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Damage and Weight Loss to Dried Chips of Cassava, Cocoyam, Yam and Plantain Exposed to *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) over Three Different Time Durations

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ABSTRACT

Laboratory experiments were conducted at the University of Ghana, Legon, to determine the extent of damage and weight loss caused by *Prostephanus truncatus* to dry chips of varieties of cassava (biafra, bosomensia), yam (pona, takyeman), cocoyam (mankanipa (red), mankaniserwa (white) and plantain (apantu, asamienu) grown in Ghana and kept over 3 separate storage durations of 30, 60 and 90 days. Data on insect preferences for the various dried chips as well as the susceptibility of the substrates; number of adults produced, weight of adults that developed on them, weight loss of the chips and the weight of frass produced from insect feeding over the 30, 60 and 90 days exposure periods were recorded. The beetles exhibited higher levels of preference for cassava (biafra and bosomnsia) and plantain varieties (apantu and asamienu), compared to the cocoyam (white and red) and yam (pona and takyeman) varieties. Also significantly more *P. truncatus* ($p<0.05$) survived and bred on the cassava (biafra and bosomnsia) and plantain (asamienu, apantu) varieties, than yam (pona, takyeman) and cocoyam (red, white). Also, the mean weight of adults recorded on the chips of plantain (apantu, asamienu), cassava (biafra, bosomnsia), cocoyam (red and white) were heavier than those recorded on yam (pona and takyeman). Furthermore, the results showed that the amount of frass produced and percentage weight loss recorded due to the activity of *P. truncatus* increased with time over 3 months exposure period. More losses were also recorded on the cassava and plantain than the yam and cocoyam chips.

Key words: *Prostephanus truncatus,* damage, cassava, cocoyam, yam

INTRODUCTION

Root and tuber crops, namely cassava, yam, cocoyam and the fruit crop, plantain are among the most economically important and widely used food crops in Sub–Saharan Africa (Osei *et al.*, 2009). They play a major role in diets of the sub-region and contribute significantly towards efforts to alleviate food crisis in Africa because of their efficient production of energy, their year-round availability, tolerance to extreme stress conditions and suitability to the peasant farming system on the continent (Hahns and Keyser, 1985). IITA (1999) reported that over half of the world's cassava is produced in the humid and sub humid tropics of Sub-Saharan Africa. Also grown are major species of yams indigenous to Africa (Assuming-Brempong, 1991). Cocoyam and plantain, which are exotic crops, have become established in sub-Saharan Africa and are also used in alleviating the problems of food insecurity.

There are many different varieties of yam, cassava, cocoyam and plantain that are cultivated in Sub-Saharan Africa. These include 3 white yam varieties; *Araba*, pona and *Asaana*, which are widely cultivated in Ghana (Cornelius and Oduro, 1999). For cocoyam, *Xanthosoma sagittifolium* red flesh, *Xanthosoma sagittifolium* white flesh and *Colocasia esculenta* are the main varieties grown in Africa (Sefa-Dedeh and Sackey, 2002). Among the main cassava varieties grown in Africa and Ghana in particular, there are three improved varieties, such as Gblemoduade, Abasafifaa and Afisiafi which have been developed and released under the Nation Root and Tuber Crops Improvement Programme. For plantain and banana, two improved varieties (apemhema) and banana (kwadubempa), respectively were released in 1999. These crops can be boiled and eaten fresh or converted and used in the production of "fufu", "amala", or "garri" or incorporated into other African dishes which are cherished delicacies. They can also be sun-dried and stored, so as to prolong their availability during their off-season and also for the production of such delicacies, such as instant "fufu"and "kokonte" in Ghana (Coursey, 1967; Ogbo *et al.*, 2009; Amoah *et al.*, 2010) or amala in Nigeria and Benin Republic and also as raw materials for Agro allied industries (Isah *et al.*, 2009).

