Husk characteristics of maize conferring protection against *Sitophilus zeamais*

Dansou K. Kossou
Faculté des Sciences Agronomiques, Université Nationale du Bénin, 06 BP 258, Cotonou, République du Bénin. E-mail : gnima@syfed.bj.refer.org

Accepted 22 March 2001

ABSTRACT

Ear husk characteristics which may influence infestation by *Sitophilus zeamais* were investigated in four maize varieties; Gbogbe, NH2, Sekou 85 TZSR-W-1 and EV 8443-SR. Seven replicates were used for each variety consisting of 25 ears. An ear was confined to 20 adult 0-1 week old weevils using three ear exposure methods; tip, base and complete ear, for 14 days. Of the different variables used to assess weevil behaviour and husk performance, number of weevils that penetrated maize ears, husk extension and compression, and number of husk leaves, were better indicators of good husk cover. The complete ear or ear tip could be exposed to weevils when screening maize for husk protection.

Keywords: Maize, husk, maize weevil, varietal susceptibility, storage, *Zea maize*.

INTRODUCTION

High degree of susceptibility of some improved maize varieties to the maize weevil, *Sitophilus zeamais* is a concern in West Africa. Reports from Kenya (Giles and Ashman 1971), Malawi (Golob 1981, 1984; Kydd 1989), Nigeria (FAO 1980), Ghana (Badu-Apaku *et al.* 1992), Cameroon (Almy and Asanga 1988) and Benin Republic (Anon. 1989 a, b; Kossou *et al.* 1993) confirm this information. Husk characteristics are important in protecting the cob against insect infestation (Eden 1952; Floyd and Powell 1958; La Prade and Manwiller 1977; Barry *et al.* 1986; Golob and Hanks 1990). The maize weevil is one of the most serious storage pests in the tropics and often lays eggs in the ripening crop before harvest (Caswell 1962). These pre-harvest infestations could be conducive to post-harvest insect population build-up (Floyd 1971; Pointel 1969; Kossou *et al.* 1992). Although the techniques for artificially infesting field plots with weevils have been revised and improved (McMillian *et al.*1968), systems for measuring and improving laboratory assessment of resistance to maize weevil have been confined to the assessments of kernel damage and infestation (Widstrom *et al.* 1972; Schoonhoven *et al.* 1972; Dobie 1974,1977). The characteristics of husk in relation to maize resistance to weevils have not been extensively researched. Yet maize ears remain a popularly used form of storage in both tropical and sub-tropical regions (Markham *et al.* 1994; Abate *et al.* 2000).

The objectives of this study were to: 1) identify husk characteristics that could be used to measure ear resistance to the maize weevil, 2) study weevil behavior in relation to husk cover quality in local and improved maize varieties and 3) compare three methods of ear exposure to the maize weevil.

MATERIALS AND METHODS

Maize varieties

Four maize varieties grown at the farm of the Faculty of Agriculture, National University of Benin, were used for this study. Two of these, Sekou 85 TZSR-W-1 and EV 8443-SR were improved varieties obtained from The International Institute of Tropical Agriculture, Ibadan, Nigeria. NH2 a local improved variety and Gbogbe a farmers traditional variety, were obtained from the Centre de Recherche sur les Cultures Vivriéres, Niaouli and Centre d'Action Régionale pour le Développement Rural, Mono Province, respectively, both in Benin Republic. The varieties were planted on April 29th, 1997 using a randomized complete block design with seven replications. Each replicate was made up of twelve 10 m rows; seeds were planted at 75 cm x 50 cm spacing and plants were thinned to two per hill. A compound fertilizer equivalent of 60 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} was applied during land preparation and was supplemented with urea at the rate of 60 kg N ha^{-1}, 4 weeks after planting. Seventy-five ears from the six middle rows of each plot were randomly harvested and sets of 25 ears were subjected to one of three treatments (see below). Ears were handled gently in order to avoid tearing of husk leaves, placed in cotton cloth bags and stored in a freezer for at least three weeks to eliminate any insect infestation carried over from the field.

Insects

Samples of *S. zeamais* obtained from Faculté des Sciences Agronomiques, Université Nationale du Bénin, were cultured on bulk grain to ensure an abundant supply of newly emerged adults.

