

Entomocidal activity of *Alstonia boonei* de wild oil extracts against cowpea beetle, *Callosobruchus maculatus* fabricius (Coleoptera: Bruchidae) infesting stored cowpea seeds

Olusola Michael Obembe^{1*}, Mary Tejumade Philip-Attah² and Mary Adeola Adegbola³

¹Department of Plant Science and Biotechnology, Ekiti State University, Nigeria.

²Department of Animal and Environmental Biology, Federal University, Oye, Ekiti State, Nigeria.

³Department of Zoology and Environmental Biology, Ekiti State University, Nigeria.

*Corresponding author. Email: olusola.obembe@eksu.edu.ng

Copyright © 2025 Obembe et al. This article remains permanently open access under the terms of the [Creative Commons Attribution License 4.0](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received 23rd July 2025; Accepted 30th August 2025

ABSTRACT: This study was conducted to investigate the entomocidal effects of the oil extracts of *Alstonia boonei* plant parts (root barks, stem barks, leaves, and seeds) as contact insecticides against the activities of *Callosobruchus maculatus* in stored cowpea seeds. Air-dried parts of *A. boonei* were ground into fine powder using an electric grinder (Model: Binatone electric grinder BL 400). The plant parts were extracted with a Soxhlet extractor at 60°C in the laboratory, using ethanol as the solvent. The efficacy of the oil extracts was investigated on the weevils for adult mortality, oviposition, emergence, viability, and seed damage. The oil extracts were applied at the rate of 1.0 mL/20 g of cowpea seeds. The results obtained showed that all oil dosages (1 mL/20g) of the different parts of the plant used caused mortality of *C. maculatus*, which increased with increased time of exposure. The stem bark oil was able to achieve 100 ± 0.00 % mortality within 72 h post-treatment, while other plant parts' oil extracts achieved 100 ± 0.00% mortality within 96 h. Oviposition and adult emergence by adult *C. maculatus* in the treated seeds were significantly lower than those of the control. There was no egg laid in the seeds treated with stem bark oil extracts. There was no adult emergence in all the treated cowpea seeds. The percentage damage and weight loss of cowpea seeds exposed to different oil dosages of *A. boonei* were significantly ($p \leq 0.05$) lower than that of the untreated seeds. After 7 days of germination, all the treated grains recorded high percentage germination ranging from 95.25 ± 2.33% to 100 ± 0.00%. The seed bark and leaf oil extracts were able to record 100 ± 0.00% germination. The results obtained from this study showed that oil extracts of *A. boonei* were effective in controlling *C. maculatus*.

Keywords: Adult emergence, *Alstonia boonei*, *Callosobruchus maculatus*, entomocidal, mortality, oviposition.

INTRODUCTION

Food insecurity undoubtedly is a fundamental problem ravaging the world, most especially in African countries (FAO, 2021). The setback in food security is due to post-harvest food losses, climate instability, and lack of adequate infrastructure to mitigate against it (Gustavsson *et al.*, 2011; Beddington *et al.*, 2012). Due to food insecurity, about 870 million people in the world are

undernourished as a result of inadequate intake of proteins, vitamins, and minerals in their diets (FAO 2012). Problems posed by food insecurity can be reduced in the African continent by increasing agricultural productivity and, at the same time, by reducing pre- and post-harvest losses. Due to an increase in population of the world, the demand for food has also increased, and it is essential to

protect stored grains and crops from the attack of insect pests.

Legume seeds are good sources of protein, which offer a solution to malnutrition. In fact, the seeds are the second most important group of crops worldwide after cereals. Among legumes, cowpea serves as a source of dietary protein for humans, mostly in developing countries where a balanced diet is sometimes a problem (Ojo *et al.*, 2013). The dry seed contains about 25% protein and 67% carbohydrate. Cowpea also contains calcium, iron, vitamins, and carotene (Adedire *et al.*, 2011).