The conversion of these products into chips, followed by drying and storage for long periods until needed, is what exposes them to attack by insect pests, thus threatening food security in Sub-Saharan Africa. Some of these insect pests include *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), *Araecerus fasciculatus* (Degeer) (Coleoptera: Anthribidae) and *Dinoderus* spp. (Coleoptera: Bostrichidae). Among these insects, the Larger Grain Borer (LGB) *P. truncates*, a native of Mexico and Central America was accidently introduced into Africa in the early 1980s (Dustan and Magazini, 1981). The beetle has since spread to atleast 17 countries on the continent (Farrell, 2000). In Africa, the lesser grain borer, *Rhyzopertha dominica* Fab. (Ukeh and Umoetok, 2007) the maize weevil, *Sitophilus zeamais* Motsch (Ukeh *et al.*, 2008) and *Ptruncatus* are important pests of economic importance on stored sorghum (Mailafiya *et al.*, 2007) maize and dry cassava chips.

There are many records on the biology, ecology and the control of the pest on maize and cassava (Chijindu, 2002; Chijindu *et al.*, 2008; Danjuma *et al.*, 2008), sorghum grains (Mailafiya *et al.*, 2007, 2008), cocoyam, yam and plantain (Nwana, 1993; Isah *et al.*, 2009; Danjuma *et al.*, 2008). There is however, no information on the damage and weight loss caused by this insect pest to specific Ghanaian varieties of cassava, yam, cocoyam and plantain. The main objective of this study was to investigate the susceptibility of dry chips made from cassava, cocoyam, yam and plantain to *P. truncatus* when stored over 3 different storage durations.

MATERIALS AND METHODS

Experiments were conducted under laboratory conditions of 25.8-31.2°C temperature and 35.9-77% RH Recording was done using a mounted thermohygrometer in the laboratory, from September, 2007 to April, 2008. Batches of adult *Prostephanus truncatus* used for the experiments were obtained from the Kpeve Agricultural Station, Volta region and the Plant Protection and

Regulatory Service Directorate (PPRSD), Pokuase, Ghana. To set up the laboratory cultures, fifteen, 1 L kilner jars containing 500 g of shelled maize were infested with 100-200 unsexed adults, which were kept in the laboratory and covered with a metal screen. All adult beetles were removed after 2 weeks and the culture allowed placed in the laboratory desk till adult emergence. Emerged adults from this culture, aged 1-3 weeks old were used for the experiments. Two Ghanaian varieties each of plantain (apantu, asamienu), cassava (biafra, bosomensia), Yam (pona, takyeman) and cocoyam; red (mankanipa) and white (mankaniserwa) used for the experiments were obtained from Madina market in Accra and Ghana. These food crops were peeled and cut into small cubes of about 1x1x1 cm, which were sun dried for two weeks under ambient environmental conditions. The dried chips were later oven-sterilized at 60°C for 3 h to kill any insects or organisms that might have infested them during the period of drying. The percentage moisture content (%mc) of the initial uninfested chips used for the experiments was determined by the oven dried method as described by Rajamma *et al.* (1994) and Stumpf (1998).

Relative preference for the different products: Substrate preference by *P. truncatus* was determined as described by Chijindu (2002) and Mailafiya *et al.* (2007) with some modifications. Twenty grammes each of dried chips of the varieties of cassava (biafra, bosomnsia), cocoyam (red, white), yam (pona, takyeman) and plantain (apantu, asamienu) were placed separately on a filter paper (10 mm diameter) and placed in a petri-dish. The petri-dishes containing the dried chips of the various varieties were arranged in a circular pattern with the chips of the same crop arranged diagonally from each other in the tray and at least 8 cm from a centrally placed petri dish and 4 cm away from each other, in an enclosed aluminium tray to prevent the insects from flying out of the tray. Fifty unsexed adult beetles that were pre-starved for 24 h were introduced in the centrally placed petri-dish to allow the beetles to move freely to any type of dry chips of their choice. Observations were conducted at 3 hourly intervals for 12 h and the number of adults found in each petri dish were counted and recorded. Each treatment was replicated 3 times.

