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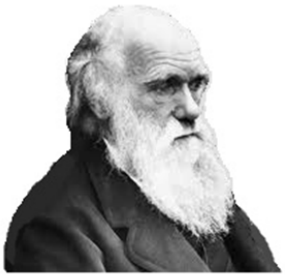

World News of Natural Sciences

An International Scientific Journal

WNOFNS 58 (2025) 183-193 EISSN 2543-5426

Efficacy of powders of some spices for the control of *Callosobruchus subinnotatus* (Pic) on stored Bambara groundnut (*Vigna subterranea* (L.) Verdc.) seeds

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ABSTRACT

A study was conducted in the laboratory of the Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe state, to evaluate the effects of powders of some spices (pepper, ginger and garlic) for the control of *Callosobruchus subinnotatus* on stored Bambara groundnut. The experiment was laid out in a Completely Randomized Design (CRD) with three (3) treatments, and control. Each treatment was replicated three times. The results from the research showed that garlic powder caused a significantly ($p \leq 0.05$) higher adult *C. subinnotatus* mortality, which was followed by pepper powder and ginger powder in that order. In addition, there was no significant ($p > 0.05$) difference in number of exit holes between Bambara groundnut treated with the three different spices. However, 4 and 8 grams gave best results on days 12 and 16 evidenced with significantly ($p \leq 0.0$) fewer exit holes in Bambara groundnut. Results further showed higher weight loss from *C. subinnotatus* infested stored Bambara groundnut treated with garlic than the other treatment combinations and control, though this was not significant ($p > 0.05$) when compared with Bambara groundnut treated with pepper and ginger. The experiment further showed that higher levels of the spices (12g) caused highest adult *C. subinnotatus* morality compared with lower ones and control. It is therefore recommended that both farmers and storeowners should adopt the use of these spices, and in higher levels in protecting stored Bambara groundnut against infestation by *C. subinnotatus,* as there is the added advantage of avoiding synthetic insecticides for the more environmentally friendly botanical ones.

***Keywords*:** Bambara groundnut, spices, *Callosobruchus maculatus*, adult mortality, *Vigna subterranea*

(Received 03 November 2024; Accepted 10 December 2024; Date of Publication 12 December 2024)

1. INTRODUCTION

Grain legumes are an essential part of diets of a great number of people, especially in arid and semi-arid areas of the world, and an important industrial raw materials (Aremu *et al*., 2006). Nutritional composition of pulses have been reported, as well as their functional properties, protein solubility and amino acid content (Onwuliri and Obu, 2002; Aremu *et al*., 2006). This is in addition to containing dietary fibres with protein content more than cereals and by far more than root and tuber corps (Mahazib *et al*., 2013).

A member of the legume family, the Bambara groundnut (*Vigna subterranea*), is one of the most important sources of protein in rural Africa and one of the most underutilized and neglected legumes. This important pulse, which is draught resistant (Amarteifio *et al*., 2006; Mkandawire, 2007), has been in cultivation for time immemorial, especially in sub-Saharan Africa (Mkandawire, 2007), which guarantees an all year round supply of much needed protein for rural dwellers and small scale farmers (Azam-Ali *et al*., 2001; Mwale *et al*., 2007).

Traditionally cultivated by the womenfolk in order to support their families, Bambara groundnut is cultivated under the harshest conditions of the tropical climate without access to irrigation facilities and other inputs of production (Mwale *et al*., 2007). Third in importance only to cowpea and groundnut as a protein source (Sesay *et al*., 2001), Bambara groundnut yields well under conditions, which are not favourable for groundnut (*A. hypogea*) and other crops. Its drought tolerance makes it adapted as a changing climate friendly crop (Hillocks *et al*., 2012).

Available records show that Bambara groundnut originated from Nigeria, particularly the Northeastern parts extending to areas around Northern Cameroun.

This was confirmed by report by Effa and Uko (2017) of the prevalence of a plethora of varieties of Bambara groundnut in Nigeria, mostly in the northern parts. Aside its high nutritive and dietary value, which is copiously reported (Brink and Belay, 2006; Hillocks *et al*., 2012, Effa and Uku, 2017), Bambara groundnut has a unique and an appealing flavour, which is reflected in its demand from small local and niche markets (Hillocks *et al*., 2012). Among the many attributes of Bambara groundnut is its medicinal value, especially in healing diseases such as helminthosis, schistomiasis and diarrhea, among others.

However, in spite of the nutritional values and usefulness of Bambara groundnut, the crop is reported to be threatened by the devastating activities of stored products pests, notable among them is, *Callosobruchus subinnotatus* (Lale and Vidal, 2003).

