain yield for the infested trials and for other agronomic traits including disease ratings for the uninfested trials. A base index is then used to select desirable progenies based on the damage parameters and grain yield and disease ratings. Using this approach, seven cycles of selection have been completed in TZBR Eldana 1, three in TZBR Eldana 3 and three each in TZBR Sesamia 1 and TZBR Sesamia 3. Evaluation of progress from selection in TZBR Eldana 1 carried out in 1999 and presented in Table 1 revealed that changes in gene frequencies due to S1 recurrent selection had resulted in increased grain yield with reduced insect damage symptoms.

Formation of new stem borer resistant maize populations:

Out of the four stem borer resistant populations developed in the mid 1980s, only TZBR Eldana 3 that was formed from adapted materials had immediate usefulness in on-farm trials. In order to increase the number of populations developed from adapted genotypes, two new synthetics, TZBR Syn-W and TZBR Syn-Y, were formed from six and eight selected inbreds, respectively. Although TZBR Syn-W performed well in multilocational trials, the two synthetics had low acceptance and are now being used as sources of resistant lines. The demand for stem borer resistant maize varieties also increased with the launching in 1997 of the African Maize Stress (AMS) Project, a joint initiative between CIMMYT and IITA that aims to address the yield limiting stresses of drought, low soil fertility, *Striga* and stem borers in appropriate ecologies. This project thus provided the added impetus needed to identify and develop new maize varieties for strategic on-farm deployment.

Two approaches were followed in developing the new stem borer resistant varieties. One approach was to develop better performing new genotypes from adapted populations, while the other was to introgress genes from other populations into existing resistant genotypes or to pool resistant genotypes together to form broad- based genotypes having combined resistance to the two borer species. The earlier approach resulted in the development of a stem borer resistant population (Ama TZBR-W) that was tested on-farm and it is now being deployed in south-eastern Nigeria. Ama TZBR-W C1 was developed by growing bulk seeds from each of ten populations in a hotspot location (Amakama) of south-eastern Nigeria. Individuals with stem borer damage rating of ≤ 3 (1 = resistant and 9 = susceptible) from each of the populations were selfed *in situ*. Further selection was done at Ibadan by planting seeds of the selfed plants ear-to-row in the screen house and artificially infesting these with egg masses of *Sesamia calamistis* at three weeks after emergence and *Eldana saccharina* at flowering.

From these evaluations, a total of 37 S1 lines made up of 26 from DMRLSR-W, seven from TZBR Eld 3C2, three from TZBR Syn-WC1 and one from TZBR Ses 3C3, were selected. Plants having damage ratings of ≤ 3 from each row were then tagged and used for recombination to form C0 of Ama TZBR-W. A cycle of mass selection was again carried out in this population by planting and infesting bulk seeds in the screen house followed by recombination of selected individuals with ratings of ≤ 3 to form Ama TZBR-WC1. This new variety has consistently performed well in trials across the region and it is currently being disseminated through on-farm trials in south-eastern Nigeria.

In 2000, 215 S1 lines from Ama TZBR-W C1 and five checks were evaluated in three environments of Nigeria. One of the environments is a hotspot location of Egbema in south eastern Nigeria, while the other two environments were two trials planted at Ibadan that were artificially infested with *Sesamia* and *Eldana*, respectively. Primary data obtained from these evaluations and presented in Table 2 showed that enough variability existed in the population for selection to be effective. Consequently, selection indices involving both the damage and desirable agronomic features were constructed to utilize the variability inherent in the populations and 30 lines have been selected and recombined to form C2 for further evaluation and improvement.

Stem borer attack is more severe in the forest ecology of West and Central Africa, an area that also harbours an array of foliar diseases, ear rot and downy mildew. It is therefore desirable to have appreciable levels of resistance to all these other stresses in genotypes destined for the forest ecology. Selection against foliar diseases and ear rot is routinely practised at Ikenne, while a separate breeding program is maintained for downy mildew. Progress in breeding for downy mildew resistance has reduced levels of infection in most populations to less than ten percent (IITA, Project 4 Annual Report, 2000). Furthermore, evaluation of forest adapted populations had identified three downy mildew resistant populations with acceptable levels of resistance to stem borers. Consequently, a programme of tandem selection was initiated in three (Acr 9922 DMRSR, Acr 9928 DMRSR and Acr 9943 DMRSR) widely cultivated downy mildew resistant populations to upgrade resistance to stem borers. Acr 9922DMRSR is for example a downy mildew (DMR) and streak (SR) resistant population obtained from upgrading Ak 9522 DMRSR for DMR in 1999. Ak 9522 DMRSR is currently being used in on-farm trials for

Table 2. Primary data obtained from the evaluation of 215 S1 lines from Ama TZBR-W and five checks in three environments of Nigeria in 2000.

