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TOWARDS ACHIEVING AN INTEGRATED PEST MANAGEMENT FOR CONTROL OF THE GROUNDNUT BRUCHID (*Caryedon serratus* OLIVIER) ON STORED GROUNDNUTS AND TAMARIND IN YOLA, NIGERIA

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Abstract
An attempt for developing an Integrated Pest Management (IPM) for the control of the groundnut bruchid, *Caryedon serratus* (Olivier) [Coleoptera: Bruchidae] on stored groundnut and tamarind in Yola, Adamawa State, Nigeria was evaluated. The experiment evaluated the different storage methods which were chemical (actellic dust) biological (bio-agent), cultural (plant materials) and controlled atmosphere (air - tight) and the combination of two or more of these methods. Combinations of Chemical + Plant material + air tight gave the highest mean percentage undamaged seeds (95.00 and 95.33), least mean percentage damaged seeds (5.00 and 4.67) and least percentage weight loss (2.33 and 2.00) for both groundnut and tamarind. The plant material, bio-agent and air-tight storage jars also had significant control on the bruchids compared to the control. Results showed that *Mesostena pica* (Kraatz) [Coleoptera: Tenebrionidae] could be used as a biological agent for the control of *C. serratus* in stored groundnut.

Key words: Integrated, Groundnut, Tamarind, Stored, Bruchids.

1. Introduction
Groundnut (*Arachis hypogeae* Linn.) also known as peanut, earthnut, gobbers, pinders, manilanuts, etc. belongs to the family Leguminosae (Fabacea) (Beghnin and Sewadah, 2003). Other members of this family include cowpea, soyabeans, peageon pea, melon etc. (Ashley, 1993). Groundnut originated from South America (Brazil) and was introduced in Nigeria by the Portuguese after the 16th century and its production spread to the Northern part of the country (Adeyemi, 1968). According to him, the crop has become an important cash crop used for export since the colonial era. Its production in Africa has been estimated at 4.6 metric tons, with Senegal, Nigeria, Gambia, Democratic Republic of Congo (DRC) and Sudan being the major producers in Africa (Ashley, 1993). According to Nyilra (1988), Nigerian's production of unshelled nut is about 2.6 metric tons annually from a land area of approximately 2.5million hectares. Groundnut thrives best on a well-drained sandy-loam soil, this type of soil facilitates easy penetration of pegs and their development, hence their harvesting (Yayock, 1984). Weiss (2000) suggested that, temperature range of 25-30^{0}c, rainfall of 500- 1000mm and a pH range of 6.0-6.5 is considered optimum for groundnut production. Groundnut is a major cash crop which serves as a foreign exchange earner prior to the petroleum boom in Nigeria (Adeyemi, 1968). According to Aribisala (1993), the crop is a good source of protein, fats and oil, vitamins etc. Shelled groundnuts are fried, roasted and salted which is eaten as snacks. The crop serves as raw materials for some food industries and also as feed concentrates for livestock (David and Adamu, 1988; Oaya *et al*., 2012). Tamarind (*Tamarindus indica* L.) from the Arabic word tamar, is a tree in the family Fabacea (Hooker, 1991). The genus *Tamarindus* is monotypic that is, having only a single species. It is a tropical tree, native to tropical Africa (Dalton, 1991). The fruit was known to the ancient Egyptians and the Greeks in the 4th century B.C. (Hooker, 1991). The tamarind is a slow growing, long-lived massive tree which reaches the height of 24-30m and may attain a spread of 12m and a trunk circumference of 7.5m under favourable condition (Malton, 1987). The fruits and the pulp are edible and is popular among the villagers. In India, the tamarind seeds are processed into powder used for sizing and finishing cotton and Jute which is certified as 30% efficient and more economical than the cornstarch (Dalton, 1991). In Africa, tamarind has the potential to improve the nutrition status of the people, boost food security and support sustainable land care (Fosberg, 2005). In Nigeria, the seeds are processed and made into 'dawa dawa' and the soaked pulp used as thickening in groundnut and rice pudding or cereal commonly known as 'kunun gyeda' (Dalton, 1991).

