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**ORIGINAL RESEARCH ARTICLE**

# FABRICATION OF PROBE TRAP FOR MONITORING COWPEA WEEVIL INFESTING STORED COWPEA

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## ABSTRACT

Insect probe traps are effective in detecting grain insects but neglected because it is time consuming and precise method of interpreting the catch have not been adequately specified. Interestingly, this is not readily available in Nigeria and where available, it is expensive due to foreign exchange rates. Therefore, there is need for a locally available and more acceptable insect probe trap for integrated pest management practice during postharvest handling of cowpea. Locally sourced materials were used to fabricate a probe trap for monitoring *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) infesting stored cowpea. The fabricated probe trap was evaluated together with a standard probe trap. Treatments were repeated three times, and also tried in three different insect densities (3, 7 and 15 insects per kg respectively) artificially infested into 10 kg cowpea grains contained in plastic storage buckets, and traps were inspected after every 24 hours for five days. The probe trap was also evaluated in 100 kg cowpea sample contained in sack bag to determine the effect of grain volume on the performance of the trap. Data collected were subjected to ANOVA and means were separated using Student Newman Keuls test (SNK) at 5 % confidence level. The result of total trap catches revealed that the fabricated traps' mean catch (36.6) was significantly ($P \leq 0.05$) higher than the standard probe trap which had lower trap catch mean (12.7) value. Thresholds for management decisions were also determined and the fabricated trap was found to be economically profitable (₦ 936.75 cheaper); hence, objectives of the study were achieved. It is recommended for cowpea handlers in Nigeria to use the fabricated insect probe trap because it is effective in monitoring beetles, it is less expensive and also locally available.

## 1.0 Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is a popular leguminous crop in Africa which is commonly known as beans, *ewa* (Yoruba), *agwa* (Igbo), or *wake* (Hausa) in Nigeria. The grain is rich in protein and other micronutrients necessary for healthy living. Many societies endowed with cowpea have evolved different ways of utilizing the grain for food and perhaps the reason for the coinage "*naman talaka*" (poor man's meat) by Hausas of West and

Central Africa (Institute for Agricultural Research Policy Brief, 2012). Rapid progress has been made in production research related to this crop, particularly since the establishment of the Grain Legume Improvement Program at International Institute for Tropical Agriculture and the strengthening of the research program for grain legumes in a number of West African Agriculture Research Centres (Ajeigbe *et al.,* 2008). Nigeria produces more than two million tons (Adeola *et al.,* 2011) which represents 58 % of the total world cowpea production annually (Peace, 2015). The crop is seen as a major cash crop by Central and West African farmers, with an estimated two hundred million (200,000,000) people consuming cowpea on a daily basis (Langyintuo *et al*., 2003). According to Langyintuo *et al*. (2003), at least two hundred and eighty five thousand (285,000) tons of cowpea is shipped among countries in the African region each year.

The drive to reduce post harvest loss of crops has been great. This is attributed to increasing world population, which is a threat to future global food security. In view of this, Food and Agricultural Organization has indicated the need to reduce post harvest losses in order to ensure future global food security (FAO, 2013). Cowpea bruchid, *Callosobruchus maculatus* (F) (Coleoptera: Chrysomelidae) is a cosmopolitan pest that causes considerable economic damage to dried cowpea and other related stored legumes Kingsolver, (2004), and is the main constraint to increased cowpea production and storage (Carlos, 2004). Similarly, Carlos (2004) also stated that unprotected cowpea grains are often completely consumed by bruchids in the first 10 to 12 months of storage. *C. maculatus* multiplies rapidly in storage, giving rise to a new generation every month in grains at temperature of 30 to 35 °C and 70 to 90 % relative humidity (RH) (Fatima *et al*., 2016). Grains attacked by the bruchids losses some weight, nutritional composition, and viability, which makes them unfit for use as food or seed (Sarwar, 2015). Currently, emphases on the management of pests such as cowpea bruchid rely upon a combination of methods (Integrated Pest Management) which are environmentally friendly to offer effective management (Lester, 2006). According to Christian and William (2011), inspection during storage is an important component of Integrated Pest Management (IPM) which prevents losses during storage. Stored product entomologists have a variety of new monitoring and decision making procedures which changes as grain and grain products move from field to consumers (Hagstrum and Flinn, 2014).

Insect probe trap, originally conceived by Loschiavo (1975) is a type of pitfall trap which is buried in grains and it catches insects which drop through small pitfall apertures into the trap (Anugwom *et al*., 2017). The device exploits the wandering behavior of the insects which help in timely detection of insects in stored produce leading to timely control (Michael and Christian, 2012). This trap is a hollow metal plate tube with a series of perforations (holes) all along the sides (Anugwom *et al*., 2017). The top is a cap, and the bottom is a cone-like translucent plastic that screws in place. It is very effective in detecting beetles that move readily in grains and different designs of the insect probe trap have been made. The trap catches depends on the insect population present in samples, i.e. if insect density is low the trap may take longer time to trap insects, which makes its use to be neglected and also underestimated because there is no precise method for interpreting the trap catches (Toews and Phillips, 2002; Flinn *et al.* 2009 and 2010; Cuperus *et al*., 1990).