Variable	Mean	Min.	Max.	Range	CV (%)
Egbema					
Days to silk	64	56	75	19	5
Plant ht. (cm)	157	85	240	155	17
Plant Aspect Rating*	4	2	7	5	23
Stalk Breakage No	2	0	10	10	74
Ear damage Rating	3	1	7	6	33
Leaf feeding Rating	2	1	7	6	39
Plant damage Rating	2	1	7	6	32
Deadheart count	2	0	10	10	105
Grain yield (kg/ha)	2625	164	7730	7566	4
***Sesamia* infested**					
Days to silk	66	57	78	21	5
Plant ht. (cm)	135	70	197	127	15
Plant aspect Rating	4	2	7	5	20
Stalk breakage count	2	1	5	4	45
Deadheart count	1	0	7	7	169
Stem tunnelling (%)	9	0	31	31	69
Grain yield Inf. (kg/ha)	1169	0	3521	3521	48
Grain yld Uninf (kg/ha)	1120	15	2871	2856	46
***Eldana* infested**					
Days to silk	63	58	74	16	5
Plant ht. (cm)	140	76	214	138	18
Stalk breakage count	2	1	8	7	58
Cob damage count	2	0	7	7	56
Stem tunnelling (%)	10	0	37	37	68
Grain yield Inf. (kg/ha)	1093	17	4441	4424	59
Grain yld Uninf (kg/ha)	1090	53	4080	4027	57

* Rating is on 1 – 9 scale with 1 = resistant and 9 = susceptible

Busseola control in Cameroon. In 2001, S1 lines from each of the three populations were evaluated in three environments one of which was under artificial infestation with egg masses of *Sesamia* at Ibadan, the second being under natural infestation at Egbema, while the third was for disease screening at Ikenne. Results from each of the three populations revealed wide genetic variation for effective selection. For example, results obtained from the evaluations of Acr 9922 DMRSR and pooled across environments (Table 3) revealed wide variability for effective selection of stem borer resistance parameters and desirable agronomic characteristics.

The second approach used in the development of new stem borer resistant populations resulted in the formation of three stem borer resistant populations namely TZBR Eldana 4, TZBR Comp 1 and TZBR Comp 2. TZBR Eldana 4 was developed by introgressing genes from nine other populations into TZBR Eldana 1, an unadapted but stem borer resistant population. To form TZBR Eldana 4, nine populations with moderate to high levels of resistance to *Sesamia* and *Eldana* were crossed to TZBR Eldana 1. Selfed progenies from these crosses were artificially infested with *Sesamia* and *Eldana* and selected lines backcrossed to the recurrent parent. After two generations of backcrossing, progenies were mass selected under artificial infection with maize streak virus and allowed to random mate twice in isolation. S1 progenies from TZBR Eldana 4 were evaluated in 1999 and the results obtained (Table 4) revealed that increased levels of resistance to stem borer attack with desirable changes in other agronomic characters were feasible.

Table 3. Primary data obtained from the evaluation of 263 S1 lines from Acr 9922 DMRSR and five checks in three environments of Nigeria in 2001.

Variable	Mean	Min.	Max.	Range	CV (%)
Set A					
Days to silk	62	57	72	15	5
Plant ht. (cm)	155	90	215	125	13
Ear damage Rating*	3	2	8	6	27
Leaf feeding Rating	4	2	8	6	26
Plant damage Rating	3	2	6	4	28
Deadheart count	2	0	10	10	91
Stem tunnelling (%)	6	0	37	37	71
Curvularia leaf spot rating	5	2	7	5	16
Grain yield (Kg/ha)	1226	37	4396	4359	50
Set B					
Days to silk	63	58	72	14	4
Plant ht. (cm)	154	89	232	143	14
Ear damage Rating	3	2	5	3	25
Leaf feeding Rating	4	1	8	7	31
Plant damage Rating	3	2	6	4	29
Deadheart count	0	0	6	6	216
Stem tunnelling (%)	5	0	23	23	76
Curvularia leaf spot rating	4	3	8	5	21
Grain yield (Kg/ha)	1613	159	4584	4425	43

* Rating is on 1 – 9 scale with 1= resistant and 9 = susceptible.