Groundnut and tamarind are vulnerable to insect pests attack throughout their growing stages and in store, though the extent of insect damage varies from one agro-ecological zone to the other (Hooker, 1991 Malgwi and Onu,2004). Some of the insect pests of stored groundnut and tamarind are *Tribolium castenium* Herbst, *Trogoderma granarium* Evert., *Ephestia cautella* Walker, *Oryzaephilus mercator* Fauvel etc. In northern Nigeria alone, yield loss of groundnut due to *C. serratus* infestation is estimated at 150,000 - 250,000 tons annually, about 35% loss resulting to several million naira loss to the country (Dick, 1987 and IITA, 2001). No exact figure has been presented as accurate in terms of the degree of infestation of *C. serratus* on stored tamarind. However, Oaya *et al.* (2012) under artificial infestation found that *C. serratus* could give up to 80 and 90 % loss on unshelled and shelled groundnuts respectively within three months of storage. Further to this, 78.68 % loss was also recorded on tamarind within the same period. Both groundnut and tamarind are susceptible to attack by insect pests in store and the degree of susceptibility depends largely on whether or not these stored product are shelled or not and also the extent to which they are damaged before being placed in store (ICRISAT, 1987). Insect pest infestation causes loss in dry mass of the kernels, increased levels of free fatty acids in the oil, thereby lowering the quality, and if the seeds are heavily damaged, germination potential was drastically reduced (ICRISAT, 1987).

The extent of post-harvest losses has prompted several studies of insect population development on groundnut and tamarind in store. However, few or no attempts have been made to measure the degree of losses caused by this insect pest (*C. serratus*) by Dick (1987) either in farmers store or in a large scale commercial storage in India; but in Nigeria, except what Edan (2000) and Oaya *et al*. (2012) documented as stated earlier. Consequently, there is inadequate information on appropriate methods for assessing post-harvest losses especially for tamarind which share the same storage pest with groundnut. Moreover, no work has been done in identifying a bio-agent (biological agent) to control this insect pest, except the one carried out by Edan (2000) on groundnut which was not conclusive. Therefore, it is imperative to look at the different control methods (cultural, chemical, biological, air-tight and their various combinations) with the aim of towards developing an IPM/ integrated control for *C. serratus* which was the main focus of this study.

2. Materials and Methods

2.1 The Study Area

The experiment was carried out in the Laboratory of the Department of Crop Protection, Federal University of Technology, Yola in 2010. The University is located in Sangere Village, Girei Local Government Area, within longitude 9° 14^1 North and Latitude 12° 13^1 East of the equator in the Northern Guinea Savannah agro- ecological zone of Nigeria (Adebayo, 1999).

2.2 Groundnut and Tamarind seeds

The groundnut seeds used were obtained locally from groundnut farmers in the village of the study area (Girei), a popular cultivated striped and variegated seed groundnut cultivar called *kampala*, while the tamarind was bought from the farmers in the market just at harvest and then sorted out to remove injured or infested ones with pests.

Plate 1: shelled Groundnut

Plate 2: Tamarind seed in its pulp

2.3 The Test Insect

The adult of C. serratus was collected from an infested seeds of groundnut and tamarind fruits maintained or cultured in a large stock. The age of insect used were appropriated by collecting larvae that were about to emerge within the range of 0- 24 hours old. This gave room for uniform oviposition period and the percentage which was laid thereafter.

2.4 Collection and preparation of plant material (Ficus congensis Engl.)

Ficus congensis Engl. leaves were collected from the wild in Michika Local Government Area of Adamwa State. The leaves collected were relatively matured and were shade dried and pulverized to powder using a Binatone electric blender (Model BLG- 400). The leaf powder was kept in a clean bottle ready for use.

2.5 Rearing/Storage jars and Air - tight storage plastics

Containers were used with their mouth covered with Muslin cloth in order to prevent the bruchids and the biological agent from escaping which is a typical condition most subsistence farmers store their produce for immediate consumption. The size or volume of the container used was 500mls. Also, small plastic air- tight containers were used because they represent a typical air - tight condition most subsistence farmers store their harvested crops. It does not permit the flow of air both from within and without the container. It has a topper which increases the air - tightness. The volume of containers used was 500mls.

2.6 The Biological Agent

The bio-agent, *M. picca* was obtained at Song and Michika Local Government Areas where they were reported to be found and was identified in the Department of Crop Protection, Ahmadu Bello University, Zaria/Institute for Agricultural Research Insect Museum (Plates 1a and 1b). The bio-agent, *M. pica* Kraatz, were cultured and kept in a batch of groundnut seeds infested with bruchids. The culture was done in a 2litre Kliner jar covered with muslin cloth to allow air circulation. The bio-agents were reared at an ambient temperature of 29-30^{oc} and relative humidity of 54-56%. One day old adults were obtained by sifting the stock cultured a day before the experiments.