Relative susceptibility of the different products: Two hundred grammes of each of the test varieties of yam, cassava, cocoyam and plantain were weighed into 1 L kilner jars after determining their moisture contents (Rajamma *et al.*, 1994; Stumpf, 1998). Each jar was infested with thirty 1-3 weeks old (Scholz *et al.*, 1997), unsexed adults of *P. truncatus* obtained from the maize cultures were introduced into each glass jar using an aspirator and covered by wire gauze to prevent entry by any unwanted organism. The culture was left in the laboratory, arranged in a completely randomized design for 30, 60 or 90 days but data were collected on these after every 30 days. Each treatment was replicated 4 times. The susceptibility of the dried chips to attack by the insect was assessed by determining the following parameters: total number of adults that developed and emerged from each product, weight of adults that emerged percentage weight loss of productand weight of frass produced at the end of the 30, 60 and 90 days exposure periods.

Data analysis: Count data of adult insects were log (log [x+1]) transformed (Zar, 1999), while percentage weight loss of chips was transformed using arcsine. The weight of adults and weight of frass produced through insect feeding were also recorded. The data and results obtained were subjected to Analysis of Variance (ANOVA), using Genstat statistical software (version 9.2). Where significant differences were observed ($p<0.05$) and means were separated using Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Relative preference for the different food products: Results obtained after the analysis showed that insect counts obtained after 6, 9 and 12 h of observation were significantly higher than those obtained during 3 h of observation. Consequently, the results obtained from the 12 h of observation were selected for the analysis because these were significantly higher ($p<0.05$) than those from 6 and 9 h of exposure. The results in Table 1 showed that more adults were recorded on cassava (biafra and bosomnsia) and plantain (apantu and asamienu) than the cocoyam (white and red) and yam (pona and takyeman) varieties. Compared with all varieties and crop, significantly more adults were recorded on the biafra variety of cassava than any other (Table 1). No significant differences ($p>0.05$) in preference were observed between the two varieties of any of the other crops studied (Table 1).

Number of adults that completed development on the products: After 30 days exposure no new emergences were recorded on any produce, obviously because this period was shorter than the developmental period of 35.5 to 41.5 days recorded on chips (Isah *et al*., 2009). By 60 days, significantly more adults were recorded on the cassava (biafra) dried chips than any other dried chips (Table 2). The results also showed that significantly ($p<0.05$) more adults were recorded on chips of the *bosomensia* variety of cassava and the apantu and asamienu varieties of plantain than on those of the yam (pona and takyeman) or cocoyam (red and white) varieties. After 90 days of exposure both varieties yielded significantly more adult insects than any other crop or variety (Table 2), though no differences could be detected between the two varieties of each crop. The increase in the number of the adult *P. truncatus* from 60-90 days can be explained by the longer exposure period to which the chips were subjected to.

Weight of adults that emerged from the different products: Table 3 shows that the mean weight of *P. truncatus* adults that emerged from the different dried chips on which they developed. The highest weights were recorded on all crops after 60 days of exposure. There were no significant differences ($p>0.05$) between varieties of the same crop. After, 90 days, adult insects that emerged from both varieties of yam were significantly less than those from any of the other crops.

Table 1: Mean number of *P. truncatus* adults (±SE) recorded on chips of different varieties of cassava, plantain, cocoyam and yam over a 12 h observation period

Varieties	
Cassava	
Biafra	11 ± 0.17^{d}
Busumnsia	7 ± 0.39^{c}
Cocoyam	
Red	2.67 ± 0.67^{ab}
White	2 ± 0.22^{a}
Plantain	
Apantu	5.33 ± 0.23^{bc}
Asamienu	5 ± 0.26^{bc}
Yam	
Pona	2 ± 0.13^{a}
Takyeman	2 ± 0.5^{a}

Means followed by the same letter vertically are not significantly different from each other ($p>0.05$). Substrate Mean±SE number of insects