Eberhart *et al* (1967, 1991) had proposed a comprehensive breeding program to, among other things, articulate breeding efforts through the creation of reciprocal pools that would serve the dual purpose of generating improved open pollinated populations and first generation inbreds for hybrid production. Furthermore, noting that different stem borer species occur together and infest maize in the same ecology, a desirable situation was to generate a pair of broad-based reciprocal pools with combined resistance to both *Sesamia* and *Eldana*. Thus in 1997, a ten parent diallel was made from among six stem borer resistant populations and four other forest ecology adapted maize populations including an acid tolerant population (ATP). In addition, the ten populations were crossed to a pair of reciprocal populations as testers for evaluation and assignment into alternate heterotic groups. Both the diallel and the tester crosses were evaluated from 1998 to 1999 and both general (gca) and specific combing abilities (sca) were estimated. Results obtained from the evaluation of the diallel crosses in ten environments of Nigeria are presented in Table 5. Using information gathered from both gca and sca effects from both diallel and tester analyses, five maize populations each were assigned to form TZBR Comp1 and TZBR Comp 2. Thus TZBR Comp 1 was formed from TZBR Eldana 1, TZBR Sesamia 1, TZBR Syn-W, TZBR Syn-Y and Ak 9445 DMRSR. The other five populations (TZBR Eldana 3, TZBR Sesamia 3, ATP, DMRLSR-W and Suwan-1 SR) formed TZBR Comp 2. Both composites are undergoing reciprocal full-sib and half-sib selection (Obilana *et al.* 1979; Betran and Hallauer, 1996) to upgrade levels of resistance.

Extraction of inbred lines:

Inter-mating adapted and non-adapted populations in various forms formed the first generation of stem borer resistant populations. Open pollinated genotypes thus developed were improved further using an S1 recurrent

Table 4. Performance of the best 12 entries of selected 22 entries from 196 S1 progenies of TZBR Eldana 4 evaluated at Ikenne, Egbema and under artificial infestation at Ibadan in southern Nigeria in 1998.

Entry	Stalk breakage	Cob damage (1-9)	Days to silk	Plant height (cm)	Ear aspect (1-9)	Grain Yield (kg/ha Infested	Un-infested	RSI
S1 – 168	1.3	3.3	58.5	191.0	3.0	2826	4016	83
S1 – 165	1.3	3.3	59.3	194.8	3.3	2495	4131	95
S1 – 104	1.0	3.0	58.0	206.5	2.5	3169	3497	120
S1 – 39	1.3	3.8	61.0	230.0	2.3	3627	4123	171
S1 - 83	1.3	3.3	62.3	165.8	3.8	2556	3026	171
S1 – 136	0.8	3.3	55.3	212.8	3.3	3267	2657	174
S1 – 60	0.8	3.5	60.0	198.8	2.5	3160	3665	185
S1 – 13	1.8	3.0	58.5	236.5	2.3	4105	4730	190
S1 – 102	0.8	3.5	58.5	216.3	2.8	2926	3197	191
S1 – 30	0.5	3.3	60.0	189.5	2.8	3076	2854	210
S1 – 174	0.8	3.5	56.3	175.8	3.5	2127	2362	214
S1 - 93	2.0	3.3	59.3	213.0	3.5	3497	3417	215
Mean of all entries	2.1	4.0	59.4	197.9	3.3	2702	2996	
Mean of selected 22	1.3	3.4	59.4	199.0	3.0	3006	3227	
SED	0.1	0.1	0.2	1.0	0.1	59	53	
*Sel differential (%)	-38.1	-15.0	0	0.6	-9.1	11.2	7.7	

* Selection differential estimated as a proportion (%) of the mean of all entries

Table 5. Gca (on diagonal, bold and italics) and sca (off diagonal) effects for grain yield from a ten parent diallel of stem borer resistant populations evaluated in ten environments of Nigeria from 1998 to 1999.

