Effect of maize variety and storage form on oviposition and development of the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)

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Abstract

The effect of maize variety and form of storage (shelled, dehusked, or with husks on) on oviposition and development of *Sitophilus zeamais* Motschulsky was studied under artificial infestation conditions in the laboratory. Three improved West African maize varieties—Abeleehi, EV8725-SR and Pop63-SR—and the local variety Volta were used. Maize stored in the shelled form showed significantly more weevil eggs laid than maize stored as ears with or without husks. Maize variety and form of storage did not affect survival of eggs. For all varieties, significantly more F_1 weevils emerged from shelled grain than from ears stored with or without husks. The highest numbers of adults emerging were recorded from the soft endosperm varieties Pop63-SR and Volta Local, and the least from Abeleehi and EV8725-SR, both hard endosperm varieties. Across all varieties, median development period of weevils was significantly shorter on shelled grain (45 days) than on ears with or without husks (52 days).

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops throughout sub-Saharan Africa and is grown in a wide range of agro-ecological and economic environments. The crop is mainly grown by small-scale farmers and is a major staple in many African countries. One of the most important constraints African maize farmers face is postharvest losses to storage insect pests like the maize weevil, *Sitophilus zeamais* Motschulsky.

The oviposition behaviour of *Sitophilus* species has been studied under different environmental conditions, on resistant and susceptible maize varieties and on cereals such as rice and wheat (Teotia and Singh 1968; Singh et al. 1972 1974; Dobie 1974; Okelana and Osuji 1985; Urrelo and Wright 1989; Urrelo et al. 1990).

Kossou et al. (1992) investigated the effects of shelling maize cobs on the oviposition of *S. zeamais* on the flint, early maturing, maize variety BDP. They also studied the susceptibility of improved and local maize varieties to this insect using shelled maize and ears stored with or without husks (Kossou et al. 1993). However, no work has been carried out combining these three storage forms with contrasting maize varieties commonly found in West Africa. This study was thus undertaken to further the understanding on the oviposition behaviour and development of *S. zeamais* on diverse maize varieties stored as shelled grain and as ears with or without husks.

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Materials and Methods

Experiments were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Maize varieties were selected in order to combine a number of basic contrasting characteristics of commonly grown maize types found in West Africa, so that specific comparisons could be made. Three improved white varieties: Abeleehi (a hard dent type derived from Population 49), EV8725-SR (a flint), Pop63-SR (a soft dent, quality protein maize) and the Ghanaian white variety Volta Local (a floury type) were used for the study. The varieties were grown at IITA fields, and at harvest maize cobs were collected with the husks intact. During harvesting, care was taken not to pull out the dried silks from the husk tips, or accidentally open or widen them and thereby facilitate entry of *S. zeamais*. After harvest, cobs were artificially dried at 35°C for two weeks and then placed in large transparent plastic bags. To kill any insects resulting from field infestations, cobs were deep frozen within the bags until required for the experiments, when they were removed for moisture equilibration for three weeks. Moisture contents of the varieties during the experiments were 12.3%, 11.9%, 11.2% and 11.1% for Abeleehi, Pop63-SR, Volta Local and EV8725-SR, respectively.

S. zeamais used for the experiments were collected from maize fields at IITA. Weevils were reared on clean grain of the white maize variety TZPB for three generations in a dark room maintained at 25±2°Cand 70±5% r.h.

Sixteen averaged-sized, tightly sheathed cobs with husk cover ratings between 1.0 and 1.5 (Kossou et al. 1993) were selected for each variety and storage form (four replicates of four cobs each). Altogether, there were 12 treatments (4 varieties × 3 storage forms) for a total of 192 cobs. Cobs in each treatment were placed into 30 × 35 cm cotton cloth bags and subjected to their appropriate storage forms by: leaving the husks intact (storage with husks on), removing the husks (storage without husks), or removing the husks and shelling the grain (shelled storage). Bags were kept in a room maintained at 25 ± 2°C and 70 ± 5% r.h. The cobs, or equivalent amount of grain, were infested with eight (five females and three males) two-week-old *S. zeamais* per cob for a seven-day oviposition period, after which weevils were removed.

The number of egg plugs was determined using the acid-fuchsin method of staining (Pedersen 1979, cited by Horber 1989). Prior to staining cobs with the husk leaves on, husks were carefully pulled back from the cobs to expose the kernels and the area with kernels was immersed in the solution. After the cobs were dry and egg plugs counted, husk leaves were returned to their original position. It was assumed that every egg plug covered an egg and that every egg was covered by an egg plug.