Treatment design

Cloth bags (60 cm x 35 cm) served as infestation containers. Three treatments were used to test the ability of weevils to reach the maize grain: (1) exposure of the tip of the ear (from the middle portion to zone of husk extension around the silks); (2) exposure of the base of the ear (from the middle portion to the shank). In the third treatment (3) a complete ear was exposed in a cloth bag with the insects. One replicate was set up at a time with 25 ears per treatment and per variety. Twenty insects of 0 to 1 week age were randomly chosen from stock culture. They were used to infest a single ear for a 2 week exposure period. The three lots of 100 units each were randomly arranged by treatment in storage cages. Each cage made of ply-wood, measuring 60 cm x 90 cm x 60 cm had three air holes of 30 cm diameter covered with fine wire mesh. The storage chamber had a mean temperature and relative humidity of 22 ± 3°C and 72 ± 2% respectively, over the test period.

Data assessment and analysis

At the end of the exposure period, ear samples were assessed individually for different variables related to weevils, husk, cobs and grains. Counts of number of insects entering the ears and damaged grains were made for all samples. Husk compression and husk extension were determined at ear tip on treatments (1) and (3). Husk compression was determined using a device (Figure 1), which gave a measure of how loose the husk is; the lower the value the tighter the husk. The numbers of husk leaves were counted in all treatments (2) and (3). Ears from treatment (2) were used for measuring husk weight (excluding extended portion of the tip), weight of 3 cm x 3 cm cut portion in half husk leaves, number of xylem vessels within 3 cm portion on the third external husk leaf and diameter and length of cob. Weight of husk leaf per square centimeter was expressed in two ways using dimensions of cob and husk weight (WTHCM 2) or husk dimensions and weight (WTHCM1).

Analysis of variance was performed by treatment across varieties and correlation coefficients among variables were determined. Treatment means were also compared for variables using Newman Keuls test.

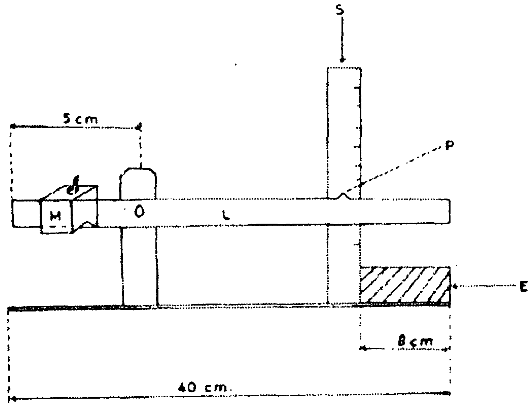

Fig.1 : Husk compression measurement device
M- Compression load (= 645.0g), L- Lever, P- Pointer, E-Support, S-Graduated scale

RESULTS

Ear husk tip characters varied among varieties and showed significant effects on weevil activities (Table 1). Improved varieties had loose husk and short husk extension when compared with local variety (Gbogbe). Mean values of husk compression ranged from 7.31 to 5.77 mm for improved varieties and was 4.57 mm for Gbogbe. Husk extended longer in local variety ears (9.5 cm) as compared with improved ones (7.1 to 7.8 cm) and variety ranking was not similar for the two variables. As a consequence, more insects penetrated improved variety ear tips, attacked grain on cobs and more insects were found alive. Altogether, ears with loose husks had a tendency to be shorter in extension as indicated by a highly significant negative correlation coefficient between these two variables (Table 2). Besides, while a positive relationship was found between husk compression and each of the variables describing the weevil's behaviour on the ear, the effect of husk extension with the same variables was negative. Number of insects that penetrated husk leaves was highly positively correlated with number of live insects or damaged kernels recorded at the end of exposure period.

When ear husk base was exposed to weevils, varieties Sekou 85 TZSR-W-1 and EV 8443-SR were penetrated about three times more than NH2 and Gbogbe (Table 3). At least one damaged kernel was found per ear on all tested varieties. Mean number of xylem vessels per square centimeter was lower (36) in husks of Gbogbe variety which exhibited higher pressure on cob (71.8 and 111.7 mg cm^{-2}) for the two computation methods used. Correlations with insect behaviour were weak among variables for ear husk base characteristics (Table 4). Variables describing insect behaviour were highly and positively correlated.

