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EFFECT OF FUMIGATION OF POWDER LEAF AND SEED EXTRACTS OF *JATROPHA CURCAS* L. ON *CALLOSOBRUCHUS SUBINNOTATUS* (PIC) ON STORED BAMBARA (*VIGNA SUBTERRANEA* (L.) VERDCOURT) NUTS

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ABSTRACT

The research was conducted in the year 2017 at the Entomology Laboratory of the Department of Crop Protection, Bayero University, Kano to assess fumigation properties of *Jatropha curcas* L. leaf and seed powders on *Callosobruchus subinnotatus* (Pic) infesting stored bambara nut, *Vigna subterranea* (L.) Verdcourt. The study aimed at comparing the effectiveness of the products with conventional chemical insecticide (pirimiphos-methyl 2%). Factorial experiment of 2×2×2 levels (leaf and seed powders at the rates of 0.0, 0.5. 1.0 and 1.5 g, with and without addition of the synthetic chemical at 0.01 g/20 g bambara nut seed) were laid out in a completely randomized design and replicated three times. Fumigant toxicity effect was observed on the emerged insects, though the result was significantly ($P< 0.001$) lower. In conclusion, appreciable level of protection on bambara nut seeds was achieved using seed powder of *J. curcas*. Therefore, it is recommended that for effective management of *C. subinnotatus* infesting bambara nut, farmers could use 1.0 g seed powder on 20 g bambara nut seeds.

Keywords: Bambara nut,*Callosobruchus subinnotatus,* fumigation, *Jatropha,* , oviposition

INTRODUCTION

Grain legumes are important major sources of plant protein and fat in tropical countries. The industrial applications of these depend on the knowledge of their nutritional importance and functional properties (Aremu *et al*., 2006a). Many workers (Adeyeye *et al*., 1999; Onwuliri and Obu, 2002; Aremu *et al.,* 2006b) have reported the compositional evaluation, functional properties, amino acids and protein solubility of legume flours. In terms of dietary balance, grain legumes or pulses contain more proteins than cereals and about ten times as much protein as most root and tuber crops. They serve as a cheap source of protein to a large proportion of the population in poor countries of the tropics. For rural and urban dwellers in developing countries, especially where animal protein is scarce and/or expensive, grain legumes serve as a source of protein to a large proportion of the population by being the least expensive and non-processed protein source (Rachie and Silvestre, 1997).

An indigenous African legume, bambara nut, *Vigna subterranea* (L.) Verdcourt (Fabales: Fabaceae) whose origin reportedly extend from Jos in Plateau State and Yola in Adamawa State of Nigeria to Garoua in Cameroon (Goli, 1995), has been cultivated for centuries in sub-Saharan Africa, mainly in the semi-arid regions and has in the past contributed to food security especially for small holder farmers (Azam-Ali *et al*., 2001; FAO, 2001; Mwale *et al*., 2007). Bambara nut has the potentials to provide a balanced diet in areas where animal protein is scarce and/or expensive and where cultivation of other legumes is not feasible due to low rainfall (Quaye and Kanda, 2004). Bambara nut compares favourably in nutritional status with other well-known and highly commercialized beans and it is a good source of fibre, calcium, iron and potassium (Quaye and Kanda, 2004; Hillocks *et al.,* 2012). Sharing a high nutritive value with other widely consumed legumes, bambara nut also has an appealing flavour which is reflected in its demand from small local and niche markets (Hillocks *et al*., 2012).

This underutilized legume grown in the Northern part of Nigeria was once said to be the third most important grain legume after groundnut (*Arachis hypogea* L.) and cowpea (*Vigna unguiculata* Walpers). Its compact habit seems to be an adoption to growing in hot, windy environment. Mainly grown by women for the sustenance of their families, bambara nut was cultivated in extreme, tropical environments by peasant farmers without access to irrigation and/or fertilizers and with little guidance on improved practices (Mwale *et al*., 2007). Bambara nut yields well under conditions which are not favourable for groundnut (*A. hypogea*), maize (*Zea mays* L.) and even sorghum (*Sorghum bicolor* (L.) Moench) (Brink and Belay, 2006). Its drought tolerance makes it a useful candidate in climate change adaptation strategies (Hillocks *et al*., 2012).