Infestation by *C. subinnotatus* starts in the field before harvest by females first laying their eggs on dry pods that are near the soil surface, which continues in stocks after harvest.

The weevil populations of this species persist in stocks as long as Bambara groundnut seeds are available, which can result in weight loss (Amuti and Larbi, 1981; Uddin *et al*., 2017), viability and the market value of seeds (Mbata, 1994). Weight losses of stored Bambara groundnut were estimated to be nearly 50% in Nigeria. These substantial losses are related to the multivoltine nature of this beetle, which is capable of producing about ten generations in a year on stored Bambara groundnut (Ketoh *et al*., 2001).

This storage challenge can easily be mitigated by control measures (Buba *et al*., 2023). However, toxic synthetic insecticides being applied for the control of *C. subinnotatus* have a plethora of problems associated with it, which include being carcinogenic, mutagenic, teratogenic and being hazardous to non-target organisms and the environment alike (Buba and Salisu, 2023).

There is therefore overwhelming interest in utilizing botanicals to serve as alternatives to synthetic pesticides (Buba *et al*., 2023). Certain botanicals such as pepper, ginger and garlic have been utilized variously for the control of insect pests of stored commodities (Upadhyay, 2016; Mohamed and Sleem, 2021; Buba *et al*., 2023; Buba and Salisu, 2023). This study was carried out to evaluate the effect of some spices on the mortality of *C. subinnotatus* infesting stored Bambara groundnut.

2. MATERIALS AND METHODS

The study was conducted in Gombe state, Sudan Savanna agro-ecological zone of Nigeria with coordinates of 09°69′N and 11°56′E of the equator, and an altitude of 431m above sea level (GSADP, 2013).

Sourcing of Experimental Material

Insect free, stored Bambara groundnut seeds were purchased from the open market in Kashere, Gombe state and put in airtight containers, labelled and kept for future use. Bambara groundnut seeds infested with *C. subinnotatus* were sourced from grain stores out of which adult *C. subinnotatus* were recovered and used to culture subsequent generations of insects.

Three spices (pepper, ginger and garlic) were purchased bought from Kashere local market and kept in air tight containers until required.

Preparation of the Powdered Extracts of Spices

The Botanical spices (pepper, ginger and garlic) were dried under the sun and ground to powder. These were sieved differently using a wire mesh. The respective powders were kept separately in labelled airtight containers and were used as treatments in the ensuing experiment.

Culture of *C. subinnotatus*

Three 1L transparent plastic containers were filled with *C. subinnotatus* infested Bambara groundnut and their openings were secured with fitting muslin cloths and rubber bands; this allowed for adequate ventilation for the insects as well as preventing them from escaping and disallowing other organisms from gaining access into the containers. This is to make a culture from which parent stock of *C. subinnotatus* were obtained. The culture was maintained for 28 days, which was enough for mating between adult males and females, oviposition, emergence and perpetuation of at least one generation of *C. subinnotatus*.

From the insect culture, 100 adult *C. subinnotatus* were picked and put in three containers of uninfested stored Bambara groundnut weighing 1 kg each. These were allowed to mate for seven days and oviposit. They were afterward removed and discarded. The containers were left for a further seven days undisturbed in the laboratory for pristine adult *C. subinnotatus* to emerge. This is the first filial (F_1) generation of *C. subinnotatus* of uniform age, which were used for the experiment.

Treatment of Bambara groundnut with botanical powders

Twenty grams of uninfested Bambara groundnut were put in three plastic containers. Fifty pristine adult F_1 *C. subinnotatus* were introduced to each container. Ground powders of the

already prepared spices were introduced into each container and mixed thoroughly. Each container was covered with a piece of muslin and secured with a rubber band and well labelled.

These were the treatments, with each replicated three times. There was also a control treatment, which had no spice applied to it. The treatments are shown below:

T1 = consisting of garlic powder, Bambara groundnut and *C. subinnotatus*.
T2 = consisting of pepper powder, Bambara groundnut and *C. subinnotatus.*
T3 = consisting of ginger powder, Bambara groundnut and *C. subinnotatus.*
To = consisting of Bambara groundnut grains and *C. subinnotatus* without any spice powder.

Experimental Design

The experiment was set up on a workbench in a Completely Randomized Design (CRD) replicated three times with four treatments making 36 plastic containers.

Data Collection and parameters measured

Adults Mortality of *C. subinnotatus* on Bambara Groundnut Treated with Spices

Number of *C. subinnotatus* adult mortality were recorded by counting the dead insects after 4 days intervals. Counted dead *C. subinnotatus* were discarded after counting.

