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Jatropha curcas (L.) and J*atropha gossypifolia* (L.), Botanical Entomocides For Poor Resource Farmers As Protectants Of Cowpea Seeds Against Infestation by *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae)

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ABSTRACT

The powder, wood ash and latex of *Jatropha carcus* and *Jatropha gossypifolia* were bioassayed for their insecticidal potential against cowpea bruchid, *Callosobruchus maculatus* in the laboratory at ambient temperature and humidity. The plant wood ash, powder and latex were tested at rate 2g/20g of cowpea seeds. Adult mortality and adult emergence of the insect were investigated. Result showed that wood ash of J. carcus evoked 100% mortality of adult cowpea bruchid after 4 days of application. This is followed by powder of *J. carcus* which caused 92.5% mortality while powder of *J. gossypifolia* was the least effective that caused 90% mortality of adult bruchids. There was no adult emergence in seeds treated with wood ash and latex of both *J. carcus* and *J. gossypifolia* compared with untreated that had 81.1% adult emergence. The result obtained from this study revealed that *J. carcus* and *J. gossypifolia* wood ash and latex were effective in controlling *C. maculatus* and could serve as an alternative to synthetic insecticides for the protection of stored cowpea against cowpea bruchid for the poor resource farmers in developing countries.

INTRODUCTION

Domestic food production is low in the developing countries such as Nigeria as it is not sufficient to meet the national food demand; and the little that were produced are facing losses because of insufficient processing techniques as well as storage structures and infestation by insect pests including coleopterans and lepidopterans (Ogungbite *et al*., 2014). In order to boost food security in Nigeria, government had increase food security in Nigeria, government had established various agricultural research institutes. Institute for Agricultural Research was established in 1924 to take care of genetic improvement and development of production and utilization technologies for sorghum, cowpea, cotton, groundnut, and sunflower and the improvement of farm based farming system in Nigeria (Adegbola *et al*., 2013, Ogungbite *et al*., 2014). However, most Nigerian farmers are uneducated and lack knowledge of modern storage techniques that could boost food security in the country; thereby there are colossal losses of their harvested legumes especially to insect pest such as *Callosobruchus maculatus*. The larvae are the major destructive stage because adult cowpea bruchid do not feed (Gbaye and Holloway 2011, Ileke *et al*., 2014a).

Effective control of coleopteran pests has long been the aim of entomologists throughout the world (Ileke *et al*., 2013). The use of conventional synthetic insecticides to manage insect pest of stored products had been found to be most effective against insect pest but with adverse effect on the environment and human health. Also, many of them are unavailable at critical period, they are expensive and some of the insects developed resistant to them (Ofuya and Lale, 2001; Lale, 2002; Ileke and Olotuah, 2012; Akinneye and Ogungbite, 2013). The setbacks in the use of synthetic chemical insecticides led to continuous research towards their substitution with botanical powders and oil extracts as a cheaper, biodegradable and eco-friendly safer means of controlling stored product insects pest (Adedire et al. 2011; Ileke and Oni, 2011; Akinneye and Ogungbite, 2013). Many of the botanicals that were effective against stored product insect pest had been noted to have medicinal properties and tropics are well endowed with such plant (Adedire and Lajide 2003, Ileke and Oni, 2011; Akinneye and Ogungbite, 2013). The Specific objective of this research is to investigate the insecticidal potential of Jatropha curcas and *J. gossypifolia* wood ash, powders and latex against cowpea bruchid, *C. maculatus*.

MATERIALS & METHODS

Insect Culture

The initial culture of *C. maculatus* was obtained from infested cowpea seeds from the Environmental Biology Research Laboratory, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria. The insects were subsequently reared in the laboratory on cleaned cowpea seeds (Ife brown) at temperature of 28 ± 2°C and relative humidity of 75 ± 5%. The cowpea seeds were kept in plastic containers with the open end covered with muslin cloth to prevent escape of insects and provide aeration (Ogungbite *et al*., 2014).