Crosses	1	2	3	4	5	6	7	8	9	10
1	***-75.7***	322.2	-258.5	147.1	-183.3	-2.9	92.6	-16.6	18.3	-119.0
12		***49.7***	60.4	-185.8	208.3	-42.9	-130.1	-72.5	-101.7	58.6
23			***-130.8***	-33.7	-85.8	-190.3	-28.9	35.9	246.0	254.4
34				***47.1***	-25.1	307.7	3.0	-323.5	9.5	100.9
45					***-144.3***	85.0	141.6	6.6	-33.0	-114.3
56						***-99.3***	145.8	102.7	-222.9	-183.0
67							***-112.2***	35.0	-43.6	-215.9
78								***259.4***	12.0	199.8
89									***113.3***	115.4
910										***92.8***

selection procedure. However, the extraction and use of resistant inbred lines from improved cycles of selection, synthetics and new varieties will significantly boost the development of stem borer resistant varieties. An advantage of the S1 recurrent selection procedure is that lines selected for recombination can be bred to homozygosity until desirable genes are fixed. Using this approach, several lines are generated and tested each year as lines *per se* or in topcross trials. In 2000 alone, over 250 inbreds at different levels of inbreeding were tested in topcross trials. Additionally, 71 preselected S5 lines from two synthetics were evaluated as lines *per se* under artificial infestation with *Sesamia* and/or *Eldana* in Ibadan and in Cotonou, Benin Republic. Results obtained from the evaluation of the white S5 lines are presented in Tables 6 and 7. In general, eight inbreds with resistance to *Sesamia calamistis* were identified. Six of the identified lines originated from two ancestors 11 and 27 (Table 6). Results obtained from the evaluations of the same set of lines under artificial infestation with *Eldana* also identified seven resistant lines (Table 7) with four of them, 9-1, 11-1, 27-1 and 27-3 having cross resistance to *Sesamia calamistis*.

Deployment of stem borer resistant varieties:

Interdisciplinary efforts are required to develop stem borer resistant varieties. However, such efforts are wasted if the varieties are not distributed and utilized by farmers. In addition to host-plant resistance, other research interventions

Table 6. Evaluation of S5 lines from TZBR-Syn-W C2 for resistance to the pink stem borer *Sesamia calamistis* in three environments in 2000.

Line	Damage ratings* Ibadan SH+	Ibadan Field	Cotonou
S5 9-1	1 (13)**	3 (85)	3
S5 11-1	1 (12)	2 (45)	3
S5 11-2	2 (64)	3 (24)	3
S5 11-3	2 (31)	2 (49)	3
S5 25-2	1 (28)	3 (78)	4
S5 27-1	1 (53)	4 (57)	6
S5 27-2	1 (83)	4 (49)	7
S5 27-3	2 (38)	3 (19)	4
Checks			
S5 19-1	4 (96)	5 (98)	5
S5 20-2	3 (94)	7 (112)	9
Tzmi 103	3 (47)	4 (78)	5
4001	4 (57)	5 (62)	6
Mean	3	4	5
SED	1	1	1
CV (%)	32	32	27

*Rating is on 1 = resistant and 9 = susceptible

**Values in parenthesis represent Rank Summation Indices (RSI), an aggregate resistant trait.

+SH = Screen House

Table 7. Evaluation of S5 lines from TZBR Syn-W C2 for resistance to the sugarcane borer *Eldana saccharina* in two environments in 2000.

Line	Damage ratings*		
	Ibadan SH+	Ibadan Field	RSI**
S5 9-1	4	4	34
S5 11-1	3	2	42
S5 12-1	2	3	41
S5 26-2	3	4	9
S5 27-1	3	4	24
S5 27-3	4	2	42
S5 34-1	2	3	52
Checks			
S5 19-2	5	4	80
S5 20-2	4	4	72
Tzmi 103	4	4	80
4001	5	3	40
Mean	4	3	
SED	2	1	
Cv (%)	42	31	

*Rating is on 1 = resistant and 9 = susceptible
**Rank Summation Indices (RSI) generated to obtain an aggregate resistant trait + SH = Screen House

for the control of stem borers include biological control including the use of bio-pesticides and habitat management involving different combinations of crops. Strategic deployment of host plant resistance in appropriate intercrop patterns is usually considered since it often involves minor changes in farmer's practice. Farmers in the region usually intercrop their maize, thus, only a change of the maize variety being grown may be required to increase maize yield on-farm. Using this approach, several on-farm trials involving stem borer resistant maize cultivars have been conducted using different crop combinations. On-farm trials conducted in south-eastern Nigeria during the second planting season of 2001 revealed highly significant differences in the number of marketable cobs obtained with the use of Ama TZBR-W C1, a stem borer resistant variety (Olaoye, G. pers. comm.). Well-filled maize cobs with good ear aspect are considered marketable for green maize production. The use of strip relay intercropping, a system that allows for the double planting of maize in a year gave the most marketable ears followed by the use of the traditional maize-cassava intercrop system but using the improved variety. In both cases, borer damage on maize was not significant whereas, in all the farmers' fields, the use of a local variety intercropped with cassava produced the least number of marketable cobs and had the highest borer damage. (Table 8).

