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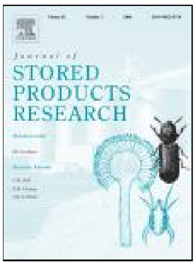

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Augmented release of *Teretrius nigrescens* Lewis (Coleoptera: Histeridae) for the control of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in stored cassava chips

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Abstract

A trial was set up in northern Benin to evaluate the potential of *Teretrius nigrescens* to reduce the infestation and damage to cassava chips caused by storage insects. Cassava chips were stored for 5 months in mud silos and 50 adults of *T. nigrescens* were added when the stores were first filled. Stores where no predator was released were monitored as controls. The main storage insects observed were *Prostephanus truncatus* and *Dinoderus* spp. Initial chip weight varied between 102 and 246 g with no difference between treatments. Chip weight and number of holes on chips initially differed between treatments after 2 months of storage. After 3 months of storage, losses reached 40–50% without *T. nigrescens* and 30–40% when cassava chips were stored with *T. nigrescens*. A farmer can increase his profit by 1437 Fcfa/100 kg (1\$ = 560 Fcfa, 1£ = 968 Fcfa; 1€ = 656 Fcfa, as on 2 December 2005) through the use of *T. nigrescens* because losses are reduced by 11%. Data analysis showed that there were significant differences ($P<0.0001$) between the two treatments for the number of holes, number of insects, weight of each chip as well as damage. There were twice as many *P. truncatus* and holes on chips in stores where *T. nigrescens* was not released. The addition of the predator to farmers' stores is an economic option for controlling losses due to insects in cassava chips.

Keywords: *Teretrius nigrescens*; *Prostephanus truncatus*; Cassava chips; Insect losses; Storage; West Africa

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1. Introduction

In western Africa, more than 50% of the supply of calories is derived from the consumption of roots and tubers. One of the constraints to the expansion of root and tuber cultivation is their high water content, making storage and transport difficult (Hahn, 1989). Losses of roots and tubers during post-harvest handling amount to around 30% (Lancaster and Coursey, 1984). Traditionally, cassava roots are left in the ground after physiological maturity to avoid degradation, but with population growth and decreasing agricultural land availability, the highly perishable cassava root is now harvested and immediately processed. A study revealed that about 42% of harvested cassava roots in West and East Africa are processed into dried chips and flour (Nweke et al., 1992). Cassava chips are a high-value commodity, mostly used for animal feed, but in West Africa, dried chips are mainly used for human consumption. Processing comprises peeling, slicing into pieces and sun drying for 2–3 weeks (Knoth, 1993). Tuber size affects the rate of drying, microbial and insect contamination, and quality. Cassava chips are stored in baskets, wooden containers or sacks, or in bulk in storage rooms as well as in various traditional storage systems like mud silos (Ingram and Humphries, 1972) and can remain in store up to 1 year. In these mud silos, farmers store 1.5–2 tonnes of cassava chips.

Cassava quality is severely affected by insect infestation. Ingram and Humphries (1972) listed 15 insect species that infest dried cassava chips. Many stored-product insects that cause damage to cereals also infest cassava chips (Delobel, 1992). *Prostephanus truncatus* (Horn), *Dinoderus minutus* (Fabricius) (Coleoptera: Bostrichidae) and *Tribolium* spp. (Coleoptera: Tenebrionidae) are among the pests that infest cassava chips (Nyakunga, 1982; Hodges et al., 1985). One of the most damaging pests of this product is *P. truncatus* (Schäfer et al., 2000). Losses due to this borer increase with storage time and can reach up to 50% for unfermented and 70% for fermented chips after a storage period of only 4 months (Hodges et al., 1985). Since the introduction of *P. truncatus* to West Africa, losses on maize and cassava chips have increased (Borgemeister et al., 1997), and the storability of cassava chips, previously 1 year or more (Stumpf, 1998), has reduced to 4–5 months. Most farmers used chemical insecticides to control *P. truncatus* (Meikle et al., 1999). The most readily available insecticides in Benin are cotton insecticides for which the distribution system is well organized. Naturally, the application of cotton insecticides to food products presents health risks for consumers. In Benin, 87 persons reportedly died in 1999 from cotton pesticide-related health problems (Ton et al., 2000). No study has been published on insecticide use in stored cassava chips in Benin. Yam chips are products that are produced with very similar techniques and by the same ethnic groups; Hounhouigan and Akissoé (1997) reported that 59% of the interviewed yam chip producers used lindane and only 17% the recommended product Sofagrain (deltamethrin + pirimiphos-methyl) to protect their produce against storage pests. In contrast, Bassa (2000) observed that 65% of the yam chip producers used no insecticide, 19% Sofagrain, and 3% cotton insecticide or DDT. It seems that the use of dangerous, inappropriate insecticides in stored products in Benin is quite common (Meikle et al., 1999).