Data were also collected on number of F_1 weevils which emerged daily. The percentage survival of eggs, Median Development Periods (MDPs), and susceptibility indices of treatments were determined (Dobie 1974). For cobs with the husk leaves on, husks were carefully pulled back from the cobs to expose the kernels before weevil counts were made.

Rubber bands were used to hold the husk leaves on the cobs and prevent insect escaping before the next count.

Data on the numbers of egg plugs and number of F_1 weevils were log-transformed and analysed as a completely randomised design. F tests and Duncan's multiple range tests were used to test pre-planned comparisons. Percentage survival of eggs was analysed using Chi-square.

Results and Discussion

Number of F_1 weevils

The log number of F_1 adults that emerged from the different maize varieties under the different storage forms is shown in Figure 1. Across all varieties, retransformed weevil emergence means were 1.18, 7.25 and 14.13 in the with husks, without husks and shelled storage forms, respectively. These numbers were significantly different from each other ($P<0.05$), and suggest that in the shelled storage form, conditions are more favourable for high oviposition, egg and larval development and/or survival of the maize weevil, than when ears are stored with or without husks. Such conditions would reduce egg and larval mortality, and also enable developing larvae to obtain more nutritious food.

The low numbers of F_1 weevils that emerged from cobs with husks on confirm the protective role of the husk leaves and may further explain why traditional small-scale farmers in Africa have continued to store the crop in this form over the years with relatively low losses, without the use of chemical protectants.

Mean log numbers of F_1 adults (per four cobs) across storage forms were 2.03, 1.84, 1.73 and 1.33 for Pop 63-SR, Volta Local, Abeleehi and EV8725-SR, respectively. No F_1 weevils emerged from EV8725-SR stored with the husks on and the reasons for this were not clear. The numbers of F_1 weevils for EV8725-SR (across the other two storage forms) were significantly lower ($P<0.05$) than for the other varieties, except for Abeleehi. The relatively higher F_1 weevil emergence in Pop63-SR, a quality protein maize (QPM) variety (i.e. high lysine content), with the opaque-2 gene, confirms a similar report by Gupta et al. (1970) who found other soft endosperm maize types carrying this gene to be more susceptible to weevil attack. The utilisation of this variety in West Africa will not contribute as much as desired to the improvement of human and animal nutrition, unless it receives protection from weevil damage. Volta Local, a variety with floury endosperm did not produce as many F_1 weevils as Pop 63-SR, probably because of the rounded nature of the kernels in the former variety. It is possible that the low number of F_1 weevils recorded on EV8725-SR was due to its flinty endosperm.

Urrelo et al. (1990) explained that the F_1 progeny produced by *S. zeamais* females is the ultimate measure of fitness of a population. Final numbers are greatly influenced by proximate mechanisms, which are basically related to influences of oviposition, growth and development. The F_1 numbers give an estimate of the type of insect-host interaction in resistance or susceptibility of the host and reproductive capabilities of the insect attacking it. Judging from the numbers of F_1 adults that emerged, EV8725-SR may be characterised as resistant and Pop63-SR as susceptible. There is a need to incorporate resistance characteristics and carry out further selection on Pop63-SR in order to improve this variety. Efforts in this regard, however, would require resources and time, and may also result in the loss of some of the high protein qualities in this variety.

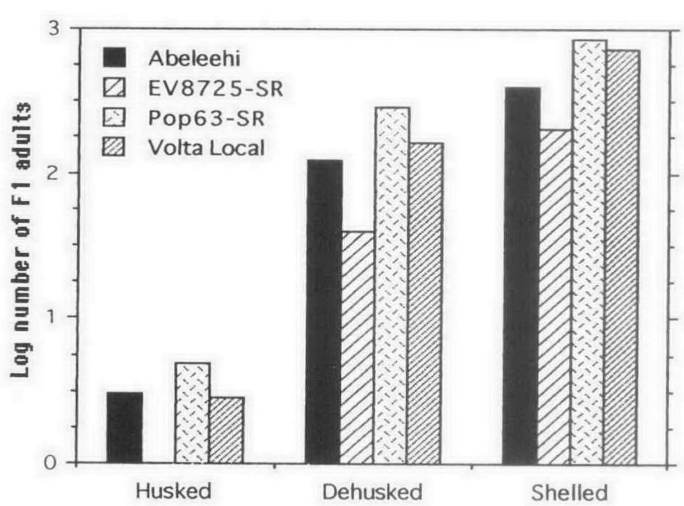

Fig. 1. Log number of F_1 maize weevils (*Sitophilus zeamais*) that emerged from four maize varieties stored as ears with husks on (husked), ears without husks (dehusked) and shelled grain.

