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Performance of *P. Truncatus* Strains on maize varieties in choice and no-choice tests

[1] EN Nwankwo, [2] NJ Okonkwo, [2] RI Egwuatu, [1] Adibe FU, [1] Ukonze CB, [1] Obiefule IE, [1] Asogwa JN

[1] Department of Parasitology and Entomology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Nigeria.

[2] Department of Crop Science, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria.

Abstract
The larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) is the most damaging insect pest of maize, an important staple food crop for people living in sub-Saharan Africa. A laboratory assessment was conducted to evaluate the performance of *P. truncatus* originating from three geographical locations in Nigeria and one from Ghana on ten maize varieties in no-choice and choice test. Performance assessment of the strain in no-choice test was based on adult mortality, F1 adults, population density, body weight and size of F_1 adults, developmental period, weight loss and damage. These parameters were significantly correlated with each other using Analysis of variance (ANOVA). Adult survival and subsequent damage was poorer on some varieties of maize. The extent of damage, loss and dust produced were significantly different (P<0.05) among the maize varieties. The order of the weight loss recorded for these varieties was Yellow Mangu Jos > Acr.91-SUWAN-1SRC$_1$ > Western yellow > Oba Super I > Oba Super II > Yellow Popcorn > TZESR-W> Acr.89-DMR-ESR-W and Acr.97-TZL > BR 9928-DWR-SR-Y. *P. truncatus* from different geographical locations differed in some ways and their overall responses and performance on the different maize varieties were different although not significant (P> 0.05) in both choice and no-choice test. The developmental period of the Ibadan strain on the highly susceptible Yellow Mangu Jos was lowest (40.0$\pm$0.6 days) followed closely by the Enugu strain (40.7$\pm$0.7 days). *P. truncatus* from Benue and Ghana had longer mean developmental periods on the same variety, 45.3$\pm$0.3 and 47.0$\pm$0.0 days respectively.

Keywords: *P. truncatus*, strains, Performance, Maize, geographical location.

Introduction

Prostephanus truncatus, the larger grain borer (LGB) remains the sporadic but most serious threat to stored maize and dried cassava in the tropics. It was thought to be a native of Central America and was accidentally introduced into hot Tabora region of Tanzania in the late 1970s. It was found attacking farm-stored maize and dried cassava causing severe losses [1]. It subsequently spread widely within Tanzania and into southern Kenya, Burundi and Malawi [2] and has spread to other countries in the region. In West Africa, a serious outbreak was first found in Togo in 1984, in Ghana in 1989 and Nigeria in 1992. It has now spread to many African countries becoming the most destructive pest of stored maize and dried cassava in both West and East Africa. At present it seems likely to invade all maize and cassava growing areas of Tropical Africa, and it is the only recent example of invasion by a serious storage pest on a regional and continental scale. Transport of foodstuff from surplus regions into deficit regions across the continent and the exchange of foods across the continent in traditional market places promote the rapid propagation of this pest [3]. The larger grain borer is spread over longer distances almost entirely through the import and export of infested grain. Local dispersal is through the local movement of infested maize and dried cassava and by flight activity of the adult beetles.

Apart from maize and cassava, adults can, however, live in and damage many stored products such as millet, sorghum, yam, and wheat, as well as structural wood and wooden utensils [1]. Adults also bore into a wide range of foodstuffs and other materials such as bamboo, gourds, plastic and soap. In heavy infestations, wooden storage structures may become damaged and act as reservoirs of infestation from which the new harvest may be attacked. The insect also occurs in the natural environment, it is able to breed on dead, dry wood of a range of trees, as well as dried stems of cassava and maize plants [1]. Studies of this pest using pheromone traps showed that it was widespread in the natural vegetation in the Tsavo National Park, Kenya [4], thus, a major threat to food security and building industry.

Against these backgrounds, the present studies evaluate the performance of *P. truncatus* from three geographical locations of Nigeria and a strain from Ghana on ten maize varieties.

Materials and Methods

Investigations on performance and development of *P. truncatus* on maize varieties were conducted in the research laboratory, General Biology Laboratory, Nnamdi Azikiwe University, Awka.

Experimental insect and crop

Prostephanus truncatus adults were collected from three geographical zones of the country namely, Enugu, Benue and Ibadan, representing, South- East, North- East and South-Western parts of Nigeria and a strain collected from Ghana. These strains were reared on a standard maize variety, white Mangu Jos obtained from open market in Enugu.