The plant is also used in traditional medicines as a remedy for many ailments of livestock and human beings, which include helminthosis, schistosomiasis, leprosy, diarrhoea and psoriasis (Burkill, 1995). However, in spite of the nutritional values and

usefulness of bambara nut, the crop is reported to be threatened by the devastating activities of stored products pests, notable among them is, *Callosobruchus subinnotatus* (Pic.) (Lale and Vidal, 2003).

MATERIALS AND METHODS

EXPERIMENTAL SITE

The experiment was conducted in the Entomology Laboratory of the Department of Crop Protection Faculty of Agriculture, Bayero University, Kano, Kano State, Nigeria. The State is located on 11°59'47"N, 8°31'0"E (Kowal and Knabe, 1972).

PREPARATION OF BAMBARA NUT SEEDS

Fifty Kilogrammes (50 kg) of unshelled bambara nut, cream/brown eye variety seeds wre purchased at a local market in Dambatta Local Government Area, Kano State. The seeds were decorticated manually. Shrivelled (shrunken) and damaged seeds as well as all other debris were removed. To disinfest the cleaned whole seeds, they were put in a polythene bag together with two phostoxin tablets (in an envelope) for 24 hours. The mouth of the bag was tied securely to ensure that any insect pest present within the seeds was killed according to the method of Ogunwolu *et al.,* (2002). Thereafter, the seeds were opened and spread in a shaded well ventilated place for 48 hours to ensure that the seeds were free from the phostoxin residue. To avoid subsequent re-infestation and to ensure that any insect pest that might still remain within the seeds was killed the previously fumigated seeds were transferred into a fresh and different polythene bag and kept at -4˚C inside a fridge for four days (Ahmed, 2007).

COLLECTION OF THE EXPERIMENTAL PLANT PARTS

The leaves and seeds of the physic nut *J. curcas* were collected at the orchards of Audu Bako College of Agriculture, Dambatta, Kano State, while the Actellic dust was purchased from a pesticide store at Abubakar Rimi market, Sabon-gari, Kano, Kano State, Nigeria.

Preparation of Experimental Plant Parts

The plant parts were dried in shade to crispy condition. Thereafter, it was pounded in a mortar with pestle and then passed through a sieve 40 µmm to give a very fine powder as described by Youdeowei (2004) and Yusuf and Ahmed (2005). The fine powdered plant materials were kept in sterile polyethylene bags until needed.

SOURCE AND REARING OF INSECT CULTURE

The initial culture of the bambara nut bruchids was obtained from naturally infested bambara nut seeds at Kurmi market, Kano city, Kano State, Nigeria. A sample of the insects on infested seeds was taken to the Department of Crop Protection, Ahmadu Bello University, Zaria, Kaduna State, Nigeria for proper taxonomic identification as *Callosobruchus subinnotatus* (Pic.). These were then massively reared in transparent plastic buckets measuring 30 cm in height and 15 cm top diameter. The top end of the plastic buckets was covered with white muslin cloth, secured firmly into place with rubber bands, hence allowing for ventilation. These were incubated in Kliner jar at an ambient temperature and relative humidity (32±3^{o}C and 57±3% respectively) with alternating light and dark cycle for 12 hours as previously described by Abduljalal *et al.* (2011). One kilogramme of the clean disinfested bambara nuts were transferred into ten plastic buckets each. In addition, 100 adults of *C. subinnotatus* from the initial culture were introduced into the buckets. To ensure that the introduced bruchids did not escape away, the top ends of the buckets were covered with white muslin cloth and secured firmly with rubber bands. The insects were allowed to mate and oviposit for 10 days after which they were removed.

