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Research Article
Occurrence and Control of *Prostephanus truncatus* (Coleoptera: Bostrichidae) on Stored Dried Cassava Chips in Southwestern, Nigeria

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Abstract

Background and Objective: Larger Grain Borer (LGB) *Prostephanus truncatus* is a major stored insect pest of Dried Cassava Chips (DCC) that reduces its quality and quantity. Conversion of cassava roots into dried chips exposes them to insect pest attacks. Control using synthetic insecticides is being discouraged due to its adverse effects on human and other organisms. Diatomaceous Earth (DE) dust is environmentally safe as an alternative control. This study was designed to survey presence of LGB in stored DCC in selected markets, Oyo state and control utilizing DE. **Materials and Methods:** About 4 kg stored DCC were sampled monthly within a year in stores for the presence of LGB in 4 Locations/markets; Ibadan/Bodija, Iseyin/Oja-Agbe, Saki/Sango and Oyo town/Sabo, based on product availability between April, 2016 and March, 2017. Samples collected were split and sieved. Thereafter, LGB were identified and counted. Diatomaceous Earth (DE) dusts were applied at dosages 0.0 g (control), 0.5, 1.0, 1.5, 2.0 and 2.5 g per 50 g of DCC treatments, thoroughly admixed and introduced 10 adults LGB. Setups, replicated 4 times were left undisturbed for 30 days in a wooden screen cage of 30×60 cm in laboratory. Data collected were adult emergence, mortality and DCC percentage weight loss. Data were analyzed using descriptive and ANOVA ($\alpha = 0.05$). **Results:** A total number of 4,425 LGB were found. Oja-agbe market recorded the highest percentage occurrence while Bodija market recorded the least values. Also, highest percentage occurrence was recorded in rainy season while dry season recorded a low occurrence. The DE dusts treatments recorded a significant reduction ($p<0.05$) in emergence of LGB and weight loss of DCC compared to control set up. Mean mortality rate of LGB was significantly higher with higher concentrations of DE compared to control set up. **Conclusion:** The DCC in Nigeria markets are not immune to LGB while DE dust is an effective environmentally safe control measures at higher dosage.

Key words: Diatomaceous earth, dried cassava chips, *Prostephanus truncatus*, Oyo state

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Larger Grain Borer (LGB) *Prostephanus truncatus* (Horn) is a stored product pest beetle that belongs to the family Bostrichidae. It is indigenous to Central America[1], where it has spread to many countries[2]. In Africa, it was accidentally introduced through Tabora region of Tanzania in the late[3] 1970s. It outbreak followed the pattern of many other insects outbreaks which is an exotic species proved to be able to exploit a new environment[4]. This pest has become a serious pest of stored maize and dried cassava in part of east, south and west Africa[2]. In, southwestern part of Nigeria, the earliest reports of *P. truncatus* indicated its presence in areas of Oyo, Ogun and Lagos states, mostly in areas near the border with the Republic of Benin[5]. However, Echendu and Ojo[6] reported that *P. truncatus* has moved out of the border areas of the south-west from where it probably entered into the country but extent of spread is yet unknown.

Cassava is a staple food crop in Africa, it is produce in large quantity by peasant and commercial farmers and this resulted into Nigeria being the highest producer in the world[7]. In order to prevent its deterioration and wastage, fresh roots cassava *Manihot esculentus* are converted into dried chips. The process of conversion 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. Parker and Booth[8] reported that cassava chips are heavily infested during sun drying and when in store by a number of stored product pests including the larger grain borer *P. truncatus*[9]. According to Espinal *et al.*[10], adult and larval stages of *P. truncatus* has ability to damage wide range of commodities including some roots and tubers, cereals, pulses, cocoa, coffee, groundnut and wooden structures. The pest cause infestation by tunneling extensively in the grains of stored maize, dried cassava chips and other favourable crops by feeding directly on it and excavating side chambers off the main tunnel[11]. This boring activity converts these stored food crops products to frass or powder. The pest attacks usually resulted into high losses[12]. Weight losses of up to 83% was recorded in laboratory studies in Nigeria within 60 days on the check on larger grain borer *P. truncatus* using crude *Neem Azadiracthta* indica extract on contaminated dried cassava chips[13]. Hassan and Popoola[14] also reported infestation of *P. truncatus* on dried cassava chips (TME-30572 and TME-1) in the laboratory recorded weight loss of 36.92 and 63.20%, respectively over a period of 112 days. Weight losses of up to 40% have been recorded in Nicaragua from maize cobs stored on the farm for 6 months[15].