Table 2: Mean number of adult *P. truncatus* (±S.E) that completed development after 30, 60 or 90 days of exposure to different varieties of food substrates

	Food Substrate Mean±SE number of insects		
Varieties	30 days	60 days	90 days
Cassava			
Biafra	30±0.00[a]	457±11.94[d]	646±13.96[d]
Bosomnsia	30±0.00[a]	312±12.13[bc]	564±15.03[d]
Cocoyam			
Red	30±0.00[a]	129.25±6.41[a]	275±8.57[abc]
White	30±0.00[a]	152±7.22[a]	290±10.99[abc]
Plantain			
Apantu	30±0.00[a]	303±26.47[bc]	383±11.25[c]
Asamienu	30±0.00[a]	322±9.64[c]	374±10.23[bc]
Yam			
Pona	30±0.00[a]	203±11.35[a]	224±9.2[a]
Takyeman	30±0.00[a]	219±8.73[a]	264±8.50[ab]

Means followed by the same letter vertically are not significantly different from each other (p>0.05)

Table 3: Mean weight (mg) of adult *P. truncatus* (±SE) that developed on dried chips of cassava (biafra, bosomnsia), cocoyam (white, red), yam (pona, takyeman) and plantain (apantu, asamienu) after 30, 60 or 90 days exposure to the food substrates

	Substrate Mean±SE weight of insects		
Varieties	30 days	60 days	90 days
Cassava			
Biafra	2.23±0.73[a]	3.78±0.13[c]	3.23±0.07[b]
Bosomnsia	3.00±0.65[a]	3.50±0.04[abc]	3.23±0.03[b]
Cocoyam			
Red	2.27±0.22[a]	3.30±0.15[ab]	3.30±0.04[b]
White	2.20±1.09[a]	3.20±0.1[ab]	3.08±0.09[b]
Plantain			
Apantu	1.77±0.01[a]	3.58±0.03[bc]	3.55±0.06[b]
Asamienu	3.00±0.49[a]	3.50±0.24[abc]	3.08±0.03[b]
Yam			
Pona	1.85±0.39[a]	3.28±0.11[a]	2.38±0.01[a]
Takyeman	1.38±0.08[a]	3.13±0.15[a]	2.40±0.05[a]

Means followed by the same letter vertically are not significantly different from each other (p>0.05)

Weight loss in different dried chip types: A comparison of losses in weight recorded for all chip types showed that weight losses increased with increasing exposure to *P. truncatus* from 30 to 90 days (Table 4). At all the exposure periods used, no significant difference in weight loss was observed between varieties of the same crop but cassava and plantain generally suffered more weight loss than yam and cocoyam over all the exposure durations.

Weight of frass produced: The weight of frass produced from chips of cassava and plantain after exposure to *P. truncatus* showed no significant differences after 30, 60 and 90 days (Table 5) but both were significantly more than was recorded on chips of yam and cocoyam over similar durations. Frass produced on all chip types increased with exposure time from 30 to 90 days.

Table 4: Mean % weight loss to dried chips of different varieties of food products exposed to *P.truncatus* (Horn) over 30, 60 or 90 days

	Substrate Mean±SE number of insects		
Varieties	30 days	60 days	90 days
Cassava			
Biafra	22.46±2.08^{b}	57±4.67^{d}	75.5±5.55^{d}
Bosomnsia	22.80±2.92^{b}	49.3±5.17^{cd}	68.5±5.71^{cd}
Cocoyam			
Red	10.49±0.73^{a}	16.3±1.30^{a}	16.2±1.27^{a}
White	10.71±0.75^{a}	22.7±2.04^{ab}	25.8±2.18^{ab}
Plantain			
Apantu	23.25±2.56^{b}	47.2±4.46^{cd}	71.4±5.59^{cd}
Asamienu	24.06±2.52^{b}	43.1±4.58^{c}	59.1±5.14^{c}
Yam			
Pona	6.98±0.21	27±2.43^{ab}	34.2±3.06^{b}
Takyeman	9.75±0.59^{a}	29.4±2.51^{b}	36.9±3.07^{b}