Ten maize varieties out of which eight improved varieties namely; Oba Super I, Oba Super II, Western yellow, Acr 89-DMR- ESR-W, Acr 97- TZL, TZESR-W, Acr-91 SUWANI-SRCI and BR 9928-DWR-SR-Y (identified as varieties 1-8) were collected from International Institute for Tropical Agriculture (IITA), Ibadan and two local varieties; Yellow popcorn and Yellow Mangu Jos (identified as varieties 9 and 10) obtained from open market in Enugu were used for the study.

The maize samples from market were cooled sterilized for two weeks and later subjected to heat sterilization at 70 °C for three hours before use. This was to ensure that any existing infestation was cleared.

Performance of *P. truncatus* from different locations in no-choice test

Ten grammes each of the ten maize varieties were infested with different strains of F1 adults of *P. truncatus* from three locations in Nigeria and a strain from Ghana. Twenty unsexed 1day- 2 weeks old adults were introduced into the maize varieties in wide-mouth 60cm^3 plastic jars covered with nylon netting materials to ensure ventilation. Each treatment was replicated three times and then allowed to stand on the laboratory bench in completely randomized design (CRD). A thermo-hygrometer was mounted throughout the study period to record temperature and relative humidity. The parent insects of *P. truncatus* were not removed because of the difficulty in retrieving the adults embedded in the grains without damaging the eggs laid. Mortality was however, taken 7 days after treatment. At the end of the laboratory studies, the samples were left to stand for 40 days [5] when the eggs laid by LGB had hatched and developed into adults. Weight loss and damage were determined after 60 days (2 months) of storage. *P. truncatus* perfomance was assessed based on percentage adult mortality, F_1 progeny, population density, grain weight loss, grain damage and weight of dust.

Performance of *P. truncatus* from different locations in a choice test

Thirty grammes each of the ten maize varieties were weighed onto corrugated cardboard sheets measuring 4 cm by 10 cm [6] and placed in circular plastic troughs. One hundred and fifty, 1 day- 2 weeks old unsexed F_1 adults of *P. truncatus* were released inside a Petri-dish placed at the centre of the trough approximately 10cm away from each replicate and the replicates were approximately 3 cm away from each other. They were allowed to naturally infest the grains in the corrugated cardboard sheets. The troughs were eventually covered with trough of equal size.

After 24 hours, the number of insects attracted to each grain was counted. Subsequently, the grains with the insects were transferred into and stored in polystyrene bags measuring approximately (9.2 cm by 16.5 cm) and subsequently stacked on pallets arranged at random in the store room for three months. Each variety was replicated three times. *P. truncatus* performance was assessed based on the number of *P. truncatus* adults that entered their choice variety of maize, number of damaged grains and grain weight loss.

Development of *P. truncatus* strains on the maize varieties

The developmental period of the insect was conducted at the research laboratory, General Biology Laboratory (GBL), Nnamdi Azikiwe University, Awka under ambient temperature range of 29-36 °C and relative humidity of 51-85%. Twenty adults of *P. truncatus* from three zones of Nigeria and a strain from Ghana were put into Plastic vials containing 10 g each of the ten maize varieties. The insect were allowed to lay eggs for one week after which all adults (both dead and alive) were removed and the ones that bored inside the grains noted. Samples were kept for emergence of new adults. These adults were counted daily and removed. The minimal time needed for insect development was calculated from the third day after insect release until the first day of emergence [7]. The mean weights of three F1 adults that emerged were measured at the Biotechnology center, Nnamdi Azikiwe University, Awka using a sensitive Mettler balance model AE 166 and body size was measured using a calibrated hand lens.

Data Collection

At the end of all experiments, all insects, both dead (those that did not respond to probes by a pin) and alive were removed and counted. The dust produced by the insect was sieved through a mesh of 0.25 mm size and each weighed. Damage assessment was carried out on the infested maize varieties by separating the grains damaged (grains with characteristic holes) and undamaged categories and the grain damage calculated using the formula:

$$\%Damage = \frac{A}{B} \times 100$$

where A = number of undamaged grains, B = Total number of grains.

Percentage weight losses of maize grains were also calculated using the standard formula according to [8];

$$\%Weight\ loss = \frac{A - (B+C)}{A} \times 100.$$

Where A= the initial weight, B= weight of damaged maize, C= weight of undamaged maize (sample size less than 100).

Statistical Analysis.