Plate 3a: Ventral View of *Mesostena picca* Kraatz [Coleoptera:Tenebrionidae]

Plate 3b: Dorsal View of *Mesostena picca* Kraatz [Coleoptera:Tenebrionidae]

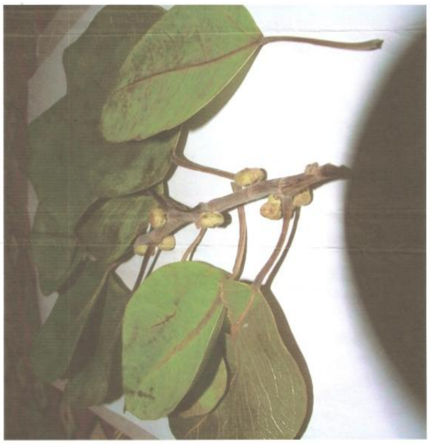

Plate 4: *Ficus congensis*Engl.

Plate 5: Adult *Caryedon serratus* Olivier [Coleoptera: Bruchidae]

2.7 Experimental Design and Procedure

There were nine (9) treatments each for groundnut and tamarind and each replicated three times (3) arranged in a Completely Randomized Design (CRD), which gave a total of fifty four (54) experimental unit.

Groundnut and tamarind seeds were treated with the nine (9) storage or control measures with *C. serratus* placed in either 500ml storage jars or plastics, or air-tight and bags depending on the combinations with ten (10) paired *C. serratus* introduced. In each of the experiments, 100g of seeds were used. The nine treatments were: Plant material, Air tight, Chemical, Bio-agent, Plant material + airtight, Bio-agent + plant material in bags, Chemical + plant material in bags, Chemical + plant Material + airtight and Control. The powder of *F. congensis* used was 8.0g/100 seeds (80kg/tone) on groundnut and tamarind. The chemical used was actellic dust and dosage/quantity 3.0g/100g of seeds or 30kg/tone.The actellic dust was introduced into containers already containing the test insects' where100g of both groundnut and tamarind were placed separately. The controls of both the stored products were infested with the test insects with no control measures applied. This was replicated three (3) times arranged in a

Completely Randomized Design (CRD). Duration of storage was13weeks and the experiment was repeated twice. October 2010 - January, 2011, average temperature of 30°C and relative humidity was 50%.The second repetition was in February - May 2011, average temperature of 32.5°C and relative humidity was 55%.

2.8 Data Collection

The data collected included the following;

i. Mean percentage mortality count.
ii. Mean number of adults alive.
iii. Mean percentage number of damaged seeds.
iv. Mean percentage number of undamaged seeds.
v. Mean number of eggs lay.
vi. Mean percentage weight loss at 26 weeks.

2.9 Formulae used

$$\text{Percentage damaged seeds} = \frac{\text{Number of damaged seeds}}{\text{Initial number of seeds}} \times 100$$

$$\text{Percentage undamaged seeds} = \frac{\text{Number of undamaged seeds}}{\text{Initial number of seeds}} \times 100$$

$$\text{Percentage Mortality} = \frac{\text{Number of Dead adult Bruchid}}{\text{Total Number of Bruchid alive and dead}} \times 100$$

$$\text{Percentage Weight Loss} = \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100$$

Source: Zetter, *et al*. (1997) and Oaya *et al*. (2012)

2.10 Data Analysis

Data collected were subjected to the analysis of variance (ANOVA) appropriate to Completely Randomized Design according to Gomez and and Gomez (1984). The means were separated using the Student Newman Keuls (SNK) at $P \leq 0.05$ level of probability according to Fisher and Hedge (1935).

3. Results

The highest mean percentage damaged seeds for both groundnut and tamarind were recorded in the control for the two stored products (90.00 and 85.33) significantly followed by the bio-gent (32.00 and 31.00), plant materials powder alone (28.00 and25.00),bio-agent + plant material in bags (27.33 and 22.67), airtight alone (22.67 and 20.33), Plant material powder + airtight (17.33 and 15.67) and the least mean percentage damaged seeds for both groundnut and tamarind were recorded in chemical + plant material powder + airtight (6.00 and 4.67), chemical plus plant material in bags (5.67 and 6.33) and chemical alone (6.00 and 5.67) respectively at $P \leq 0.05$ using the Student Newman-Keuls (SNK) test for variables as shown on Table 1 and Figure 1. There was significant difference among the treatments especially when compared to the controls.