Means followed by the same letter vertically are not significantly different from each other (p>0.05)

Table 5: Mean weight (g) of frass produced by *P. truncatus* (±SE) placed on dried chips of different varieties of food products after 30, 60 or 90 days of exposure

	Mean±SE weight of substrate		
Varieties	30 days	60 days	90 days
Cassava			
Biafra	24.23±0.15^{b}	111.1±0.08^{d}	147.6±0.14^{d}
Bosomnsia	30.73±1.51^{b}	92.2±2.29^{cd}	126.5±1.24^{cd}
Cocoyam			
Red	3.19±0.63^{a}	7.8±0.22^{a}	11.6±0.20^{a}
White	5.87±0.20^{a}	24.0±0.14^{ab}	32.0±0.16^{a}
Plantain			
Apantu	27.80±1.32^{b}	91.7±0.75^{cd}	147.2±0.06^{d}
Asamienu	26.00±0.83^{b}	75.3±1.69^{c}	114.8±0.85^{c}
Yam			
Pona	1.10±0.06^{a}	36.6±0.19^{ab}	57.0±0.46^{b}
Takyeman	0.96±0.02^{a}	42.9±1.05^{b}	65.5±1.35^{b}

Means followed by the same letter vertically are not significantly different from each other (p>0.05)

Data obtained from this experiment clearly showed that more adults*P. truncatus* could survive and breed on the substrates of cassava (biafra and bosomnsia) and plantain (apantu, asamienu) more successfully than yam (pona, takyeman) or cocoyam (red, white) under tropical room temperatures. Also, the weight of beetles that developed on chips of plantain (apantu, *asamienu)*, cassava (biafra, bosomnsia) and cocoyam (red and white) were heavier than those recorded on yam (pona and takyeman). The high numbers and weight of adults recorded on the dry chips of cassava and plantain could be due to the softness and texture of the chips (Hodges *et al*., 1985), the higher moisture content of the dried chips prior to drying (Shires, 1979; Parker and Booth, 1979; Hodges *et al*., 1985). Stumpf (1998), which could have led to the fermentation of the cassava and plantain dried chips during sun drying, thus permitting easy tunneling by the beetle (Haines, 1991). Adults from 60 day old cultures were heavier than 90 day old cultures. It may be suggested that the increased population between days 60 and 90 could have introduced competition for food and space, which may explain the loss in weight recorded in the older culture. The results also showed that the weight of frass produce and weight loss in chips recordedwere all due to the activity of *P. truncatus* which increased with the age of the culture from 30 to 90 days. These results clearly demonstrate the ability of the insect to penetrate, tunnel and develop on the different food substrates as well as its ability to cause considerable damage to dry chips over increasing longer periods of exposure to the pest. The results further showed that cassava and plantain suffered significantly higher weight losses than did yam or cocoyam. For cassava, the losses were as high as 93.6 and 81.5% for biafra and busumnsia while for plantain they were 88.4 and 71.8 for apantu and asamienu.

Between the 2nd and 3rd months of exposure to the pests, the increased population resulted in increased frass production, accompanied by a foul and pungent smell, especially in the cassava and plantain cultures. This pungent smell suggests a high concentration of ammonia and other metabolic products from increased activity (defeacation, excretion, reproduction and competition) (Mullins and Cochran, 1997) which accompany population increase. From this, it can be inferred that chips kept for more than one month in the presence of *P. truncatus* would be under serious threat (Hodges, 1986). The results are in agreement with Mulungu *et al.* (2011) who also reported the infestation and damage caused by *P. truncatus* on stored paddy rice in Tanzania.Reducing post-harvest losses is increasingly recognized as a part of an integrated approach to realizing agriculture's full potential and enhancing food security for the ever increasing population. To succeed, control measures must be sensitive to indigenous knowledge, skills, conditions and practices using participatory methodology.

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