Unless improved probe traps are introduced together with a strategy for their use in commercial grain storage practice, the potential benefits of any new technique will be lost. However, Marianne and Rebecca (2011) reported that light is an important component in the environment of insects, which according to Adriana and Lars (2001) is due to visual stimuli. Light may act as a token stimulus guiding the insect to situations where it may find the optimal requirements for existence Arnold *et al.,* (2016), insects' response to light in most cases is to the intensity of the light (Ashfaq *et al*., 2005). Therefore, light lures/repellants can be useful in the practice of IPM, in order to limit the use of toxic insecticides during storage of grains (Dadmal and Suvarna, 2014). In order to modify this important IPM tool in the form of locally available and more acceptable among grain handlers, some locally sourced material were used to fabricate a probe trap (Mbogo, 2013). According to Anugwom *et al.* (2017), ambient/natural light lure can improve the performance of perforated insect probe trap for monitoring *C. maculatus* infesting stored cowpea. Therefore, ambient light source was created on the cap of the newly designed probe trap as cap window to lure insects to the trap.

Farmers are faced with a lot of problem in monitoring insect pests in stored cowpea. Insect specimens collected with probe traps are undamaged and so are good for research purpose. The standard probe trap is used to monitor *C. maculatus* infestations in stored cowpea but it is not efficient in trapping the insect due to variation in atmospheric conditions, leading to inappropriate management decisions regarding the action threshold. The standard probe traps is also scarcely available in Nigerian markets, and are unknown to grain handlers; even where available, it's expensive due to high rate of foreign exchange. The standard probe trap with 3 mm perforations is specific to *C. maculatus* which cannot be used for other larger bruchids like *Callosobruchus subinotatus,* infecting cowpea. Thus, there is the need for a probe trap that can be used to monitor all insects infecting stored cowpea. Furthermore, since the insect probe trap can be fabricated from locally sourced materials, waste can be converted into wealth.

The objective of this Study was to fabricate a probe trap for monitoring *Callosobruchus maculatus* using locally sourced materials, determine the thresholds for management decisions during postharvest handling of cowpea, and assess the cost benefit of using the locally fabricated probe trap.

## 2. Materials and Methods

### 2.1 Research Location

Fabrication and evaluation of the performance of the modified probe trap on *C. maculatus* infesting stored cowpea was conducted in the Entomology Laboratory of Nigerian Stored Products Research Institute (NSPRI), Kano Sub-Station (Coordinate 11°30'N, 8°30'E) Nigeria, between March 2016, to October 2016, at average temperatures of 29 ± 3 °C and 52 to 75 % relative humidity.

### 2.2 Trap Development

### *2.2.1. Materials for fabrication of probe trap*

Materials used to fabricate the trap included; Anvil, Bench-vise, work/vise bench, 1 mm plumbing sockets; threaded male, threaded female and plain respectively, plastic cone (cosmetic container), sand paper, scissors, saw-blade, plastic gum, glue gum, screw driver, measuring tape, plastic materials, plastic funnel, hammer, chisel, steel pipe (1 mm), perforated steel plate (from obsolete automobile silencers and heavy duty equipment casings), needle/office pins, knife, iron sponge, wood-ash, soap and water.

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### 2.2.2. Fabrication and Assembly

Perforated steel material obtained from obsolete automobile parts were first de-coupled using chisel, hammer and anvil, and were straightened back into a flat plate, washed with wood-ash, iron sponge, soap and water to remove rusts. A dimension of 12 x 9.5 cm was measured and cut out using a measuring tape, hammer and chisel. The measured plates were then rolled into cylindrical shape using steel pipe, hammer, bench-vise and anvil. Funnels of desired shapes and sizes were cut and glued to the threaded male plumbing socket, to make up the trapping chamber (funnel/tunnel). On the other hand, the threaded female socket was fitted to the plastic cone using glue gum to form the reservoir. About 31.84 mm diameter circle marked out from transparent plastic material was glued to the plain socket at depth of 1.7 cm, forming the cap window of the trap (Anugwom *et al.*, 2017). The fabricated components of the trap are presented in Figure 1.

**Figure 1:** Uncoupled parts of the fabricated trap

Coupling was done by fixing the threaded male socket having the funnel with plastic gum to one end of the perforated steel cylinder, while at the other end; the plain socket with transparent plastic (cap) was fixed with gum. After gum had dried, the threaded female socket (receptacle/reservoir) was screwed to the male socket (funnel) on the perforated probe body to complete the coupling procedure.

### 2.2.3 Trap description

Unlike the standard probe trap, the cap of the newly developed probe trap is lighted to enhance the attraction of insects to the trap. Like most other perforated probe traps, the bottom is cone-shaped with an elongated steel cylinder made up of 4 mm diameter perforations to allow the entry of cowpea weevils but precluding the grains. Trapped insects will pass through the funnel into a detachable reservoir from where they can be disposed. The trap assembly and modified cap are shown in Figures 2 and 3, respectively.