On the other hand, the highest mean percentage undamaged seeds for groundnut and tamarind were observed in a combination of chemical + plant material powder + airtight (94.00 and 95.33) closely followed by chemical alone (94.00 and 95.33), chemical + plant material powder in bags (92.00 and 93.67), plant material powder + airtight (82.67 and 84.33), airtight (77.33 and 73.67), plant material powder alone (72.00 and 75.00), bio-agent + plant material powder in bags (70.00 and 69.67), bio-agent (68.00 and 69.00) and the least mean percentage undamaged seed were observed in both controls (10.00 and 14.67) at $P \leq 0.05$ as shown in Table 1 and Figure 2. There was significant difference among the treatments especially when compared to the controls.

The highest mean percentage mortality of *C. serratus* for both groundnut and tamarind were the chemical control (97.23 and 95.33) respectively, closely followed by chemical + plant material + airtight (96.97 and 93.93); chemical + plan t material in bags (94.43 and 93.83); plant material + airtight (91.90 and 93.63); bio-agent + plant material (89.83 and 91.70); plant material powder (88.90 and 87.33); bio-agent (86.27 and 86.67) and the least mean percentage mortality for both stored products were recorded in both controls (20.80 and 17.47) at $P \leq 0.05$ using the Student Newman - Keuls (SNK) test for variables each respectively as shown in Table 2. There was slight significant difference among the treatments. Moreover, controls for both groundnut and tamarind gave the highest mean number of adults alive (18.33 and 18.00) which were significant, followed by the bio-agent (3.67 and 3.67); plant material powder (3.00 and 3.33); airtight alone (2.67 and 2.00); bio-agent + plant material powder in bags (2.00 and 1.67); plant material powder + airtight (1.67 and 1.33) and the least mean number of adults alive for both stored products were recorded in chemical + plant material powder + airtight (0.33 and 0.67) each respectively at $P \leq 0.05$ as shown in Table 2. There was significant difference among the treatments especially when compared to the controls.

Table 1: Effects of different control measures of *C. serratus* and their combinations showing mean percentage damaged and undamaged seeds on stored groundnut and tamarind.

Treatments	Mean percentage damaged Seeds (%)		Mean percentage undamaged seeds (%)	
	Groundnut	Tamarind	Groundnut	Tamarind
Plant material	28.00^{b}	25.00^{c}	72.00^{c}	75.00^{c}
Air tight	22.67^{c}	20.33^{cd}	77.33^{c}	79.67^{bc}
Chemical	6.00^{d}	4.67^{e}	94.00^{a}	95.33^{a}
Bio-agent	32.00^{b}	31.00^{b}	68.00^{cd}	69.00^{cd}
Plant material + airtight	17.33^{cd}	15.67^{cd}	82.67^{b}	84.33^{b}
Bio-agent + plant material in bags	27.33^{b}	22.67^{c}	70.00^{cd}	69.67^{cd}
Chemical + plant material in bags	5.67^{de}	6.33^{d}	92.00^{a}	93.67^{a}
Chemical + plant Material + airtight	5.00^{de}	4.67^{e}	95.00^{a}	93.67^{a}
Control	90.00^{a}	85.33^{a}	10.00^{d}	14.67^{de}
Mean	26.00	23.96	73.44	75.00
C.V. (%)	6.00	5.50	13.10	11.00
S.E.	0.62	0.09	1.34	1.10

Mean followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation. CV = Coefficient of variability and S.E. = Standard Error.