EXPERIMENT AND EXPERIMENTAL DESIGN

The bioactive (fumigant toxicity) effect of the treatments was assessed on the adult bruchids. In a 2×2×2 factorial experiment, the leaves and seeds of physic nut, *J curcas* L. were used for the assessment. The leaves and seeds powder were applied at two levels each (0 and 1.5 g/20 g seed) with and without pirimiphos-methyl (Actellic dust) applied at the reduced rate of 0.01g/20 g (Gwinner, *et al.,* 1996). There were eight treatments, which were replicated three (3) times in a completely randomized design. The treatments were admixed with the bambara nut and shaken vigorously after which, five pairs of emerged insects were introduced into each treatment in plastic cups, as indicated in Plate 5. A total of 24 transparent plastic cups measuring 10 cm in depth and 9 cm top diameter were kept in the laboratory at ambient temperature and relative humidity of 32±3^{o}C and 57±3%, respectively.

FUMIGANT TOXICITY

Clean bambara nut seeds (1 kg) were selected and infested with 200 freshly hatched adult *C. subinnotatus*, which were removed after seven (7) days of oviposition. 20 g each of cream brown eye bambara nut variety bearing previously infested *C. subinnotatus* eggs were tied in a piece of muslin cloth and suspended inside 24 plastic bottles containing 0.5 g of both test plant materials and 0.02 g Actellic dust. The lids of the plastic bottles were covered in such a way that the muslin cloth containing the bambara nut seeds was suspended in space and not touching the test materials. The set up was also made airtight by the aid of adhesive tape that held the lids tightly around the plastic cups. Untreated control without the test plant materials was also similarly prepared. Number of adults that emerged from eggs of the treated and untreated eggs was counted as described by Ofuya *et al.* (2010).

PHYTOCHEMICAL SCREENING

Phytochemical analyses of the crude leaf and seed powder collected were conducted according to standard procedures to identify their chemical components (Sofowora, 1993; Harborne, 1988; Trease and Evans, 1989; and Kokate *et al.*, 2008). This was conducted at the National Research Institute for Chemical Technology (NARICT) Zaria, Kaduna State, Nigeria. Ferric chloride (FeCl3) test for tannins, organic acid (OAT) test for oxalates, foam test for saponins, Keller-Killiani test for glycosides, ferric chloride (FeCl3) test for flavonoids and Wagner's Reagent as well as

Meyer's Reagent tests for alkaloids were carried out to identify the chemical constituents present in the leaf and seed products of the plant.

Tannin test
Five millilitre (5ml) of each of the plant part (leaf and seed) extract was treated with 2 ml of Ferric chloride (FeCL3) and boiled for five (5) minutes. Formation of red precipitate confirmed the presence of tannins.

Oxalate test
To three milliners (3 ml) portion of the extracts, a few drops of ethanoic acid glacial were added. Greenish black colouration indicated presence of oxalates.

Saponin test
To one millilitre (1 ml) of each of the plant part extract, four millilitres (4 ml) of distilled water was added and shaken vigorously for a stable persistent froth. The frothing was mixed with three drops of olive oil and shaken vigorously; and then for the formation of emulsion as evidence for presence of saponins.

Glycoside test
The plant part extracts were treated with few drops of glacial acetic acid and Ferric chloride solution and mixed. Concentrated sulphuric acid was added, formation of two layers two layers was observed. Lower reddish brown layer and upper acetic acid layer which turns bluish green indicated a presence of glycosides.

Flavonoid test
Test plant parts were treated with few drops of Ferric chloride (FeCl3) solution which resulted in the formation of blackish red colour indicating the presence of flavonoids.

Alkaloid test
Five millilitre (5 ml) of 2% of hydrogen chloride (hydrochloric acid HCL) was added to 2ml of each of the plant part extract in a test tube placed on a steam bath and warmed. It was filtered and divided into two parts for the following tests:
Few drops of Wagner's Reagent (Potassium-iodine solution) were added to one part of the filtrate in a test tube. A reddish brown precipitate was observed.
Few drops of Meyer's Reagent (Potassium mercuric iodine solution) were added to the other filtrate of the solution in a test tube. A cream coloured precipitate was observed.
In both cases, formation of precipitation indicated presence of alkaloids.