In reviewing control measures against *P. truncatus* infecting dried cassava chips. Residual insecticides are the most commonly used protectants in stores against stored-product pests, generally toxic to mammals and leave residues in the product while many insect species are resistant. Therefore, one of the most promising alternatives to contact insecticides is the application of diatomaceous earths (DEs)[16]. Diatomaceous Earth (DE) based inert dust derives from diatomaceous algae fossils, which naturally possesses a thin silica layer. Dust particles adhere to the insect's body by contact, acts by removing the epicuticular wax, causing loss of water and so death by dehydration[16,17]. It is a user-safe product and of lasting insecticide effect, as it does not lose efficiency over long time. The aim of this study was to survey the presence and control of *P. truncatus* dried cassava chips as substrate using Diatomaceous Earth in Oyo state, southwestern Nigeria.

MATERIALS AND METHOD

Study area: This study was carried out in Oyo state, located in southwestern Nigeria, with latitude 8.12° N and longitudes 3.42°E. The state has an area of 28,454 km^2 with equatorial climate notably with dry season (November to March) and wet season (April-October) and high relative humidity. Average daily temperature ranges between 25 and 35°C almost throughout the year. Agriculture is the main occupation of the people of Oyo State. Its climate favours the cultivation of crops like cassava maize, yam, millet, rice, plantains, cocoa, palm produce, cashew.

Four major markets; Bodija, Sabo, Oja-Agbe and Sango markets were chosen based on the availability of processed stored dried cassava chips in the markets. As shown in Fig. 1, Bodija Market is located in a district in Ibadan north local government between latitude 7°26' 18" N and longitude 3°54' 98" E.; Sabo Market is located in Oyo North, Oyo town between latitude 7°52' 67" N and 3°56' 68" E; Oja-Agbe market is located in Iseyin Local government area with latitude 7°58' 18" N and Longitude 3°34' 11" E and Sango market located in Saki west local government with latitude 8°40' 70" N and longitude 3°23' 60" E.

Monthly survey for occurrence of *P. truncatus* in stored Dried Cassava Chips (DCC): About 1 kg dried cassava chips were sampled monthly from selected stores within each market from April, 2016 to March, 2017. Thereafter, samples were pooled together to form 4 kg per location,

