The effect of maize cob selection and the impact of field infestation on stored maize losses by the larger grain borer (*Prostephanus truncatus* (Horn) Col., Bostrichidae) and associated storage pests

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Abstract

An integrated control strategy is being developed for *Prostephanus truncatus* (Horn) (Col., Bostrichidae), a neotropical pest accidentally introduced to Africa. To investigate the origin of infestation of traditional maize stores and the effect of farmers' practices, a nine-month trial was established in Benin, West Africa. The experiment comprised four different treatments: (i) cobs selected before storage for complete husk cover and absence of visible insect damage (a common practice in the pest's area of origin); (ii) cobs fumigated (to eliminate field infestation) but not selected; (iii) cobs selected and fumigated; (iv) cobs without selection or fumigation. Each treatment was replicated three times, a replicate consisting of an entire half-tonne store, divided into 12 vertical rigid wire mesh cylinders. Every three weeks one cylinder per replicate was emptied, providing a stratified sample (80 cobs), and refilled with identical maize from adjacent reserve stores. All adult insects in the samples were collected, the moisture content, damage level and weight loss assessed, and a subsample incubated to rear out immatures. Results indicate that *P. truncatus* densities were more important in explaining grain losses than the presence of any other insect pest, and that field infestation was important, at least earlier in the season, to pest population dynamics.

Introduction

Since the introduction of the larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) from its area of origin in Central America to East and West Africa (Dunstan and Magazini 1981; Krall 1984) the insect has become the most destructive pest in rural maize stores (Markham et al. 1991). As an exotic pest *P. truncatus* was considered a prime candidate for classical biological control in Africa. Investigations in Central America indicated the presence of some natural enemies (Boeye et al. 1988; Laborius et al. 1989), and one predator, the histerid beetle *Teretriosoma nigrescens* Lewis was identified as a promising biocontrol agent. Results from laboratory studies suggested that *T. nigrescens* would be an effective predator (Rees 1985; Leliveldt and Laborius 1990), and *T. nigrescens* was released in 1991 in Togo by the Plant Protection Agency of Togo and the Deutsche Gesellschaft für technische Zusammenarbeit (GTZ), and in 1992 in Kenya by the Kenyan Agricultural Research Institute and the Natural Resources Institute, U.K. (NRI) and the International Institute for Biological Control, U.K. (IIBC). Studies of impact assessment are underway, and preliminary data suggest that complete control of *P. truncatus* cannot be expected by the predator alone (P. Mutlu, GTZ, pers. comm.; G. Hill, IIBC, pers. comm.). Therefore other control measures may be needed to augment these efforts to contain *P. truncatus*.

Within the framework of an integrated control strategy against *P. truncatus* and associated pests, modification of maize storage techniques is a promising possibility. In the area of origin of *P. truncatus*, where smallholder farmers have long experienced serious losses of maize to this insect, selection of maize cobs for complete husk cover and absence of visible insect damage prior to storage provides some degree of protection against subsequent losses in store (R. Espinal, Escuela Agrícola Panamericana, Honduras, pers. comm.). Good husk cover of the maize cob has been found to reduce *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) infestation (Giles and Ashman 1971; Schulten 1976; Dobie 1977; Golob 1984; Kossou et al. 1993). Although it is clear from field and laboratory observations that *P. truncatus* is capable of boring directly through intact husk, there seems to have been no systematic study of the effect of husk cover on the incidence of this beetle. One of the objectives of this study was to closely investigate the effect of selection on the population dynamics of, and the damage caused by, *P. truncatus* and associated pests.

A second objective of the experiment was to analyse the relative importance of field infestation by *P. truncatus* to subsequent pest build-up in rural maize stores. Infestation of maize cobs by *S. zeamais* prior to harvest is important to population dynamics of the weevil in the store (Eden 1952a, b; Giles and Ashman 1971; Markham 1981). There is equivocal evidence in the literature regarding the extent and the impact of field infestation by *P. truncatus*. Mushi (1984) in Tanzania and Henckes (1992) in Kenya both reported significant field infestations, whereas Novillo (1991) in Honduras, Wright et al. (1992) in Togo and our own observations in Benin (C. Borgemeister and F. Djossou, unpublished) failed to detect the presence of *P. truncatus* prior to storage.