DATA ANALYSIS
Data in percentages were transformed into arc sine percentages, while numerically count data were transformed using √n+1 before analysis, as described by Little (1978). All the data were subjected to analysis of variance using computer software (SAS for windows) statistical package. Treatments with significant differences were compared and separated at 0.05% level of probability using Duncan's multiple range test (DMRT).

RESULTS
The results of the fumigation effect of the treatment combinations, with and without actellic dust on the number of hatched eggs and number of live insects from the hatched eggs is presented in Table 1. In terms of number of hatched eggs, there was neither significant difference among the treatments and their combinations, with and without Actellic dust, and the check, nor between the treatments, on one hand and the control on the other. However, fumigant effect was observed on the emerged insects. Numbers of live insects in all treatments and their combinations, with and without Actellic dust, were significantly ($p<0.001$) lower than the number of live insects in bambara seeds under the control.

Table 1: Fumigation effect of *Jatropha curcas* extracts with and without synthetic chemical application on hatchabity of eggs and emerged adults of *Callosobruchus subinnotatus*

Treatment				
Leaf powder(g)	**Seed powder(g)**	**Pirimiphos-methyl(g)**	**Number of hatched eggs$^{\triangle}$**	**Number of emerged adults$^{\triangle}$**
0.0	0.0	0.00	18.00 (25.10)	14.00$^{a\Omega}$ (21.97)
0.0	0.0	0.01	9.00 (17.46)	0.33^{b} (0.99)
0.0	0.5	0.00	8.00 (16.43)	1.33^{b} (6.55)
0.0	0.5	0.01	6.00 (14.18)	0.67^{b} (1.40)
0.5	0.0	0.00	13.00 (21.13)	0.33^{b} (0.99)
0.5	0.0	0.01	8.67 (17.06)	3.00^{b} (9.98)
0.5	0.5	0.00	7.67 (16.00)	0.67^{b} (1.40)
0.5	0.5	0.01	2.33 (8.72)	0.33^{b} (0.99)
	L.S.*		N.S.	0.001
	SE±		2.118	0.999

$^{\Omega}$Means within a column followed by different letters are statistically significantly different at $0.001 = P \leq 0.001$ and NS = not significant, Duncan's multiple range test. $^{\triangle}$Figures in parentheses are Arcsine √percentage transformations. *L. S = level of significance.

Table 2: Fumigation effect of pirimiphos-methyl application on hatchabity of eggs and emerged adults of *Callosobruchus subinnotatus.*

Pirimiphos-methyl(g)	Number of hatched eggs[△]	Number of emerged adults
0.00	11.67[aΩ] (19.91)	4.08[aΩ] (11.54)
0.01	6.50[b] (14.77)	1.08[b] (5.74)
L.S.[*]	*	0.01
SE±	1.059	0.500

[Ω]Means within a column followed by different letters are statistically significantly different at * = P ≤ 0.05 and 0.01 = P ≤ 0.01, Duncan's multiple range test. [△] Figures in parentheses are Arcsine √percentage transformations. [*]L.S = level of significance.

Table 2 shows that fumigant effect was obtained by using pirimiphos-methyl, both on egg hatchability and emerged adults. Significantly (p<0.01) low number of eggs (6.50) were hatched in Bambara nut seeds fumigated with pirimiphos-methyl compared to the unfumigated seeds where more eggs (11.67) were found hatched. Moreover, number of adult insects that were found alive (4.08) in the control was significantly (p<0.001) higher when compared to that (1.08) found in the fumigated seeds (Table 2). The bioactivity tests of the leaf powder in table 3 shows no significant fumigation effect was observed on hatchabity of eggs and the emerged adult bruchids. Compared to the number of insects found alive (4.08) observed in the control, significant (p<0.001) low number of living insects (1.08) were found using all of the treatments (Table 3).