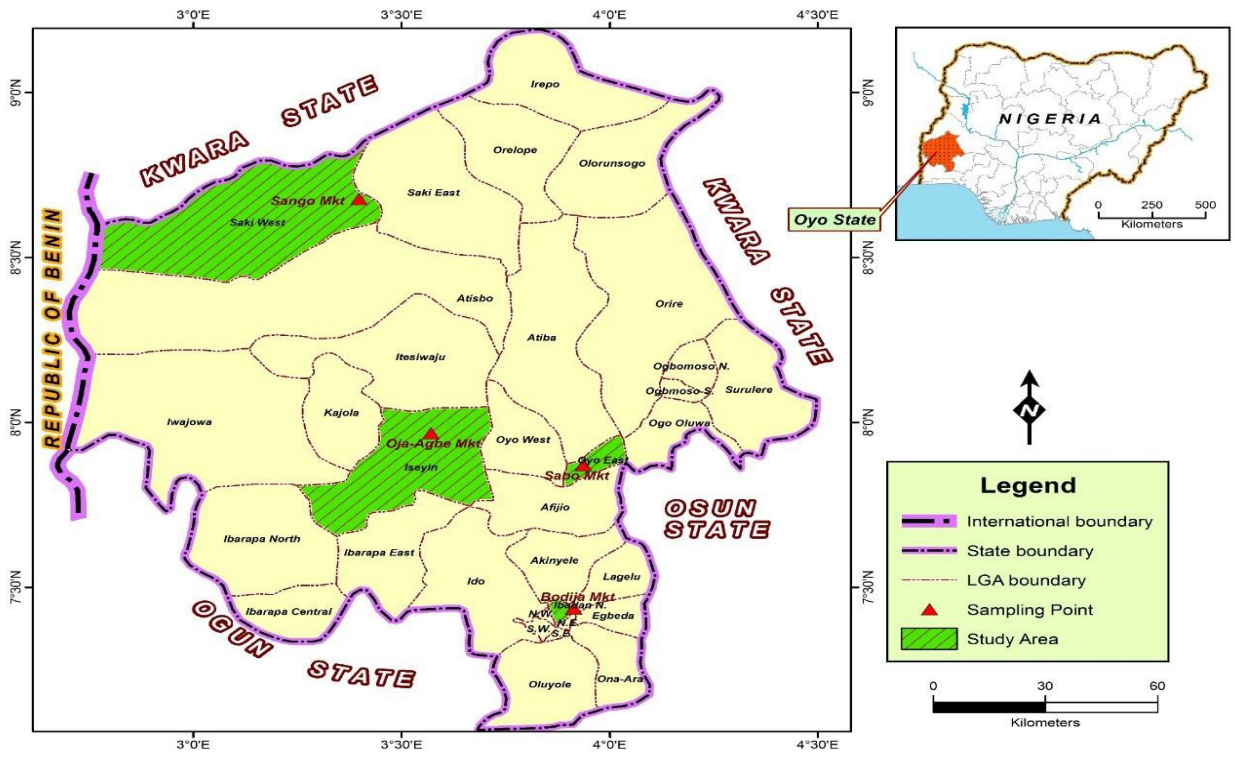

Fig 1: Map of Oyo state showing the study area with map of Nigeria inserted

these were taken to Entomology Laboratory, Department of Zoology, University of Ibadan for analysis. Collected dried chips were split into pieces and sieve using 0.55 mm mesh size for easy recognition of *P. truncatus* on white tray and identified. All adult *P. truncatus* found were properly identified using dissecting microscope and counted. Thereafter, percentage occurrence was calculated using the method of Bueno and Esouza[18]. This was expressed by the following equation:

$$\text{Occurrence}(\%) = \frac{\text{Monthly number occurrence of } P.truncatus \text{ per market}}{\text{Total number of occurrence of } P.truncatus \text{ in all markets per month}} \times 100$$

Morphological identification of *Prostephanus truncatus*: Morphological identification of *Prostephanus truncatus* was carried out with the aid of Rees[19] identification guide. Also, knowledge of the basic structure of the beetle was required for its identification. Identification was based on adult's body length 3-4 mm, brown, cylindrical in cross- section. Head bent downwards, concealed. Tip of abdomen square, boundary between end and side of elytra marked with ridge. The identification was carried out in Entomology Laboratory, Department of Zoology and Department of Crop Protection and Environmental Biology, University of Ibadan. Oyo state. Nigeria.

Collection and process of dried cassava chips: Fresh cassava root (TMS 4(2) 1425) were collected from Genetic Resource Centre, International Institute of Tropical Agriculture (IITA) Ibadan. Peeled, cut into chips and soaked in clean water for 72 h. Thereafter, it was sun-dried for 7-14 days to a moisture content of about[20] 10-12%. It was latter sterilized in the oven dried at 60°C for 3 h (to kill any insect pest present) until constant weight was obtained. Thereafter, sterilized dried cassava chips were used for subsequent research.

Culture of *Prostephanus truncatus*: The initial stock of *P. truncatus* used for the experiment were obtained from Bodija market, Ibadan. Thereafter, stock cultures were raised in the Entomology Laboratory, Department of Zoology, University of Ibadan, Nigeria. In preparing the culture stock, 200 g sterilized dried cassava chips was used and kept under fluctuating ambient temperature and relative humidity of

25-28°C and 65-85%, respectively. The stock culture was rejuvenated at intervals of 3 months for breeding.

