

Full Length Research Paper

Importance of husk covering on field infestation of maize by *Sitophilus zeamais* Motsch (Coleoptera: Curculionidea) at Bako, Western Ethiopia

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Accepted 3 September, 2008

An experiment was conducted to determine the importance of husk covering on field infestation of maize by the maize weevil, *Sitophilus zeamais*, at Bako, western Ethiopia. Five maize genotypes, G1 (SZSYNA99- F₂-33-4-2 X SC₂₂), G2 (CML-197 X SZSYNA99- F₂-33-4-1), G3 (SZSYNA99-F₂-79-4-3 X CML-197), G4 (BH-140) and G5 (Bukuri) were used. There were differences among the maize genotypes in their resistance to the maize weevil. The genotypes, G2, G3 and G5 had good husk characteristics (extended tip and tight husk) and flint grains resulted in low number of weevils and damaged ears. On the contrary, the genotype G1, with dent-flint-grain, poor husk characteristics (bare tipped and loose husk cover), harbored the highest number of weevils and suffered ear damage followed by the genotype, G4. Therefore, husk tip extension and husk tightness were the two most important characters conferring resistance to maize ears against the maize weevil in the field.

Key words: Host resistance, husk covering, maize, *Sitophilus zeamais*.

INTRODUCTION

Maize (*Zea mays* L.) is well known for its food, feed values and raw materials for many commercial industrial products (Payak and Sharma, 1985). In Ethiopia, maize ranks first in total production and yield per hectare (CSA, 2005). It is the staple food and one of the main sources of calories in the major producing areas (Kebede et al., 1993). The crop has been selected as one of the national commodity crops to satisfy the food self-sufficiency program of the country to feed the alarmingly increasing population.

The maize weevil *Sitophilus zeamais* Motsch is the most serious field-to-storage pest of maize in the tropics (Bosque-Perez and Buddenhagen, 1992). The insect infests the ripening crop of maize before harvest and during storage, and multiplies further during storage (Caswell, 1962). Maize weevil can penetrate the husk in the field. Therefore, good husk cover that is tight at the tip

with many husk leaves that are extended above the ear contributes to reduce insect damage and attack by microorganisms in the field (Bosque-Perez and Buddenhagen, 1992). Similarly, Schulten (1976), Dobie (1977) and Golob (1984) reported that the presence of long and tight husk is known to reduce weevil infestation in the field. Unfortunately, the development of hybrid maize varieties was directed towards the production of high yielding plants with no consideration for resistance to field-to-storage insects, on the understanding that insecticides could control storage insects. However, farmers in Ethiopia have few resources to invest in insect pest control.

Use of resistant maize genotypes is the most promising methods of minimizing damage due to *S. zeamais* where high-input control measures such as insecticides are difficult (Bosque-Perez and Buddenhagen; 1992; Tigar et al., 1994). In his studies, Abakemal (2004) reported the degree of resistance of the grains five maize genotypes, SZSYNA99-F₂-33-4-2XSC₂₂ (resistant), CML-197 X SZSYNA99-F₂-33-4-1 (resistant), SZSYNA99-F₂-79-4-

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Table 1. Pedigree, weevil reaction, grain surface texture and color of the maize genotypes used in the present study.

Code	Pedigree	Weevil Reaction ^a	Grain texture	Grain color
G1	SZSYNA99- F ₂ -33-4-2 X SC ₂₂	Resistant	Dent-flint	White
G2	CML-197 X SZSYNA99- F ₂ -33-4-1	Resistant	Flint	White
G3	SZSYNA99-F ₂ -79-4-3 X CML-197	Moderately resistant	Flint	White
G4	BH-140 (Commercial variety)	Susceptible	Dent	White
G5	Bukuri (Local variety)	Moderately resistant	Semi-flint	Mixed

^aSusceptibility indices (0 to 11 scale), where; 0 - 3 = resistant, 4 - 7 = moderately resistant, 8 - 10 = susceptible and ≥ 11 = highly susceptible (Dobie, 1974).

3XCML-197 (moderately resistant), (BH-140 susceptible) and Bukuri (moderately resistant) to the maize weevil in the laboratory. However, the level of resistance and agronomic traits contributing towards the resistance of these genotypes was not determined under field conditions. Such information is important to identify sources and traits of resistance to the maize weevil among maize genotypes and design appropriate management strategy. The present study, therefore, reports on the level of field infestation of five maize genotypes by *S. zeamais*, and possible agronomic traits that might be used in resistance to the weevil.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted at Bako, West Ethiopia. It is located at 9°6'N latitude and 37°09'E longitude. Bako represents a mid altitude sub-humid zone with high potential for maize production. The altitude of the area is about 1650 m above sea level. It receives an average annual rainfall of 1237 mm. The area is warm and humid that makes it a favorable environment for storage insect pests like the maize weevil. Meteorological data during the experimental season indicated that the mean minimum, maximum and average air temperatures of the site were 13.5, 29.7 and 21.4°C, respectively. The type of soil is reddish brown and is classified under the Nitosole order.