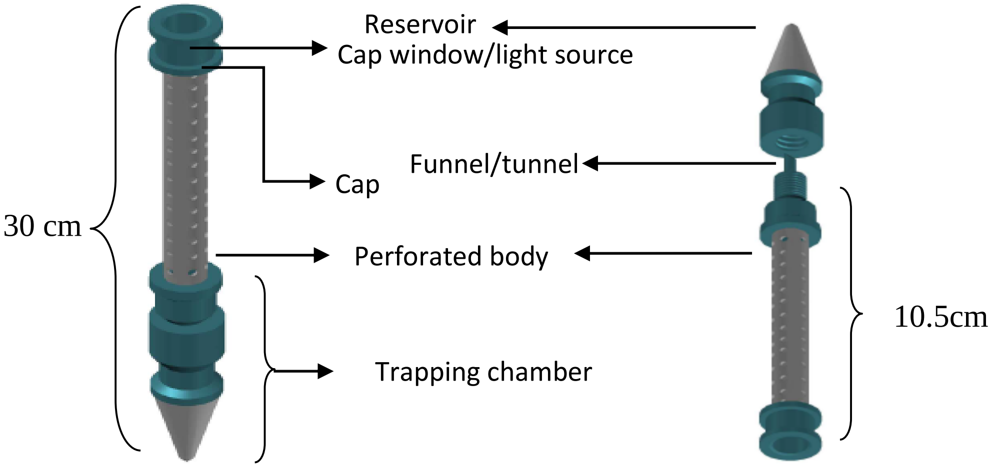

**Figure 2:** Components of the fabricated insect probe trap

**Figure 3:** Modified cap of an insect probe trap for monitoring cowpea beetle

The trapping chamber (receptacle/reservoir) is large, making it appear as a tunnel as well as a pit inside, which prevents captured insects from escaping (Lochiavo, 1975; Neethiraja *et al.,* 2007; Anugwom *et al.*, 2017).

### 2.3. Research Materials

The experimental materials used in evaluating the performance of the modified trap and the standard check trap were: Cowpea grains (*Kananado* variety), cowpea bruchids (0 – 24 hours of emergence), moisture analyzer (OHAUS MB25®, USA), illuminance meter (Konica-Minolta® T10, Japan), digital probe thermometer (HANNA® instruments, USA), digital thermo-hygrometer (BRESSER® meade instruments Europe), digital calliper, freezer (Thermocool), kilner jars, weighing scale (CAMRY, NT-100 kg), sack bags, polyethylene bags, ropes, probe traps (Standard check and modified/locally made), insect aspirators, insect collection bottles, storage buckets (34 cm depth with 1037.1 mm body diameter), and clock.

### 2.4. Evaluation of Light Sources

Illuminance meter (Konica-Minolta® T10, Japan) was used to determine the intensity of light illuminating through the cap of the fabricated probe trap from the ambient and the result was recorded in Lux. The average illuminance intensity of the light source within 24 hours period in the laboratory environment was determined to be 14.30 Lx.

### 2.5. Procurement and Disinfestations of Cowpea Grains Used for the Experiment

Cowpea grains (900 kg) collected in sealed polyethylene bags were bought from Dawanau grain market, Kano, Nigeria and disinfested by freezing at -20°C to -24°C for 72 hours to keep the sample free of insects (Judy and Karen, 2000; Patrick, 2013; Anugwom *et al.*, 2017). After three days, the grains in sealed bags were removed from the freezer and left under ambient conditions for 27 hours to prevent condensational effect on the seeds before use.

### 2.6. Determination of Moisture Content of Cowpea Grains Used

Determination of moisture content of grain was done before and after the experiment using the moisture meter (OHAUS MB 25) according to Mettler (2016) to ascertain if the grain moisture level was affected due to artificial infestations or abiotic conditions; and moisture content of cowpea grains used was determined to be 13.9 % before and 14.1 % after the experiment.

### 2.7. Insect Culture

Adults of *C. maculatus* were collected from an existing pure culture in Entomology Laboratory of NSPRI, Kano. Clean cowpea grains were disinfested using the cold shock method, to exterminate any insect contamination on the grains prior to culturing of the beetles. The stock culture of *C. maculatus* were raised by paring 50 adults (male and female

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respectively) in each two-liter kilner jar containing 2 kg of disinfected cowpea and numbering five jars to mate and oviposit. The kilner jars (cultures) were covered with netted cover to prevent the bruchids from escaping. The jars were left to stand for about 30 days until adult emergence under prevailing laboratory conditions with temperature ranging from 29°C – 35°C and relative humidity of 52 to 75 %. Freshly emerged adult beetles (0 to 24 hours old) were sieved out, with stipulated numbers counted using the aspirator and placed into labeled collection bottles, for artificial infestation.