Collection and preparation of Diatomaceous Earth (DE) dust: A crude DE ore of fresh water origin was collected from Bularafa community, Yobe state, northern Nigeria. The DE collected was moist and soft blocs, dried in a ventilated oven at 40°C for 6 h, to about 4.5% moisture content[21]. After drying, the DE sample was gently crushed into a dust with a simple grinding machine. The sample was sifted (dry sieving) through a sieve of 4 mm; particles larger than 150 µm were discarded because this fraction usually contains sands, rocks and only a few very large diatoms[22]. The DE was kept in Kliner jar for 24 h before use.

Experimental set up on control of *P. truncatus* on dried cassava chips using Diatomaceous Earth (DE) dust: About 50 g un-infested, sterilized Dried Cassava Chips (DCC) were used for the experiment. Various fractions of weighed DE; 0.5, 1.0, 1.5, 2.0 and 2.5 g were added to the weighed DCC in a 20 mL jar bottle and admixed. The jars were tightly sealed with lids and thoroughly shaken by hand for 1 min, to achieve equal distribution of the DE in the chips mass. Thereafter, jars were infested with unsexed 10 adult's *P. truncatus.* Untreated control was run for each set ups. Treatments were replicated 4 times. Mortality of *P. truncatus* adults was assessed after 1, 3, 5 and 7 days. While, the effect of tested DE on the mortality and progeny was assessed 60 days after the introduction of insect pest into jars. This was kept in a wooden screen cage 60×30 cm. Data collected were rate of adult emergence, mortality and percentage weight loss of DCC. Percentage weight loss was calculated using the equation according to Niber[23]:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight of sample before infestation} - \text{Final weight of sample after infestation}}{\text{Initial weight of sample before infestation}} \times 100$$

Data analysis: Data collected were subjected to descriptive statistics (Simple percentage) and analysis of variance (ANOVA) ($p<0.05$) means separated using Tukey's test.

RESULTS

Monthly occurrence of *P. truncatus* in 4 kg stored dried cassava chips in 4 selected markets in Oyo state: A total number of 4,425 adults of the pest were encountered in all the markets. Oja-agbe markets recorded the highest percentage occurrence of 35.90%, followed by Sabo and Sango markets 32.93 and 23.55%, respectively. Bodija market recorded the least occurrence of 7.62% (Table 1).

On monthly basis assessement, Bodija market recorded the highest percentage occurrence 2.15% of *P. truncatus* in the month of August while, month of November recorded the least percentage occurrence of 0.14%. No record of occurrence was recorded from the months of December to February (Fig. 2).

Sabo market in Oyo town, recorded monthly percentage occurrence of 9.49% in the month of May, while the

Table 1: Overall occurrence (%) of *Prostepahnus truncatus* in selected markets in Oyo state between April, 2016 and March 2017

Markets	Locations	No occurred	Occurrence (%)
Bodija	Ibadan	337	7.62
Sabo	Oyo town	1, 457	32.93
Oja-agbe	Iseyin	1, 589	35.90
Sango	Saki	1, 042	23.55
Total		4, 425	100.00

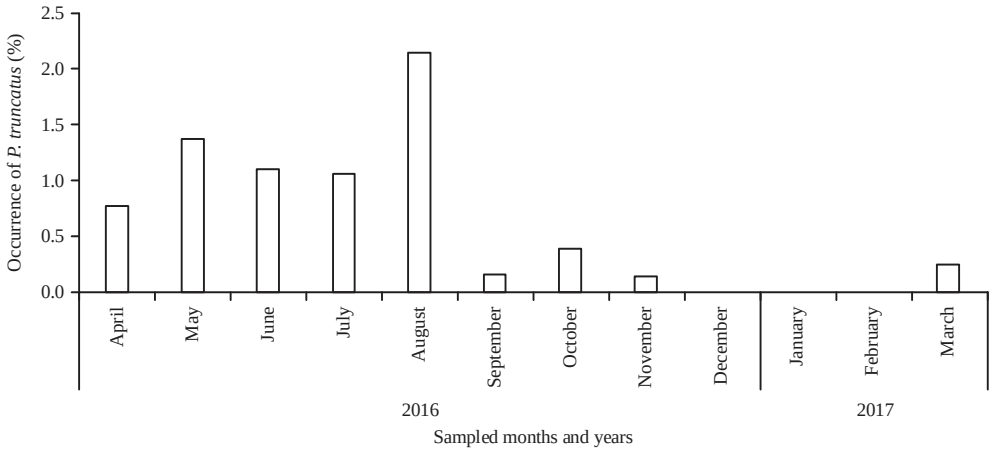

Fig. 2: Monthly occurrence (%) of *P. truncatus* in 4 kg dried cassava chips in Bodija

