

International Journal of Agriculture Extension and Social Development

Volume 9; Issue 7; July 2026; Page No. 187-191

Received: 19-04-2026
Accepted: 23-05-2026

Indexed Journal
Peer Reviewed Journal

Bioactivity of some aqueous plant extracts against larval and adult stages of *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae)

Yusra Jamal Talib

Marshes Research Center, University of Thi-Qar, Iraq

DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i7c.3846>

Corresponding Author: Yusra Jamal Talib

Abstract

The present laboratory study evaluated the insecticidal efficacy of aqueous extracts of three botanicals - neem (*Azadirachta indica* A. Juss, leaves), turmeric (*Curcuma longa* L., rhizome), and mint (*Mentha* spp., leaves) - at three concentrations (3%, 6%, and 10%) against both larval and adult stages of the pulse beetle, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) on mung bean (*Vigna radiata* L.) at three exposure periods (24, 48, and 96 hours). Results indicated that all plant extracts induced significant, concentration- and time-dependent corrected mortality across both life stages (LSD 0.05). At 96 h exposure and 10% concentration, neem and mint extracts achieved complete larval and adult mortality (100%), while turmeric caused 56.99% larval and 42.56% adult mortality. The overall highest larval efficacy was attributed to neem (59.89% average), while mint exhibited the highest adult efficacy (60.14% average). These findings endorse the potential of neem and mint extracts as eco-friendly, cost-effective, and sustainable grain protectants within an Integrated Pest Management (IPM) framework for mung bean storage.

Keywords: botanical insecticides, *Azadirachta indica*, *Curcuma longa*, *Mentha* spp., bruchid management

Introduction

Grain legumes as mung bean (*Vigna radiata* L. Wilczek) constitute an important part of a healthy diet as it source of dietary protein, micronutrients, and caloric energy to millions of families (Hanus, 2025) ^[9]. Losses of agricultural products, including grain legumes before and after harvest, lead to losses that may threaten food and nutritional security (Shahbazi *et al.*, 2025) ^[23]. Like awise, using post-harvest loss reduction mechanisms can help increase the shelf life of agricultural products and enhance their contribution to achieving food security (Vutula, 2024) ^[26].

Postharvest insect infestations cause substantial losses in stored legumes worldwide. Under traditional storage conditions without adequate protection, grain damage in legumes may range from 25.2% to 100%, with average weight losses reaching up to 32.3% (Stathers *et al.*, 2024) ^[25].

The pulse beetle, or Cowpae beetle, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae), is globally recognized as the most economically damaging primary pest of stored grain legumes. It is cosmopolitan in distribution and has been reported infesting 28 genera of leguminous plants, including: *V. unguiculata*, *Vigna radiata*, *Cajanus cajan*, *Cicer arietinum* and *Phaseolus vulgaris* (Hajam & Kumar, 2022) ^[8]. This bruchid is capable of infestation in the field prior to harvest, subsequently completing its entire development cycle within the grain seed under storage conditions (Ebadi *et al.*, 2025) ^[5]. Under optimal conditions of temperature (25–35°C) and relative humidity (40–70%), a single female can oviposit 50–150 eggs directly onto seed surfaces, and emerging larvae bore into individual seeds to

complete development through four instars before emerging as adults. Through successive generations, infestation densities can produce up to 90% seed damage within three to six months of unprotected storage, rendering infested grain unfit for human consumption or commercial trade (Revathy *et al.*, 2025; Alhoqail, 2025) ^[22, 2].

The conventional management strategy for stored product insects has relied heavily on synthetic chemical fumigants - principally phosphine (PH₃) and methyl bromide - and contact insecticides. Although chemical pesticides are effective in the short term, however their repeated use may lead to several negative effects, including the emergence of pesticide-resistant individuals, the accumulation of pesticide residues on stored foods, impacts on non-target organisms, and due to the effects of fumigant on the ozone layer, increasing restrictions on their use (Ogbonnaya *et al.*, 2025; Fan *et al.*, 2025; Muhammad & Rashid, 2024) ^[18, 6, 15]. These effects have catalyzed global interest in the development of more safe alternatives as botanical insecticide that are both efficacious and suitable with food safety and environmental sustainability objectives (Li *et al.*, 2025) ^[12].

Several studies have investigated the ability of plant extracts to control the *C. maculatus*. Akbar *et al.* (2024) ^[1] found that plant extracts showed great effectiveness as insecticides against *Callosobruchus maculatus*. Among the five plant extracts evaluated, *Azadirachta indica* (neem) proved to be the most effective, recording the lowest infestation rate, minimum seed weight loss, and least adult emergence. The turmeric *Curcuma longa* extracts at 20% concentration have been documented to completely suppress adult emergence

of *Tribolium castaneum* and achieve substantial mortality in *Callosobruchus maculatus* (Revathy *et al.*, 2025) [22]. Farhadi *et al.* (2025) [7] found that peppermint essential oil (EO) lead to the effect in male and female adults of *C. maculatus*, as well as its beyond direct lethality, sublethal concentrations significantly suppressed fecundity. Although neem, turmeric, and mint extracts have been tested individually against various stored grain pests, studies that compare all three together against both larval and adult stages of *C. maculatus* on mung bean, using different concentrations and time periods, are still scarce. This study was therefore conducted to compare the effectiveness of aqueous extracts of: Neem (*Azadirachta indica* A. Juss), turmeric (*Curcuma longa* L.) and mint (*Mentha* spp.) against both larval and adult stages of *Callosobruchus maculatus* at three exposure periods (24, 48, and 96 hours) under controlled laboratory conditions.