Count of dead insects was taken to determine mortality rate after 7 days. The data collected on insect number, damage and percentage weight loss were analyzed using simple factorial ANOVA model in SPSS version 17 for windows statistical package [9] and Minitab version 15. Means were separated after accessing level of significance by Multiple Comparison Test using LSD at ($P = 0.05$).

Results

The mean values of *P. truncatus* adult mortality, F_1 progeny, population density and F_1 body weight assess for their performance on ten maize varieties in no-choice test are shown in Table 1. Also, the mean values of %weight loss, %grain damaged and weight of frass were presented. A critical examination of the data shows that low adult mortality was recorded on Yellow Mangu Jos, (28.3%), Oba Super I (29%) and Oba Super II (29%) and highest mortality on Br.9928-DWR-SR (87.7%), Acr.89-DMR-ESR-W (81.5%), Acr. 97-TZL Comp 4^C (82.5%) and TZESR-W (67.2%). No dust was sieved from variety, Br.9928-DWR-SR as it was not damaged by LGB. The adult insects introduced into this variety died without leaving any F_1 progeny. A similar trend was observed in all indices used in determining the performance of the maize varieties attacked by *P. truncatus* strains in the present studies.

Table 1: Performance and grain damage by P. truncatus on ten maize varieties in no-choice test.

S/No	Variety	Adult Mortality (%)	F_1 progeny	Population Density	F_1 body weight (mg)	Weight loss (%)	Grain damage (%)	Frass (g)
1	Oba super I	29.0	2.7	9.8	2.5	3.2	7.4	0.2
2	Oba Super II	29.0	2.8	10.8	2.6	3.5	10.3	0.3
3	Western yellow	37.5	3.3	8.9	2.6	4.5	7.6	0.3
4	Acr.89-DMR-ESR-W	81.5	0.9	2.9	2.1	0.3	3.1	0.03
5	Acr.97-TZL comp 4^C	82.5	0.9	2.7	2.1	1.6	2.6	0.03
6	TZESR- W	67.2	0.8	4.0	1.0	0.7	2.2	0.03
7	Acr.91-SUWAN-1SRC$_1$	42.3	4.7	10.5	2.7	6.8	12.9	0.3
8	BR.9928-DWR-SR	87.7	0.0	1.3	0.0	0.0	0.0	0.0
9	Yellow Pop Corn	42.5	0.8	6.6	1.0	1.9	2.3	0.04
10	Yellow Mangu Jos	28.3	5.6	12.8	2.7	7.7	17.5	0.6
	Mean(±s.e)	52.75±7.7	2.25±0.6	7.03±1.3	1.93±0.3	3.02±0.8	6.59±1.8	0.18±0.06

However, in the choice test (Table 2), the results indicate that Yellow Mangu Jos had the highest weight loss (7.3%), highest damage level (22.5%) and also highest amount of frass (1.5g) generated from it by *P. truncatus*. Analysis of the data showed that this variety was more significantly damaged ($P< 0.020$) than other varieties. However, the variety, BR.9928-DRW-SR-Y did not record any sign of damage, nor weight loss or frass production caused by the infesting insect. The order of the weight loss recorded for these varieties was Yellow Mangu Jos > Acr.91-SUWAN-1SRC$_1$ > Western yellow > Oba Super I > Oba Super II > Yellow Popcorn > TZESR-W> Acr.89-DMR-ESR-W and Acr.97-TZL > BR 9928-DWR-SR-Y. Considering the level and quantity of frass generated by this pest, there appeared to be no clear trend in the values, although, Yellow Mangu Jos was the most damaged.

Table 2: Performance of P. truncatus strains on the ten maize varieties in a choice test.

S/NO	Variety	Weight Loss (%)	Grain Damage (%)	Frass(g)
1	Oba Super I	2.2	3.9	0.1
2	Oba Super II	1.2	3.9	0.2
3	Western Yellow	2.7	6.5	0.2
4	Acr.89-DMR-ESR-W	0.3	1.3	0.02
5	Acr.97-TZL	0.3	0.7	0.02
6	TZESR-W	0.4	0.5	0.01
7	Acr.91-SUWAN-1SRC$_1$	5.9	5.0	0.3
8	BR .9928 –DWR-SR-Y	0.0	0.0	0.0
9	Yellow Popcorn	1.0	0.8	0.03
10	Yellow Mangu Jos	7.3	22.5	1.5
	Mean	2.13±0.8	4.51±2.1	0.24±0.1