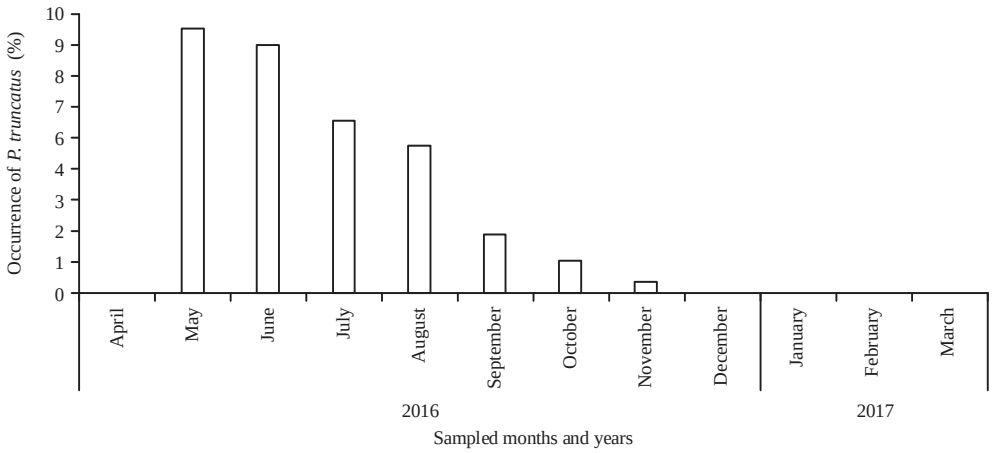

Fig. 3: Monthly occurrence (%) of *P. truncatus* in 4 kg dried cassava chips in Sabo market, Oyo town

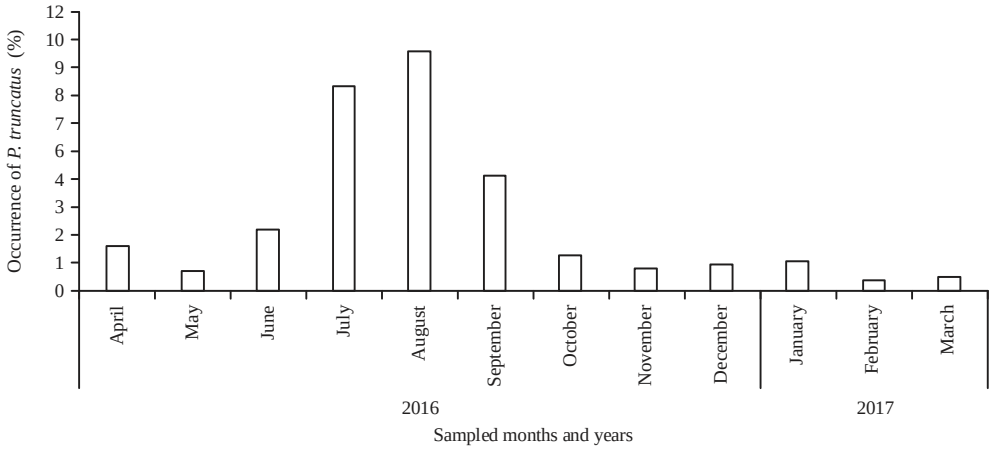

Fig. 4: Monthly occurrence (%) of *P. truncatus* in 4 kg dried cassava chips in Oja-agbe market, Iseyin

least occurrence was in the month of November. No record of *P. truncatus* was observed from the month of December to March (Fig. 3).

