

Response of some Bambara groundnut [*Vigna subterranea* (L.) Verdc.] seeds to *Callosobruchus subinnotatus* infestation in Gombe*

Ajiya B. Cleophas¹, Kamalu K. Abubakar¹ , Damfami Abigail², Abdulmalik B. Shui'bu³, Adamson Daniel⁴, Ismai'la Muhammad¹

¹ Department of Plant Sciences, Gombe State University, Tudun Wada, Gombe, Gombe State, Nigeria

² Department of Plant Science and Biotechnology, University of Jos, Jos, Nigeria

³ Department of Zoology and Wildlife Ecology, Gombe State University, Tudun Wada, Gombe, Gombe State, Nigeria

⁴ Gombe State Ministry of Agriculture, Animal Husbandry and Cooperatives, Gombe, Nigeria

Corresponding author: Ajiya B. Cleophas (cleophasbillah1@gmail.com)

Academic editor: Faisal Hayat ♦ Received 7 July 2025 ♦ Accepted 13 October 2025 ♦ Published 31 October 2025

Abstract

Despite the economic and nutritional status (rich in lysine and methionine) of Bambara groundnut seeds, it is been considered as underutilized and susceptible to infestation by insect pests in storage. The current study was aimed to determine if *Callosobruchus subinnotatus*, the Bambara groundnut seed beetles, could infest eight different types of Bambara groundnut seeds. Significant varietal differences were observed in resistance to storage insect pests based on progeny emergence, weight loss, susceptibility index, and development time. The highest progeny emergence was recorded in Deep brown with white eyes (34.62%), Cream with black stripes (33.71%), and Cream with brown eyes (30.99%), indicating high susceptibility. In contrast, cream with black eye (18.56%) and Brown with white eye (18.97%) showed lower emergence, suggesting stronger resistance. Percentage weight loss (PGWL) was highest in Cream with black eyes (5.7%) and Deep brown with white eyes (5.3%), while the least was in Cream with brown stripes (1.5%). Susceptibility index and median development time further confirmed varietal resistance, with CBEB (SI = 1.6; MDT = 104.2 days) and CWBS (SI = 2.6) showing strong resistance, while Black with White Eye (SI = 7.7; MDT = 28.7 days) and Cream with Black Eye (SI = 8.8; MDT = 25.8 days) were highly susceptible. Cream with Brown Eye had the highest retained seed weight (8.52 g), while Black Bambara groundnut showed the highest PGWL (6.88%) and the lowest seed retention (3.21 g), indicating severe damage. As a result, for resource-strapped subsistence farmers, using resistant varieties like Cream with a black eye and brown stripes may be the most straightforward and cost-effective option to improve Bambara groundnut varieties during storage.

Keywords

Bambara groundnuts, pest infestation, susceptibility, *Callosobruchus subinnotatus*, infestation

Introduction

The Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an underappreciated African Fabaceae species. It's known for its great nutritional content, resistance to poor soils,

drought, and salt stress, and its capacity to produce even where peanuts fail (Jideani and Diedericks 2014). Seed legumes, particularly Bambara groundnut, have an essential socioeconomic significance in tropical Africa, where they are a part of culinary history (Massawe et al. 2005).

* Topical Collection "Emerging Pests and Their Management in Global Agriculture", edited by Dr. Habib Ali.

Northeastern Nigeria and northern Cameroon are home to the Bambara groundnut. Their green stalks are often employed as a source of nutrition for cattle (Brink et al. 2006). The seeds have an average of 63 percent carbohydrates, 19 percent proteins, and 6.5 percent fats, which are enough to make this legume a complete food. Calcium, potassium, iron, and nitrogen are all found in abundance (Bamishaiye 2011).