Unfortunately, grains are extensively infested by a number of insect pests, including *Callosobruchus maculatus*, which is a primary field-to-store pest, causing considerably greater losses to farmers (Ofuya, 2001; Ojo *et al.*, 2013) both in the field and storage (Adedire *et al.*, 2011; Thakur, 2012). *C. maculatus* is a multivoltine pest that causes heavy damage to stored grains and pulses (Khan *et al.*, 2015). It is one of the most destructive insect pests of stored legumes in the tropics (Adedire, 2002; Adedire and Ajayi, 2003). According to previous work of Agour *et al.* (2022), *C. maculatus* alone causes 90% infestations within 3 to 6 months of storage period.

Presently, *C. maculatus* can be managed by the use of fumigation with phosphine and methyl bromide and synthetic pyrethroids (Rajendran, 2020). The complications associated with the use of synthetic insecticides are not only the poisoning of the crops but also include the pollution of our environment, and this threatens the safety of food and feed (Santhoshkumar *et al.*, 2024). As an alternative to the use of the aforementioned synthetic insecticides, researchers have been able to discover other control strategies. Plant extracts are capable of replacing synthetic insecticides and conventional fumigants, which were phased out after their roles in ozone layer depletion potential were discovered (Stejskal *et al.*, 2021). Botanical insecticides have remained the major weapons amongst tropical zone farmers to combat hexapod infestation of stored cowpea seeds in lieu of expensive synthetic chemical insecticides that have toxic effects on our environment (Ileke, 2018).

Alstonia boonei De Wild (Apocyanaceae) is an evergreen deciduous tree. The plant is about 45 m tall and 1.2 m in diameter; it sheds its leaves annually. It has roots, barks, stems, leaves, fruits, seeds, flowers, and sap. The plant has medicinal values in some cultures in African countries (Moronkola and Kunle, 2012).

The objectives of this research were to evaluate the entomocidal activity of *A. boonei* root barks, stem barks, leaves, and seed oil extracts against cowpea beetle *C. maculatus* infesting cowpea seeds, using adult mortality, oviposition, adult emergence, long-term storage-ability, and seed viability as indices. *A. boonei* was considered to be used in this study because few studies have only been carried out on the effects of its extracts against *C. maculatus*.

MATERIALS AND METHODS

Insect rearing

The parent stock of *C. maculatus* was obtained from naturally infested cowpea seeds bought from Iworoko Market, Iworoko, Ekiti, Nigeria. The insects were reared on the Ife brown variety of cowpea inside a plastic container covered with muslin cloth held firmly with a rubber band. The purpose of the muslin cloth was to prevent the escape of insects as well as hinder the entry of intruding insects. The plastic containers were placed in insect rearing cages at an ambient temperature of $30 \pm 3^\circ\text{C}$ and $70 \pm 5\%$ relative humidity. The newly emerged adult *C. maculatus* were used in every stage of this research work.

Collection and preparation of the *A. boonei* plant parts

Fresh root barks, leaves, stem barks, and pods of *A. boonei* were collected from the Faculty of Science, Ekiti State University, Ado Ekiti, Nigeria. *A. boonei* pods that have started turning brown colour and showed signs of splitting were carefully detached from the tree before they open naturally. The collected pods were kept on a dry and safe laboratory table. The pods were gently opened, and the seeds were carefully removed.

The root barks, stem barks, leaves, and seeds were air-dried in the laboratory for 20 days. The air-dried parts were separately milled into powder using an electric grinder. The powders were stored in a black cellophane bag until needed for extraction.

Preparation of *A. boonei* oil extracts

The method of cold extraction was used to extract the powders of the *A. boonei* roots, stem barks, leaves, and seeds. Two hundred and fifty grams (250 g) of *A. boonei* powder was soaked separately in extraction bottles containing absolute ethanol. The mixture was stirred occasionally with a glass rod, and extraction was terminated after 72 h. Filtration of the mixture was carried out using a double layer of Whatman No. 1 filter paper. The filtrates were concentrated using a rotary evaporator at 30°C to 40°C with a rotary speed of 3 to 6 rpm for 8 h (Ileke and Olotuah, 2012). The resulting extract was exposed to a slow-blowing fan in order to remove traces of solvents.