Identification and sexing of adult *Callosobruchus maculatus*

The identification and sexing of *C. maculatus* were carried out in the Research Laboratory, Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba Akoko, Ondo State using Binocular Microscope based on observations of Halstead (1963), Appert (1987), Odeyemi and Daramola (2000). Male have comparative shorter abdomen and the dorsal side of the terminal segment is sharply curved downward and inward (Ileke, 2014). In contrast the females have comparatively longer abdomen and the dorsal side of the terminal segment is only slightly bent downward. The female also has two dark visible spots on their elytra (Halstead, 1963; Odeyemi and Daramola, 2000).

Plant Collection

The plants evaluated in this work were *J. curcas* and J. *gossypifolia* wood ash leaf and latex. They leaf and wood were harvested fresh from Supare Akoko, Ondo State, Nigeria and authenticated by the Plant Science and Technology Department of Adekunle Ajasin University, Akungba Akoko, Ondo State. These plant parts were rinsed in clean water to remove sand and other impurities, cut into smaller pieces before air dried in a well ventilated laboratory and ground into very fine powder using an electric blender. The powders were further sieved to pass through 1mm^2 perforations (Ileke and Oni, 2011). The powders were packed in plastic containers with tight lids and stored in a refrigerator at 4°C prior to use.

Collection of Plants latex

The stem of *J. curcas* and *J. gossypifolia* each was cut with knife to allow the plant latex or sap to come out into a container. Ten (10ml) of each of the plant latex were collected in separate beaker and corked tightly to prevent evaporation and solidification (Ileke *et al*., 2014a). They were then labeled and kept in refrigerator to keep then fresh.

Collection of cowpea seeds

Cowpea seeds used for this study were obtained from a newly stocked seeds free of insecticides at Agricultural Development Program (ADP), Akure, Ondo State, Nigeria. Firstly, the seeds were cleaned and disinfested by keeping at -5oC for 7 days to kill all hidden infestations. This is because all the life stages, particularly the eggs are very sensitive to cold (Koehler, 2003; Ileke and Oni 2011). The disinfested cowpea seeds were then placed inside a Gallenkamp oven (model 250) at 40oC for 4 hours (Jambere et al. 1995; Ileke and Oni 2011) and later air dried in the laboratory to prevent mouldiness (Adedire et al. 2011; Ileke et al. 2013; 2014b) before they were stored in plastic containers with tight lids.

Effect of contact toxicity of *Jatropha* leaf powders and wood ash on adult mortality, oviposition and progeny development of *C. maculatus*

Fine powders of *J. curcas (L.)* and *J. gossypifolia* wood ash and leaf were admixed with cowpea seeds at the rate 2g /20g of cowpea seeds

seeds in 250ml plastic containers. The seeds in the controls contained no plant powders. The containers with their contents were mixed with the aid of glass rod to ensure uniform loading of the plant material with the cowpea seeds. Ten pairs of 2 – 3 days old adult C. maculatus were introduced to each of the containers and covered. Four replicates of the treated and untreated controls were laid out in Complete Randomized Design. The adult mortality was assessed after every 24 hours for 96 hours. Adults were considered dead when probed with sharp objects and there were no responses. At the end of day 4, all insects, both dead and alive, were removed from each container and ovipositions were counted and recorded before returning the seeds to their respective containers. Percentage adult mortality was corrected using Abbott (1925) formular thus:

$$P_T = \frac{P_o - P_c}{100 - P_o} \times \frac{100}{1}$$

Where PT = corrected mortality (%)
PO = observed mortality (%)
PC = control mortality (%)

The experimental set up was kept inside the insect rearing cage for further 30 days for the emergence of the first filial (F1) generation. The containers were sieved out and newly emerged adult cowpea bruchid were counted and recorded. The percentage adult emergence was calculated using the method of Odeyemi and Daramola (2000).

$$\%\ \text{Adult emergence} = \frac{\text{Total number of adult emergence}}{\text{Total number of eggs laid}} \times \frac{100}{1}$$

Percentage weight loss of the cowpea seeds was determined by re-weighing after 35 days and the % loss in weight was determined as follows:

$$\%\ \text{Weight loss} = \frac{\text{Change in weight}}{\text{Initial weight}} \times \frac{100}{1}$$

After re-weighing, the numbers of damaged cowpea seeds were evaluated by counting wholesome seeds and seeds with bruchid emergent holes. Percentage seed damaged was calculated as follows:

$$\%\ \text{Seed damage} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds}} \times \frac{100}{1}$$

Beetle Perforation Index (BPI) used by Fatope et al. (1995) was adopted for the analysis of damage. Beetle perforation index (BPI) was defined as follows:

$$\text{BPI} = \frac{\%\ \text{treated cowpea seeds perforated}}{\%\ \text{control cowpea seeds perforated}} \times \frac{100}{1}$$

BPI value exceeding 50 was regarded as enhancement of infestation by the weevil or negative protectability of the extract tested.