In the tropics, beetles (Coleoptera: Bruchidae) are the most harmful insects for storing grain legumes (Dick and Credland 1984). Various beetles wreak havoc on grains when they're in storage. These insects' infestation begins right from in the field and grow while they are stored (Hite 2001). The losses produced by these insects to stored grains are significant, and in the case of a *C. maculatus* infestation, the most prevalent beetles in hot climates, losses can exceed 100% (Maina et al. 2011). Female beetles may produce more than 100 eggs, and a generation of only one month enables infestations to develop rapidly until the stock is completely destroyed in a few months (FAO 2009). Maina et al. (2011) found that the severity of damage caused by *C. subinnotatus* increases starting from the third month of storage of Bambara groundnut seeds and that the longer the storage term is, the more significant the damage is due to increased spawning and adult emergence of *C. subinnotatus*.

The study aimed to determine the infestation and susceptibility status of different varieties of Bambara groundnut by the insect pest *C. subinnotatus*, considering seed weight loss and severity damage of each variety of Bambara groundnut infested with *C. subinnotatus*.

Methodology

Study area

The research was conducted in Gombe, Gombe State, Nigeria's North East. With an average rainfall of 850 mm, it has two different climates: the dry season (November-March) and the rainy season (April-October). Gombe, Nigeria is located at 10°17'22.88"N, 11°10'2.24"E.

Experimental site

The experiment was carried out in the Department of Plant Science (Botanical Garden) Gombe State University, under ambient temperature and relative humidity conditions.

Collection of Bambara groundnut seeds

The seeds were collected from major local markets. The experiment was conducted using a local Bambara groundnut variety. Eight (8) varieties of Bambara groundnut seeds were hand-picked to eliminate broken seeds, seeds with holes, and seeds that contained the beetle's egg. BBN = Black Bambara nut, BWE = Brown with White-eye, CBE

= Cream black eye, CBS = Cream with Black stripes, CBRS = Cream with Brown stripes, CBRE = Cream with brown eye, CBS = Cream with brown Stripes, CBEB = Cream with black and brown Stripes, DBWE = Deep brown with white eye. were the colors obtained. The Bambara groundnut seeds were average in size and smooth in texture.

Disinfestations

To prevent pre-existing insect contamination, visibly infested or egg-bearing Bambara groundnut seeds were manually removed. The remaining seeds were disinfested by freezing at 4 °C for 72 hours, a method effective against all developmental stages of *C. subinnotatus*. After freezing, seeds were kept at room temperature (27 °C) for 24 hours before use in bioassays, ensuring consistent and insect-free experimental material (Jackai and Asante 2001; Amoako-Attah et al. 2022).

Insect culture

Seed size for each Bambara groundnut variety was determined by weighing 10 grams and calculating the average weight per seed. To establish a culture of *C. subinnotatus*, 50 g of clean, uninfected seeds from each variety were infested with five pairs of adult beetles and kept in perforated containers under controlled conditions for seven days to allow oviposition, following established procedures (Ojo and Ogunleye 2019).

Experimental design and seed infestation

To evaluate the susceptibility of the Bambara groundnut varieties to *C. subinnotatus* infestation, 10 g of seeds per variety were placed in 24 containers arranged in a completely randomized design with three replicates. Each container received five pairs of newly emerged adult beetles and was kept at 30 ± 2 °C and $65 \pm 5\%$ RH for seven days to allow oviposition. Afterward, adults were removed, and the containers were incubated for 21 days to monitor insect development (Ojo and Ogunleye 2019).

Data were collected on oviposition, development time, adult emergence, and seed damage. A susceptibility index (SI) was then calculated to classify the resistance level of each variety. This method follows standard procedures for artificial infestation and pest resistance screening as described by Dobie (1974), Jackai and Asante (2001).

Severity of seed damaged

Observation of adult insect emergence commenced three weeks post-infestation and was conducted daily thereafter. Seed damage assessment was performed by counting the number of seeds with visible emergence holes, which served as a direct indicator of infestation intensity for each variety.

Severity Seed damage = No. of Adult progeny ÷ No. of damaged seeds Ojo and Ogunleye (2019).

Susceptibility index

The susceptibility index (SI) for variety was calculated using the Dobie methods explained by Dobie (1974).

$$SI = \log F_1 \div D \times 100$$

Where: F_1 is the total number of emerging adults and D is the median developmental period, which will be calculated as the time from the mid-oviposition period to

50% emergence of the F_1 generation. The Dobie index was then used to categorize the 8 Bambara groundnut varieties as modified by Maina et al. (2011): < 4 = Resistant, 4.1–6.0 = moderately resistant. 6.1–8.0 = moderately susceptible. 8.1–10 = Susceptible, > 10 = highly susceptible.