Description of the maize genotypes

Four selected maize hybrids with differing levels of reaction to the maize weevil and one local maize genotype were used for the experiment. The hybrids were obtained from the Bako National Maize Research Project while the local genotype was obtained from the local farmers. The maize genotypes used and their level of reaction to the maize weevil as determined in preliminary laboratory studies (Abakemal, 2004) are indicated in Table 1.

Trial design and management

The experiment was conducted at the Bako Agricultural Research Center. The plot size was 38.25 m² for each of the five maize genotypes. Each plot consisted of ten rows of 5.1 m long. The spacing between rows and plants within rows were, 0.75 and 0.3 m, respectively. The experiment was laid out in randomized complete block design (RCBD) with four replications. Planting was done on

June 6, 2005. One month before harvest, the plots were artificially infested with the maize weevil. Artificial infestation methods recommended for obtaining more uniform damage ratings include scattering infested ears or kernels in and around plots or broadcasting collected weevils throughout the test plots (Kirk and Manwiller, 1964). Therefore, scattering infested kernels in and around the plots infested the field. Each plot was infested with nine kilogram of infested kernels where three kilograms of kernels having approximately 900-1000 adult weevils was located at three different directions within 2.25 m interval. Bird scarers were employed to reduce damage caused by birds. All cultural practices were done as recommended.

Husk tip extension

For each genotype husk cover qualities were characterized as both bare tipped or complete husk cover, and loose or tight husk cover. From each plot at harvest, ten ears with husk were selected randomly at harvest. For each sampled ear husk cover rating was done using a newly devised scale, from 1 to 5, where the rating is done by placing the hand around the husk leaves as they extend beyond the ear tip and making a fist such that the base of the hand rests on the tip of the ear (Kossou et al., 1993). If the husk leaves are longer than 4 fingers the rating is one, longer than 3 fingers the rating is two, longer than 2 fingers the rating is three, longer than 1 finger the rating is four. When the husk leaves are not longer than one finger the ear tip is exposed and the rating is five. Ears with bare tip were expressed as percentage of total samples.

Husk tightness

Husk tightness rating was also done for the above sampled ears on a scale of 1 - 4 based on a visual assessment of cob sheath looseness or tightness (Giles and Ashman, 1971), where: 1 = very tight husk (all husks are strongly attached to the ear), 2 = slightly tight (half of the upper husk leaves are detached from ear), 3 = loose (all except the last sheath are detached from the ear) and 4 = very loose husk (ears are totally protruded from the sheath).

Ear damage

Each of the above sampled ears was dehusked separately after husk cover (husk extension at the tip and husk tightness) ratings were done and ears were inspected for the presence of adult weevils and adults' emergence holes. Each weevil encountered on the ears during inspection was removed from each ear. Each ear was placed in labeled and clean cotton cloth bag. The bags were then kept in the storehouse at ambient temperature for 30 days in order to investigate latent infestation. The storage bags were maintained tight closed to serve as a measure of field infestation

Table 2. Kruskal-Wallis non-parametric analysis of ratings of husk tip extension, husk tightness and maize weevil damage to maize ears.

Parameters	Genotype	Mean rank*	χ^2	P-value**
Husk tip extension	G1	18.0a	12.45	0.014
	G2	9.50b		
	G3	6.75b		
	G4	12.88ab		
	G5	5.38b		
Husk tightness	G1	17.75a	11.95	0.018
	G2	8.88b		
	G3	5.63b		
	G4	13.00ab		
	G5	7.25b		
Ear damage	G1	18.00a	13.67	0.008
	G2	6.38c		
	G3	8.75c		
	G4	14.25b		
	G5	5.13c		

*Mean ranks with the same letter did not differ at $P > 0.05$.

**Degrees of freedom 4.

and to avoid new infestation in the store. A storage time of 30 days was chosen because it was sufficient time to allow larvae to complete their development but short enough to prevent eggs laid by emerging adults to complete developmental stages to adults (Weston et al., 1993). At the end of the storage period, the number of adult weevils per ear was counted and insect damage rating for each sampled ear was visually evaluated by rotating the ear in fingers at least twice to estimate ear damage rating using 1 - 5 scale (Compton and Sherington, 1999), where; 1 = slight damage (10-20% damage), 2 = light damage (30-40% damage), 3 = moderate damage (50-60% damage), 4 = heavy damage (70-80% damage) and 5 = extremely heavy damage (90-100% damage). At harvest, number of infested ears per plot were recorded and expressed as percent of total. Similarly, at harvest number of adult weevils per ear, and number of adult weevil emergence hole per ear, and number of adult weevils per ear after 30 days of storage were recorded.