Effect of *A. boonei* oil extracts on the mortality, oviposition, and adult emergence of *C. maculatus*

The effect of *A. boonei* oil extracts on *C. maculatus* was accomplished using a 250 mL plastic container. Twenty grams (20 g) of disinfested and pristine Ife brown variety

of cowpea seeds were measured into 4 plastic containers. One milliliter (1 mL) of *A. boonei* leaf oil was pipetted into each plastic container containing the cowpea seeds. The mixture was thoroughly agitated and mixed together using a glass rod to ensure uniform coating of the extracts on the cowpea seeds. The cowpea seeds were exposed to air for 1 h to allow the traces of the solvent to dry off. Thereafter, 10 newly emerged (0 to 24 h) adult cowpea weevils were introduced into the plastic containers and then covered with muslin cloth. Untreated cowpea seeds were set up as the control experiment. The same procedure was carried out for *A. boonei* roots, stem barks, and seeds. All treatments were replicated four times in a Complete Randomized Design (CRD). Mortality of the insect was observed and recorded at 24 hours intervals for 96 hours. The insects were confirmed dead when there was no response to probing on the abdomen with a sharp pin. After 96 hours, all insects, both dead and alive, were then removed. Thereafter, the number of eggs laid in each container was counted and recorded. The experiment was allowed to stay for 6 weeks when the adult insects started emerging. The percentage adult emergence was calculated by expressing the number of adults that emerged as a percentage of the number of eggs laid, as shown below:

$$\% \text{ Adult emerged} = \frac{\text{Number of adults emerged}}{\text{Number of eggs laid}} \times 100$$

Assessment of grain damage after treatment with *A. boonei*

Twenty grams (20 g) of clean cowpea seeds were counted into a transparent plastic container (5 cm diameter and 6 cm depth) and admixed with 1 mL of *A. boonei* stem bark oil extract. Similar preparation was made for other plant parts extracts (root bark, leaves, and seeds). A control experiment containing untreated cowpea seed was also set up. Thereafter, 4 copulating pairs of adult *C. maculatus* were introduced into each of the containers. The plastic containers were covered with muslin cloth held in place with rubber bands so as to enhance ventilation and to prevent the insects from escaping. All treatments were arranged in a completely randomized design and replicated four times, and then stored in a wooden cage in the laboratory for 90 days. After 90 days, the extent of damage was observed, counted, and recorded using the procedure of Fatope *et al.* (1995). The cowpea seeds in each container were re-weighed and the percentage loss in weight was calculated.

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

To calculate the number of damaged cowpea seeds, the

number of wholesome seeds and seeds with emergence holes were counted and recorded. The percentage of seed damaged was calculated as shown below:

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

Effects of *A. boonei* oil extracts on germination of cowpea seeds

Twenty grams (20 g) of uninfested cowpea seeds were weighed into plastic containers treated with 1 mL of each of the different extracts and allowed to air dry. Each part of the plant (root barks, stem barks, leaves, and seeds) oil extract was replicated four times. The control comprised four replicate samples of untreated seeds. The seeds were treated with Apron Plus to prevent fungal growth. The plastic containers were covered with muslin cloth and left in the laboratory for 90 days. After 90 days, 20 cowpea seeds were randomly selected from each treatment and grown on a moistened filter paper in 9 cm diameter Petri-dishes in the laboratory. The number of seeds that germinated was counted for each of the plant part used and the control and expressed as a percentage of total seeds planted.

$$\% \text{ seed germinated} = \frac{\text{No of seeds germinated}}{\text{Total no of seeds}} \times 100$$

Data analysis

All the data collected from the study were analyzed using analysis of Variance (ANOVA) and means separated by Fisher Least Significant Difference (LSD).