Oja-Agbe market, Iseyin recorded highest percentage occurrence (10.31%) in the month of August followed by 8.81% in the month of July. The least percentage occurrence (0.61%) was recorded in the month of February (Fig. 4).

Sango market, Saki, the highest percentage occurrence of 10.71% was recorded in the month of May. The least percentage occurrence of 2.67% was recorded in the month of August. No record of *P. truncatus* was recorded from the month of November -February but the pest started re-surfacing in stored dried cassava chips from stores in the month of March and April which recorded percentage occurrence of 0.09 and 0.29%, respectively (Fig. 5).

Effect of Diatomaceous Earth (DE) dust at different dosages on *P. truncatus* in DCC within 60 days exposure: This result showed that Diatomaceous Earth (DE) dust was an effective tool against *P. truncatus* infesting dried cassava chips. On 7 days post-treatment of dried cassava chips infested with *P. truncatus* with DE dust showed that, highest percentage mortality of 36.70% was recorded in the 3rd day of exposure at concentration of 2.0 and 2.5 g DE dust, followed by 1.5 g concentration which recorded 23.3% mortality. About 5th day also recorded 6.70% mortality recorded in 1.0 g DE dust concentrations. When compared to control set up, no mortality were recorded in control in all exposure days (Fig. 6).

On 60 days post treatment (Table 2), result indicated that at 60 days exposure, the mean mortality rate at all dosages was significantly different ($p<0.05$) compared to control set up. The highest mean mortality rate 30.00 ± 2.08 was recorded at dosages 2.5 g compared to control 5.67 ± 1.20. Meanwhile, the least mean emergence adults 53.00 ± 5.51 was found in dosages 2.5 g compared to control that recorded 90.00 ± 10.02 emergence. Percentage weight loss was significantly difference ($p<0.05$) in control compared to all dosages examined.

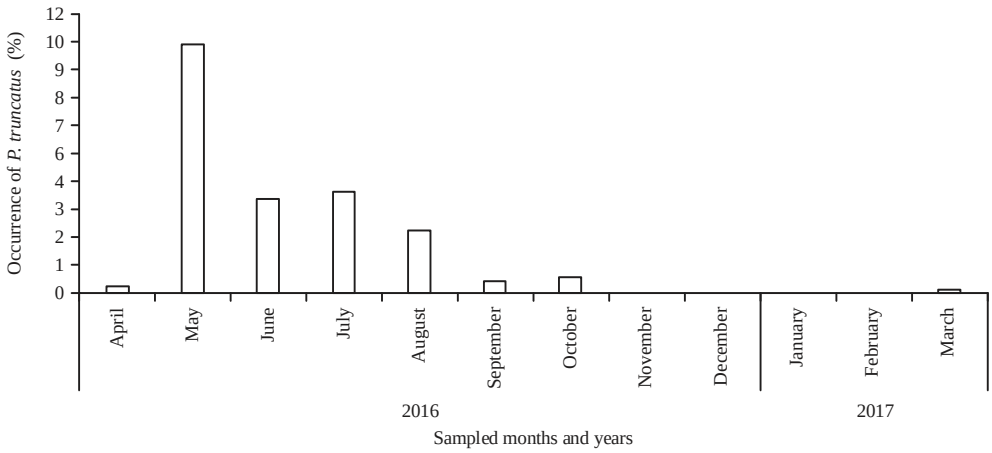

Fig. 5: Monthly occurrence (%) of *P. truncatus* in 4 kg dried cassava chips in Sango market, Sak