Materials and Methods

1. Insect Culture

A colony of *Callosobruchus maculatus* was established and maintained under controlled laboratory conditions (27 ± 2 °C and 60 ± 5% relative humidity), with a 12:12 h (Light:Dark) photoperiod. Initial colony stock was sourced from naturally infested mung bean grain and reared through successive generations on cleaned, sterilized mung bean seeds (*Vigna radiata* L.) prior to the study, following the rearing protocol described by Singh *et al.* (2024) [24].

2. Preparation of Plant Extracts

Three plant materials were prepared (obtained from local markets) including:
A- Neem (*Azadirachta indica* A. Juss): The fresh leaves were shade-dried for 14 days, then into powdered. The 3%, 6% and 10% (w/v) concentrations were prepared (Akbar *et al.* 2024) [1].
B- Turmeric (*Curcuma longa* L.): The dry rhizomes powdered, the 3%, 6% and 10% (w/v) concentrations were prepared (Alhoqail, 2025) [2].
C- Mint (*Mentha* spp.): The fresh leaves were air-dried (ambient temperature), the 3%, 6% and 10% (w/v) concentrations were prepared (Farhadi *et al.* 2025) [7].
According to Akbar *et al.* (2024) [1], the plant extracts attended freshly (on the day of bioassay) then maintained at 4 °C (to minimize phytochemical degradation).

3. Bioassay Design

The insecticidal activity of plant extracts was evaluated separately against larval and adult stages of *C. maculatus* using a filter paper contact bioassay method. Petri dishes (9 cm diameter) were lined with Whatman No. 1 filter paper and treated with 1 mL of each plant extract at the designated concentrations, following the standard contact bioassay procedure described by Akbar *et al.* (2024) [1]. Control dishes received 1 mL of distilled water. Treated filter papers were air-dried for 30 minutes before introducing test insects. For larval bioassays, mung bean seeds were surface-treated with extracts at each concentration and infested with 10 adult pairs of *C. maculatus* for oviposition over 48 hours. Following oviposition, adults were removed and the seeds with eggs were maintained under the same controlled conditions. Larval mortality was assessed by surface

examination and seed dissection at 24, 48, and 96 hours post-treatment, as described in Alhoqail (2025) [2]. For adult bioassays, 10 newly emerged adult *C. maculatus* (5 male, 5 female) were introduced into treated Petri dishes and mortality was recorded at 24, 48, and 96 hours. An insect was considered dead when it failed to respond to a gentle probe stimulus at the thorax (Farhadi *et al.*, 2025) [7]. Each treatment was replicated three times in a Completely Randomized Design (CRD).

4. Statistical Analysis

Percentage corrected mortality was calculated using Orell and Schneider equations (Püntener, 1981) to adjust for natural mortality in control groups. All data were subjected to analysis of variance (ANOVA) using a two-factor factorial design (Plant type × Concentration) at each exposure period. Means were compared using the Least Significant Difference test (LSD) at the 5% probability level (P ≤ 0.05). Statistical analyses were performed using SAS 9.4 software.

Results

1. Efficiency of plants aqueous extracts in the C. maculatus Larval Stage Mortality

1.1. Effect of plants aqueous extracts in the C. maculatus Larval Stage Mortality at 24 hours exposure

After 24 hours of exposure, all the treatment, the plant extract, the concentration and the interaction between them have a statistically significant effects in larval mortality (Table 1). The lowest Mean corrected larval mortalities averaged were 20.52% for neem and the highest 24.43% for turmeric. The highest average concentration-dependent mortality was recorded at 10% concentration (29.62%), while the 3% concentration recorded the lowest average mortality, it's reached to 18%. As the interaction between the plant extract and the concentration, the highest and the lowest mortality-corrected average reached to 30.55, 15% in the neem extract (10% and 3% concentration respectively).

Table 1: Corrected larval mortality (%) of C. maculatus under influence of plant extracts after 24 h exposure.

Conc. (%) Plant	3	6	10	Av. Plant
Neem	15.00	16.00	30.55	20.52
Turmeric	20.00	24.00	29.30	24.43
Mint	19.00	19.00	29.00	22.33
Av. Conc.	18	19.67	29.62	—
LSD (0.05)	Plant (A) = 1.5*		Conc. (B) = 2.3*	A×B = 1.7*

1.2. Effect of plants aqueous extracts in the C. maculatus Larval Stage Mortality at 48 hours exposure

At 48 hours, larval mortality increased substantially across all treatments, demonstrating a clear time-dependent response (Table 2). Neem produced the highest plant-averaged mortality at 33.97%, while the least was the turmeric (26.27%). At the 10% concentration level, neem achieved 45.66% corrected larval mortality - the highest recorded at this exposure period. While the mint at 3% concentration achieved the lowest, it's amounted 17.77%. Average concentration-dependent mortalities increased progressively from 21.82% at 3% to 40.1% at 10% concentration. All treatment effects remained statistically

significant.