RESULTS

Effects of *A. boonei* parts oil extracts on adult mortality of *C. maculatus*

Table 1 shows the mortality rate of *C. maculatus* in 20 g of cowpea seeds treated with 1 mL of *A. boonei* oils. The effect of oils on mortality was significantly ($p \leq 0.05$) higher in the treated cowpea seeds than in the untreated ones. Mortality increased with increased time of exposure of the weevils to the oils and was significantly ($p \leq 0.05$) higher in seeds treated with stem bark oil within 24 hours post-treatment. Within 24 hours post-treatment, the percentage mortalities were $47.28 \pm 1.23\%$, $41.37 \pm 1.31\%$, $43.50 \pm 1.17\%$, and $45.23 \pm 1.08\%$ when treated with stem bark, root bark, leaf, and seed oils, respectively. The highest mortality was recorded within 48 hours post-treatment with stem bark oil. Within 48 hours post-treatment, the percentage mortalities were $77.50 \pm 2.33\%$, $65.64 \pm$

Table 1. Mortality of adult *C. maculatus* in cowpea seeds treated with different oil extracts of *A. boonei* parts.

<i>A. boonei</i> oil	% mortality at	hours post	Treatment	
	24	48	72	96
Stem bark	47.28 ± 1.23 ^a	77.50 ± 2.33 ^a	100.00 ± 0.00 ^a	100.00 ± 0.00 ^a
Root bark	41.37 ± 1.31 ^d	65.64 ± 2.14 ^d	82.67 ± 2.76 ^d	100.00 ± 0.00 ^a
Leaf	43.50 ± 1.17 ^c	71.25 ± 3.66 ^b	88.71 ± 2.44 ^c	100.00 ± 0.00 ^a
Seed	45.23 ± 1.08 ^b	68.43 ± 2.21 ^c	91.25 ± 3.18 ^b	100.00 ± 0.00 ^a
Control	0.00 ± 0.00 ^e	0.00 ± 0.00 ^e	0.00 ± 0.00 ^e	0.00 ± 0.00 ^b

Each value is the mean + standard error of four replicates. Means within the same column followed by the same letter(s) are not significantly different.

Table 2. Effects of *A. boonei* oil extracts on oviposition and adult emergence of *C. maculatus*.

<i>A. boonei</i> oil	Number of eggs laid	% Adult emergence
Stem bark	0.00 ± 0.00 ^d	0.00 ± 0.00 ^b
Root bark	8.78 ± 0.57 ^c	0.00 ± 0.00 ^b
Leaf	8.25 ± 0.62 ^c	0.00 ± 0.00 ^b
Seed	11.78 ± 0.36 ^b	0.00 ± 0.00 ^b
Control	78.75 ± 2.43 ^a	85.36 ± 3.15 ^a

Each value is the mean + standard error of four replicates. Means within the same column followed by the same letter(s) are not significantly different.

2.14%, 71.25 ± 3.66%, and 68.43 ± 2.21% in stem bark, root bark, leaf, and seed oil, respectively. While within 72 hours post-treatment, 100 ± 0.00% insect mortality was recorded when treated with stem bark oil. The trend of mortality within 24 hours was 100 ± 0.00%, 82.67 ± 2.76%, 88.71 ± 2.44%, and 91.25 ± 3.18% when treated with stem bark, root bark, leaf and seed oil, respectively. All the extracts were able to achieve 100 ± 0.00% within 96 h post-treatment with the plant parts oils.