Means of three replicates (**±s.e)**, LSD= 5.61; F= 2.031; df= 9/20; $P< 0.02$

The mean developmental period of *P. truncatus* strains on the different maize varieties is shown in Table 3. The developmental period of the Ibadan strain on the highly susceptible Yellow Mangu Jos was lowest (40.0±0.6 days) followed closely by the Enugu strain (40.7±0.7 days). *P. truncatus* from Benue and Ghana had longer mean developmental periods on the same variety, 45.3±0.3 and 47.0±0.0 days respectively (Table 3). On the highly resistant variety, BR.9928-DWR-SR, there was no F_1 emergence indicating that there was no development of the insect on it. Thus no damage was recorded on this variety. It is interesting to note that no strain of *P. truncatus* from all the locations could develop on this variety. Statistical analysis showed that there were significant differences ($P< 0.012$) in the developmental periods of the insects.

Table 3: Developmental Periods (days) of P. truncatus from different locations on the ten maize varieties.

Variety	Enugu	Ibadan	Benue	Ghana
1.Oba Super I	44.0±0.6	45.0±0.6	48.0±0.6	49.3±0.3
2.Oba Super II	40.3±0.3	41.3±0.3	48.0±0.0	49.7±0.3
3.Western Yellow	41.3±0.3	41.7±0.3	50.3±0.3	50.7±0.3
4.Acr.89-DMR-ESR-W	48.0±0.0	46.0±1.1	50.0±0.0	0.0±0.0
5.Acr.97-TZL	48.3±0.3	47.0±0.0	48.7±0.7	0.0±0.0
6.TZESR-W	50.0±1.1	0.0±0.0	0.0±0.0	50.0±0.0
7.Acr.91-SUWAN-1SRC$_1$	43.0±0.0	44.0±0.0	45.3±0.3	46.3±0.3
8.BR .9928 –DWR-SR-Y	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
9.Yellow PopCorn	0.0±0.0	0.0±0.0	50.3±0.3	50.7±0.8
10.Yellow Mangu Jos	40.7±0.7	40.0±0.6	45.3±0.3	47.0±0.0

Means of three replicates (± s.e), LSD= 26.58; F= 2.956; df= 9/30, $P< 0.05$

It is also interesting to note that the Ghanaian strain was unable to develop on varieties Acr.97-TZL COMP 4^C and Acr.89-DMR-ESR-W. Similarly, the Ibadan and Benue strains could not develop on variety TZESR-W, while the Enugu strain as well as Ibadan strain did not develop on Yellow Pop Corn. For the rest of the varieties, there was no significant difference (LSD value of 26.58) in the developmental periods of all strains of the insect.

Table 4: Performance of P. truncatus from different locations in no-choice test

Geographical Zone	Mortality (%)	F_1 progeny	Population density	F_1body weight(mg)	F_1body size(mm)	Developmental Period(days)
Enugu	39.3	2.7	8.8	2.8	0.33	35.5
Ibadan	53.0	2.8	7.0	3.4	0.35	30.5
Benue	59.7	2.0	6.7	2.5	0.28	38.6
Ghana	59.0	1.5	5.6	1.4	0.23	34.4
Mean	52.75±4.7	2.25±0.3	7.03±0.7	2.53±0.4	0.32±0.03	34.75±1.7

Means of three replicates (**±s.e)**, F= 0.025; df= 3/20; *P*> 0.05 (Not significant)

The general performances of *P. truncatus* from different geographical locations in a no-choice and choice test were presented in Tables 4 and 5 respectively. A careful examination of the indices used in determining their performance shows there were differences between the strains of *P. truncatus* from Ghana and those from Nigeria. Comparing the strains from the three geographical locations of Nigeria, *P. truncatus* from Ibadan appears to be more damaging to the maize grains than those from Enugu and Benue. However, statistical analysis showed that these strains were not significantly different from each other (*P*> 0.05). The mean body weights and body size of newly emerged F_1 adults of *P. truncatus* strains from different locations were recorded and presented in Table 4. The mean body weight of the insect strains from Enugu, Ibadan, Benue and Ghana were, respectively, 2.8±0.03 mg, 3.4±0.03 mg, 2.5±0.02 mg and 1.4±0.03 mg. The Ibadan strain was significantly heavier (3.4± 0.03 g) than the others. This was followed by the Enugu strain while the Ghana strain was very small (1.4±0.03). The body size of insects from these locations were also showed similar trend.