In an effort to control *P. truncatus*, a predator *Teretrius nigrescens* Lewis was introduced to Africa (Borgemeister et al., 2003). Pre-release tests showed that the population of *P. truncatus* was reduced by 81% and losses by 40%, but the predator and prey were not able to disperse naturally since they were confined in cages (Helbig et al., 1992) and the experimental design might have increased the efficacy of the predator in controlling the pest. The effectiveness of this predator in controlling *P. truncatus* in grain stores is not conclusive. The predator appears to control the insect in the natural forest habitat, but seems to be incapable of containing the pest once a certain prey density threshold is passed (Borgemeister et al., 1997). These authors suggest that the release of the predator in the enclosed mud silos used in northern Benin, Ghana and Togo would be more successful. Cassava chips are much more susceptible to attack by insects (Schäfer et al., 2000), so that control measures would be more economical. Previous reports stated that *T. nigrescens* controls *P. truncatus* on cassava chips (Helbig and Schulz, 1996). In glass jars, the population was suppressed by 52% after 8 weeks and by 64% after 12 weeks; losses were reduced by 27% and 32%, respectively. Based on the above considerations, the present study was undertaken to investigate the effectiveness of the predator *T. nigrescens* to control *P. truncatus* in traditional mud stores.

2. Materials and methods

The trial was set up in the village of Badjoudé located in the Northern Guinean Savanna (NGS) zone in the Republic of Benin between May and October 2001. The NGS is located between the ninth and tenth parallel, the rainfall is mono-modal, from 900 to 1200 mm/annum, with mean temperatures between 26 and 38 °C. Cassava chips were stored in mud granaries, similar to those described by Fiagan (1995). Cassava chips were prepared using traditional methods, as described by Knoth (1993), in February and March 2001. Fifty adults of *T. nigrescens* were released in each of 20 clay granaries immediately after filling. These granaries were compared to 20 stores where no predators were released. Infestation by *P. truncatus* was natural in each granary. In every granary, 50 chips were labeled for followup. Each month, the numbers of holes were counted on each cassava chip, the individual chip weight assessed and then chips were replaced into the granary. Ten other chips were taken to the lab each month for determination of the insect spectrum, moisture content measurement and determination of the number of holes per chip. Damage was assessed according to the visual damage scale method used in Togo (Compton et al., 1993) and Ghana (Stumpf, 1998), where damage is classified from 1 to 5, with 5 being the worst with too many holes to count. Farmers would remove chips for their consumption during the trial period, so that the amount of chips stored in each granary varied from month to month. Secondary data such as market prices of cassava chips and volume traded were collected from public services. Data were analyzed with Statistical Analysis System version 8 (SAS Institute, 1997) with the mixed-model procedure. The number of insects, number of holes and weight were $\log(x+1)$-transformed and the moisture content arc sin square root $(x/100)$-transformed to normalize data. Student–Newman–Keuls (SNK) test was used to separate averages of the different treatments. Correlations were computed to establish relationships between variables.