## 2.8. Trial of the Modified Trap Using 10 kg and 100 kg Cowpea Sample

A total of two treatments were used which include the fabricated probe trap and a standard check probe trap, each treatment was repeated three times, and in three different insect population densities (3 insects per kg, 7 insects per kg and 15 insects per kg) which were tagged; low, medium and high densities respectively and labeled accordingly. The bruchids were artificially infested into a 10 kg weight of cowpea grains contained in plastic storage buckets (34 cm depth and 1037.1 mm body diameter). The modified trap alone was also evaluated on 100 kg weight of cowpea grains contained in sack bags and artificially infested with three different bruchids population densities (as above), and was repeated three times and labeled accordingly. Traps were inspected every 24 hours for five days in both trials and data collected were recorded for further use.

### *2.8.1. Barrier control*

In order to prevent insects from either leaving or entering the samples, barrier was created, while considering the working conditions. The storage bucket covers were re-constructed for easy insertion and removal of the trap from samples without having to open the covers completely during trap use; such a container also ensured the vertical placement of traps as required for its functionality as well as preventing insects crossing samples (Anugwom *et al.*, 2017).

The buckets were grey in colour, and resistant to passage of ambient light which prevents insects from being disturbed by ambient light or movement of persons/objects. Also, samples in sack bags were stacked in vertical position on pallets and tied to the base of traps' cap with the trap in top/centre position, leaving the cap of the trap above to receive ambient light.

### *2.8.2. Experimental layout*

All the traps (18) used for the study were coded and labeled base on trap type and population density of the insect infested. Insect collection bottles containing the three different insect densities were labeled as: L, M, and H for low, medium and high insect densities respectively. Plastic storage buckets as well as sack bags used were also labeled in-line with the insect collection bottles "L, M, and H" respectively for easy application of treatments.

Samples after artificial infestation were arranged in Complete Randomized Design (CRD) format on laboratory benches, while on the other hand, 100 kg samples were stacked on pallets in vertical position on the laboratory floor.

### *2.8.3. Use of traps*

Traps were pre-assigned (labeled) to treatment levels, and then arranged on the laboratory bench for easy allocation to cowpea samples and data collection. Traps were first inspected for any residual sample or other contaminants, cleaned, screwed and inserted vertically into the grains through the circular window (for 10 kg samples) created on the storage buckets'

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cover. The traps' body was inserted vertically into the grain bulk excluding the cap of the traps, at grain depth of 26 cm (modified traps), and 21 cm (standard check probe trap). While in the case of 100 kg sample, traps were inserted leaving the cap above the sack bag and bag was tied to the base of traps' cap to receive ambient light.

#### *2.8.4. Inspection of traps*

Traps were inspected hours directly after every 24 h for 5 days, they were pulled out from the sacks or buckets and gently hit on a hard surface while still in vertical position to ensure trapped insects were in captured position, before un-screwing to inspect. Considerations were made in keeping insects in place during inspection of trap catch each day, water was also used to wet trapped insects in the reservoir before they were discharged and counted. Traps after inspection each day were cleaned and returned into the grain samples for another run.

### 2.9. Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using the SAS (2000) statistical package, version 9.0 and means were separated using the Student Newman Keuls Test (SNK) at 5 % confidence level. Correlation analysis was done to determine the relationship in trap catches between trapping duration and population density, trapping duration and grain volume, and population densities and grain volume.

### 2.10. Cost Benefit Analysis

Profitability of fabricating the insect probe trap was measured in terms of gross margin and net profit in order to ascertain the economic effectiveness of fabricating the probe trap locally (Firth, 2002).

## 3. Results and Discussion

### 3.1 Fabricated Trap and its Components

The newly fabricated probe trap has a transparent cap window as light lure (Figure 3), perforated body made of steel from obsolete automobile silencers, and other body parts made from locally sourced plastic materials as shown in Figures 4 and 5. Improvised plastic materials and other components used in fabricating the trap were of the desired dimension and shape, and as such fitted well.

**Figure 4**: Locally made probe trap for monitoring *C. maculatus* infesting stored cowpea

The probe body of the trap has a pointed end made from cosmetic containers, beneath which is the trapping chamber made of plastic funnel. The plastic funnel is lengthy, appearing as tunnel inside, and the reservoir which is 12.5 cm deep, is also detachable (Figures 5 and 6).

From the results, the insect probe trap fabricated from locally sourced material was able to trap *C. maculatus* in stored cowpea. The perforation size chosen could permit entry of *C. maculatus* (3 mm) and other pulse insects of 4 mm and below in size, while also precluding entry of cowpea grains into the trap (Anugwom *et al.*, 2017). Which means the trap can be used to detect other pests of cowpea like *C. subinotatus* which is 4mm in size. The differences between standard and modified traps are presented in Table 1.