Percentage survival of eggs

Kossou et al. (1992) suggest that the reasons for the low numbers of F_1 weevils emerging from unshelled maize (cobs without husks) as against shelled, could be due to reduced oviposition and/or lower egg or larval survival. In our study, ratios of the numbers of eggs laid to the numbers of F_1 adult weevils were computed for the four maize varieties and three storage forms (Table 1). Chi-square analysis indicated that storage form did not influence survival of eggs (χ^2=2.05, 2 df, $P>0.05$), nor did variety (χ^2=0.17, 3 df, $P>0.05$), nor their interaction (χ^2=1.73, 6 df, $P>0.05$). It is therefore concluded that the most likely cause for the observed low numbers of F_1 weevils in cob-stored maize, as opposed to shelled maize, is reduced oviposition.

Median development periods (MDPs)

The MDP for each treatment was determined from the middle of the oviposition period to the emergence of 50% of F_1 adults (Dobie 1974). Across all varieties, mean MDP values were 51.9, 52.0 and 44.6 days for ears with husks on, ears without husks and shelled maize, respectively (Fig. 2). No significant differences ($P<0.05$) were observed in the MDPs for the two ear-storage forms, however, MDP was significantly longer on maize ears than on shelled maize. Kossou et al. (1992) reported a similar 7.7 day difference in weevil MDPs between shelled and unshelled maize. These longer weevil MDP values for cob-stored maize are thought to be due to the long time it might have taken the larvae to tunnel through the kernel from the crown end before reaching the germ end, where more nutritious food is available, as well as the difficulty for newly developed adults to emerge from kernels due to obstruction by adjacent kernels fixed onto cobs (Kossou et al. 1992, 1993). Across storage forms, mean weevil MDP values on the varieties were 49.3, 49.9, 48.3 and 47.5 days for Abeleehi, EV8725-SR, Pop63-SR and Volta Local, respectively (Fig. 2). Since no F_1 weevils emerged from EV8725-SR stored with the husks on, MDP values could not be determined for the insects from this treatment.

Susceptibility Indices

The Susceptibility Index (SI) defined as $[(\log_e F)/D]100$, where F= number of F_1 weevils and D= MDP (Dobie 1974)

Table 1. Ratio of the number of *Sitophilus zeamais* adults that emerged to the number of eggs laid in four maize varieties under three storage forms[a]

	Storage forms			
Variety	With husks	Without husks	Shelled	Total
Abeleehi	6/10 (60)	29/43 (67)	47/68 (69)	82/121 (68)
EV8725-SR	0/0[b]	8/29 (62)	37/50 (74)	55/79 (70)
Pop63-SR	8/15 (53)	36/51 (71)	62/100 (62)	116/166 (70)
Volta Local	5/7 (71)	33/49 (67)	67/97 (69)	105/153 (69)
Total	19/32 (59)	116/172 (67)	223/315 (71)	358/519 (69)

[a] Means of four replicates (4 cobs per replicate). Figures in parentheses are percentages of eggs that survive. Chi-square analysis revealed that storage form did not influence survival of eggs (χ^2=2.05, 2 df, P>0.05), nor did variety (χ^2=0.17, 3 df, P>0.05), nor their interaction (χ^2=1.73, 6 df, P>0.05).
[b] No F_1 weevils emerged from EV8725-SR stored with the husks on.

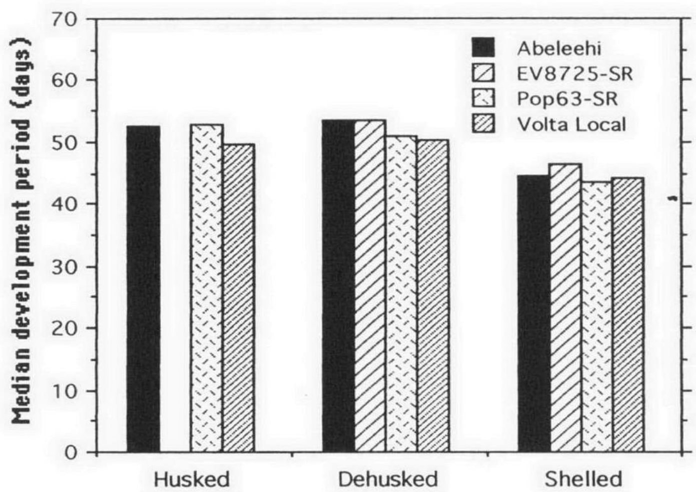

Fig. 2. Median development periods (MDPs) of *Sitophilus zeamais* reared on four maize varieties stored as ears with husks on (husked), ears without husks (dehusked) and shelled grain.