Exit Holes on Bambara Groundnut infested by *C. subinnotatus*

Number of exit holes on Bambara groundnut bored by *C. subinnotatus* were counted and recorded. This was done by randomly picking five seeds of Bambara groundnuts, counting the number of exit hole(s) on each Bambara groundnut grain, calculating the mean and recording.

Weight Loss on Bambara Groundnut infested by *C. subinnotatus*

The weight loss was obtained by subtracting the final weight of Bambara groundnut nut seeds from the initial weight of Bambara groundnut seeds at the end of the experiment.

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SAS software package and means were separated by Least Significance Difference (LSD) at the 5% probability level.

3. RESULTS

On day 4, Table 1 shows significant ($p \leq 0.05$) difference in mortality of adult *C. subinnotatus* on Bambara groundnut treated with garlic compared with both ginger and pepper, which showed no significant ($p > 0.05$) difference between them. On days 8 and 12 there was significant ($p \leq 0.05$) difference in adult *C. subinnotatus* mortality when treated with pepper powder, Garlic powder compared with when treated with Ginger powder. The highest numbers of adult *C. subinnotatus* mortality were recorded on day 20 with 12 grams spice treatment.

The result further shows a highly significant (p≤0.05) at the interaction of spices and levels on 12 and 16 day after treatment.

Table 1. Number of adult *C. subinnotatus* mortality on stored Bambara groundnut treated with three spices.

SOV	AM4	AM8	AM12	AM16	AM20
SPICE					
Pepper	2.42	2.83	3.00	2.92	2.83
Ginger	1.75	2.17	2.25	2.33	2.42
Garlic	2.75	3.33	3.42	2.5	2.83
Level of Sig. (p≤0.05)	**	**	**	**	**
LSD	0.7297	0.5617	0.5958	0.5439	0.688
TREATMENT (g)					
0	0.67	2.22	2.55	2.22	1.56
4	2.56	2.89	2.44	2.33	2.33
8	2.67	2.89	3.33	2.78	3.11
12	3.33	3.11	3.22	3.00	3.78
Level of Sig. (p≤0.05)	**	**	**	**	**
LSD	0.8426	0.6486	0.688	0.628	0.7944
INTERACTION					
Spice * Treatment	NS	NS	**	**	NS

SOV = Source of Variation, AM = Adult Mortality, LSD = Least Significant Difference, NS = Not Significant

Table 2 shows the interaction effects of spices and the rate of treatments on number of adult mortality of *C. subinnotatus* on stored Bambara groundnut. Result shows that the interaction of spices and the rate of treatments were significant (p≤0.05) on day 12.

The interaction effects of spices at the rate of 8 grams was significantly higher than 0, 4, and 12 grams on day 12. In addition, the interaction of spices at the rate of 12 grams was significantly (p≤0.05) higher on day 16 than the interaction of 0 gram, 4 grams, and 8 grams.

Table 2. Interaction table adult mortality on days 12 and 16.

	AM 12 DYS			AM 16 DAYS		
TREATMENT (g)	Pepper	Ginger	Garlic	Pepper	Ginger	Garlic
0	1.33	3.33	3.00	2.00	2.33	2.33
4	2.33	1.33	3.67	2.00	1.33	3.67
8	4.33	2.00	3.67	3.67	2.67	2.00
12	4.00	2.33	3.33	4.00	3.00	2.00
Level of Sig. (p≤0.05)	**	**	**	**	**	**
SE±	0.190			0.161		
LSD	0.688			0.628		

AM = Adult Mortality, SE = Standard Error, LSD = Least Significance Difference

Table 3 shows that there was no significant (p>0.05) difference in exit holes by adult *C. subinnotatus* on stored Bambara groundnut treated with pepper, ginger and garlic powders. However, numbers of exit holes recorded on stored Bambara groundnut when treated with ginger powder was lowest, though not significantly different compared to when treated with garlic and pepper powders.

Furthermore, treatment rates of 8 grams gave the best protection against *C. subinnotatus*, especially on days 12 and 16, evidenced by lowest number of exit holes, which showed significantly (p≤0.05) lower number of exit holes compared with other rate.

Table 3. Number of exit holes due to adult *C subinnotatus* on stored Bambara groundnut treated with some spices.