Seed weight loss

Observation on seed weight loss was made and the weight infested seed was taken at the end of the emergence of F_1 progeny. Percentage weight loss (Nwana et al. 2021) was determined using the formula:

$$\text{Seed weight loss} = \frac{\text{Initial weight of seed} - \text{Final weight of seed}}{\text{Initial weight of seed}} \times 100$$

Data analysis

Data collected were subjected to Excel to calculate the percentage mean progeny, the mean of seed damaged, and the percentage weight loss by *C. subinnotatus*. Dobie susceptibility index was used to determine the susceptibility of the different Bambara groundnut varieties used in this study.

Results

Emergence Progeny of *C. subinnotatus* from Infested Bambara groundnut Seeds

The results showed how (10) *C. subinnotatus* was introduced into 10 grams of the Bambara groundnut seed (Table 1). The highest variety with a percentage emergence of 34.62% was recorded from Deep brown with white eyes, followed by 33.71% from Cream with black stripes, followed by 30.99% from Cream with brown eyes, then 30.00% from Black, and then followed by 29.17 from

Table 1. Mean emergence of *C. subinnotatus* from infested Bambara groundnut seeds.

S/N	Variety	Weight of Seed (g)	Number of Insects	% Mean Emergence Progeny	Inference
1	BBN	10	10	30.00	Susceptible
2	BWE	10	10	18.92	Moderatly Resistant
3	CBE	10	10	18.56	Moderatly Resistant
4	CBS	10	10	33.71	Susceptible
5	CBRS	10	10	21.01	Moderatly Resistant
6	CWBS	10	10	30.99	Susceptible
7	CBEB	10	10	29.17	Susceptible
8	DBWE	10	10	34.62	Highly Susceptible

Note: BBN = Black Bambara nut, BWE = Brown with White-eye, CBE = Cream black eye, CWBS = Cream with Black stripes, CBRS = Cream with Brown stripes, CBRE = Cream with brown eye, CBS = Cream with brown Stripes, CBEB = Cream with black and brown Stripes, DBWE = Deep brown with white eye.

Cream with black eye and brown stripes, followed by 18.97 from Brown with white eye, and the least was 18.56% from Cream with a black eye. This shows that the percentage emergence depends on the variety and exposure period.

Percentage weight loss of Bambara groundnut seed infested with *C. subinnotatus*

The percentage seed weight loss of different varieties of Bambara groundnut infested with *C. subinnotatus* was recorded (Table 2). The highest percentage of weight loss was 5.7% from Cream with black eyes, followed by 5.3% from Deep brown with white eyes followed by 4.8 from Brown with white eyes, followed by 4.0% from Cream with black stripes, followed by 3.1% from Black, followed by 2.8% from Cream with brown eye, and then followed by 2.0% from Cream with black eye and brown stripes, and the least seed weight loss was 1.5% from Cream with brown stripes.

The study of percentage mean progeny emergence in Table 1 revealed significant variation in the resistance levels of the Bambara groundnut varieties. The varieties

Table 2. Percentage weight loss of Bambara groundnut seed Infested with *C. subinnotatus*.

S/N	Variety	MDT	Susceptibility Index (S.I)	Resistant Status
1	BBN	50.0	4.0	Moderately Resistant
2	BWE	28.7	7.7	Susceptible
3	CBE	25.8	8.8	Highly Susceptible
4	CBS	56.2	3.5	Resistant
5	CBRS	36.2	5.9	Moderately Resistant
6	CWBS	70.4	2.6	Highly Resistant
7	CBEB	104.2	1.6	Highly Resistant
8	DBWE	64.1	3.0	Resistant

BBN = Black Bambara nut, BWE = Brown with White-eye, CBE = Cream black eye, CWBS = Cream with Black stripes, CBRS = Cream with Brown stripes, CBRE = Cream with brown eye, CBEB = Cream with black and brown Stripes, DBWE = Deep brown with white eye, MDT = Median Developmental Period.