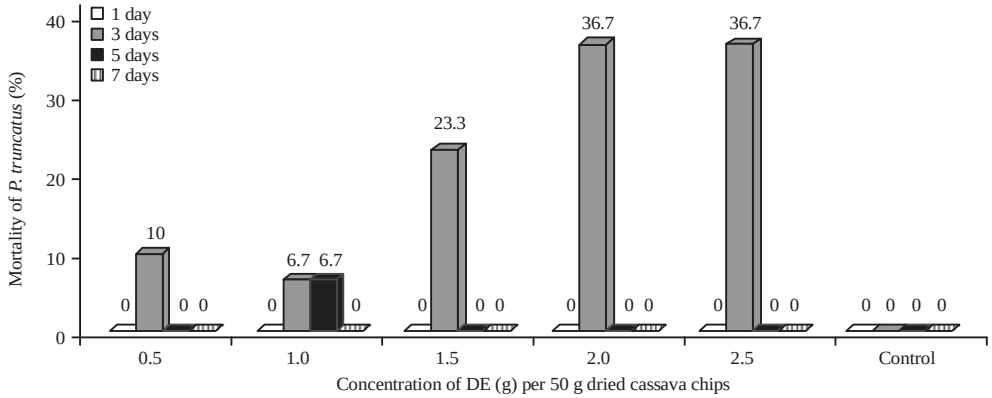

Fig. 6: Mortality (%) of *P. truncatus* exposed to DE within 7 days exposure

Table 2: Effect of diatomaceous earth (DE) dust on *P. truncatus* infested in dried cassava chips within 60 days exposure

Dosages (g)	Emergence rate	Mortality rate	Weight of frass produced (g)	Weight loss (g) (%)
0.5	68.33±16.33^{a}	13.33±2.33^{ab}	12.10±1.43^{ab}	60.50±7.17^{ab}
1.0	71.33±8.09^{a}	18.67±5.78^{ab}	11.31±0.32^{ab}	56.57±1.61^{ab}
1.5	59.33±2.96^{a}	16.00±1.73^{abc}	11.21±1.21^{ab}	56.05±6.05^{ab}
2.0	62.67±11.46^{a}	21.00±1.15^{c}	12.11±1.12^{ab}	60.53±5.61^{ab}
2.5	53.00±5.51^{a}	30.00±2.08^{a}	8.74±0.30^{a}	43.70±1.50^{a}
Control (0.0)	90.00±10.02^{a}	5.67±1.20^{a}	15.25±1.17^{b}	76.28±5.83^{a}

Each datum is a means of 4 replicates. Mean numbers followed by different letters within a column are significantly different (LSD). Tukey's test ($p<0.05$)

DISCUSSION

Insect pest infestations are the most important constraint to stored dried cassava chips, causing low quality and quantity to the crop because of its hygroscopic nature, which increases its susceptibility to damage by insect pests [24]. The knowledge of occurrence and abundance of insect pest such as *Prostephanus truncatus* is an integral part for pest management. Therefore, *P. truncatus* detection, monitoring of the spread and seasonal dynamics is one critical activity in management of the pest[25]. This research has revealed that stored dried cassava chips are not immune to *P. truncatus* infestation. This agrees with the findings of Hodges *et al.*[26], who reported losses caused by *P. truncatus* in dried cassava roots to be very high; the dried roots are readily reduced to dust by boring adults and a loss of 70% has been recorded after only 4 months of farm storage. In Togo average cumulative losses of 9.7% after 3 months storage, this figure rose to 19.5% after 7 months[27,14], also reported that infestation of *P. truncatus* on dried cassava chips (TME-30572 and TME-1) in the laboratory. From this study, it is established that seasonal variation affects the population dynamics of

P. truncatus infesting stored dried cassava chips. High percentage occurrence of *P. truncatus* was observed from samples collected in rainy season compared to low number in dry season could partly be explained by the meteorological differential between the periods and time of harvest and the length of time it took in storage. This finding concurs with the studies of Maina and Lale[28] on bruchids in which they indicated that beetles developed better in the raining season, characterized by high temperature and humidity. Also, Vaidya *et al.*[29] recorded the highest infestation of stored grains by the stored pests during rainy season (77.50%) followed by dry (62.50%). Thakur *et al.*[30] also confirmed that, maximum number of insect damaged grains is found in wheat during the rainy season followed by the dry season. In the findings, reduction in occurrence of *P. truncatus* infestation during the dry season could partly be due to the cultural habits of the marketers or store owners who spread and dry infested chips in scorching sun which reduce number of pest found compared to rainy season when the chance of drying infested chips is limited. This is in line with previous studies which showed that temperature influences various biological characteristics of insects such as sex-ratio[31], adult life-span, survival, fecundity and fertility[32]. From the study, Oja-agbe market, Iseyin had the highest percentage occurrence of *P. truncatus* across the markets surveyed. This is in accordance with the work of Echendu and Ojo[6] who reported catches of *P. truncatus* were heaviest in the traps set at Okeho/Iseyin, Oyo state. This is also very similar to research work of Pike *et al.*[5] who recorded 60% of their total survey catch from this area alone.