SOV	DAT 4	DAT 8	DAT 12	DAT 16	DAT 20
SPICE					
Pepper	-	0.58	1.00	1.25	1.50
Ginger	-	0.67	0.67	1.25	1.33
Garlic	-	0.58	0.92	1.08	1.42
Level of Sig. (p≤0.05)	-	NS	NS	NS	NS

TREATMENT (g)					
0	-	0.56	0.78	1.22	1.67
4	-	0.89	0.67	1.11	1.11
8	-	0.33	0.56	0.67	1.11
12	-	0.67	1.44	1.78	1.78
Level of Sig. (p≤0.05)	-	NS	*	*	NS
LSD	-		0.7068	0.7431	
INTERACTION					
Spice * Treatment	-	NS	NS	NS	NS

SOV = Source of Variation, DAT = Day After Treatment, LSD = Least Significant Difference, NS = Not Significant

Table 4 shows that the treatment rate with highest weight loss was recorded at 12 grams, followed by the remaining rate 8g, 4g and lowest was recorded at 0g, which showed no significant (p>0.05) weight losses in both interaction and main effects of spices.

Table 4. Seed weight loss on stored Bambara groundnut treated with spices due to infestation by *C. subinnotatus.*

SOV	INITIAL WEIGTH (g)	FINAL WEIGHT (g)
SPICE		
Pepper	20	19.5358
Ginger	20	19.5417
Garlic	20	19.4583
Level of Sig. (p≤0.05)		NS
LSD		0.4141
TREATMENT (g)		
0	20	19.1756
4	20	19.3911
8	20	19.5833

12	20	19.8978
Level of Sig. (p≤0.05)		NS
LSD		0.4782
INTERACTION		
Spices × Treatment		NS

SOV = Source of Variation, LSD = Least Significant Difference, NS = Not Significant

4. DISCUSSION

The current study revealed that application of spices to stored Bambara groundnut seeds resulted in mortality of adult *C. subinnotatus*. It further revealed that the higher the rates of application of powders of spices, the higher the mortality of adult *C. subinnotatus*. To consolidate this finding, control measures were effective as adult *C. subinnotatus* on stored Bambara groundnuts without any spice showed high survival rates. This may be because of the potency of the spices used in control, where adult *C. subinnotatus* showed high mortality especially towards the end of the experiment. These findings are in agreement with the report of Holtz *et al*. (2019), Buba and Salisu (2023) and Buba *et al*. (2023) who reported that powder from plant leaves and some spices promoted the death of weevils to a significant level. Other workers such as Oparaeke and Bunmi (2006) and Devi and Devi (2011) reported similar results where it was discovered that insect pests of stored products were adversely affected by powders of spices, especially at high dosages. Emeasor *et al*. (2005) and Nadra (2006) reported that the effectiveness of these spices might be due to their toxic or repellant properties.

The study further showed that Bambara groundnut seeds treated with Spices showed fewer seeds with exit holes compared to the untreated (control). This may be due to the action of the spices, which directly retarded all developmental stages, and feeding activities of the insect pests. This is in agreement with Lale (1994), Oparaeke and Bunmi (2006), Devi and Devi (2011) and Rosulu *et al*. (2022) who reported reduction in number of adult insect emergence, through exit holes, on stored grains. Bambara groundnut weevil is known to bore holes through seeds when emerging from the late instar larvae. Feeding activity during progeny development results in exit holes in seeds. This act usually results in grain with holes and reduces both quantity and quality attributes of grains to a significant level.

The present study showed a comparatively lower weight loss recorded in treated Bambara groundnut. Insects damage cowpea seeds by direct feeding. The insects feed on the endosperm resulting in loss of weight and quality of the grain. Also, the inherent properties of the Bambara groundnut seeds such as genetic factors, possible presence of biochemical content, such as tannins, phenols etc. make them more palatable to *C. subinnotatus* larvae since the quantity of food consumed by the developing larvae of the insect is proportional to the amount of weight loss of the seed. However, there was no significant difference in weight loss between Bambara groundnut treated with spices and those without spices, those without spices gave the highest weight loss. This could be due to absence of control measures, which allowed insects to feed unhindered. Rosulu *et al*. (2022) supported the assertion that spices suppressed feeding activities and consequently weight loss on stored grains. This reduced weight loss in the control

treatment may be due to presence of some active ingredients in the spices as reported by Lawan *et al*. (2016).

5. CONCLUSION

Based on the results obtained from this work, it can be concluded that all the tested spices showed bioactivity against *C. subinnotatus*. However, garlic powder exhibited remarkable efficacy against *C. subinnotatus*, followed by pepper powder and ginger powder. It was equally demonstrated that these spices at different application rates were highly effective against *C. subinnotatus*. Although these spices did not show an instantaneous activity against *C. subinnotatus*, their gradual activities came to bear as more mortalities were recorded towards the concluding parts of the research. Moreover, preparation of powders of these spices is simple and easy even to peasants. These formulations can successfully be implemented by farming community for the management of *C. subinnotatus* during storage of Bambara groundnut.

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