3. Results

The minimum, average and maximum prices of cassava chips sold in the regional markets during the year 2003 are shown in Fig. 1. From January to April, the price of cassava chips was relatively low and from April to October, the price increased, then decreased again from October

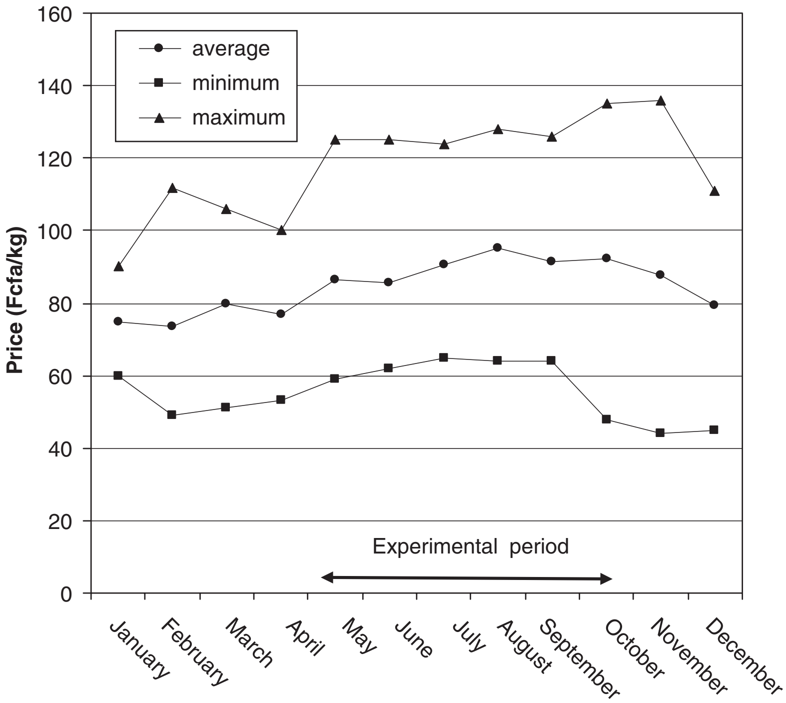

Fig. 1. Minimum, maximum and average cassava chip prices (Fcfa/kg) on markets from the experimental region during 2001 (670 Fcfa = 1US$—August 2003). Source: Direction Générale/Carder—agricultural extension service.

to January. The minimum price was 45 Fcfa/kg (Fcfa—Franc de la Communauté Financière Africaine of West Africa) and the maximum was 139 Fcfa/kg. These prices reflect supply and demand; cassava chips are produced from December to February, and quality and quantity decreases throughout the following 6 months. From October to January other crops are consumed (Fig. 1).

The initial chip weight varied from 113 to 226 g in the controls and between 102 and 246 g where *T. nigrescens* had been added. The changes in weight of the chips during the 5 months of storage are shown in Fig. 2. No difference was found between the two treatments during the first 2 months. After 3 months of storage, significant differences were observed between chips in granaries where *T. nigrescens* had been added and in the controls.

The numbers of holes on chips increased with storage time in the two treatments; significant differences between treatments were found after 2 months of storage (Fig. 3). The number of holes practically doubled between the second and the third month of storage (Fig. 3). At the end of storage, after 5 months, a mean of 66 holes were found on each chip in the treatment without *T. nigrescens*, and 51 holes when *T. nigrescens* was added.

The cumulative loss of cassava chips in kg per 100 kg is represented in Fig. 4. Losses increased sharply after 3 months of storage and reached 40–50% without *T. nigrescens* and 30–40% with *T. nigrescens*.

The net effect of *T. nigrescens*, the difference between losses in treatments with or without *T. nigrescens* expressed in monetary terms, is shown in Fig. 5. In June, after 1 month of storage,

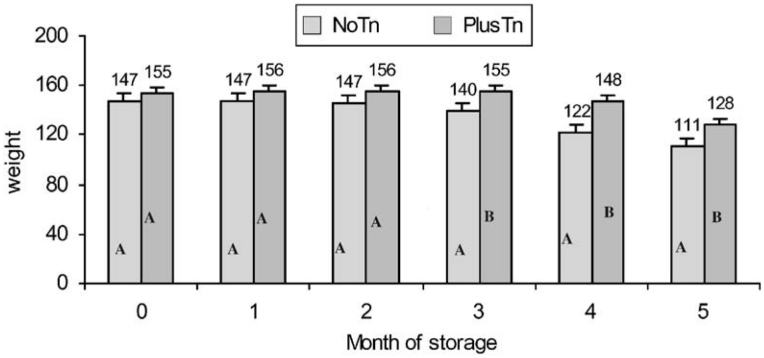

Fig. 2. Average chip weight (g) during storage in stores with no added predator (no Tn) and where predators were added (plus Tn). Columns with the same letter are not significantly different.