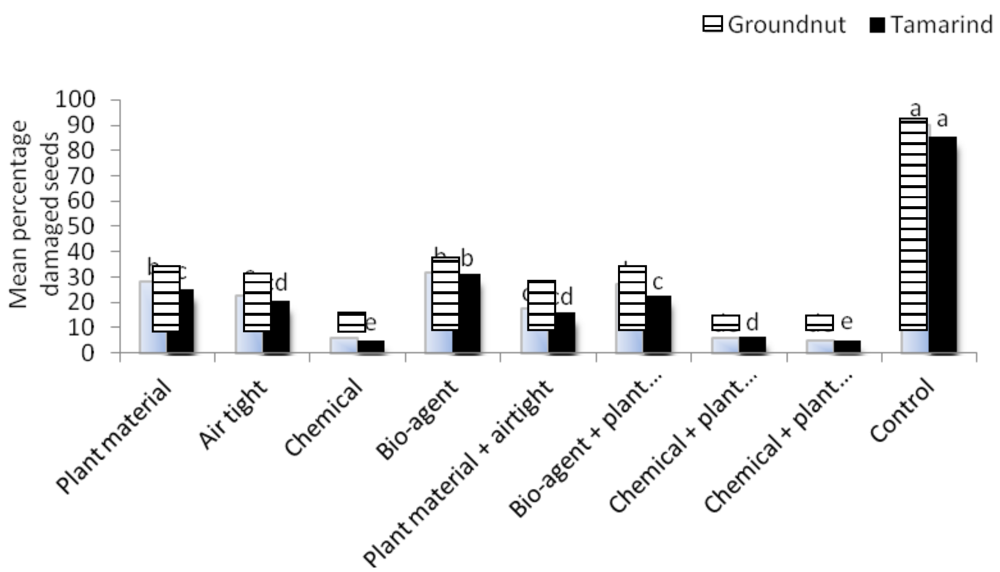

Fig. 1: **Mean percentage damaged seeds caused by *C. serratus* on stored groundnut and tamarind using different control measures.**

Means followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation.

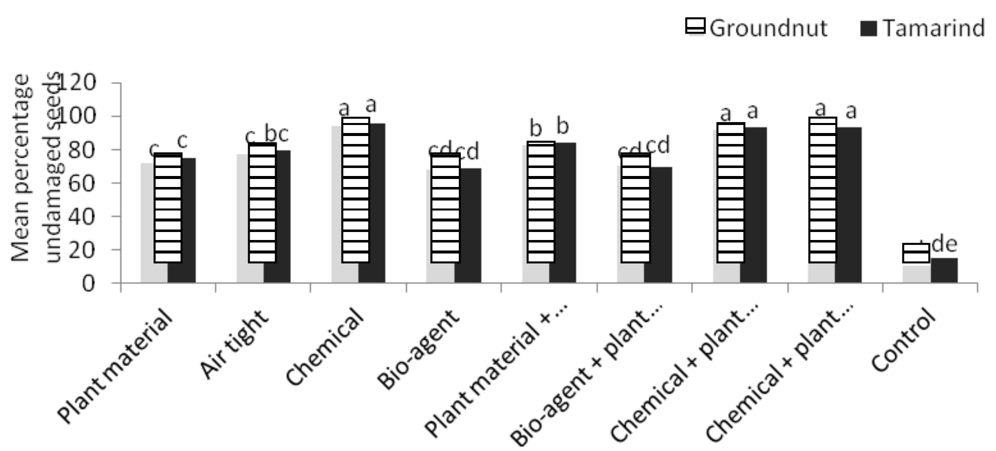

Fig. 2: Mean percentage undamaged seeds caused by *C. serratus* on stored groundnut and tamarind using different control measures. Means followed by the same letter(s) in the same column is not Significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation.

Table 2: Different control measures of *C. serratus* and their combinations showing mean percentage mortality and mean number of adults alive

Treatments	Mean percentage (%)		Mean number of adults alive	
	Groundnut	Tamarind	Groundnut	Tamarind
Plant material	88.90^b	87.33^b	3.00^b	3.33^b
Air tight	89.83^b	91.79^{ab}	2.67^{bc}	2.00^c
Chemical	97.23^a	95.33^a	0.67^{cd}	0.7^d
Bio-agent	86.27^b	86.17^b	3.67^b	3.67^b
Plant material + airtight	91.90ab	93.63^a	1.67^c	1.33^{cd}
Bio-agent + plant material in bags	90.90^{ab}	93.57^a	2.00^{bc}	1.67^{cd}
Chemical + plant material in bags	94.43^a	93.83^a	1.00^c	1.00^d
Chemical + plant Material + airtight	96.97^a	93.93^a	0.33^d	0.67^d
Control	20.80^c	17.47^c	18.33^a	18.00^a
Mean	84.14	83.67	3.70	3.60
C.V. (%)	19.10	15.40	10.20	9.80
S.E.	1.30	1.78	0.90	0.63