Bioassay for *Jatropha* latex

2ml of *J. curcas* and *J. gossypifolia* latex was mixed separately with 20g of un-infested cowpea seeds in 250ml plastic containers. The latex and seeds were thoroughly mixed using a glass rod and then agitated for 5-10 min to ensure uniform coating (Ileke *et al.,* 2014a). Control experiment was also set up without latex. Ten pairs of 2 – 3 days old adults *C. maculatus* were introduced to each of the containers and covered. Four replicates of the treated and untreated controls were laid out in complete randomised design. The adult mortality was assessed after every 24 hours for 96 hours. Adults were considered dead when probed with sharp objects and there were no responses. At the end of day 4, all insects, both dead and alive, were removed from each container and ovipositions were counted and recorded before returning the seeds to their respective containers. Percentage adult mortality were corrected using Abbott (1925) formula as described above.

The experimental set up was kept inside the insect rearing cage for further 30 days for the emergence of the first filial (F1) generation. The containers were sieved out and newly emerged adult cowpea bruchid were counted and recorded. The percentage adult emergence was calculated using the method of Odeyemi and Daramola (2000) as described above.

Percentage weight loss of the cowpea seeds was determined by re-weighing after 35 days and the % loss in weight was determined as described above.

After re-weighing, the numbers of damaged cowpea seeds were evaluated by counting wholesome seeds and seeds with bruchid emergent holes. Percentage seed damaged was calculated as described above.

Beetle Perforation Index (BPI) used by Fatope *et al.,* (1995) was adopted for the analysis of damage. Beetle perforation index (BPI) was determined using the method described above.

Viability bioassay

Clean wholesome cowpea seeds were used for this experiment. The seeds were first sorted out and disinfested by putting them in a deep freezer at -5°C for 7 days. The seeds were then removed and air-dried for 1 h in the laboratory, in order to prevent mouldiness. Then, twenty grams of the cowpea seeds were weighed into 250ml transparent plastic containers and powders, latex, and wood ash at concentrations described above were added. The *J. curcas* and J. *gossypifolia* powders, latex and wood ash were thoroughly mixed with the cowpea seeds with the aid of a glass rod and agitated for 5-10 min to ensure uniform coating. There were four replicates for each treatment. The control experiments consisted of samples that were not treated with any of the powder, latex, oil and extracts and solvents treated. Both the treatments and control were left in a wooden cage in the laboratory for 90 days thereafter 40 seeds were randomly selected from each treatment and planted on a moistened filter paper in Petri dishes and left for seven days (Adedire *et al.,* 2011). Thereafter, the number of germinated seeds in each Petri dish were counted and recorded as follows:

$$\%\ \text{Germination} = \frac{\text{Number of seeds tha germinated}}{\text{Total number of seeds planted}} \times \frac{100}{1}$$

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) and treatment means were separated using the new Duncan's multiple Range Test. The ANOVA was performed with SPSS 16.0 software (SPSS, 2007).

Table 1: Percentage mortality of adult C.maculatus treated with plants ash and powder at rate 2g/20g of cowpea seed.

Plant ached and powders	Mean % Mortality ± SE on Days			
	1	2	3	4
J. carcus (WA)	40.00 ±4.08 b	52.50 ±7.50 b	92.50 ±7.50 b	100.00 ±0.00 b
J. carcus (P)	35.00 ±2.89 b	45.00 ±2.89 b	85.00 ±2.89 b	92.50±7.50 b
J. gossypyfolia (WA)	37.50 ±2.50 b	45.00 ±2.89 b	87.50±2.50 b	97.50±2.50 b
J. gossypyfolia (P)	30.00 ±4.08 b	42.50 ±7.50 b	80.00 ±4.08 b	90.00 ±4.08 b
Control	0.00 ±0.00a	0.00 ±0.00a	0.00 ±0.00a	0.00 ±0.00a

Each value is a mean +standard error of four replicates. Means within the same column followed by the same letter (s) are not significantly different at (P > 0.05) using New Duncan's multiple range t ests.(WA – Wood AshP – Powder)

Table 2: Percentage mortality of adult *C. maculatus* treated with plant latex at rate 2ml/20g of cowpea seeds.