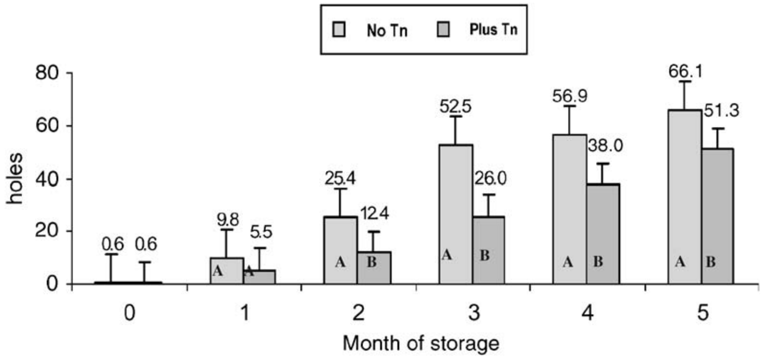

Fig. 3. Mean number of holes in cassava chips during storage in stores with no added predator (no Tn) and where predators were added (plus Tn). Columns with the same letter are not significantly different.

the use of *T. nigrescens* reduced losses by 5%, which corresponds to 321, 445 and 648 Fcfa/100 kg, respectively, when calculating profit with the minimum, average and maximum prices. In September, after 4 months of storage, losses were reduced by 11% through the use of *T. nigrescens*, which corresponds to 730, 1042 and 1437 Fcfa/100 kg. The profit found through the application of the predator increased with storage period and varied between 445 and 1042 Fcfa/100 kg on average.

Moisture content (m.c.) varied between 14.68% and 9.46%. The lower m.c. was observed at the beginning of storage. No store was above the critical m.c. of 12% at the start of the trial, whereas after 3 months of storage, 77.5%, and after 4 months, 100% of the stores had chips with over 12% m.c. In regard to insect distribution in the treatments, significant differences were found between the treatments for *T. nigrescens* ($P = 0.0163$) and *P. truncatus* ($P < 0.0001$), but not for *Dinoderus* spp. ($P = 0.0810$) (Table 1). Apart from these species, only *T. castaneum* (Herbst) and *Carthartus* spp. (Coleoptera: Silvanidae) were observed in the chips in low numbers. There were twice as many *P. truncatus* and holes in chips in stores where *T. nigrescens* was not released. No significant

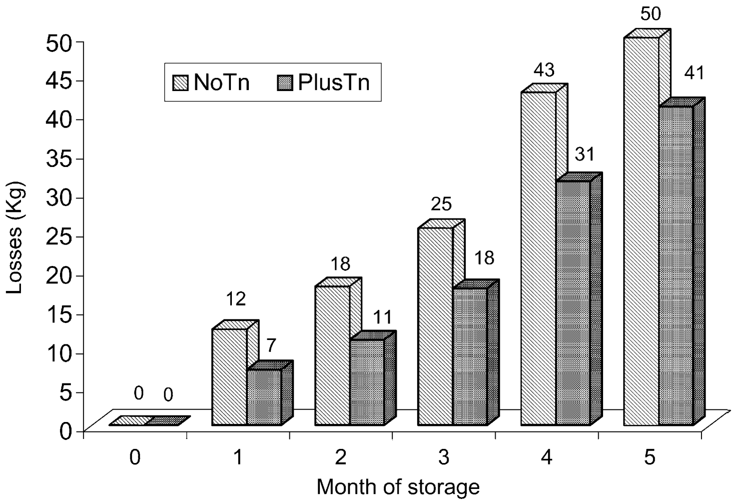

Fig. 4. Losses (per 100 kg) for cassava chips during storage in stores with no added predator (no Tn) and where predators were added (plus Tn).