Table 1. Effect of *Sitophilus zeamais* infestation on husk tip characteristics after two weeks of exposure

Maize Variety[a]	Husk tip compression (mm)	Husk tip extension (cm)	No. of insect penetrations ear (out of 20)	No. of live insects ear^{-1} (out of 20)	No. of damaged grains cob^{-1}
Gbogbe	4.57 c	9.5 a	1.4 c	1.3 c	0.8 c
NH_2	5.77 b	7.8 b	3.0 b	2.8 b	1.5 b
Sekou 85 TZSR-W-1	7.37 a	7.3 bc	5.4 a	5.2 a	2.7 a
EV 8443-SR	7.31 a	7.1 c	4.5 a	4.2 a	2.3 a

Means within a column not followed by similar letters are significant at 5% level (Newman-Keuls test).
a : Seven replicates of 25 ears per variety

Table 2. Correlation coefficients among ear husk tip characteristic variables on *Sitophilus zeamais* infestation across varieties[a]

Variables	Correlation coefficients[b] (1)	(2)	(3)	(4)	(5)
Husk compression	(1)	-0.29	0.29	0.29	0.27
Husk extension		(2)	-0.34	-0.32	-0.32
Insect penetration/ear			(3)	0.98	0.86
No.of live insects/ear				(4)	0.84
No.of damaged grains/cob					(5)

a : Gbogbe, NH_2, Sekou 85 TZSR-W-1, EV 8443-SR
b : All values are significant at P<0.001

When insects were given a choice for site of penetration between the tip and the base of ear husk, variety EV 8443-SR was penetrated most by weevils, resulting in more live insects recorded (Tables 1 and 3). The number of damaged grains recorded per cob was similar to that of Sekou 85 TZSR-W-1 and higher than those of NH2 and Gbogbe (Tables 1,3 and 5). Husk compression and extension data showed a similar ranking for the varieties when compared with the results obtained from samples submitted to husk tip characteristics. Gbogbe recorded the tightest (4.70 mm) and the longest (10.1cm) husk, but mean numbers of husk leaves per ear were similar among varieties (Table 5). Numbers of recorded live insects or damaged grains per ear were higher for international improved varieties (Sekou 85 TZSR-W-1 and EV 8443-SR). But when the whole cob was offered, more live insects and insect penetrations were found in Sekou 85 TZSR-W-1 compared to EV 8443-SR (Table 5). Correlation coefficients among variables for the ear husk characteristics when whole cob was infested were similar to those found when maize samples were tested for husk tip effects (Tables 2 and 6). Mean numbers of husk leaves appeared to be negatively correlated to husk extension.

Comparison of results across varieties for the three ear exposure procedures to weevil attack showed that ear tip and complete ear are comparable methods for assessing the *S. zeamais* activities on ear husk and did not seem to affect the number of

Table 3. Ear husk base characteristics and *Sitophilus zeamais* infestation of four maize varieties after two weeks of exposure

Maize variety	No.of husk Leaves/ear	No. of xylem vessels 3cm	Weight of husk (mg.cm^{-2}) (WTHCM1)*	Weight of husk (mg.cm^{-2}) (WTHCM2)**	Insect penetrations/ear (out of 20)	No.of live insects/ear (out of 20)	Number of damaged grains/cob
Gbogbe	9.4 a	36.2 b	71.8 a	111.7 a	0.8 b	0.7 b	0.6 b
NH_2	9.5 a	37.9 a	64.1 b	102.3 b	0.6 b	0.5 b	0.3 b
Sekou 85TZSR-W-1	9.1 a	37.8 a	59.9 b	85.2 d	1.9 a	1.7 b	0.9 ab
EV 8443-SR	9.4 a	37.3 a	60.6 b	94.0 c	2.2 a	1.9 a	1.4 a

Means within a column followed by dissimilar letters are significant at 5% level (Newman - Keuls test).
a : Seven replications of 25 ears per variety
* : Computation based on a 9 cm² husk cut portion weight
** : Computation based on cob length and diameter and husk weight without extended tip portion

Table4. Correlation coefficients of ear husk base characteristic variables on *Sitophilus zeamais* infestation across varieties[a].