BWE (34.62%), CBS (33.71%), and CWBS (30.99%) recorded the highest progeny emergence, indicating greater susceptibility to insect infestation. In contrast, BWE (18.92%), CBE (18.56%), and CBRS (21.01%) had the lowest emergence rates, suggesting comparatively higher resistance. Varieties such as BBN and CBEB exhibited intermediate progeny emergence levels, indicating moderate susceptibility.

The result in Table 2 demonstrated significant varietal differences in resistance to storage pests based on Susceptibility Index (SI) and Median Development Time (MDT). Varieties CBS (SI = 3.5), DBWE (SI = 3.0), CWBS (SI = 2.6), and CBEB (SI = 1.6) exhibited strong resistance, as indicated by their low SI values and prolonged MDTs ranging from 56.2 to 104.2 days. In contrast, varieties BBN and CBRS showed moderate resistance, with SI values of 4.0 and 5.9, respectively, and intermediate MDTs between 36.2 and 50.0 days. Highly susceptible varieties such as CBE (SI = 8.8, MDT = 25.8 days) and BWE (SI = 7.7, MDT = 28.7 days) supported more rapid pest development.

Table 3. Susceptibility index of different infested Bambara groundnut seeds.

S/N	Variety	Weight of Seed (g)	Number of Insect	Mean of Average Final weight	PGWL	Inference
1	BBN	10	10	3.21 ± 3.1	6.88	Highly susceptible
2	BWE	10	10	5.21 ± 4.8	47.9	Moderately susceptible
3	CBE	10	10	4.28 ± 5.7	57.2	Susceptible
4	CBS	10	10	5.98 ± 4.0	40.2	Moderately resistant
5	CBRS	10	10	7.24 ± 1.5	14.8	Resistant
6	CWBS	10	10	8.52 ± 2.8	27.6	Resistant
7	CBEB	10	10	7.98 ± 2.0	20.2	Resistant
8	DBWE	10	10	4.74 ± 5.3	56.2	Susceptible

BBN = Black Bambara nut, BWE = Brown with White-eye, CBE = Cream black eye, CWBS = Cream with Black stripes, CBRS = Cream with Brown stripes, CBRE = Cream with brown eye, CBEB = Cream with black and brown Stripes, DBWE = Deep brown with white eye PGWL = percentage weight loss.

The results show significant variability in insect resistance among the tested seed varieties based on Percentage Grain Weight Loss (PGWL) and final seed weight. BBN recorded the highest PGWL (6.88%) and the lowest retained seed weight (3.21 g ± 3.1), indicating severe insect damage and variability in infestation levels. In contrast, varieties such as CBRS (14.8%), CBRE (27.6%), and CBEB (20.2%) exhibited the lowest PGWL values, suggesting higher resistance to insect damage. Among these, CWBS had the highest retained weight (8.52 g), indicating minimal deterioration during storage. Conversely, varieties BBN, BWE, CBE, and DBWE recorded higher weight losses, with PGWL values exceeding the 50% susceptibility threshold confirming their classification as highly susceptible.

Discussion

The susceptibility indices for various sample types were determined based on the length of development, the number of F1 adults, and the duration of development. Formation of the bruchid was encouraged among Bambara groundnut cream with brown eyes, deep brown with white eyes, cream with black eyes, black, cream with brown stripes, cream with black eyes and brown stripes, cream with black stripes, and brown with white eye. As a result, they are more prone to sustain significant damage in standard storage circumstances. Because the emerging adults from the varieties that encouraged the development of the bruchid were heavier than those from the other kinds, it's likely that the varieties that favored the development of the bruchid offered greater nutrition than the other types.