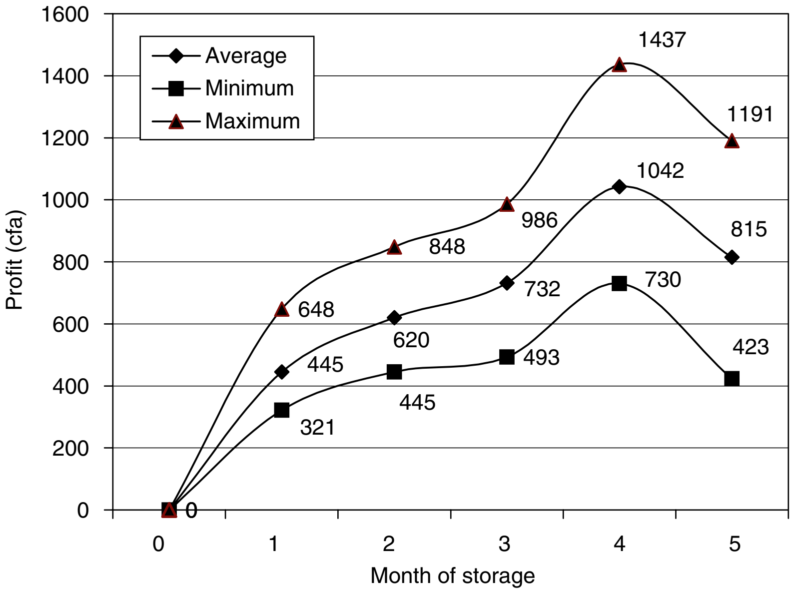

Fig. 5. Profile of the profit of the use of *T. nigrescens* (Fcfa/100 kg) for cassava chips during storage, calculated with minimum, average and maximum prices (Fig. 1).

difference for m.c. was recorded between the treatments, but for the number of holes, weight and damage, significant differences were found (Table 1). Positive correlations were determined between *P. truncatus* and the number of holes (0.8217, $P<0.001$), *P. truncatus* and damage (0.6808, $P<0.001$), and holes and damage (0.8984, $P<0.001$).

Table 1
Effect of treatment on mean number of insects, holes, damage and moisture content averaged over the 6 months storage

Treatment	Tn	Pt	*Dinoderus* spp.	Holes	Damage	Weight	m.c.
No Tn	0.18 ± 0.09a	17.62 ± 3.49a	0.26 ± 0.07a	18.17 ± 2.60a	2.80 ± 0.16a	133.64 ± 3.92a	12.53 ± 0.64a
Plus Tn	0.39 ± 0.12b	8.04 ± 2.30b	0.13 ± 0.05a	7.67 ± 1.37b	2.26 ± 0.14b	148.65 ± 3.52b	12.59 ± 0.08a

Means within a column followed by the same letter do not differ significantly from each other in a *t*-test ($P > 0.05$). Tn = *T. nigrescens*; Pt = *P. truncatus*, m.c. = moisture content.

4. Discussion

With the introduction of *T. nigrescens* into their granaries, farmers involved in the trials were able to prolong the storage of cassava chips by 1–2 months, the chip weight was significantly higher and the number of holes on the chips was significantly lower. Cassava chip losses assessed by Wright et al. (1993) reached 14% after 4 months of storage, 20% after 7 months and rose to 30% when *P. truncatus* attacked the dried chips. In this study, losses reached 40–50% without *T. nigrescens* and 30–40% with *T. nigrescens*. However, the methods used for loss assessment were not comparable to those described by Wright et al. (1993), since in our trials visual damage was estimated and weight loss measured. The visual assessment method can result in inaccuracy because not every hole is the beginning of a frass tunnel and results in weight losses. For example, during investigations under controlled conditions one *P. truncatus* beetle was observed to drill seven boreholes before it made its way into the cassava chip (Stumpf, 1998). The author noted that while visual scoring gives a better indication of losses at a particular time, this method is not applicable over an entire loss–assessment study. Compton and Sherington (1999) remarked that visual scale scores can be calibrated against a laboratory-based loss assessment method, so that quantitative data can be obtained. In the present study, some chips were totally destroyed after 5 months of storage and hence damage assessment on these chips could only be recorded as total.