From this research work, the DE dust collected from Bularafa Yobe state, Nigeria is an effective DE with insecticidal properties against *P. truncatus*. The DE dust was toxic to the adult *P. truncatus* causing significant mortality to the beetle. This corroborates with the work of Otitodun *et al.*[33] who reported mortalities caused by Bularafa DE against *R. dominica* and *S. oryzae* and the reduction in progeny production. Nwaubani *et al.*[34], also reported the efficacy of this DE in which they found out that it caused 61.2% mortality in *R. dominica* after 14 days in treated wheat and 79.6 and 100% mortality in *S. oryzae* after 7 and 14 days in treated wheat, respectively. Mortalities of *P. truncatus* was first observed in the third day of exposure to high concentration of DE, the toxic action increases with increase in dosage concentration. This result is in accordance with the work of Korunic *et al.*[35], who suggested that DEs is needed to be applied in high-dose rates for effectiveness in control of stored product insect pests. A field trials in Zimbabwe, demonstrated that DE duats are highly effective and persistent grain protectants against the major storage insect pest attacking maize, sorghum and cowpea when applied in high rates to prevent bostrichidae beetle damage[36]. Also, this work also revealed that, the rate of emergence of *P. truncatus* exposed to Bularafa DE dust reduced by increasing adult mortality and reducing percentage weight loss. This supported the work of Ibrahima *et al.*[37], who observed that DE reduced the production of progeny by increasing adult mortality, reducing oviposition, ovicidal and larvicidal activities.

However, this study showed that mortality of adult *P. truncatus* introduced into dried cassava chips admixed with Bularafa DE dust did not record 100% mortalities. Some adults found their way into the chips, feeding within and reducing the dried chips to frass/dust, this dust diluted with the DE dust thereby reducing its efficacy. This shows that the significant amount of frass produced through the feeding activities of *P. truncatus* may reduce the efficacy of DEs admixed with dried cassava chips. A study by Stathers[36] on the effect of DEs on survival of the natural enemy *Teretrius nigrescens* (Lewis) (Coleoptera: Histeridiae) found *T. nigrescens* mortality was much higher in all the DE application rates in the absence of *P. truncatus*. Observation suggested that dust produced by *P. truncatus* during feeding diluted the DE, reducing the likelihood of *T. nigrescens* coming into physical contact with enough DE dust to cause death.

CONCLUSION

This study has showed that stored dried cassava chips in Oyo markets, Nigeria are not immune to insect pest infestation with infestation occurring all year round which revealed that seasonal variation have effects on population dynamics of insect pests in storage with the highest occurrence in the rainy season. More so, infestation rate is probably due to personal hygiene of the marketers. Furthermore, duration of storage also have great influence on the infestation rate of pests especially when products are stored in a contaminated environment/store.

ACKNOWLEDGMENT

We appreciate International Institute of Tropical Agriculture (IITA) and Mr. Nwabani, S.I and Mrs. Otitudun, G.O of Nigeria Stored Product Research Institute (NSPRI) where cassava roots and Diatomaceous Earth (DE) were collected for the research respectively.

SIGNIFICANCE STATEMENT

This research work revealed that *Prostephanus truncatus* is a serious pest of stored dried cassava chips. Its control using Diatomaceous Earth (DE) collected from Bularafa Yobe state, Nigeria was an effective tool against the pest, since it reduce *P. truncatus* survival and breeding rate. Also, with the use of this DE as control measures, it will reduce the dependent on synthetic insecticides for the management of stored-product pest, resulting in a number of problems including toxic residues in treated products, handling and health hazards, pest resurgence and resistance of insect species. This DE is natural and ecologically acceptable insecticide product.

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