The high progeny emergence observed in varieties such as BWE, CBS, and CWBS suggests a high level of susceptibility to infestation. This aligns with the findings of Ajayi et al. (2020), who emphasized that high progeny emergence in stored grains contributes to rapid insect population growth, increased postharvest losses, and reduced seed quality. As such, susceptible varieties like DBWE and CBS may pose significant storage risks and should either be treated with biopesticides or excluded from long-term storage without protection. Conversely, the lower insect emergence in BWE, CBE, and CBRS indicates the presence of resistance mechanisms, potentially due to physical (e.g., thick seed coats) or chemical (e.g., secondary metabolites) traits. This observation is consistent with Adebayo and Olatunji (2018), who reported that lower progeny emergence correlates with natural seed defenses such as tannins and flavonoids.

Varieties like BBN and CBEB, which demonstrated moderate emergence, may possess promising resistance traits that could be enhanced through selective breeding. Overall, the findings provide critical insight for postharvest grain management and serve as a useful guide for breeding programs aimed at developing insect-resistant grain varieties.

The lower susceptibility indices and longer development times recorded for varieties CWBS, CBEB, CBS, and DBWE suggest enhanced resistance to storage pests, likely due to seed characteristics that inhibit insect development. This supports the hypothesis that resistance mechanisms may include unfavorable nutritional quality, physical barriers such as seed coat hardness, or the presence of biochemical deterrents. Intermediate resistance levels observed in BBN and CBRS may be attributed to moderate physical or chemical traits that partly inhibit pest development. On the other hand, the high susceptibility of CBE and BWE is associated with shorter development times and high SI values, implying a lack of effective resistance traits. This pattern aligns with findings by Ajayi and Adedire (2019), who reported that resistance in stored grains may be linked to seed coat thickness, low moisture content, and the presence of anti-nutritional compounds like tannins and flavonoids.

These results reinforce existing literature and highlight the potential for selecting pest-resistant varieties based on SI and MDT parameters. Incorporating such varieties into postharvest storage systems could significantly reduce grain losses and contribute to food security strategies in regions prone to storage pest infestations. The observed differences in PGWL and retained seed weight across the varieties suggest inherent varietal resistance mechanisms to insect infestation. The lower PGWL in CBRS, CBRE, and CBEB may be attributed to physical and chemical defense traits such as seed hardness, thick seed coats, or anti-nutritional compounds that deter insect feeding. This is consistent with the findings of Ojo et al. (2019), who reported that seed coat characteristics play a crucial role in reducing insect penetration and feeding damage in cowpea and maize. Additionally, the role of phytochemicals in resistance is evident, as supported by Ileke and Odeyemi (2020), who demonstrated that compounds such as tannins and alkaloids inhibit the development of *C. maculatus* and other bruchid beetles in resistant grain varieties. The superior performance of CBRE, both in terms of reduced weight loss and high seed retention, points to the potential presence of such protective traits.

On the other hand, the susceptibility of BBN, BWE, CBE, and DBWE, as indicated by their higher PGWL and lower final weights, highlights the absence of effective resistance traits. Their performance aligns with the threshold values established by Nwana et al. (2021) for identifying highly susceptible varieties. These findings underscore

the importance of screening for resistance-related traits and provide valuable direction for breeding programs aimed at enhancing postharvest insect resistance and reducing storage losses.

Conclusion

According to the findings of this study, among the Bambara groundnut types, cream with black eye and brown stripes have consistently showed lesser vulnerability to *C. subinnotatus* infestation. The seed weight loss due to *C. subinnotatus* infestation revealed that there was variance in the expression of resistance to *C. subinnotatus* infestation among the eight (8) Bambara groundnut varieties. Farmers should be encouraged to grow cream with black eye and brown stripes because it can be stored without synthetic chemicals and the use of resistant varieties like Cream with black eye and brown stripes could offer the simplest and cheapest way of improving Bambara nuts for resource poor subsistence farmers.

Author contributions

Conceptualization: ABC, DA. Data curation: KKA. Formal analysis: KKA. Methodology: ABS, AD, ABC, DA. Software: AD. Supervision: ABC. Validation: IM. Writing – original draft: ABS. Writing – review and editing: IM.