**Table 1:** Variations between the Modified Trap and Standard Trap

| Trap part | Standard trap | Fabricated trap |
|---|---|---|
| Trap body diameter | 28.49 mm | 31.84 mm |
| General length of trap | 22.5 cm | 30 cm |
| Length of perforated part | 12.5 cm | 10.5 cm |
| Perforation size | 3 mm | 4 mm |
| Length of trapping chamber | 8.3 cm | 15 cm |
| Length of funnel/tunnel | 4.3 cm | 10 cm |
| Size of reservoir | 6.8 cm | 12.5 cm |
| Cap length/design | 1.3 cm, no cap window | 4.4 cm, with cap window |
| Weight of trap | 51.5g | 154.7g |

The difference between the funnel/tunnel and trapping chamber of the modified and standard check traps were as presented in Figures 5 and 6 respectively.

**Figure 5:** The funnel/tunnel of the locally made probe trap

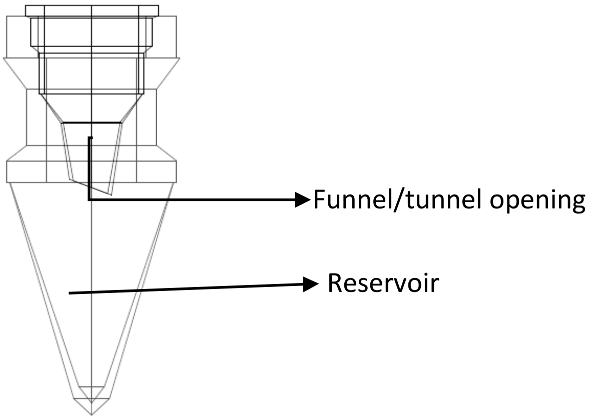

**Figure 6:** Schematic illustration of fabricated trapping chamber

The modified probe trap has an increased trapping chamber (both in size and length) with a cone-like end. It has a long funnel, which enables the discharge of bruchids into the reservoir as required and as well, prevents their escape from the reservoir. The reservoir is large, resembling a pit inside, while the trapping chamber (funnel) is like a tunnel inside, which means the modified trap can carry larger number of insects. Because the reservoir was

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detachable, and cone-like, it was easier for the traps to be inserted and withdrawn from grains as well as inspection/disposal of trapped insects. The locally fabricated trap was similar to the standard and it is in conformity with the designs described by Anugwom *et al.* (2017).

## 3.2 Daily Trap Catches

The result of daily trap catches presented in Table 2, showed that at day one, the locally fabricated trap had the best trap catch mean (21.0) and was significantly higher ($P \leq 0.05$) than the standard check traps' mean catches. The fabricated trap was also the best mean (8.2) on day 2; it was significantly higher than the standard probe trap mean catch (3.2). At day three, the fabricated trap was higher and significantly different from the standard probe trap. On day four and five, the fabricated trap was higher but similar ($P \geq 0.05$) to the standard probe trap.

**Table 2:** Daily Trap Catches

| | Trapping Days | | | | | |
|---|---|---|---|---|---|---|
| Treatments | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | TOTAL |
| Insect Densities | | | | | | |
| High density | $25.3^{a}$ | $9.0^{a}$ | $5.2^{a}$ | $3.2^{a}$ | $3.3^{a}$ | $46.0^{a}$ |
| Medium density | $8.5^{b}$ | $5.8^{b}$ | $2.0^{b}$ | $1.2^{b}$ | $1.2^{b}$ | $18.7^{b}$ |
| Low density | $4.8^{c}$ | $2.3^{c}$ | $1.0^{b}$ | $0.5^{b}$ | $0.5^{b}$ | $9.2^{c}$ |
| SE ± | 0.95 | 0.88 | 0.74 | 0.42 | 0.59 | 1.35 |
| Trap Types | | | | | | |
| Fabricated | $21.0^{a}$ | $8.2^{a}$ | $3.8^{ab}$ | $2.0^{a}$ | $1.6^{a}$ | $36.6^{a}$ |
| Standard | $4.8^{b}$ | $3.2^{c}$ | $1.7^{b}$ | $1.2^{a}$ | $1.8^{a}$ | $12.7^{c}$ |
| SE ± | 0.78 | 0.72 | 0.60 | 0.34 | 0.48 | 1.10 |
| Density * Trap | ** | NS | NS | NS | NS | ** |

Means with the same letter are not significantly different at 5 % level of significance using SNK.

Trap catches were decreasing as days goes because insect densities were been reduced by the trap on daily bases, which supports findings by Toews and Phillips (2002). The fabricated probe trap was quick to reduce insect populations from samples because it is readily visible and the insects find it attractive which was in accordance with findings by Ashfaq *et al. (*2005) who reported that insects are attracted to lights. The standard probe trap became similar to the modified trap on the fourth and fifth days because samples containing the standard probe trap had more un-trapped insects during these days compared to the modified probe traps' samples with most of its insect already trapped, which supports Toews and Phillips (2002) and Michael and Christian (2012) who reported that trap catches are affected by insect density and trapping duration.