Variables	Correlation coefficients[b] (1)	(2)	(3)	(4)	(5)	(6)	(7)
No. of huck leaves/ear	(1)	0.14***	0.12**	0.18***	-0.08*	-0.06	-0.06
No. of xylem vessals/3cm		(2)	-0.02	-0.04	0.03	0.04	0.01
Weight of husk (wg.cm^{-2}) (WTHCM)[c]			(3)	0.62**	-0.04	-0.02	-0.04
Weight of husk (wg.cm^{-2}) (WTHCM)[d]				(4)	-0.06	-0.04	-0.02
Insect penetration/ear					(5)	0.96***	0.70***
No. of live insects/ ear						(6)	0.71***
No. of damaged grains/cob							(7)

a : Gbogbe ; NH2 ; Sekou 85 TZSR-W-1 ; EV 8443-SR
b : Level of signicaance of vaalues followed by ***= P<0.001 ; ** = 0.001 < P<0.01 ;* = 0.01 < P < 0.05
c : Computation based on a 9cm² husk cut portion weight
d : Computation based on cob length and ddiameter and husk weight without extended tip portion.

Table 5. Ear husk characteristics on *Sitophilus zeamais* infestation after two weeks of exposure

Maize variety [a]	Husk tip compression (mm)	Husk tip extension (cm)	No. of husk leaves/ ear	Insect penetrations/ ear (out of 20)	No of live insects/ ear (out 20)	No. of damaged grains/cob
Gbogbe	4.70 c	10.1 a	9.1 b	1.4 c	1.3 c	0.1 b
NH_2	5.75 b	8.1 b	9 5 ab	1.7 c	1.7 c	1.6 b
Sekou 85TZSR-W-1	7.49 a	7.2 c	9.2 b	6.0 a	5.6 a	3.1 a
EV 8443-SR	7.46 a	6.8 c	9.3 b	4.7 b	4.3 b	3.5 a

Means within a column not followed by similar letters are significant at 5% level (Newman - Keuls test).
[a] : Seven replicated of 25 ears each per variety

Table 6. Correlation coefficients among ear husk characteristic variables on *Sitophilus zeamais* infestation across varieties[a].

Variables		Correlation coefficients[b]				
	(1)	(2)	(3)	(4)	(5)	(6)
Husk compression	(1)	0.14***	0.12**	0.18***	-0.08*	-0.06
Husk extention		(2)	-0.02	-0.04	0.03	0.04
No.of husk leaves			(3)	-0.04	-0.04	-0.02
Insect penetration/ear				(4)	0.98***	0.71***
No. of live insects/ear					(5)	0.71***
No.of damaged grains/cob						(6)

a : Gbogbe ; NH2 ; Sekou 85 TZSR-W-1 ; EV 8443-SR
b : Level of signicaance : ***= P<0.0001 ; 0.01 :* = 0.01 < P < 0.05

recovered weevils when the complete ear was exposed.

DISCUSSION

In a study of pre-harvest infestation of maize with *S. zeamais*, by covering and infesting ear tips in the field, Giles and Ashman (1971) observed successful breeding of the weevils. They also showed that 42 percent of sheathed ear, hitherto rated tight, were infested. But Dobie (1977) using tied cotton bags to hold weevils on rated ears suggested that visual rating of ear is a good indicator of the likelihood of an ear to be attacked. However, data from Mbata (1992) and this investigation have proved the latter suggestions to be questionable.

Results obtained for the site of ear infestation revealed non significant differences between ear husk tip and complete ear exposure to weevil infestation, in terms of number of insects that penetrated the ear and the number of insects found alive after the exposure period (Table 7). This indicates that husk tip of the maize ear was probably the major site of *S. zeamais* entry to the stored maize heads. The contribution of ear husk base appeared minor when complete ear was exposed to weevils. Therefore, complete ear or ear tip could be exposed to adult weevils when screening maize varieties for husk protection. Ranking of tested varieties for different variables studied showed husk compression, which reflects the tip looseness as a good indicator of weevil behaviour on the ear for these two exposure methods (Tables 1 and 5). Varieties with loose husks lodged more insects. Significant and positive correlations found between husk compression and variables describing weevil behaviour (number of insect penetration, live insects and damaged kernels) strongly suggest that husk tightness could play an important role in reducing the infestation of stored maize ear by the weevils (Tables 2 and 6). Also, cultivars with more xylem vessels showed less susceptibility to weevil damage. Hence, increase in number of husk leaves will probably yield husks with more xylem, heavier on cob and reduce insect penetration.