Plant ached and powders	Mean % Mortality + SE on Days			
	1	2	3	4
J. curcas	40.00 +4.08[b]	60.00 +4.08[b]	87.50 +2.50[b]	100.00 +0.00[b]
J. gossypyfolia	35.00 +2.50[b]	50.00 +5.79[b]	80.000+4.08[b]	92.50+7.50[b]
Control	0.00 +0.00[a]	0.00 +0.00[a]	0.00 +0.00[a]	0.00 +0.00[a]

Each value is a mean +standard error of four replicates. Means within the same column followed by the same letter (s) are not significantly different at (P > 0.05) using New Duncan's multiple range tests.

Table 3: Oviposition and adult emergences of C. maculatus treated with plant latex, ash and powder.

Plants	Oviposition	% adult emergence
J. curcas (WD)	9.50 + 1.23[a]	0.00 + 0.00[a]
J.curcas (L)	10.75 + 0.85[a]	0.00 + 0.00[a]
J. curcas (P)	12.25+ 1.70[a]	16.33 + 2.14[b]
J. gossypyfolia (WD)	10.25 + 1.70[a]	0.00 + 0.00[a]
J. gossypyfolia (L)	12.00+ 0.91[a]	0.00 + 0.00[a]
J. gossypyfolia (P)	15.00+0.91[a]	20.00+ 4.08[b]
Control	83.75+ 2.81[b]	81.93+ 4.13[c]

Each value is a mean +standard error of four replicates. Means within the same column followed by the same letter (s) are not significantly different at (P > 0.05) using New Duncan's multiple range tests. (WA – Wood Ash, P – Powder L – Latex).

Table 4: percentage seeds damaged, weight loss Beetle perforation index caused by C. maculatus in cowpea seeds treated with plant wood ash, latex and powder.

Plants	Mean number of seeds	Mean number of damaged seeds	Mean % seed damaged	Mean % weight loss	*Beetle Perforation Index (BPI)
J. curcas (WD)	94.50	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]
J.curcas (P)	94.75	2.00+ 0.85[a]	2.11+ 0.72[a]	3.14+ 0.17[a]	2.86+0.47[a]
J. curcas (L)	91.75	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]
J. gossypyfolia (WD)	93.00	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]
J. gossypyfolia (P)	95.00	3.25+ 1.70[a]	3.42+ 0.67[a]	3.64+ 0.93[a]	4.64+ 0.52[a]
J. gossypyfolia (L)	94.50	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]	0.00+ 0.00[a]
Control	93.25	68.75+ 4.85[b]	73.73+ 4.31[b]	62.44+ 4.11[b]	50.00+ 0.00[b]

Each value is a mean +standard error of four replicates. Means within the same column followed by the same letter (s) are not significantly different at (P > 0.05) using New Duncan's multiple range tests.
*Beetle perforation index (BPI). Value lower than 50 is an index of positive protectant effect while BPI greater 50 is an index of negative protectability. (WA – Wood Ash,P – Powder, L – Latex).

Table 5: Effect of plant wood ash, latex and powder on viability of stored cowpea seeds.

Plant	% viability
J.carcus(WA)	95.00+ 2.89[a]
J. carcus (L)	90.00+ 4.08[a]
J. carcus (P)	97.50+ 2.50[a]
J. gossypyfolia (WA)	100.00+ 0.00[a]
J. gossypyfolia (L)	90.00+ 4.08[a]
J. gossypyfolia (P)	100.00+ 0.00[a]
Control	100.00+ 0.00[a]

Each value is a mean +standard error of four replicates. Means within the same column followed by the same letter (s) are not significantly different at (P > 0.05) using New Duncan's multiple range tests. (WA – Wood Ash, P – Powder, L – Latex).