## 3.3 Day One Trap Catches at Different Population Density

The result of trap catches at different population densities on day one is shown in Table 3. The results showed that at high insect population density, the fabricated probe trap had high trap catch mean value (43.0) and significantly ($P \leq 0.05$) higher than the standard check traps' mean catch (7.7). In medium insect density, the fabricated trap was the best mean and significantly different from the standard check probe trap. At low bruchids population density, the locally fabricated trap was the best mean but it was similar ($P \geq 0.05$) to the standard probe tr

**Table 3:** Interactive Effect of Trap Type and Population Density on Number of Insect Catches on Day One

| Treatments | Population Densities | | |
|---|---|---|---|
| Trap Types | High | Medium | Low |
| Fabricated | 43.0$^{a}$ | 12.7$^{b}$ | 7.3$^{c}$ |
| Standard | 7.7$^{c}$ | 4.3$^{c}$ | 2.3$^{c}$ |
| SE ± | | 1.35 | |

Means with the same letter are not significantly different at 5 % level of significance using SNK.

The fabricated trap caught relatively higher number of cowpea weevils compared to the standard probe trap on the first day because of modifications (i.e. cap window, perforation size and total size of trap) which was designed to improve the performance of the trap (Anugwom *et al*., 2017). Which means that the modified probe trap was improved compared to the standard check probe trap in early detection of *C. maculatus* in stored cowpea.

### 3.4 Effect of Modifications on the Fabricated Probe Traps performance

The result of total trap catches presented in Table 2 revealed that the fabricated traps' mean catches (36.6) was significantly ($P \leq 0.05$) higher than the standard probe trap which had lower trap catch mean value of 12.7.

The fabricated trap was improved in detecting cowpea weevils; this means that introduction of ambient light source was effective in improving the probe trap for early detection of *C. maculatus* infesting stored cowpea. Findings by Ashfaq *et al.* (2005); Dadmal and Suvarna (2014) and Anugwom*et al.* (2017), described that insects (Coleopterans) are attracted to light and this according to Adriana and Lars (2001); Arnold *et al.* (2016) was due to visual stimuli.

### 3. 5 Evaluation of Trap Catches at Different Population Densities

The result of trap catches at different population density is illustrated in Table 4. The result showed that at high insect population density, the fabricated probe trap had high trap catch mean value (71.7) which was significantly different from the standard check probe trap which had the least mean catch (20.3).

At medium bruchids population density, the fabricated trap had mean trap catch of 25.3, which was significantly ($P \leq 0.05$) higher than the standard check traps' mean catch (12.0).

Under low bruchids population density, the fabricated trap had mean catch of 12.7 which was similar ($P \geq 0.05$) to the standard check trap which had lower mean catch of 5.7.

**Table 4:** Interactive Effect of Trap Type and Population density on the Total Number of Insects Caught by Probe Traps

| | Population Densities | | |
|---|---|---|---|
| Trap type | Low | Medium | High |
| Fabricated | 38 (12.7)$^{d}$ | 76 (25.3)$^{b}$ | 215 (71.7)$^{a}$ |
| Standard | 17 (5.7)$^{d}$ | 36 (12.0)$^{d}$ | 61 (20.3)$^{cd}$ |
| SE ± | | 1.91 | |

Note that values in parenthesis are the mean value and means with the same letter are not significantly different at 5 % level of significance using SNK. The modified probe trap was improvement upon and at variance with the standard probe trap catches in the highly

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populated treatment. This can be attributed to presence of light which attracted the insects as supported in findings by Arnold *et al.* (2016). This means that the locally fabricated probe trap was improved in detecting cowpea bruchids in stored grains due to introduction of ambient light source

### 3.6 Correlation of Trap Catches between Trapping Duration, Population Density, and Volume of Grain

The results (Table 5) showed that the correlation between trapping duration and population density was negative, and the correlation between trapping duration and volume of grain was also negative, while the correlation between population density and volume of grain was positive.

Which means that irrespective of population density trap catches were affected by trapping duration and it was contrary to the findings by Cuperus *et al.* (1990) who reported that trap catch increased with increase in trapping duration, and this can be attributed to differences in experimental methods used; either because insect densities were been reduced by the modified trap on daily basis (Michael and Christian, 2012) or the insects were becoming less active with time (Kingsolver, 2004) or due to mortality of the bruchids with increase in time (Michael and Christian, 2012). While on the other hand, result of correlation between population density and volume of grain showed that both variables affected trap catches. This was because insect densities were the same per kilogram of grain used in both weights (10 kg and 100 kg). The result supports Toews and Phillips (2002) who reported that probe trap catches are affected by insect density, but was at variance with Flinn *et al.* (2010) whose reports showed that because insect densities are greater at the top and centre of grains and decreasing with grain depth due to temperature effects (Flinn *et al.*, 2009). Probe trap catches are not affected by grain volume. This was because the cowpea weevils trapped were artificially and homogeneously infested in the grain samples.