References

- Adebayo RA, Olatunji AT (2018) Assessment of insect emergence and damage on cowpea varieties under storage conditions. *Journal of Stored Products Research* 77: 55–61. <https://doi.org/10.1016/j.jspr.2018.03.004>
- Ajayi FA, Adedire CO (2019) Resistance mechanisms in grains: Role of biochemical and physical properties in pest suppression. *African Journal of Agricultural Research* 14(2): 67–75.
- Ajayi FA, Akinlade AO, Adedire CO (2020) Grain quality deterioration by storage insects and its implication on food security in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development* 20(3): 15950–15967.
- Amoako-Attah I, Boampong DA, Ofosu-Anim J (2022) Efficacy of low temperature disinfestation treatments against storage pests in legumes. *Journal of Stored Products and Postharvest Research* 13(2): 22–29.
- Bamishaiye OM, Adegbola JA, Bamishaiye EI (2011) Bambara groundnut: An under-utilized nut in Africa. *Advanced Agricultural Biotechnology* 1: 60–72.
- Brink M, Grubben GJH, Belay G, Agrooh S (2006) *Ressources végétales de l'Afrique tropicale 1: Céréales et légumes secs*. Wageningen, Netherlands: PROTA, 328 pp.
- Dick KM, Credland PF (1984) Egg production and development of three strains of *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Journal of Stored Products Research* 20: 221–227. [https://doi.org/10.1016/0022-474X\(84\)90007-9](https://doi.org/10.1016/0022-474X(84)90007-9)
- Dobie P (1974) The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* Motsch. *Journal of Stored Products Research* 10(4): 183–197. [https://doi.org/10.1016/0022-474X\(74\)90006-X](https://doi.org/10.1016/0022-474X(74)90006-X)
- FAO [Food and Agriculture Organization] (2019) Insect pests of stored grains in hot climates. <http://www.fao.org/giews/>
- Hite NDGW (2001) *Protection des céréales, des oléagineux et des légumineuses à grain entreposés à la ferme contre les insectes, les acariens et les moisissures*. Agriculture et Agroalimentaire Canada. <http://www.agr.gc.ca/science/winnipeg>
- Ileke KD, Odeyemi OO (2020) Phytochemical screening and insecticidal activity of plant extracts on stored grain pests. *African Entomology* 28(2): 361–370.
- Jackai LEN, Asante SK (2001) A rapid and simple method for screening cowpea for resistance to the cowpea seed beetle, *Callosobruchus maculatus*. *International Journal of Pest Management* 47(1): 63–64.
- Jideani VA, Diedericks CF (2014) Nutritional, therapeutic, and prophylactic properties of *Vigna subterranea* and *Moringa oleifera*. In: Oguntibeju O (Ed.) *Antioxidant-antidiabetic agents and human health*. Intech Publishers, 22 pp.
- Maina YT, Degri MM, Sharah HA (2011) Effects of population density and storage duration on the development of *Callosobruchus subinnotatus* in stored Bambara groundnut (*Vigna subterranea* (L.) Verdcourt). *Journal of Environmental Issues and Agriculture in Developing Countries* 3(3): 70–75.

- Massawe FJ, Mwale SS, Azam-Ali SN, Roberts JA (2005) Breeding in Bambara groundnut (*Vigna subterranea* (L.) Verdc.): Strategic considerations. *African Journal of Biotechnology* 4(6): 463–471.
- Nwana EJ, Umeh VC, Okonkwo CC (2021) Assessing susceptibility of maize varieties to storage pests using percent grain weight loss (PGWL). *International Journal of Pest Management* 67(4): 298–308.
- Ojo JA, Ogunleye BS (2019) Screening cowpea cultivars for resistance to bruchid attack. *Crop Protection* 121: 95–101. <https://doi.org/10.1016/j.cropro.2019.03.007>
- Ojo JA, Adebayo TA, Aladejana SA (2019) Evaluation of resistance in cowpea varieties to *Callosobruchus maculatus*. *Journal of Stored Products Research* 82: 33–41. <https://doi.org/10.1016/j.jspr.2019.03.002>

Supplementary material

Supplementary material 1

Suppl. figure S1 (.docx file)

Link: <https://doi.org/10.3897/ia.2025.164268.suppl1>