Mean followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation. CV = Coefficient of variability and S.E. = Standard Error

The highest mean number of eggs laid for both groundnut and tamarind were observed in both controls (303.67 and 301.33) significantly followed by bio-agent as a means of control (93.33 and 92.00), closely followed by plant material powder (92.67 and 85.67), airtight alone (83.33 and 80.67), bio-agent + plant material powder in bags (83.00and 80.00), plant material powder + airtight (79.33 and 77.00)., and the least were recorded in chemical + plant material powder in bags (66.33 and 62.33) and chemical alone (67.00 and 64.33) as shown in Table 3 and Figure 3. There was slight significant difference among the treatments. The highest mean percentage weight loss for both groundnut and tamarind were observed in both controls (70.67 and 68.33), significantly followed by bio-agent (8.33 and 8.67), plant material powder alone (6.67 and 6.00), airtight alone (6.33 and 5.67),plant material powder + airtight and bio-agent + plant material powder in bags (4.00 and 4.00), chemical alone (3.67 and 3.33) and the least were recorded in chemical + plant material powder + airtight (2.33 and 2.00) and chemical + plant material in bags (2.67 and 2.33) respectively at $P \leq 0.05$ using the Student Newman-Keuls (SNK) test for variables as shown in Table 3 and Figure 4. There was significant difference among the treatments except when compared to the controls.

Table 3: Different control measures of *Caryedon serratus* Olivier and their combinations showing Mean number of eggs laid and weight loss

Treatments	Mean number of eggs laid		Mean percentage weight loss	
	Groundnut	Tamarind	Groundnut	Tamarind
Plant material	92.67^b	85.67^{bc}	6.67^{bc}	6.00^{bc}
Airtight	83.33^c	80.667^c	6.33^{bc}	5.67^{bc}
Chemical	67.00^d	64.33^d	3.67^c	3.33^c
Bio-agent	93.33^b	92.00^b	8.33^b	8.67^b
Plant material + airtight	79.33^c	77.00^c	4.33^b	4.00^c
Bio-agent + plant material in bags	83.00^c	80.00^c	4.00^c	4.00^c
Chemical + plant material in bags	66.33^d	62.33^d	57.67^{cd}	2.33^{cd}
Chemical + plant Material + airtight	56.33^e	57.67^{cd}	2.33cd	2.00^{cd}
Control	303.67^a	301.33^a	70.67^a	68.33^a
Mean	102.78	100.11	18.22	11.59
C.V. (%)	7.1	6.2	10.0	4.3
S.E.	0.89	1.35	0.21	0.19

Mean followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation. CV = Coefficient of variability and S.E. = Standard Error.

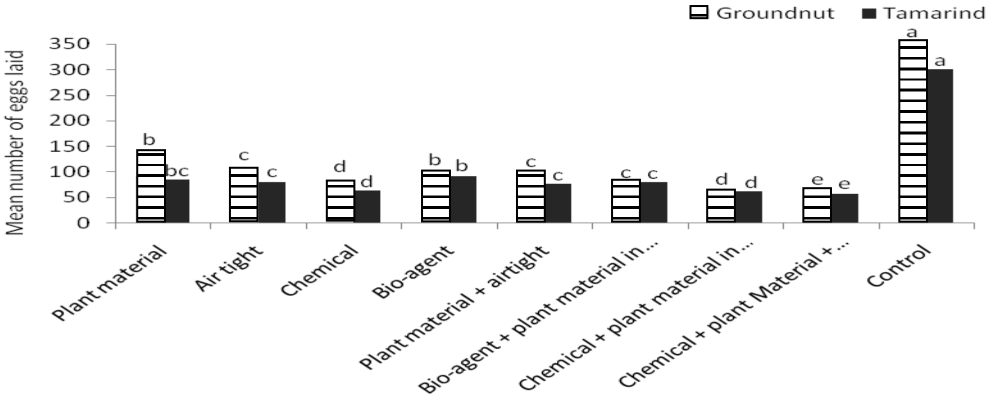

Fig. 3: **Mean number of eggs laid by *C. serratus* on Stored Groundnut and Tamarind Using Different Control Measures**
Mean followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation.