**Table 5:** Correlation Matrix of Trap Catches between Trapping Duration, Population Density, and Volume of Grain

| | Time | PD30L1 | PD70M1 | PD150H1 | PD300L2 | PD700M2 | PD1500H2 |
|---|---|---|---|---|---|---|---|
| Time | 1 | | | | | | |
| PD30L1 | -0.911** | 1 | | | | | |
| PD70M1 | -0.940** | 0.988** | 1 | | | | |
| PD150H1 | -0.854** | 0.986** | 0.949** | 1 | | | |
| PD300L2 | -0.906** | 0.989** | 0.972** | 0.986** | 1 | | |
| PD700M2 | -0.879** | 0.978** | 0.976** | 0.961** | 0.985** | 1 | |
| PD1500H2 | -0.995** | 0.896** | 0.938** | 0.824** | 0.882** | 0.868** | 1 |

PD (population density), L (low), M (medium), H (high), 1 (10 kg experiment), and 2 (100 kg experiment).

### 3.7 Pest Populations Detected by the Fabricated and Standard Check Probe Traps

The number of bruchids caught by the modified and standard probe traps respectively per day in the different population densities (high, medium and low) was as shown in Figure 7. Thirteen (13) bruchids was the average number caught by the fabricated trap per day in samples with 15 insects per kilogram of cowpea grains, while the standard caught four (4) bruchids per day. In samples with 7 insects per kilogram of grain, the average number of bruchids caught by the fabricated and standard trap per day was 5 and 2 respectively. Also, the average number of bruchids detected by the fabricated probe trap in sample with low

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insect density (3 insects per kg) was 2 per day, while the standard trap caught 1 bruchid per day.

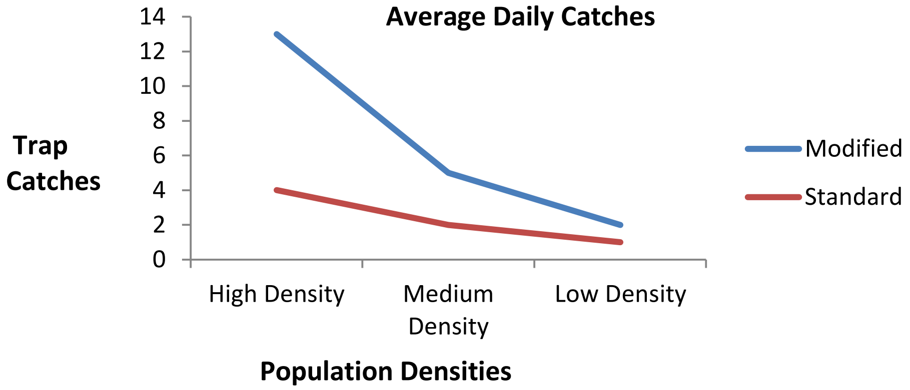

**Figure 7:** Average trap catches per day (24 hours interval trapping duration)

Trap catches of 13 bruchids and above by the modified trap at average temperature of 29 ± 3°C and 52 to 75 % relative humidity indicates that cowpea grains sampled had up to 15 bruchids per kilogram of cowpea grain sampled. Trap catches between 12 and 5 bruchids means that the grain sampled contained up to 7 bruchids per kilogram, while trap catches between 4 and 2 bruchids shows that there are about 3 bruchids per kilogram of cowpea grain sampled.

The result of trap catches by the modified trap in medium insect density according to Hagstrum and Flinn (2014) revealed that the bruchids population was within the economic threshold (ET) or action threshold (AT) where integrated pest management actions should be taken to prevent pest population from reaching Economic Injury Level (Christian and William, 2011). In addition, Hagstrum and Flinn (2014) classified a population as above or below an economic threshold (ET) when ≥ 5 insects are caught per probe trap. Therefore, other population (that is low) with less than 5 bruchids (2 or 1) caught per trap could be sampled again later to determine if the population is increasing for necessary control measures to be initiated (Hagstrum and Flinn, 2014).

On the other hand, the standard trap detected populations below the action threshold (5 insects) in high and medium densities which means the fabricated trap is improved and useful in economic threshold determination of cowpea beetle infesting stored cowpea. From the results, trap catches of 13 bruchids and above under the above mentioned abiotic conditions has reached the economic injury level (EIL) and should be fumigated.

### 3.8 Costs and Benefits of Fabricating the Probe Trap Locally

In carrying out the economic implication of fabricating the probe trap locally and cost of importing the standard check probe trap, the following costs and returns (Table 6) were considered. Most of the tools used can be re-used for other fabrication enterprise so depreciation was, however, not considered in the course of computation.

Total cost of fabricating 63 units of the modified trap was ₦ 111, 510.00, while the cost of importing 63 units of the standard trap was ₦ 170, 526.00. Price per unit of the modified probe trap was ₦ 1 770, while the price per unit standard check trap was ₦ 2 706.75, therefore, the difference in costs between the modified trap and the standard check trap was ₦ 936.75.