Materials and Methods

The experiment was conducted on a small farm approximately 25 km northwest of Lokossa in the Mono province of southwestern Benin. Maize (improved IITA cultivar TZSR-W) was planted in two fields close to the farm in mid April 1992 and manually harvested in the first week of September 1992. No fertilisers or pesticides were applied to the crop.

Four treatments were applied to the cobs before storage:

1. cobs were selected for complete husk cover and absence of visible insect damage;
2. cobs were fumigated to eliminate field infestation but not selected;
3. cobs were selected and fumigated; and
4. cobs were neither selected nor fumigated (control treatment).

To fumigate the maize, cobs were placed in 0.6 t piles under polyethylene sheets at the experimental site, and exposed for

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three days to 9.0 g Gastoxin® (56.7% aluminium phosphide, Casa Bernardo Limitado, Brasil). Given the rapid rate of decomposition of this insecticide, residual effects are assumed to be negligible.

Three stores were constructed for each treatment (12 stores total). The stores were arranged in a randomised block design consisting of three blocks of four stores in a square arrangement, with a distance of 10 m between stores within each block and 20 m between the blocks. Each store contained ca. 200 kg of maize. Stores were constructed with locally available material. The platform was made of oil palm (*Elaeis guineensis* Jaq.) and attached to a teak (*Tectona grandis* L.f.) frame. The legs of the stores were constructed of various tree species, e.g. neem (*Azadirachta indica* A. Juss.), mango (*Mangifera indica* L.), *Acacia* spp. and *Fagara* spp. The stores were 1.5 × 1.2 m in area and 0.8 m in height. Twelve rigid wire mesh cylinders 0.3 m in diameter and 0.9m in length were fixed vertically to the platform. Four mesh bags (made of large-mesh nylon fishing net), containing 20 cobs each, were stacked within each cylinder. Starting three weeks after filling the stores and continuing every three weeks thereafter for 12 sampling occasions, the contents of one cylinder per replicate were removed for sampling and then replaced with a similar quantity of identically-treated maize from adjacent reserve stores. Each cylinder was sampled only once, and the allocation of cylinders to sampling occasions within a store was at random.

When sampling, each mesh bag of maize was rapidly transferred into a plastic bag to capture as many associated insects as possible. Bags were taken to the laboratory where the mesh bag was removed, the maize was carefully shelled into the plastic bag, and the cores discarded. The shelled maize was then sieved through a series of four different mesh sizes (i.e. 4.0 mm, 0.85 mm, 0.50 mm and 0.425 mm) and all adult insects were collected for identification and counting. In order to estimate the relative proportion of live insects in the sample, all insects and associated debris of one replicate per treatment per sampling occasion were placed in a separate plastic bag and exposed to light at the closed end. Live insects attracted to the light were collected with an aspirator, identified and counted. Nine 15 g samples of kernels collected per treatment were sampled to measure the moisture content, using standard oven-drying techniques (Dick 1988). Grain loss was measured using the count and weigh method (Harris and Lindblad 1978; Boxall 1986). A 1.0 kg sample of grain per replicate was inspected using a light table to remove concealed adult insects, placed in ventilated jars, and sieved weekly for four weeks to collect emerging insects for identification and counting.

Data were evaluated using multiple regression and repeated-measure ANOVA models.

Results and Discussion

This study compared two treatments of maize cobs prior to storage: fumigation and selection of maize cobs for complete husk cover and absence of visible insect damage. Fumigation of cobs is used here purely as an experimental technique to investigate the relative importance of pre and postharvest infestation. Selection of maize cobs is frequently used in Central America as a technique to reduce storage losses (R. Espinal, Escuela Agrícola Panamericana, Honduras, pers. comm.), and was tested here for its effectiveness in reducing insect losses and for possible inclusion as part of an integrated control strategy. Selection has the advantage of having no adverse ecological effects or health risks, but it is labour intensive at a time of year when labour is expensive and in short supply. Other components of an integrated control strategy, for example the use of resistant varieties and changes in the timing of harvest and storage, are presently under investigation.