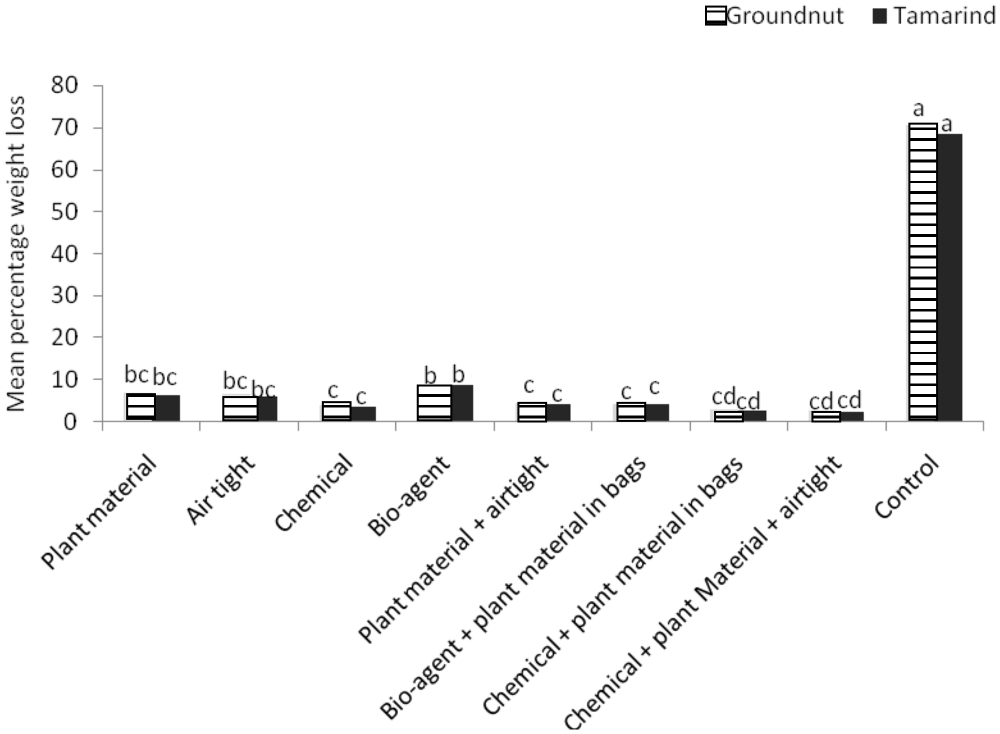

Fig. 4: **Mean percentage weight loss caused by *C. serratus* on stored groundnut and tamarind using different control measures**
Mean followed by the same letter(s) in the same column is not significantly different at $P \leq 0.05$, using the Student Newman - Keuls (SNK) method of mean separation.

4. Discussion

The storage problems of crops in developing countries, especially in tropical and semi-arid climates are not new for crops like groundnut, tamarind and other legumes particularly in Nigeria. It is apparent that, storage without the use of synthetic chemicals has been a futile exercise; however, their toxic and detrimental effect to man, his livestock and the residual damage done to the entire environment is of great concern (Zetter *et al*., 1997 and Lale, 2002).
Different storage measures or control methods such as chemical, biological (bio- agent), cultural (use of plant material powder), airtight, and the combination of two or more of these methods in order to develop an IPM/ integrated control of insect pests using parameters such as mean percentage damage and undamaged seeds, mean percentage mortality, egg laying ability, number of adults alive and the mean percentage weight loss were evaluated at the end of the experiments.

The experiment was carried out to evaluate the different control methods (chemical, biological, cultural, airtight and their various combinations) with the aim of suggesting an integrated pest control for the groundnut bruchid, *C. serratus* in stored groundnut and tamarind are an added advantage to develop an IPM for the pest in question. The results in Tables 1 and 2 clearly showed that, chemical related means of control is still the most effective control measures at hand. The least mean percentage undamaged seeds, high percentage mortality, low number of adults alive, low number of eggs laid and low mean percentage weight loss for both groundnut and tamarind recorded in the chemical, chemical plus plant material powder in bags and chemical plus plant material powder in an airtight storage jars compared to the other treatments was because the use of synthetic chemical for insect pest control is still seen as the best means of control despite the serious hazard they cause to man, his livestock and the environment in addition to the development of resistant insect pests strains. These observations suggest that, chemical have oviposition deterrence as well as ovicidal activities. They also inactivate the bruchids by their toxic effects which led to the mortality of the insects prior to oviposition or that it had ovividal and larvicidal activities which prevented eggs and larval development. This work is consistent with Ayensu (1995), who reported that, the use of chemicals with their combinations had considerable effect on the bruchids respiratory system, resulting in a knock - down within a short period of time.