Table 7. Exposed ear site effect on maize[a] infestation by *Sitophilus zeamais*

Site of Exposed ear	No. of insect penetrations/ear (out of 20)	No. of live insects/ear (out of 20)	No. of damaged grains/cob
Ear tip	3.6 a	3.4 a	1.8 b
Ear base	1.4 b	1.2 b	0.8 c
Complete ear	3.5 a	3.2 a	2.3 a

Means within column not followed by similar letters are significant at 5% level (Newman-Keuls test)

a :Gbogbe,NH2,Sekou 85 TZSR-W-1 and EV 8443-SR in 7 replilcates each

The fact that husk extension is consistently longer and tighter in local variety (Gbogbe), contributed to the protection from weevil damage. Negative and significant correlations found between variables of weevil behaviour and husk extension reflect that ears with husks extending far beyond the tip of the ear should reduce weevil penetration, damaged kernels and therefore increase insect mortality as no grain could be reached during exposure period. Loose husk tip has a tendency to be shorter and ears with short husk tip may possess more husk leaves. Besides, as indicated in Table 4, weevil penetration through the husk leaves may be reduced as the number of leaves increases leading to higher pressure on the cob. Therefore, the results indicate a need for better understanding of a "good husk cover".

As the variables used to measure weevil activity were strongly correlated in the three exposure methods, either one could be suggested as means for appraisal of insect infestation. The number of weevils that penetrated ears was significantly related to the number of husk leaves when the ear husk base was exposed to weevils. It appeared as the best indicator, capable of describing both the insect behaviour and the husk performance against weevil infestation in ear storage. Meikle *et al.* (1998) found resistance to be associated more with husk cover than with grain from the work done on varietal resistance to *Prostephanus truncatus* (Horn) and *S. zeamais*. The results of this study show evidence that husk cover influenced *S. zemais* infestation. Yet the majority of African farmers still rely on indigenous pest management approaches to manage pest problems (Abate *et al.* 2000). To establish practical criteria for husk cover evaluation, all 3 husk characteristics i.e. tip compression, tip extension, and number of husk leaves in relation to weevil penetration would probably give a better definition of a "good husk cover" in maize. The value of local variety Gbogbe as a source of better husk cover for breeding purposes was also evident from this study.

ACKNOWLEDGMENTS

I am grateful to Dr. W.G. Meikle for his assistance and critical comments.

REFERENCES

Abate T, van Huis A and Ampofo OKJ 2000 Pest management strategies in traditional agriculture: an African perspective. Ann. Rev. Entomol. 45: 631-659.

Almy SW and Asanga CT 1988 On-farm maize storage and seed preservation in Fako and Meme Divisions, Southwest Province, Cameroun. Report of the Testing and Liaison Unit, Ekona. NCRE/USAID/IITA, Cameroun.

Anon. 1989a Evaluation du Projet Benino-Allemand de Coopération Technique Auprès du CARDER - Atlantique. Republiqué du Bénin.

Anon. 1989b Développement Rural Intégré Dans la Province du Mono. Institut de Recherches et d'Applications des Méthodes de Développement, Ministère du Développement Rural et de I'Action Coopérative, République du Bénin.

Badu-Apraku B, Twumasi-Afriyie S and Sallah PYK 1992 Ghana, pp. 29-35. In : Fajemisin J. M. (ed.) Maize Production in West and Central Africa: Trends and Research Orientation. Semi-Arid Food Grain Research and Development Project (SAFGRAD)/International Institute of Tropical Agriculture (IITA), Ouagadougou, Burkina Faso.

Barry D, Lillehoj EB, Wilsdrom NW, McMillan NW, Zuber MS, Kwolek WF and Guthrie WD 1986 Effect of husk tightness and insect (Lepidoptera) infestation on aflatoxin contamination of pre-harvest maize. J. Econ. Entomol. 15: 1116-1118.