For purposes of analysis, the 12 sampling occasions were divided into three phases: early (sampling occasions 1–4), middle (5–8) and late (9–12). Four pests were common throughout the storage season: *P. truncatus*, *S. zeamais*, *Cathartus quadricollis* (Guérin) (Coleoptera: Silvanidae) and *Carpophilus* spp. (Coleoptera: Nitidulidae). Of these, *C. quadricollis* and *Carpophilus* spp. were much less abundant and are believed to contribute little to losses, and will not be discussed further. Repeated-measure ANOVA models (α=0.05) were used to evaluate treatment effects on insect population densities across time separately within each of the phases. No significant differences were found among any of the treatments in the early phase, probably because of low and highly aggregated insect populations.

P. truncatus levels were low in all treatments relative to *S. zeamais* for the first half of the experimental season (see Figs 1a and b). In the case of *P. truncatus*, densities of insects in nonfumigated treatments increased dramatically thereafter. Similar increases were observed in fumigated treatments, but

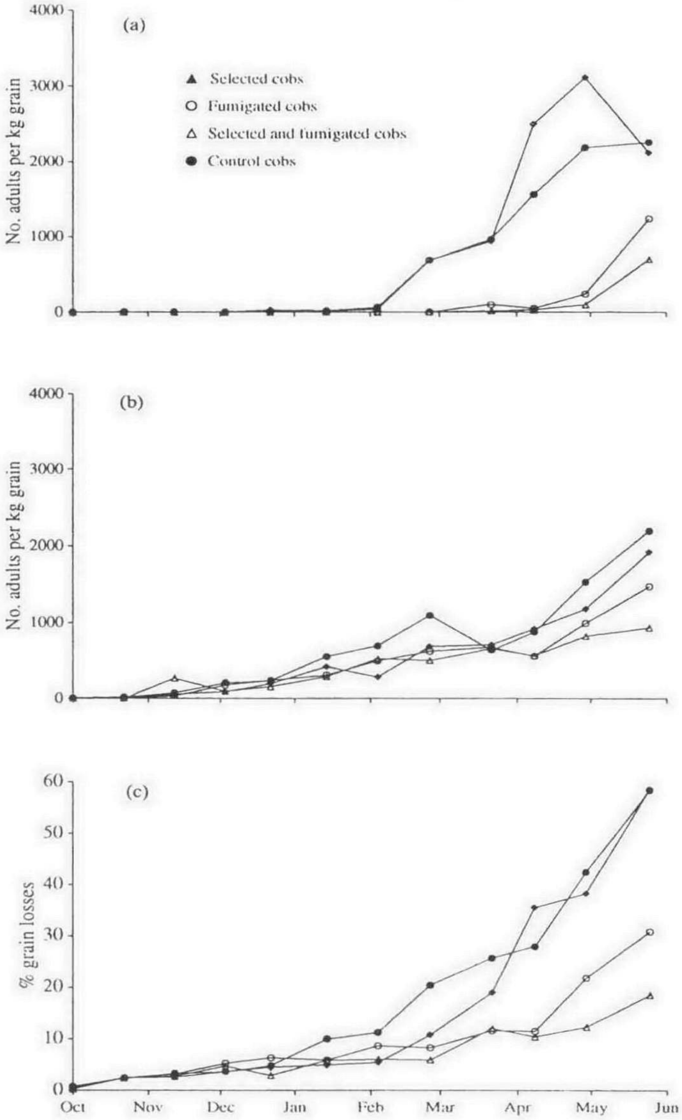

Fig.1. (a) Density of *Prostephanus truncatus*/kg grain by treatment over 12 sampling occasions, (b) density of *Sitophilus zeamais*/kg grain by treatment over 12 sampling occasions, and (c) grain losses (%) by treatment over 12 sampling occasions.

the initiation of the increase was delayed. *S. zeamais* densities did not show treatment effects as strongly, and any delays in population growth were much less marked among treatments.