Bioactive effect of the *J. curcas* seed powder was also investigated. In Table 4, fumigation effect of the seeds powder on egg hatching and number of emerged adults were presented. Compared to the control, in which 12.17 eggs were hatched, significantly (p<0.001) low number of eggs (6.00) were found hatched when the seed powder was used at 0.5 g concentration. Moreover, out of the 6.00 adults that emerged from the treated seeds, only 0.75 were found alive. This was significantly (p<0.001) lower than the number of adults (4.42) found alive in the control.

Table 3: Fumigation effect of *Jatropha curcas* leaf powder on hatchabity of egg and emerged adult *Callosobruchus subinnotatus.*

Leaf powder(g)	Number of hatched eggs[△]	Number of emerged adults[△]
0.0	10.25 (18.63)	4.08[aΩ] (11.54)
0.5	7.92 (16.32)	1.08[b] (5.74)
L.S.[*]	N.S.	0.001
SE±	1.059	0.500

[Ω]Means within a column followed by different are statistically significantly different at 0.001= P ≤ 0.001 and N.S. = not significant, Duncan's multiple range test. [△]Figures in parentheses are Arcsine √percentage transformations. [*]L.S = level of significance.

Table 4: Fumigation effect of *Jatropha curcas* seed powder on hatchabity of eggs and hatched adults of *Callosobruchus subinnotatus.*

Seed powder(g)	Number of hatched eggs[△]	Number of emerged adults[△]
0.0	12.17[aΩ] (20.36)	4.42[aΩ] (12.11)
0.5	6.00[b] (14.18)	0.75[b] (1.52)
L.S.[*]	***	0.001
SE±	1.059	0.450

[Ω]Means within a column followed by different letters are statistically significantly different at *** = P ≤ 0.001, Duncan's multiple range test. [△]Figures in parentheses are Arcsine √percentage transformations. [*]L.S = level of significance.

In Table 5 less (p<0.001) number of hatched eggs (5.00) was observed in bambara seeds treated with 0.5:0.5 g leaf/seed combination, which was statistically similar to the number of hatched eggs (7.00) in bambara nut seeds treated with 0.5 g seed powder singly. On the other hand, the number of hatched eggs (10.83) in bambara seeds treated with 0.5 g leaf powder singly, in similarity to that observed in 0.5 g seed powder treated seeds, was statistically the same as in the control. A substantial

reduction in the number of live hatched adults was also observed among all treatments and the control. Population of live hatched adults observed in all treatments, both single extracts and combinations, at all concentrations were statistically similar but significantly ($p<0.05$) different from the number of hatched live adults (7.17) found in the control.

Table 5: Fumigation effect of *Jatropha curcas* leaf/seed extracts on hatchabity of eggs and number of emerged adults of *Callosobruchus subinnotatus*

Treatment		Number of hatched eggs$^{\triangle}$	Number of emerged adults$^{\triangle}$
Leaf powder(g)	Seed powder(g)		
0.0	0.0	$13.50^{a\,\Omega}$ (21.56)	$7.17^{a\Omega}$ (15.45)
0.0	0.5	7.00^{bc} (15.34)	1.00^{b} (5.74)
0.5	0.0	10.83^{ab} (19.19)	1.67^{b} (7.27)
0.5	0.5	5.00^{c} (12.92)	0.50^{b} (1.28)
L.S.*		0.01	0.05
SE±		1.498	0.706

$^{\Omega}$Means within a column followed by different letters are statistically significantly different at* = P ≤ 0.05 and ** = P ≤ 0.01, Duncan's multiple range test. $^{\triangle}$Figures in parentheses are Arcsine √percentage transformations.
*L.S = level of significance.

Table 6: Fumigation effect of *Jatropha curcas* seed extract with and without synthetic chemical application on hatchabity of eggs and emerged adults of *Callosobruchu subinnotatus*

Treatment		Number of hatched eggs$^{\triangle}$	Number of emerged adults$^{\triangle}$
Seed powder(g)	Pirimiphos-methyl(g)		
0.0	0.00	15.50^{a} (23.19)	$7.17^{a\Omega}$ (15.45)
0.0	0.01	8.83^{b} (17.26)	1.67^{b} (7.27)
0.5	0.00	7.83^{b} (16.22)	1.00^{b} (5.74)
0.5	0.01	4.17^{b} (11.68)	0.50^{b} (1.28)
L.S.*		0.05	0.01
SE±		1.498	0.706

$^{\Omega}$Means within a column followed by different letters are statistically significantly different at 0.05 = P ≤ 0.05 and 0.01 = P ≤ 0.01, Duncan's multiple range test. $^{\triangle}$Figures in parentheses are Arcsine √percentage transformations.
*L.S = level of significance.