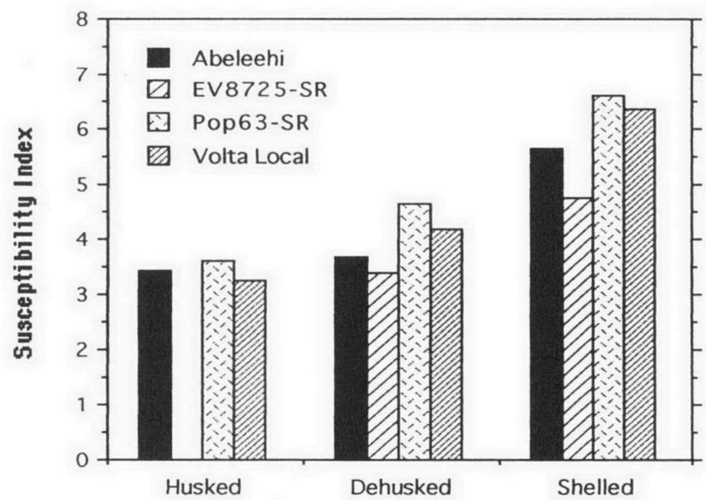

Fig. 3. Weevil susceptibility indices of four maize varieties stored as ears with husks on (husked), ears without husks (dehusked) and shelled grain.

was used to evaluate the susceptibility of the maize varieties in the different storage forms. With this index, the treatment which produced the greatest number of F_1 progeny and resulted in the shortest weevil developmental period is the most susceptible. The higher the SI the greater the susceptibility and vice versa.

SI values for the varieties obtained in this study were generally lower than those reported for other maize varieties (Dobie 1974; Okelana and Osuji 1985; Urrelo et al. 1990). These lower values were thought to be due to the relatively low moisture content of the varieties which could have resulted in the emergence of fewer F_1 adult weevils. Highly significant differences (P<0.01) were observed in SI between varieties, storage forms and their interactions, indicating that SI values in this study were highly affected by storage form and/or variety. Across storage forms, susceptibility of the varieties was in the following decreasing order: Volta Local, Pop63-SR, Abeleehi, and EV8725-SR. However, only EV8725-SR differed significantly from the rest in SI. Across varieties SI was greater on shelled maize, followed by ears without husks and then ears with husks (Fig. 3).

Dobie's index of susceptibility was developed to describe the inherent susceptibility of kernels of a maize variety in the shelled form and not in the cob storage forms. From the results obtained in this investigation it would appear that an index of susceptibility involving maize cobs may have to be determined differently.

Studies on the oviposition performance of *S. zeamais* on maize varieties using some of the different storage methods practised in sub-Saharan Africa are important for understanding how management of storage practices can be used as an independent control method or as an adjunct to other control methods. It is therefore important that more efforts be devoted to understanding the interactions between storage practices and insect depredation. The spreading of insecticide-resistant insects, the escalating costs of insecticides, and growing concern about their indiscriminate use and the health hazards they pose, increase interest in such studies.

It should be possible to improve upon the storage performance of the crop, if varieties with inherently resistant kernels are cultivated, field infestation significantly reduced by early harvesting, and maize is stored with the husks on inside improved ventilated cribs. In the West African subregion small-scale maize farmers often cultivate local varieties which usually have a long protective husk cover, and harvest and store these varieties with the husks on. In this way they reduce the chances of depredation by weevils as it takes a much longer period for a destructive population of *S. zeamais* to be attained. The cultivation of those improved maize varieties which have a poor husk cover may not be ideal for the traditional with-husks-on method of storage, and the acceptance of these varieties may pose problems as small-scale farmer storage practices do not easily change in West Africa. These varieties, however, can be subjected to further selection to improve their husk cover quality.

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