Effects of *A. boonei* oil extracts on oviposition and adult emergence of *C. maculatus*

Oviposition by adult *C. maculatus* varied with *A. boonei* oils (Table 2). The mean number of eggs laid by adult *C. maculatus* in the treated seeds was significantly lower than the number of eggs laid in the control. The mean number of eggs laid was 0.00 ± 0.00%, 8.78 ± 0.57%, 8.25 ± 0.62%, 11.78 ± 0.36% and 78.75 ± 2.43% in stem bark, root bark, leaf, seed, and control, respectively. There was no egg laid in the seeds treated with stem bark oil. There were no adult emergences of *C. maculatus* in all the treated cowpea seeds, while adult emergence in the untreated seeds was 85.36 ± 3.15%.

Effect of *A. boonei* leaf oils on long-term storage of cowpea seeds

The percentage of damaged cowpea seeds exposed to

different oil extracts of *A. boonei* were significantly ($p \leq 0.05$) lower than the damage seeds recorded in the control (Table 3). Also, seed damage and weight loss varied among different plant oils. There was no seed damage or weight loss recorded in cowpea seeds treated with stem bark oil and leaf oil.

Effect of *A. boonei* oils on germination of cowpea seeds

The percentage of cowpea seeds that germinated after treatment with a 1 mL/20 g dosage of *A. boonei* oils is presented in Table 4. After 7 days of germination, all the treated grains recorded high percentage germination ranging from 95.25 ± 2.33% to 100 ± 0.00%. The seed bark and leaf oil extracts were able to record 100 % mortality. Percentage germination recorded in the oils-treated seeds was 100 ± 0.00%, 96.48 ± 3.12%, 100 ± 0.00%, 95.25 ± 2.33% and 100 ± 0.00% when treated with stem bark, root bark, leaf, and oils, respectively.

DISCUSSION

Presently, pest infestation is a major factor affecting food security in Africa and other parts of the world due to the heavy damage to agricultural produce, both in the field and during the storage period (Adedire *et al.*, 2011). *C. maculatus* is a major pest of cowpea that has been reported to cause tremendous damage to cowpea seeds

Table 3. Effect of *A. boonei* oil extracts on long-term storage of cowpea seeds.

<i>A. boonei</i> oil	Mean number of seed	Mean number of seed damaged	Percentage of seed damaged	Mean weight loss
Stem bark	92.25	0.00 ± 0.00 ^d	0.00 ± 0.00 ^d	0.00 ± 0.00 ^c
Root bark	93.75	10.25 ± 0.36 ^c	10.93 ± 0.47 ^c	2.22 ± 0.08 ^b
Leaf	91.43	0.00 ± 0.00 ^d	0.00 ± 0.00 ^d	0.00 ± 0.00 ^c
Seed	93.43	12.34 ± 0.67 ^b	13.21 ± 0.54 ^b	2.33 ± 0.06 ^b
Control	90.42	82.25 ± 3.71 ^a	90.96 ± 3.13 ^a	17.15 ± 0.47 ^a

Each value is the mean + standard error of four replicates. Means within the same column followed by the same letter(s) are not significantly different.

Table 4. Germinability of cowpea seeds treated with 1 mL/20 g *A. boonei* oil extracts after 90 days of preservation.

<i>A. boonei</i> oil	Percentage germination
Stem bark	100.00 ± 0.00 ^a
Root bark	96.48 ± 3.12 ^b
Leaf	100.00 ± 0.00 ^a
Seed	95.25 ± 2.33 ^b
Control	100.00 ± 0.00 ^a

Each value is the mean + standard error of four replicates. Means within the same column followed by the same letter(s) are not significantly different.

and other grains during storage (Khan *et al.*, 2015; Alhoqail, 2025). Research has revealed that in 3 to 6 months of storage period. *C. maculatus* alone can cause 90% infestations (Agour *et al.*, 2022).

Effective and efficient controls of storage pests are centered mainly on the use of conventional chemical insecticides. The use of these conventional chemicals is hampered by many attendant problems. *C. maculatus* is controlled by using fumigation with phosphine, methyl bromide, and synthetic pyrethroids (Rajendran, 2020). These have necessitated the search for alternative control strategies which are cheap, non-toxic to human beings, and ecologically friendly, among which are the use of plant products.