The plant material powder and its combinations also significantly controlled the bruchids as it had less mean percentage damaged and high mean percentage undamaged seeds, high percentage mortality, few number of adults alive, not too many eggs laid and less weight loss compared to the controls for both groundnut and tamarind. This means that, the plant material *F. congensis* Engl. has insecticidal properties and effects that inhibits egg laying and hatching which agrees with Caswell (1995) and Edan (2000), who stated that, the repellant and the pungent ordour produced by the plant material powder inactivates the bruchids as a result their ability to bore into the seed was highly minimized. There was also less weight loss recorded for both groundnut and tamarind, this agrees with Lale (2003) and Oaya *et al*. (2012) that, the presence of the protective powder around the stored products reduces the weight loss. The airtight storage jars with their combinations for both stored products were significant in controlling the bruchids in all the parameters measured compared to the controls. The bruchids were inactivated and later killed as a result of the modification of the gaseous composition of the storage atmosphere through the depletion of the oxygen and following respiration of grains, microorganisms and arthropods and the eventual build- up of carbon dioxide. This observation agrees with Lale (2006), who reported that, insect pests (bruchids inclusive) within an airtight condition dies, initially from hypoxia (low oxygen) then from anoxia (lack of oxygen) and finally from hypercarbia (high concentration of carbon dioxide) three phenomena which are all together referred to as asphyxia.

The bio-agent *M. picca* (kraatz) is indeed a biological agent for the control of the groundnut bruchid, *C. serratus* in stored groundnut and tamarind. It was observed that, in the presence of the bio-agent, the bruchid could not freely feed on the stored products compared to the controls. This reduces the extent of damage on the stored products. Since the bio-agent is nocturnal in nature, it might have coincided with the active period of the bruchids, which also corroborates Edan (2000). *M. picca,* though a coleopteran was not found feeding on *C. serratus*, but its presence in store groundnut hindered multiplication of the bruchids, which could be antibiosis or antixenotic effects or both. For both stored products the parameters measured were significant in controlling the bruchids compared to the controls. The average performance of the bio-agent in some of the parameters measured was probably due to the slow build-up of the natural enemies to an effective level in storage. This agrees with Lale (2003), who reported that, many natural enemies attack bruchids, but before the population build-up becomes high in storage, considerable damage had already been done to the stored products by the bruchids.

5. Conclusion

The study showed that, the use of an integrated pest control strategy for the control of the groundnut bruchid *C. serratus* is profitable and beneficial. Minimal use of chemical combined with the plant material powder in an air-tight storage jars was outstanding. The biological agent *M. picca* was also confirmed as a natural enemy of the groundnut bruchid, *C. serratus* but could be antibiosis/antixenotic effects. The plant material used is harmless, cheap, effective and easily obtained and powder formulation could be used without any special skills, can also be integrated with other pest control methods. The use of air-tight technique is a simple flexible technology that can be practiced on almost any scale as long as the devices used are provided with tight fitting lids which keep out air.

The use of synthetic insecticide in the control of these bruchids was effective but they are likely to create health problems in the environment. Their expensive nature make them unaffordable to local farmers while their technology of application require skills which may be understood by literate farmers who are few amongst the farming population. There is also the fear over their abuse, toxic residues, workers safety and the increasing cost. Therefore, the integration of these other control measures is the way out and a step that could lead to developing an IPM for *C. serratus* and other bruchids like the notorious *Callosobruchus* spp. on cowpea. This study also provided an added scientific knowledge/literature on *Tamarindus indica* which is a local economic tree crop that its post-harvest pests is not properly documented, only a few.

However, the following recommendations are suggested for further studies:

i).The minimal use of synthetic insecticide and plant material powder in an airtight storage jars or bags provided the best means of control; this could be replicated in other places outside the study areas.

ii).The use of resistant varieties of the stored products, that is seeds with hard seed coat and unattractive to the bruchids could be incorporated as one of the components of integrated control.

iii).The effect of the plant material powder on the impairment of the stored products flavor was not carried out, though the plant material is used locally and consumed for medicinal purposes.

iv).The active ingredients of *F. congensis* has to be determined and more work on *T. indica* need to be carried out as it is a neglected tree crop, but is cherished locally in the study area in Nigeria.

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