Table 8. On-farm performance of Ama TZBR-W C1 in 23 farmers' fields during the second season of 2001 at Umuahia, south-eastern Nigeria.

Treatment	Stem borer damage		No. of marketable cobs
	%	Rating*	
Cassava + Local maize (Farmers' practice)	69.0 a	4.0 a	23.3 c
Cassava + Ama TZBR-W C1 (Farmers' practice)	34.3 b	2.5 b	41.9 b
Cassava + Ama TZBR-W C1 (Strip cropping)	38.7 b	2.6 b	48.3 a

Source: Olaoye G. (personal communication)
*rating: 1 = good, 5 = bad

DISCUSSION AND CONCLUSION

A complex interaction of several factors determines the resistance/susceptibility of maize to stem borer attack. This is further compounded when different stem borer species attack maize at different growth stages. The challenge therefore is to breed varieties that will minimize yield loss and exhibit synergistic interaction with other IPM options. This challenge has been achieved to a large extent especially with the deployment of a stem borer resistant variety in south-east Nigeria. Similar deployment programs have been reported by collaborators in the Kumasi area of Ghana and around Yaounde in Cameroon.

Breeding for resistance to stem borers is greatly enhanced when genotypes can be screened effectively thus the development of mass rearing techniques and appropriate rating schemes have greatly aided breeding programmes for *Sesamia* and *Eldana*. Significant progress has been made in developing varieties resistant to both borer species and that also exhibit some level of resistance to *Busseola fusca* commonly found in Cameroon. Moderate to high levels of cross resistance have been determined for all stem borer resistant populations and programmes of selection to improve on resistance to alternate borer species have been undertaken. Thus, all materials have some level of resistance to the two prevailing borer species. Several studies (Starks and Doggett, 1970; Mohyuddin and Attique, 1978; Barry *et al.,* 1983; Barry, 1989; Ampofo, 1986; Barrow, 1987; Bosque-Perez and Mareck, 1991; Ajala 1994, 1995: Ajala and Saxena, 1994; Gounou *et al.*, 1994) have reported moderate to high correlation for damage parameters and yield loss thus concluding on the most important parameters to use in breeding for stem borer resistance. Kling and Bosque-Perez (1994) reported on a positive relationship between stalk breakage and ear damage, while positive relationships are also known for stem tunnelling and stalk breakage. In effect, selecting for reduced levels of stem tunnelling for *Sesamia calamistis* resistance would positively influence selection for reduced stalk breakage and also, cob damage from *Eldana* attack. Thus, good progress can be made from breeding for resistance to both borers.

Reduction in larval establishment and poor utilization of ingested food have been shown to be responsible for resistance to *Sesamia* attack in selected maize lines (R. Aroga. pers. comm.). Isolating and characterizing stem borer resistance factors will greatly aid selection for higher levels of resistance. Furthermore, mechanisms of insect resistance in transgenic crops are known (Hilder and Boulder, 1999). Although, the use of transgenic sources of resistance can greatly enhance breeding activities, bio-safety regulations that would allow testing of transgenic sources of resistance are still being formulated across the region. Nonetheless, there is a need to elucidate the molecular mechanism of resistance including the development of marker systems for rapid screening.

REFERENCES

Ajala, S.O. 1994. Maize (*Zea mays* L.) stem borer (*Chilo partellus* Swinhoe) infestation/damage and plant resistance. Maydica 39:203-205.

Ajala, S.O. 1995. Selection in maize (Zea *mays* L.) for resistance to the spotted stem borer (*Chilo partellus*). Maydica 40:137-140.

Ajala, S.O. and Saxena, K.N. 1994. Interrelationship among *Chilo partellus* (Swinhoe) damage parameters and their contribution to grain yield reduction in maize (*Zea mays* L.). Appl. Entomol. Zool. 29(4):469-476.

Ampofo, J.K.O. 1986. Maize stalk borer (Lepidoptera: Pyralidae) damage and plant resistance. Environ. Entomol. 15:1124-1129.

Barrow, M.R. 1987. The effect of first generation maize stalkborer *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) on yield of different maize genotypes. J. Ent. Soc. Sth. Afr. 50(2):291-298.

Barry, D.B. 1989. Host plant resistance: Maize resistance to the European Corn Borer (Lepidoptera: Pyralidae). Acta Phytopathologica et Entomologica Hungarica 24(1-2):43-47.