The use of plant-based insecticides remains the major control strategy amongst the farmers in the tropical zones to combat insect pest infestation of stored products as an alternative to the expensive synthetic chemical insecticides. The plant (*A. boonei*) used as an insecticide in this study is readily available and has been reported to be toxic to some insects (Ileke and Arotolu, 2018). Therefore, the entomocidal effect of *A. boonei* oil extracts against cowpea beetles in storage is evaluated, using adult mortality, oviposition, hatchability, long-term protective ability, and viability of the treated seeds as indices.

The result of the current experiments demonstrated a significant reduction in oviposition and adult emergence across all treatments, with oviposition and adult emergence decreasing as the oil extract dosages of different parts of

A. boonei increased. Similar findings were reported by Idoko and Adesina (2012), where higher concentrations of *Piper guineense* extract significantly reduced oviposition and adult emergence of *C. maculatus*. The suppression of oviposition by the insects in treated grains compared to untreated may be due to locomotion impediment; hence, the beetles were unable to move freely, thereby disrupting mating activities and sexual communication (Adesina, 2013), resulting in few number of eggs observed in this study. Also, the ability of *A. boonei* oil extracts to reduce egg laying ability by the female beetles may be attributed to the obstruction of the normal embryonic development by suppressing hormonal and biochemical processes, as opined by Raja and Williams (2008). The oil extracts on application disrupted mating and sexual communication as well as deterring females from laying eggs (NRC, 1992). Adebowale and Adedire (2006) observed that treatment of cowpea seeds with *Jatropha curcas* seed oil reduced the number of eggs laid by *C. maculatus* and prevented adult emergence at concentrations between 0.5 and 2% (v/w).

The high mortalities of adult *C. maculatus* observed on the seeds treated with *A. boonei* oil extracts could be due to high toxic effects on the adult *C. maculatus* (Daniel, 1991; Adedire *et al.*, 2011). Most insects breathe by means of trachea, which usually opens at the surface of the body through spiracles (Adedire *et al.*, 2011; Ileke and Olotuah, 2012). These spiracles must have been blocked by the oil extracts, thereby leading to suffocation of the insects. Also, on application to cowpea seeds, the oil extracts must have covered the testa of the grains, serving as a food poison to the adult insects; while some of them penetrated the endosperm and germ layer, thereby suppressing oviposition and larval development (Ileke and Arotolu, 2018).

The untreated cowpea seeds suffered great damage due to *C. maculatus* infestation, whereas negligible or no damage/weight loss was recorded in the cowpea seeds treated with *A. boonei* oil extracts. The reduction of damage observed in this study was the consequence of the higher adult mortality, antifeedant, oviposition deterrence, ovicidal, larvicidal, and reproduction inhibitory properties of the oil extracts of *A. boonei*. Similar observations have been reported by Isman (2006) and

Manikanta and Dokuparthi (2014).

All the treated grains recorded high percentage germination ranging from $95.25 \pm 2.33\%$ to $100 \pm 0.00\%$. This result showed that *A. boonei* oil extracts do not have a significant effect on germination when compared to the control. This result corroborates the result obtained by Adedire *et al.* (2011), who discovered that cashew kernel oil does not have a significant effect on the viability of cowpea seeds.