P. truncatus and *S. zeamais* densities were significantly lower in the fumigated treatments than in nonfumigated treatments for the middle and late phases. This implies that both *P. truncatus* and *S. zeamais* were present in the field prior to harvest (even though only *S. zeamais* was detected in preharvest samples) and confirms the view that preharvest infestation is important to pest population build-up later in the season (Giles and Ashman 1971 and Markham 1981 for *S. zeamais*; Mushi 1984 and Henckes 1992 for *P. truncatus*). Interestingly, the differences in *S. zeamais* density between fumigated and nonfumigated maize were markedly less than for *P. truncatus*, despite the comparative abundance of *S. zeamais* in the field. This indicates that *S. zeamais* can rapidly colonise stores postharvest by active migration and is consistent with an earlier observation from Ibadan, Nigeria (Markham 1981) that *S. zeamais* populations in cribs fumigated at harvest caught up with those in untreated cribs within approximately three months.

During the middle and late sampling phases, the density of *P. truncatus* in stores containing selected but not fumigated cobs (treatment 1) was very similar to the control stores (treatment 4) and significantly higher than in either treatment containing fumigated maize (treatments 2 and 3). Since *P. truncatus* density later in the season was correlated most highly with grain losses (see below) and since selection itself is expensive in terms of labour, it is unlikely, based on these results, that the procedure could be justified as a control measure for *P. truncatus*. *S. zeamais* densities, however, were significantly lower in stores containing selected cobs during the middle phase than in stores where the maize had not been selected. A possible reason for this may be the initial population distribution of *S. zeamais* in the field. At the time of harvest, *S. zeamais* is highly aggregated in cobs with inadequate or damaged husks (Markham 1981). The selection procedure may have directly and substantially reduced the initial infestation. Since *S. zeamais* does not readily attack cobs with intact husks (Kossou et al. 1993), the selection procedure may have made the maize inherently less attractive or susceptible to *S. zeamais* migrating to the stores postharvest.

No large difference was observed between *S. zeamais* populations in nonselected and selected treatments in the late phase. This change may reflect a difference in factors, such as competition, governing growth rates of *S. zeamais* populations late in the season compared to the middle of the season. The nature of inter and intraspecific factors affecting populations at high pest densities remains to be studied.

Changes in percentage grain losses over time are also shown (Fig. 1c). Multiple regression analyses were conducted on percentage grain losses for the last four sampling occasions (late phase) with *P. truncatus* and *S. zeamais* as independent variables. All regression ANOVA F tests were significant, and the standardised regression coefficients of both independent variables were significant in all cases, with the exception of *S. zeamais* for sampling occasion 9 (Table 1). In all sampling occasions the standardised regression coefficients for *P. truncatus* were higher than those for *S. zeamais*, and they were usually much higher, indicating that *P. truncatus* density played a greater role in explaining variance in percentage losses than did *S. zeamais* density. This is consistent with field observations of Golob et al. (1985) in Tanzania.

Analysis of data on insect emergence is being carried out to determine changes in the age structures of the populations over the course of the season. These results will be used in conjunction with those from laboratory studies on interactions between *P. truncatus* and *S. zeamais* to construct and validate an insect population model. This model will serve as a basis for evaluating farmer management strategies under varying conditions, and will help to guide and develop an integrated control strategy.

Table 1. Summary of results from multiple regression analyses of percentage grain losses on insect densities during the last four sampling occasions (N = 48).

Sampling occasion	Standardised regression coefficient		Adjusted R^2	F ratio
	P. truncatus	*S. zeamais*		
9	0.846*	-0.026	0.721	59.24**
10	0.663*	0.256*	0.618	39.09**
11	0.683*	0.243*	0.598	35.95**
12	0.466*	0.426*	0.662	47.12**

* t test significant at α=0.05.
** F test significant at α=0.05.

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