Fumigation effect on the number of hatched eggs and the number live bruchids after hatching was also observed with the use of the seed powder, with and without the synthetic chemical. In both cases, similar effects different from that of the control, were observed among the treatments. Number of hatched eggs (4.17, 7.83 and 8.83) obtained by using 0.5 g seed powder, with and without the actellic, as well as in the check, respectively were similar and significantly ($p<0.05$) less than that (15.50) observed in the control (Table 6). After hatching, numbers of live bruchids (0.50, 1.00 and 1.67) found in 0.5 g seed powder, with and without the synthetic chemical, as well as the check, respectively, were also significantly ($p<0.01$) lower than that (7.17) in the control (Table 6).

The results of the fumigation effect of the treatment combinations, with and without actellic dust on the number of hatched eggs and number of live insects from the hatched eggs was presented (Table 7). In terms of number of hatched eggs, there was neither significant difference among the treatments and their combinations, with and without Actellic dust, and the check, nor between the treatments, on one hand and the control on the other. However, fumigant effect was observed on the emerged insects. Numbers of live insects in all treatments and their combinations, with and without Actellic dust, were significantly ($p<0.001$) lower than the number of live insects in bambara seeds under the control (Table 7).

Table 8 shows chemical constituents of physic nut leaf and seed. With the exception of the cynogenic glycoside (cardiac glycoside), tannins, oxalates, saponnins, flavonoids and alkaloids were present in both leaf and seed of the plant. Presence of cynogenic glycosides was indicated only in the leaf.

Table 7: Fumigation effect of *Jatropha curcas* extracts with and without synthetic chemical application on hatchabity of eggs and emerged adults of *Callosobruchus subinnotatus*

Treatment			Number of hatched eggs[⌂]	Number of emerged adults[⌂]
Leaf powder(g)	Seed powder(g)	Pirimiphos-methyl(g)		
0.0	0.0	0.00	18.00 (25.10)	14.00[aΩ] (21.97)
0.0	0.0	0.01	9.00 (17.46)	0.33[b] (0.99)
0.0	0.5	0.00	8.00 (16.43)	1.33[b] (6.55)
0.0	0.5	0.01	6.00 (14.18)	0.67[b] (1.40)
0.5	0.0	0.00	13.00 (21.13)	0.33[b] (0.99)
0.5	0.0	0.01	8.67 (17.06)	3.00[b] (9.98)
0.5	0.5	0.00	7.67 (16.00)	0.67[b] (1.40)
0.5	0.5	0.01	2.33 (8.72)	0.33[b] (0.99)
	L.S.[*]		N.S.	***
	SE±		2.118	0.999

[Ω]Means within a column followed by different letters are statistically significantly different at *** = P ≤ 0.001 and NS = not significant, Duncan's multiple range test. [⌂]Figures in parentheses are Arcsine √percentage transformations. [*]L.S = level of significance.

Table8: Phytochemical constituents in the leaf and seed of *Jatropha curcas*

Chemical compound	Leaf	Seed
Tannin	+[Ω]	+[Ω]
Oxolate	+	+
Saponnin	+	+
Cynogenic glycoside	+	-
Flavonoid	+	+
Alkaloid	+	+

[Ω] + = indication of presence and - = indication of absence of chemical compound.

DISCUSSION

Despite their health and environmental impacts, the most widely used curative measure in stored-product insect pest control is the application of synthetic residual or contact insecticides. Recently however, there is renewed interest in the use of eco-friendly botanical pesticides. The present study evaluated the bioactivity and fumigation effects of crude leaf and seed extracts of the physic nut, *Jatropha curcas* L. plant on *Callosobruchus subinnotatus* (Pic.) infesting stored bambara nut. The study also investigated the most effective rate of application that could provide optimum control.