The economic impact of insect damage on cassava chips can be severe. Wright et al. (1993) estimated that about 4% of the total national cassava production in Togo is lost during storage. This was equivalent to about 0.05% of the Togolese GNP in 1989. Similarly, the economic profit from the use of the predator in this trial was already 5% after 1 month of storage, peaking at 11% after 5 months of storage. The income that could be gained through the use of the predator varied between 321 Fcfa/100 kg and maximally 1437 Fcfa/100 kg, depending on the market price.

In this study, very few insect species were observed on cassava chips. The main species was *P. truncatus* which led to high losses and damage. The destructive potential of this species on cassava chips has previously been confirmed by experimental work in Togo (Wright et al., 1993; Compton et al., 1993) and Tanzania (Hodges et al., 1985). Pantenius (1987) noted that infestation by *P. truncatus* caused losses 3–5 times higher than those caused by indigenous pests. The highly destructive potential of this pest can be attributed to (1) its enormous frass production and (2) a high reproductive rate in comparison to the other insect species (Borgemeister et al., 2003). In India, the most important pest on cassava chips was *Araecerus fasciculatus* De Geer (Coleoptera: Anthribidae) (Prem Kumar et al., 1996) and differences in infestation levels existed between fermented and non-fermented chips for this species (Rajamma et al., 1996). This species was not observed in the reported study, but seems to cause high losses on stored cassava in the humid forest zone of West Africa (Hell, personal observation).

The number of holes and weight loss of the cassava chips increased significantly after 3 months of storage in our trials. Overall, cassava chip quality produced with rudimentary methods in rural Africa is poor. Chips are produced under unhygienic conditions, drying is normally done on concrete floors, roofs, roadsides or wooden platforms built over fireplaces in traditional kitchens, and chips are stored without enough aeration. Besides insect infestation, microbial contamination can be a problem. Fungal contamination of cassava chips has not been studied in Benin, but yam chips are very similar products produced with the same methods. Yam chips in Benin were contaminated with *Aspergillus flavus* Link, *A. tamari* Kita and *Fusarium culmorum* Saccardo (Bassa, 2000). Of the samples, 17% had aflatoxin content over the 20 ppb WHO limit and 75% exceeded the EU limit for cereals and pulses (4 ppb) (Mestres et al., 2004). Dried yam chips may be contaminated with molds, and particularly toxigenic species such as *Aspergillus* spp. were observed in Nigeria (Adisa, 1985; Adeyanju and Ikotun, 1988). No aflatoxin was detected by Wareing et al. (2001) in dried cassava products that were, however, infected by *Aspergillus* spp. In this study fungal contamination was not measured, but fungal contamination of cassava chips with mycotoxigenic fungi was observed. Further studies have been initiated to elucidate the contamination of cassava chips with mycotoxins.

The moisture content found in the chips stored in northern Benin varied between 14.7% and 9.5%. Moisture content of newly-dried cassava chips in the northern region of Ghana was between 8% and 10%, increasing to 14–16% with the onset of the rainy season (Stumpf, 1998). Higher m.c. levels are obviously beneficial to insects and could have affected the susceptibility of dried chips to their damage (Shires, 1979*)*. The insect spectrum on high moisture chips varies (Prem Kumar et al., 1996) and fungal development and mycotoxin contamination on dried products increases at higher moisture levels (Abdullah et al., 2000), causing loss of product quality.

There seems to be an effect of variety on insect infestation in cassava chips (Rajamma and Prem Kumar, 1994). The size of the cassava chips plays a role in their resistance to insect attack and fungal contamination, smaller chips being more resistant than larger ones (Knoth, 1993). The use of insecticides is an option for controlling insect infestation in cassava chips. Thus, so far, insecticide trials with dried chips have been mainly conducted in laboratories or under controlled field conditions (Golob et al., 1982; Magoma, 1988; Wright et al., 1993). However, the use of insecticides on products that are directly consumed without much further processing is problematic as there is a risk of inappropriate use of chemicals by resource-poor farmers.

In conclusion, it can be said that releasing *T.nigrescens* into traditional stores is a viable option to extend the storage life of cassava chips. Sustainable techniques should be developed so that national research institutions can raise the predator and release them into cassava chip stores and the environment. *Teretrius nigrescens* is known to suppress *P. truncatus* in its natural habit and has the potential to reduce the impact of this pest in the store environment.

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