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**Table 6:** Cost Benefit Analysis of Locally Fabricated Probe Trap and Standard Probe Trap

| LOCALLY FABRICATED PROBE TRAP | | | | | STANDARD CHECK PROBE TRAP | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **Qty** | **UP (₦)** | **TVC** | **(%)** | | **Qty** | **UP(₦)** | **TVC** | **(%)** |
| Coloured materials | 5 | 500 | 2500 | 2.24 | Traps | 63 | 1738.5 | 109525.5 | 64.23 |
| Iron sponge | 10 | 30 | 300 | 0.27 | - | - | - | - | - |
| Labour | 1 | 25200 | 25200 | 22.6 | - | - | - | - | - |
| Plumbing socket | 189 | 80 | 15120 | 13.56 | - | - | - | - | - |
| Plastic cone | 63 | 50 | 3150 | 2.82 | - | - | - | - | - |
| Perforated plate | 1 | 15500 | 15500 | 13.9 | - | - | - | - | - |
| Plastic funnel | 63 | 50 | 3150 | 2.82 | - | - | - | - | - |
| Plastic gum | 4 | 1200 | 4800 | 4.3 | - | - | - | - | - |
| Sand paper | 1 | 1000 | 1000 | 0.9 | - | - | - | - | - |
| Super glue | 48 | 50 | 2400 | 2.15 | - | - | - | - | - |
| Transparent plastic | 1 | 1890 | 1890 | 1.69 | - | - | - | - | - |
| Transportation | 1 | 5000 | 5000 | 4.48 | Shipping | 1 | 61000 | 61000 | 35.77 |
| Anvil | 1 | 5000 | 5000 | 4.48 | - | - | - | - | - |
| Bench-vise | 1 | 8000 | 8000 | 7.17 | - | - | - | - | - |
| Chisel | 1 | 500 | 500 | 0.45 | - | - | - | - | - |
| Hammer | 1 | 1500 | 1500 | 1.35 | - | - | - | - | - |
| Knife | 1 | 400 | 400 | 0.36 | - | - | - | - | - |
| Measuring tape | 1 | 700 | 700 | 0.63 | - | - | - | - | - |
| Pins/needles | 1 | 100 | 100 | 0.09 | - | - | - | - | - |
| Plastic ruler | 1 | 50 | 50 | 0.04 | - | - | - | - | - |
| Saw blade | 1 | 350 | 350 | 0.31 | - | - | - | - | - |
| Scissors | 2 | 1200 | 2400 | 2.15 | - | - | - | - | - |
| Screw driver | 2 | 500 | 1000 | 0.9 | - | - | - | - | - |
| Steel pipe | 1 | 1500 | 1500 | 1.35 | - | - | - | - | - |
| Work-bench | 1 | 10000 | 10000 | 8.97 | - | - | - | - | - |
| Total cost | 403 (item) | ₦8030 | ₦11150 | 100 | | 64 (item) | ₦6279 | ₦17056 | 100 |
| GR | ₦323810 | | | | | ₦401524 | | | |
| GM | ₦322690 | | | | | ₦384479 | | | |
| RNI | ₦1.90 | | | | | ₦1.35 | | | |

Where TVC (total variable cost), UP (unit price), Qty (quantity per material used), % (percentage cost per variable item), GR (gross revenue), GM (gross margin), and RNI (return per naira investment).

High costs (22.6 %) spent on labour can be attributed to inadequate selection of tools, which increased the amount and price of labour required during fabrication of the modified trap. The plumbing sockets as well as perforated steel plate were the most expensive materials utilized in the fabrication process because while the plumbing sockets were expensive in the local markets, the perforated steel plate was scarcely available.

Analysis of the costs also showed that the gross revenue (GR) and gross margin (GM) for profit was high in local fabrication of the probe trap than importation of the standard check probe trap, with higher return realized per naira invested compared to importing the standard probe trap. This was because locally sourced materials were utilized in the fabrication of the modified probe trap; therefore, cost of transportation was reduced as well as cost of exchange rates (Mbogo, 2013). The results support the findings by Mbogo (2013), showing that fabricating the trap locally is more profitable compared to importing the standard probe trap.

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The locally made probe trap was cheap compared to the standard (imported) probe trap because of high cost of shippment of the standard trap. This means that money was saved from fabricating the trap locally; hence, it is profitable to use the locally made probe trap in monitoring bruchids infesting stored cowpea because it does not depend on foreign exchange rates. Indeed, fabricating the trap locally provided, in important respect, a model of how the subsidiary of locally fabricated tool can promote the development of the economy in which it is embedded which can be emulated and replicated in all developing markets (Mbogo, 2013).

## 4. Conclusions

Based on the findings, the following conclusions were made:

1. The modified probe trap was fabricated using locally sourced material.
2. The light source (cap window) design and use of 4 mm perforations improved the performance of the modified probe trap.
3. The modified probe trap catches of 13 bruchid and above within 24 hours trapping period, at average temperature of 29 ± 3°C and 52 to 75 % relative humidity means the sample has reached the economic injury level (EIL) and should be fumigated. Catches between 12 and 5 is within the action threshold (AT), control measures must be applied to prevent pest populations from reaching the economic injury level. While catches of 2 or < 5 is below the action threshold (AT) and sampling must be done again before a growing brchids population can cause economic losses.
4. The modified probe trap was ₦ 936.75 cheap compared to the standard probe trap and had higher return per naira invested in the fabrication process.

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