Grain yield and its moisture content

Data on Grain yield (kg/ha) was taken by considering mean grain weight value per plot (38.25 m^2) of each maize genotype including border rows. Grain moisture content was determined by removing about 800 g kernels from the middle of sampled ears from each plot. Kernels in the middle of the ear typically represent the average moisture content of an ear (Nelson and Lawrence, 1991). It was measured by using Dickey-John moisture tester (Dickey-John Corp. Auburn, IL. 62615 USA). The sampled ears from each plot were shelled and 100 randomly picked kernels were weighed to determine 100 kernel weights in gram.

Statistical analysis

Categorical variables (scale data) such as bare tip rating, husk tightness rating and ear damage rating were subjected to Kruskal-Wallis non-parametric analyses. Multiple comparisons using rank sums were made to determine significant differences between means at $P = 0.05$. Number of weevils per ear at harvest and num-

ber of weevils per ear after 30 days of storage, number of adult weevil emergence holes and percentage of grain moisture content were square root transformed ($\sqrt{X+0.5}$) in order to stabilize variances. Percent bare tip ears per plot and percent-infested ears per plot were angular-transformed ($\arcsine \sqrt{\text{proportion}}$). Hundred kernel weight and grain yield were untransformed. A two-way analysis of variance (ANOVA) was performed on the transformed and untransformed data. When there were significant differences ($p < 0.05$) between treatments, means were separated using the Student-Newman-Keul's Test. Back transformed means are presented in tables. All data were analyzed using SPSS version 12.5 computer software.

RESULTS

Agronomic characters

There were significant differences between genotypes in husk tip extension, husk tightness and ear damage ratings after 30 days of storage (Table 2). It was observed that the genotype, G1, had the highest rating of husk tip extension and husk tightness followed by G4; where as, G2, G3 and G5 had low ratings. In general, the genotypes, G2, G3 and G5 that had good husk characteristics (extended tip and tight husk) and flint grains resulted in low number of weevils and damaged ears. The genotype G1, with dent-flint-grain, poor husk characteristics (bare tipped and loose husk cover), harbored the highest number of weevils and suffered ear damage followed by the commercial genotype, G4.

Weevil damage and maize yield

The genotype, G1, had the highest rating for damaged

Table 3. Mean squares of analysis of variance of some agronomic traits and the maize weevil damage parameters to the maize genotypes at Bako, western Ethiopia.

Source of variation	df	%BTP	%IE	NWPEAH	NAEHPE	NWPEAM	HKW (g)	%GMC	Yield (kg/ha)
Replication	3	9.15	271.34	38.54	3.46	144.35	40.68*	0.017	147178
Genotype	4	667.57**	1212.01**	146.46**	82.98**	1657.03**	34.19*	0.128*	1116855
Error	12	8.38	69.23	22.22	14.66	161.37	8.66	0.034	957714

* ** = Significant at 0.05 and 0.01 probability levels, respectively.

BTP = Percent bare tip plant; IE = infested ear; NWPEAH = number of adult weevils per ear at harvest; NWPEAM = number of adult weevils per ear after a month storage; NAEHPE = number of adult weevil emergence hole per ear; HKW = hundred kernel weight; and GMC = grain moisture content.

ear (Table 2). Analysis of variance indicated that there were significant differences between maize genotypes for weevil damage parameters (Table 3). There were, however, no significant differences among the genotypes in grain yield. Among the maize genotypes, G1, had the highest percent bare tipped ears, percent infested ears, number of adult weevils per ear at harvest and after 30 days of storage, and number of adult emergence holes per ear followed by G4 (Table 4). There were, however, no significant differences between the genotypes, G2, G3, G4 and G5 for these parameters. It appeared that genotype with more number of adult weevil per ear at harvest consequently had high number of adult weevils and damaged grains after 30 days of storage. The local genotype, G5, had the highest hundred-kernel weight. Similarly, the highest grain moisture content was recorded from G5 and the least from G1.