Barry,D., Zuber, M.S., Antonio, A.Q. and Darrah, L.L. 1983. Selection for resistance to the second generation of the European Corn Borer (Lepidoptera: Pyralidae) in maize. J. Econ. Entomol. 76:392-394.

Betran, F.J. and Hallauer, A.R. 1996. Characterization of interpopulation genetic variability in three hybrid maize populations. Heredity 87:319-328.

Bosque-Perez, N.A. and Mareck, J. 1991. Effect of the stem borer *Eldana saccharina* (Lepidoptera: Pyralidae) on the yield of maize. Bulletin of Entomology Research. 81:243-247.

Bosque-Perez N.A., Mareck, J., Dabrowski, J.H., Everett, Z.T., Kim, S.K. and Efron, Y. 1989. Screening and breeding for resistance to *Sesamia calamistis* and *Eldana saccharina.* pp.163-169. In: Toward insect resistant maize for the third world. Proceedings International Symposium on Methodologies for developing resistance to maize insects. CIMMYT, Mexico, D.F.

Eberhart,S.A., Harrison, M.N. and Ogada, F. 1967. A comprehensive breeding system. Der Zuchter. 37:169-174.

Eberhart, S.A., Kim, S.K., Mareck, J., Darrah, L. and Goodman, M. 1991. A comprehensive breeding system for maize improvement in Africa. pp.175-193. In: N.Q. Nq, P. Perrino and H. Zedan (eds). Proceedings of an international conference on crop genetic resources for Africa. Vol II. IITA Ibadan, IBPGR Rome and UNEP Nairobi.

Gounou, S., Schulthess, F., Shanower, T. Hammond, W.N.O., Braima, H., Cudjoe, A.R., Adjakloe, R. and Antwi, K.K. with Olaleye, I. 1994. Stem and ear borer of maize in Ghana. Plant Health Management Division Research Monograph No 4. International Institute of Tropical Agriculture, Ibadan, Nigeria. 31 pp.

Hilder, V.A. and Boulder, D. 1999. Genetic engineering of crop plants for insect resistance – a critical review. Crop Protection. 18:177-191.

IITA, 2000. Project 4, Improving maize-grain legume systems in West and Central Africa, Annual Report, IITA, Ibadan, Nigeria.

Kim, S.K., Brewbaker, J.L. and Hallauer, A.R. 1988. Insect and disease resistance from tropical maize for use in temperate zone hybrids. Proc. 43rd Annual Corn and Sorghum Research Conference. 194-226.

Kling, J and Bosque-Perez, N.A. 1995. Progress in screening and breeding for resistance to the maize stem borers *Eldana saccharina* and *Sesamia calamistis*. pp 182-186. In: Maize Research for stress environments. D.C. Jewell, S.R. Waddington, J.K. Ransom and K.V. Pixley (eds). Proceedings of the fourth Eastern and Southern Africa Regional Maize Conference held at Harare Zimbabwe. 28 March – 1 April 1994. Mexico D.F. CIMMYT.

MIP, 1986. Maize Research Program Annual report, IITA, Ibadan, Nigeria..

Mohyuddin, A.I. and Attique, M.R. 1978. An assessment of yield loss caused by *Chilo partellus* to maize in Pakistan. PANS 24:111-113.

Obilana, A.T., Hallauer, A.R. and Smith, O.S. 1979. Estimated genetic variability in a maize interpopulation. Heredity. 70:127-132.

Schulthess, F. and Ajala, S.O. 1999. Recent advances at IITA in the control of stem borers in West and Central Africa. pp. 35-52. In: Strategy for sustainable maize production in West and Central Africa. B. Badu-Apraku, M.A.B. Fakorede, M. Ouedraogo and F.M. Quin (eds). Proceedings of a regional maize workshop. IITA Cotonou, Benin Republic. 21-25 April 1997. WECAMAN/IITA.

Starks, R.G.D. and Doggett, H, 1970. Resistance to spotted stem borer in sorghum and maize. J. Econ. Entomol. 63:1790-1795.

Usua, E.J. 1968a. Effect of varying populations of *Busseola fusca* larvae on the growth and yield of maize. J. Econ. Entomol. 61:375-376.

Usua, E.J. 1968b. The biology and ecology of Busseola fusca and Sesamia species in south-western Nigeria. 1. Distribution and population studies. J. Econ. Entomol. 61:830-833.