Table 5: Performance of P. truncatus from different geographical locations in a choice test.

Geographical Zone	Weight Loss (%)	Grain Damage (%)	Frass(g)
Enugu	2.7	3.8	0.2
Ibadan	2.9	6.9	0.4
Benue	2.3	3.7	0.2
Ghana	1.2	3.5	0.2
Mean (±s.e)	2.28±0.4	4.48±0.8	0.25±0.05

Means of three replicates (±s.e**)**, F= 0.340; df= 3/8, *P*> 0.05 (Not significant)

The Ibadan strain was larger (0.35±0.1) followed by Enugu (0.33±0.1), Benue (0.28±0.1) and Ghana (0.23±0.06) respectively.

Discussion

The performance of *P. truncatus* on the maize varieties under investigation was determined using some indices. In this study, three strains of *P. truncatus* from three geographical zones of Nigeria and a strain from Ghana did not survival equally well or develop at the same rate on the different maize varieties. There were significant differences between these strains in terms of their relative mortality, population density of adults, body size, body weight, developmental period and other parameters. This is in line with the study by [10] that three strains of *Callosobruchus maculatus* from Brazil, Nigeria and Yemen Arab Republic did not survive at the same rate on resistant cultivar of cowpea using some of these indices. However, the strain from Ibadan consistently was found to perform better than other strains. This strain recorded higher F1 body weight and body size compared to other strains. This agrees with the study by [11] on the phenotypic comparison of egg to adult life history traits between Costa Rican and Togolese strains of *P. truncatus*, who reported differences in egg weight and body weight at emergence with the heavier Costa Rican strain ovipositing heavier eggs.

There was also significant difference between the strain from Ghana and the Nigerian strains. It is also believed that an insect's status as a pest may change in response to changing environmental conditions [12]. The Ghanaian strain in the present study though reported to be serious pest of maize in Ghana as observed by [13] that the relative economic losses suffered by three varieties of maize, Abutia, Abeleechi and Dzolokpuita were 21.1%, 21.5% and 19.4% respectively when stored for 8 months. This strain from Ghana however, could not perform relative to the Nigerian strains. However, the Ghanaian strain owing to its small size as observed in the study could bore some maize varieties with small sized seeds and as such cause reasonable damage. Also considering the fact that different countries or regions have their peculiar climatic conditions, these insects continue to adapt in response to changing environmental conditions. It is therefore possible that the Ghanaian strain though small in size compared to those from Nigeria competed favourably as to feed and cause considerable damage to some maize varieties from Nigeria due to its adaptation to the conditions under which they are subjected to.

Development of any insect from larva to adult is dependent on a number of factors, which may be related. Factors such as temperature, humidity, the nature of food, etc. are known to affect to a large extent, the development of insects. Although there is an optimum value for each insect species, varying conditions affect the development of each insect species. The development of *P. truncatus* according to [14] was found to be temperature and humidity dependent. The life cycle of this beetle can be completed within 25 to 26 days at optimum conditions of 30 °C, 70% relatively humidity, 13% grain moisture content [5]. In the present study, the developmental period of *P. truncatus* at the temperature range of 29-36 °C, relative humidity of 51-85% and moisture content of 8.0-10.5% was about 40- 50.3 days. This could be attributed to the low moisture content and probably the nature of the maize varieties. Most other authors used maize on cobs and this insect tends to develop faster on cobs than on shelled maize.

The discrepancies in the developmental period observed in this study contrary to reports by [5] may also be due to differences in the environmental conditions. Similarly, [15] observed that lower humidity resulted in increase in developmental period and mortality of 20.2 days and 13.3% respectively. Further substantial reductions in moisture according to him, may considerably limit the pest and at 32 °C and 40% RH in maize flour, *P. truncatus* completed development in an average of 38.1 days and suffered 40% mortality. [14] reported that the developmental period from egg to adult lasts for only 27 days at

32ºC and 80% r.h. The development of *P. truncatus* was reported to be more rapid on maize at 27 ºC and 70% RH than on cassava [15] hence, the mean developmental period on maize and a block of cassava took 32.5 days and 40 days respectively [16].

The study has established that *P. truncatus* from different geographical zones did not developed and perform equally well on different maize varieties. Effort should be made to establish the molecular basis for differences in the performance of different strains of *P. truncatus* and the effect of different temperature and humidity regimes (controlled conditions) on the development of *P. truncatus* from different geographical zones.

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