Caswell G H 1962 Agricultural Entomology in the Tropics. Edward Arnold, London, pp.40-76.

Dobie P 1974 The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* Motsh. (Coleoptera, Curculionidae). J. Stored Prod. Res. 10 : 183-197.

Dobie P 1977 The contribution of Tropical Stored Products Centre to the study of insect resistance in stored maize. Trop. Stored Prod. Inf. 34: 7-22.

Eden WG 1952 Effect of husk cover of corn on rice weevil damage in Alabama. J. Econ. Entomol. 45: 543-544.

FAO 1980 On-farm Maize Drying and Storage in the Humid Tropics. FAO Agric. Ser. Bull., No. 40, Food and Agriculture Organization, Rome, Italy.

Floyd EH and Powell JD 1958 Some factors influencing infestation of corn in the field by rice weevil. J. Econ. Entomol. 51: 23-26.

Floyd EH 1971 Relationship between maize weevil infestation in corn at harvest and progressive infestation during storage. J. Econ. Entomol. 64: 408-411.

Giles PH and Ashman F 1971 A study of pre-harvest infestation of maize by *Sitophilus zeamais* Motschulsky (Coleoptera, Curculionidae) in the Kenya Highlands. J. Stored Prod. Res.7: 69-83.

Golob P 1981 A pratical appraisal of on-farm storage losses and assessment methods in Malawi.2: The Lilongwe land development programme area. Trop. Stored Prod. Inf. 41: 5-11.

Golob P 1984 Improvements in maize storage for the smallholder farmer. Trop. Stored Prod. Inf. 50 : 14-19.

Golob P and Hanks C 1990 Protection of farm stored maize against infestation by *Prostephanus truncatus* (Horn) and Sitophilus species in Tanzania. J. Stored Prod. Res. 26 : 187-198.

Kossou DK, Bosque-Perez NA and Marek JH 1992 Effects of shelling maize cobs on the oviposition and development of *Sitophilus zeamais* Motschulsky. J. Stored Prod. Res. 28 : 187-192.

Kossou D K, Mareck J H and Bosque-Perez N A 1993 Comparison of improved and local maize varieties in the Republic of Benin with emphasis on susceptibility to *Sitophilus zeamais* Mostschulsky. J. Stored Prod. Res. 29 : 333-343.

Kydd J 1989 Maize research in Malawi : Lessons from failure. J. Int. Dev. 1 : 112-144.

La Prade JC and Manwiller A 1977 Relation of insect damage, vector and hybrid reaction to aflatoxin B,recovery from field corn. Phytopathology. 67 : 544-547.

Mbata GN 1992 the use of resistant crop varieties in the control of storage insects in the tropics and subtropics. Ambio. 21 : 475-478.

Markham RH, Bosque-Perez NA , Borgemeister C and Meikle WG 1994 Developing pest management strategies for the maize weevil, *Sitophilus zeamais*, and the larger grain borer, *Prostephanus truncates*, in the humid and sub-humid tropics. FAO Plant Portection Bull. 42 : 97-106.

McMillan WW, Wisdrom NW and Starks KJ 1968 Rice weevil damage as affected by husk treatment within method of artificially infesting field corn plots. J Econ. Entomol.61 : 918-921.

Meikie WG, Adda C, Azoma K, Borgmeister C, Degbay P, Djomamou B and Markham RH 1998 the effect of maize variety on the density of *Prostephanus truncates* (Coleoptera : Bostrichidae) and *Sitophilus zaemais* (Coleoptera : Curculionidae) in post-harvest stores in Benin Republic. J. Stored Prod. Res. 34 : 45-58.

Pointel JG 1969 Essai et enquête sur greniers à maïs Togolais. Agron. Trop. 24 : 709-718.

SSchoonhoven AV, Horber E, Mills RB and Wasson CE 1972 Resistance in corn kernel to the maize weevil; *Sitophilus zaemais* Motsch. Proc. N. Cent. Branch Entomol. Soc. Am. 27 : 108-110.

Widstrom NW, Redlinger LM and wiser WJ 1972 Appraisal of methods for measuring corn kernel resistance to *Sitophilus zaemais*. J. Econ. Entomol. 65 : 790-792.