Research conducted by other people had shown that *Jatropha* has insecticidal and antifeedant efficacies against wide range of insects, sometimes the effects were comparable to that provided by synthetic insecticides. In the store, *Jatropha* extracts have been used as anti-oviposition and ovicides on *Callosobruchus maculatus* in cowpea (Adebowale and Adedire, 2006), oviposition deterrence and inhibiting egg hatching of potato tuber moth, *Phthorimaea operculella* (Shelke *et al*., 1987). Similarly, Ohazurike *et al.* (2003) reported substantial control of maize weevil, *Sitophilus zeamais* infesting stored maize. Umar (2008) also observed reduced oviposition by *C. maculatus* when *Jatropha* seed and leaf powder were used on stored cowpea.

Positive effects of fumigation were also observed in all the treatments, especially where 0.5 g seed powder and 0.5:0.5 leaf/seed combination was used. Similar observations were made by Constance *et al.* (2013) when the effects of *J. curcas* extracts on *Sitophilus zeamais* infesting maize grains was investigated. In their reports on the number of eggs hatched the different plant preparations (leaf and seed extracts 0 – 100 ppm) significantly prevented egg hatching in a concentration-dependent manner. Grains pre-treated with *Jatropha* seed oil before storage bore the lowest number of hatched eggs and there was (Constance *et al.*, 2013) no significant difference ($P < 0.001$) between the effects of the leaf extracts and that of the seed oil. In an investigation on the effects of *J. curcas* and *Annona muricata* on *Sitophilus zeamais* infesting stored rice grains, Asmanizar and Idris (2012) also reported that the two plant seed extracts (oil and powder) reduced F_1 progeny production suggesting that the extracts have the potential of protecting rice grain against *S. zeamais* infesting stored rice.

This study did not aim at elucidating the chemical compounds which might have been responsible for any of the effects on the bambara nut bruchids, *C. subinnotatus*, however, phytochemical analysis of the physic nut was conducted in order to know the chemical constituents and the metabolites contained in the leaf and seed of the plant.

Phytochemical analysis indicated that apart from the cynogenic glycosides, tannins, oxalates, saponnins, flavonoids and alkaloids in varied concentrations, were also present in both the leaves and seeds of the plant. Traces of cynogenic (cardiac) glycocides were found only in the leaves of the plant. This conforms to the findings of Constance *et al.* (2013) who, while screening *J. curcas*, showed that the plant had abundant saponins and cardiac glycosides. The work further stated that the concentrations of tannin, flavonoids, and steroids were lower than that of saponins but higher than the concentrations observed in alkaloids, phlobatannins, and terpenoids. However, the concentrations of the saponins and cardiac glycosides in the plant extracts were significantly higher compared to other phytochemicals.

CONCLUSION

From the results obtained in this research, it could be concluded that by using the different plant parts have an appreciable level of protection, similar to that provided by the conventional synthetic insecticide, was achieved. Therefore, the plant parts could be used for the management of *C. subinnotatus* infesting stored bambara nut. Wide range of biocidal properties, effective on all developmental stages of the bruchid, makes the plant materials an excellent choice for admixing with bambara seeds at all stages of the bruchids' development. Resource-poor farmers should be encouraged to adopt the use of botanical pesticides, which are not only safer, but also cheaper, locally available, easier to handle and apply, for the control of agricultural insect pests both in the field and during storage. Therefore, because of the immense prospects of bambara nut as crop of the future, farmers should be encouraged to realize the potential of these botanical products for the control of the menace of *C. subinnotatus*, major insect pest attacking the seeds in storage.

RECOMMENDATIONS

From the findings of this study, it could be recommended that:

i. 1.5/20 g leaf powder and 1.0/20 g seed powder, singly each provided the best result for the control of *C. subinnotatus* on bambara nut during storage;
ii. The use of plant extracts in protecting grains against stored insect pests is safer.

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