Conclusion

This study revealed that the entomocidal activities of the oil extracts of different parts of *A. boonei* against the cowpea beetle, *C. maculatus*, infesting stored cowpea seeds in storage. The use of synthetic chemicals as pesticides is hampered by many attendant problems. These have necessitated more research work on the use of alternative eco-friendly insect pest control methods, among which are the use of plant products. *A. boonei* is readily available and has not been reported to be toxic to man. Therefore, this study showed that *A. boonei* oil extracts can be used as biopesticides against cowpea beetles in storage. Adoption of *A. boonei* as a suitable alternative to synthetic insecticides for seed protection should be encouraged amongst resource-poor farmers as a means of ensuring a steady supply of quality foods. Further future research will be focused on the isolation and characterization of the bioactive compounds responsible for the insecticidal property of *A. boonei*.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

- Adebawale, K. O., & Adedire, C. O. (2006). Chemical composition and insecticidal properties of the underutilized *Jatropha curcas* seed oil. *African Journal of Biotechnology*, 5(10), 901-906.
- Adedire, C. O. (2002). Use of nutmeg, *Myristic afragrans* (Houtt) powder and oil for the control of cowpea storage bruchid, *Callosobruchus maculatus* Fabricius. *Journal of Plant Diseases and Protection*, 109, 193-196.
- Adedire, C. O., & Ajayi, O. E. (2003). Potential of sandbox, *Hura crepitans* L. seed oil for protection of cowpea seeds from *Callosobruchus maculatus* Fabricius (Coleoptera: Bruchidae) infestation. *Journal of Plant Diseases and Protection*, 110, 602-610.
- Adedire, C. O., Obembe, O. M., Akinkurolere, R. O., & Oduleye, S. O. (2011). Response of *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae) to extracts of cashew kernels. *Journal of Plant Diseases and Protection*, 118(2), 75-79.
- Adesina, J. M. (2013). Insecticidal potential of *Momordica charantia* (L.) leaves powder against maize weevil *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae) infestation. *International Journal of Bioscience*, 3(1), 28-34.
- Adesina, J. M., & Mobolade-Adesina, T. E. (2020). *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infestation and tolerance on stored cowpea seeds protected with *Anchomanes difformis* (Blume) Engl. extracts. *Journal of Horticulture and Postharvest Research*, 3(2), 367-378.
- Agour, A., Mssillou, I., Mechchate, H., Es-Safi, I., & Allali, A. (2022). *Broccchia cinerea* (Delile) Vis. essential oil antimicrobial activity and crop protection against cowpea weevil *Callosobruchus maculatus* (Fab.). *Plants*, 11(5), 583.
- Alhoqail, W. A. (2025). Bio-efficacy of plant extracts against a major stored grain insect pest bruchid beetle *F. Callosobruchus maculatus* (Coleoptera: Bruchidae). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 53(1), Article number 14327.
- Beddington, J. R., Asaduzzaman, M., Clark, M. E., Bremauntz, A. F., Guillou, M. D., Jahn, M. M., Lin, E., TMamo, Negra, C., Nobre, C., Scholes, R. J., Sharma, R., Van Bo, N., & Wakhungu, J. (2012). The role for scientists in tackling food insecurity and climate change. *Agriculture & Food Security*, 1, Article number 10.
- Daniel, S. H. (1991). The use of neem (*Azadirachta indica* A. Juss) and some plant oils as protectants of cowpea (*Vigna unguiculata* (L.) Walp) against the cowpea weevil, *C. maculatus* (F.). Reading: University of Reading, (Ph. D. Thesis).
- FAO (2021). Africa regional overview of food security and nutrition 2020: Transforming food systems for affordable healthy diets, FAO. Retrieved 3rd November 2021 from <https://openknowledge.fao.org/items/6fad1ef5-cb18-475d-92ba-1c6b8da936d9>
- Fatope, M. O., Nuhu, A. M., Mann, A., & Takeda, Y. (1995). Cowpea weevil bioassay: a simple prescreen for plants with grain protectant effects. *International Journal of Pest Management*, 41(2), 84-86.
- Food and Agriculture Organization (FAO) (2012). The State of Food Insecurity in the World. Executive summary report. Rome, Italy. p. 2.
- Gustavsson, J., Cederberg, C., Sonesson, U. and Van Otterdijk, R. (2011). Global food losses and food waste: Extent, causes and prevention. Swedish Institute for Food and Biotechnology (SIK), Gothenburg (Sweden) FAO, Rome (Italy).
- Idoko, J. E., & Adesina, J. M. (2012). Evaluation of the powder of *Piper guineense* and pirimiphos-methyl for the control of cowpea beetle *Callosobruchus maculatus* (F.). *Journal of Agricultural Technology* 8(4): 1365-1374.
- Ileke, K. (2018). Deterrent Effects of *Alstonia boonei* Oil on Oviposition and Progeny Development of *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae]. *Journal of Crop Nutrition Science*, 4(4), 68-76.
- Ileke, K. D., & Emmanuel, A. T. (2018). Bioefficacy of *Alstonia boonei* leaf extract against cowpea beetle *Callosobruchus maculatus* infesting stored cowpea seeds in storage. *Brazilian Journal of Biological Sciences*, 5(11), 673-681.
- Ileke, K. D., & Olotuah O. F. (2012). Bioactivity of *Anacardium occidentale* (L) and *Allium sativum* (L) powders and oil extracts against cowpea bruchid, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae). *International Journal of Biology*, 4(1), 96-103.

- Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual review of entomology*, 51(1), 45-66.
- Khan, I. A., Hussain, S., Akbar, R., Saeed, M., Farid, A., Ali, I., & Shah, B. (2015). Efficacy of a biopesticide and synthetic pesticides against tobacco aphid, *Myzus persicae* Sulz. (Homoptera, Aphididae), on tobacco in Peshawar. *Journal of Entomology and Zoology Studies*, 4, 371-373.
- Manikanta, P., & Dokuparthi, S. S. K. (2014). A review on role of *Azadirachta indica* A. Juss as a Biopesticide. *International Journal of Universal Pharmacy and Biosciences*, 3, 2319-8141.
- Moronkola, D. O., & Kunle, O. F. (2012). Essential oil compositions of leaf, stem bark and root of *Alstonia boonei* De Wild (Apocyanaceae). *International Journal of Biological and Pharmaceutical Research*, 3(1), 51-60.
- National Research Council (NRC) (1992). *Neem, a tree for solving global problems*. Washington, D. C.: National Academy Press.
- Ofuya, T. I. (2001). Pest of stored cereals and pulses in Nigeria. In: Ofuya, T. I., & Lale, N. E. S. (eds.). *Biology, ecology, and control of insect pests of stored food legumes* (pp. 25-28). Dave Collins Publication, Nigeria.
- Ojo, J. A., Olunloyo, A. A., & Akanni, E. O. (2013). Efficacy of *Moringa oleifera* leaf powder against *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) on stored cowpea (*Vigna unguiculata* L. Walp). *Researcher*, 5(12), 240-244.
- Raja, M., & William, S. J. (2008). Impact of volatile oils of plants against the cowpea beetle *Callosobruchus maculatus* (FAB.) (Coleoptera: Bruchidae). *International Journal of Integrative Biology*, 2(1), 62-64.
- Rajendran, S. (2020). Insect pest management in stored products. *Outlooks on Pest Management*, 31(1), 24-35.
- Santhoshkumar, T., Govindarajan, R. K., Kamaraj, C., Ragavendran, C., Kamal, M. A., Moglad, E. H., Zaki, R.M., Priyadharsan, A., & Baek, K. H. (2024). Green fabricated silver nanoparticles as a new eco-friendly insecticide for controlling stored cowpea bug *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Biocatalysis and Agricultural Biotechnology*, 56, 103023.
- Stejskal, V., Vendl, T., Aulicky, R., & Athanassiou, C. (2021). Synthetic and natural insecticides: Gas, liquid, gel and solid formulations for stored-product and food-industry pest control. *Insects*, 12(7), 590.
- Thakur, D. R. (2012). Taxonomy, distribution and pest status of Indian biotypes of *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae: Bruchinae)-A new record. *Pakistan Journal of Zoology*, 44(1), 189-195.