DISCUSSION

The present study showed that the local maize genotype, G5, had low mean values for the three agronomic traits (husk tip extension and husk tightness, percent bare tipped plant per plot) and for five weevil damage parameters (percent infested ear per plot, number of adult weevils emergence holes per ear, ear damage rating, number of adult maize weevils per ear at harvest and 30 days of storage) followed by G2 and G3. This indicates the relative resistance of the genotypes. Feedback from farmers in the study area also suggested that the levels of grain losses they had experienced when storing improved maize varieties specially, G4, were much greater than the local genotype, G5. On the contrary, the genotypes, G1 and G4, showed the highest rating for husk tip extension and tightness with subsequent high weevil damage. These differences between genotypes in their level of exposure to weevil damage were likely due to the variation in husk tip extension and husk tightness. Maize breeders in Ethiopia released G4 for its better yield and short maturity period that makes it adapted to the area of short rainy season; however, the acceptability of the genotype by the farmers in Ethiopia was low due to

the susceptibility of the genotypes to weevil damage, due to poor husk cover and soft-dent grains. Widstrom (1987) and Warfield and Davis (1996) stated that an exposed ear is more vulnerable to weevils than one enclosed in the husk, and good husk cover is considered key to protecting the ear from insect and fungi damage. Kim (1974) and, Brewbaker and Kim (1979) reported that husk cover tightness rating and number of husk leaves are controlled by additive gene action. Moreover, equal variance components of general and specific combining ability effects were obtained for husk cover, indicating that both additive and non-additive genes control this trait.

The present result indicated that the higher the initial infestation at harvest the higher the subsequent infestation in the store. The presence of adult maize weevil on stored ears after 30 days of storage showed that the maize weevil would mate and reproduce in the field on ears before harvest.

In contrast to what Abakemal (2004) reported about the resistance of the genotype, G1, against *S. zeamais* in the laboratory, our study showed the susceptibility of this genotype under field condition, indicating that grain hardness and texture were not the only factors responsible for the susceptibility of maize to *S. zeamais*. Therefore, evaluation of maize genotypes only under laboratory conditions is not enough to determine the resistance or susceptibility of a given genotype. Of course, kernel characteristics being dent or flint are an important factor for their reaction to weevils, as it has also been confirmed in the current study. Kim et al. (1987) reported that dent maize populations are known to be highly susceptible to weevil attack in West Africa. Moreover, Kim et al. (1988) and Kossou et al. (1992) reported that cultivars having flint grains are known to be less prone to weevil damage. Most lines with flint grain texture had higher numbers of husk leaves and subsequently had tighter husk cover than dent ones (Kim, 1974; Brewbaker and Kim, 1979). Kim (1974) and, Brewbaker and Kim (1979) reported variation in weevil resistance among the limited number of materials with varying levels of grain texture and genetic background that were tested.

Table 4. Mean value (\pm SE) of agronomic performance and susceptibility of the five maize genotypes to the maize weevil at Bako, western Ethiopia.

Genotype	%BTP	%IE	NWPEAM	NAWPEAH	NAEHPE	HKW (gm)	%GMC	Yield (kg/ha)
G1	32.26 \pm 2.69a	58.60 \pm 8.48a	59.15 \pm 8.13a	17.6 \pm 2.08a	11.55 \pm 3.20a	41.43 \pm 2.46b	15.85 \pm 0.58b	7915 \pm 3.39a
G2	3.86 \pm 0.91bc	21.91 \pm 4.86b	12.78 \pm 1.44c	5.3 \pm 1.02c	2.43 \pm 0.34b	41.03 \pm 1.74b	17.55 \pm 0.23ab	9404 \pm 4.97a
G3	2.71 \pm 0.93bc	18.09 \pm 3.02b	15.85 \pm 7.76c	3.48 \pm 1.40c	2.45 \pm 1.48b	39.75 \pm 1.01b	18.83 \pm 0.45ab	8637 \pm 6.44a
G4	6.00 \pm 1.29b	23.03 \pm 5.11b	32.45 \pm 8.09b	14.48 \pm 4.52ab	8.98 \pm 1.68a	39.28 \pm 1.63b	16.55 \pm 0.38ab	8554 \pm 3.28a
G5	1.79 \pm 0.24c	17.24 \pm 2.48b	10.55 \pm 1.94c	7.93 \pm 2.03bc	1.55 \pm 0.36b	46.6 \pm 2.47a	19.50 \pm 1.43a	8609 \pm 3.32a

Means followed by the same letters in a column are not significantly different from each other using Student-Newman-Keuls Test at P = 0.05.

BTP = Percent bare tip plant; IE = infested ear; NWPEAH = number of adult weevils per ear at harvest; NWPEAM = number of adult weevils per ear after a month storage; NAEHPE = number of adult weevil emergence hole per ear; HKW = hundred kernel weight; and GMC = grain moisture content.

In conclusion, husk tip extension and husk tightness are the two most important characters conferring resistance to maize ears against the maize weevil in the field. The presence of these traits among maize genotypes, indicates possible sources of resistance to develop effective management strategy for the maize weevil.

ACKNOWLEDGMENTS

The authors are grateful to Addis Teshome and Mekides Kebede for their assistance in the field experiments. This work is part of M.Sc. thesis of the senior author. Ethiopian Institute of Agricultural Research and Agricultural Research and Training Project of Ethiopia, via the World Bank, provided financial support for the study.

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