RESULT

Toxicity of plant wood ash, latex and powder to *C. maculatus*

The effectiveness of the various plant powders and ash on the survival of cowpea bruchid, *C. maculatus* at rate 2g/20g of cowpea seeds is presented in Tables 1. The results revealed that in each treatment, the mortality of C. maculatus increased gradually with time of exposure. *J. carcus* wood ash evoked 100% mortality of C. maculatus at rate 2g/20g of cowpea seeds within 4 days of exposure (Table 1). The corresponding value for *J. carcus* powder, *J. gossypifolia* wood ash and powder were 92.5%, 97.5% and 90% mortality of adult cowpea bruchid respectively at rate 2g/20g of cowpea seeds.

Effectiveness of Plant Latex as Insecticide

The effectiveness of *J. carcus* and *J. gossypifolia* latex on the survival of cowpea bruchid, *C .maculatus* after 4 days of post treatment is presented in Table 2. The results revealed that in each treatment, the mortality of cowpea bruchid increased gradually with increase in exposure period. Jatropha curcas latex caused 100% mortality of *C. maculatus* at rate 2ml/20g of cowpea seeds after 4 days of post treatment. The corresponding values for J. gossypifolia was 92% mortality of adult cowpea bruchid at rate 2ml/20g of cowpea seeds after 4 days of post treatment.

Effect of various pant powders, ash and latex applied as contact insecticides on oviposition and adult emergence of *C. maculatus*

Table 3 presented the oviposition and percentage adult emergence of *C. maculatus* after being exposed to various plant powders, ash and latex as contact insecticide at rate 2g/20g of cowpea seeds after 4 days infestation. Progeny development was significantly suppressed by various plant powders, ash and latex with *J. carcus* and *J. gossypifolia* wood ash and latex completely inhibited the emergence of C. maculatus (100% efficiency).

Weight loss, damage and Beetle perforation index assessment of cowpea seeds

Jatropha carcus and *J. gossypifolia* wood ash and latex completely prevented infestation and damage of the treated cowpea seeds (Table 4). There was neither seed damage nor weight loss recorded in the treated cowpea seeds and Weevil Perforation Index (BPI) was zero for *J. carcus* and *J. gossypifolia* wood ash and latex except in seeds treated with *J. carcus* and *J. gossypifolia* powders that recorded 2.11% and 3.42% for seed damage respectively. However, the BPI of 2.86 and 4.64 were recorded on seeds treated with *J. carcus* and *J. gossypifolia* powders respectively. In the untreated cowpea seeds, 73.73% damage occurred as revealed by emergent holes of the bruchids. As a result of the feeding activity of *C. maculatus* larvae on the cowpea seeds, the weight of the untreated cowpea seeds was significantly ($p < 0.05$) reduced compared with the treated seeds with *J. carcus* and *J. gossypifolia* wood ash, powders and latex.

Effect of *J. carcus* **and** *J. gossypifolia* **on the germination of cowpea seeds**

The percentage of cowpea seeds that germinated after treatment with *J. carcus* and *J. gossypifolia* wood ash, powders and latex concentrations is presented in Table 5. At the end of seven-day germination period, all the treated seeds recorded high germinability. The untreated cowpea seeds and seeds treated with *J. gossypifolia* wood ash and powder had the highest percentage germination of 100%; followed by the seeds treated with *J. curcas* which had 97.5% germination. The least percentage germination was recorded in *J. curcas* and *J. gossypifolia* (90%) latex. However, this value was not significantly different from the germination observed in other treatments.

DISCUSSION

The use of plant powders and wood residues as a protectant against stored product coleopterans and lepidopterans is a common practice mostly in many developing countries of the world such as Nigeria. This practice has been suggested as one of great hope for controlling stored product pests (Singh, 2011) due to several restrictions associated with the use of synthetic chemical insecticides and fumigants. As a result, several powders and extracts of different plants have been shown to possess insecticidal activity against stored product pests (Ileke and Olotuah, 2012; Akinneye and Ogungbite 2013; Ashamo *et al*., 2013; Ogungbite *et al*., 2014).

The result obtained from this research showed that *J. carcus* and *J. gossypifolia* wood ash, powders and latex have insecticidal effects on cowpea bruchid, *C. maculatus*. The two *Jatropha* species wood ash and latex applied as contact insecticides were very effective against C. maculatus causing high mortality of adult *C. maculatus* at rate 2g/20g of cowpea seeds within 4 days of application. They also reduced oviposition and completely inhibited adult emergence. This shows that *Jatropha* species probably have oviposition deterrent, ovicidal and lavicidal properties. *Jatropha* has shown insecticidal and anti-feedant effectiveness against a wide range of insect pests. These effects may be comparable with synthetic chemical insecticides. *Jatropha* have been reported to control maize weevil, *Sitophilus zeamais* (Ohazurike *et al*., 2003), Podagrica species on okra (Emosairue and Uguru, 1999), *Spodoptera litura* (Phowichit *et al*., 2008), anti-oviposition and ovicidal effects on *C. maculatus* in cowpea seeds (Adebowale and Adedire, 2006), *Busseola fusca* and *Sesamia calamistis* (Makhar *et al*., 2007), *Helicoverpa zea* (Aiyelaagbe and Gloer 2008). The *Jatropha* oil also caused oviposition deterrence and eggs hatchability suppression in potato tuber moth, Phthorimaea operculella (Shelke *et al*., 1987).

These results are in agreement with the report of Ogunleye *et al*., (2010). According to their findings, the effects of Jatropha oil on *Sitophilus zeamais* when applied at rate of 0.1ml and 0.2ml doses, after 12 hours of application produced mortality ranged from 50% - 100% and 60%-100% respectively and cause 70% mortality for the application doses of 0.3ml and 0.4ml after 12 hours and reached 100% after 24 hours. Mechanism of action of Jatropha powders and oil on insect pests of stored products are scarce in literature. Nevertheless, Jing *et al*., (2005) reported that Jatropherol-1, a diterpene, in vitro activated PKC of silkworm mid-gut cell (4.99- fold higher than that of control at 100μg/ml). He suggested that PKC was an important intracellular target of jatropherol-1 in insects, snooping with normal message transfer system in the mid-gut cell and producing a sequence of physiological and biochemical turbulence and finally resulting in death of the insect.

The plants also prevented oviposition and adult emergence of cowpea bruchid. The effect of the plant ach, powders and latex on oviposition could be due to respiratory impairment which probably affects the process of metabolism and consequently other systems of the body of the bruchid (Osisiogu and Agbakwuru, 1978; Onolemhemhem and Oigiangbe, 1991; Adedire *et al*. 2011; Ileke *et al*. 2014b). Plant products have been reported to inhibit locomotion (Adedire *et al*. 2011; Ileke and Oni, 2011); hence, the beetles were unable to move freely thereby affecting mating activities and sexual communication (Ileke *et al*., 2012). The inability of the eggs to stick to the cowpea seed due to the presence of the ash, powder and latex also reduced adult emergence arising from egg mortality (Adedire *et al*., 2011; Ileke *et al*., 2014a). It has been reported that one of the main mechanisms of action of plant extracts is their ability to penetrate the chorion of bruchid eggs via the micropyle and cause the death of developing embryos through asphyxiation (Don-Pedro 1996a; 1996b; Adedire *et al*., 2011). Reduction in progeny development may be due to early mortality and partial or complete retardation of embryonic development (Dike and Mbah, 1992; Adedire *et al*., 2011). The protectant ability of the test plants was highly remarkable. It is evident from this study that all the plant products tested have the potential of being used as entomocides.

There were no marked differences between the percentage germination in treated cowpea seeds compared with the untreated. This shows that *Jatropha* powders, latex and wood ash have no adverse effect on germination. It had been reported that seeds treated with powders and extracts did not loose their viability (Onu and Aliyu 1995; Keita *et al*., 2001).

CONCLUSION

In conclusion, this study has revealed the insecticidal potential of *J. curcas* and *J. gossypifolia* as protectants of stored cowpea against *C. maculatus* and could serve as alternative to synthetic chemical insecticides for the protection of stored cowpea seeds against cowpea bruchid, *C. maculatus*. for poor resource farmers in developing countries such as Nigeria.

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