Table 2: Corrected larval mortality (%) of *C. maculatus* under influence of plant extracts after 48 h exposure.

Conc. (%) Plant	3	6	10	Av. Plant
Neem	25.25	30.99	45.66	33.97
Turmeric	22.45	22.70	33.65	26.27
Mint	17.77	25.00	40.99	27.92
Av. Conc.	21.82	26.23	40.1	—
LSD (0.05)	Plant (A) = 3.2*		Conc. (B) = 2.8*	A×B = 1.9*

1.3. Effect of plants aqueous extracts in the *C. maculatus* Larval Stage Mortality at 96 hours exposure:

The 96-hour exposure period yielded the most pronounced larval mortality outcomes, with neem achieving complete larval mortality (100%) at the 10% concentration, while the mint at 3% and 6% concentrations reduced the larval mortality to the least, it's reached to 25.99% (Table 3). Overall plant-averaged mortality at this period reached 59.89% for neem, while the least was 30.99% for mint. Average mortalities at 3% and 10% concentrations were the least (30.55%) and the highest (65.99%), respectively, underscoring the critical role of concentration in determining protectant efficacy. All treatments effects remained highly significant

Table 3: Corrected larval mortality (%) of *C. maculatus* under influence of plant extracts after 96 h exposure.

Conc. (%) Plant	3	6	10	Av. Plant
Neem	35.00	44.67	100.00	59.89
Turmeric	30.66	40.99	56.99	42.88
Mint	25.99	25.99	40.99	30.99
Av. Conc.	30.55	37.22	65.99	—
LSD (0.05)	Plant (A) = 4.2*		Conc. (B) = 2.6*	A×B = 1.4*

2. Efficiency of plants aqueous extracts in the *C. maculatus* adult Stage Mortality

2.1. Effect of plants aqueous extracts in the *C. maculatus* adult Stage Mortality at 24 hours exposure

Adult *C. maculatus* exhibited differential susceptibility to the three plant extracts. After 24 hours, mint produced the highest adult mortality (34.96%), while the lowest was in the turmeric treatment (25.11%) (Table 4). At the 10% concentration, mint achieved 45.99% adult mortality - the highest value at this exposure period, while the least was 19% (3%, Neem). Average concentration-dependent mortalities ranged from 20.66% at 3% to 36.96% at 10% were the lowest highest values respectively. All main effects and the interaction were statistically significant.

Table 4: Corrected adult mortality (%) of *C. maculatus* under influence of plant extracts after 24 h exposure.

Conc. (%) Plant	3	6	10	Av. Plant
Neem	19.00	22.88	33.99	25.29
Turmeric	19.99	24.44	30.90	25.11
Mint	23.00	35.88	45.99	34.96
Av. Conc.	20.66	27.73	36.96	—
LSD (0.05)	Plant (A) = 3.2*		Conc. (B) = 4.5*	A×B = 1.8*

2.2. Effect of plants aqueous extracts in the *C. maculatus* adult Stage Mortality at 48 hours exposure:

After 48 hours of adult exposure, mint maintained its superiority with a highest average mortality of 42.66%, while the lowest average mortality at neem (35.66%) (Table 5). As the interaction between plant and concentration, the highest average mortality was 53.54% in 10% concentration at mint treatment, while the neem, 3% achieved the lowest average, it's 23.99%. Average concentration-dependent mortality increased from 27.59% at 3% to 50.51% at 10%. All factorial effects remained significant.

Table 5: Corrected adult mortality (%) of *C. maculatus* under influence of plant extracts after 48 h exposure.

Conc. (%) Plant	3	6	10	Av. Plant
Neem	23.99	33.99	49.00	35.66
Turmeric	28.88	43.09	49.00	40.32
Mint	29.89	44.56	53.54	42.66
Av. Conc.	27.59	40.55	50.51	—
LSD (0.05)	Plant (A) = 4.2*		Conc. (B) = 1.83*	A×B = 3.2*

2.2. Effect of plants aqueous extracts in the *C. maculatus* adult Stage Mortality at 96 hours exposure

The most adult mortality outcomes were recorded at the 96-hour exposure period, where both neem and mint achieved complete adult mortality (100%) at the 10% concentration (Table 6), while neem and turmeric at the 3% concentration recorded least average mortality, it's reached 30%. Mean plant-highest and lowest averaged adult mortality at 96 h was 60.14% for mint and 36.81% for turmeric at respectively - with mint exhibiting the highest overall efficacy against adult *C. maculatus* in this test. Concentration-dependent means increased from 31.67% at 3% to 80.85% at 10%. All factorial effects were statistically significant.

Table 6: Corrected adult mortality (%) of *C. maculatus* under influence of plant extracts after 96 h exposure.

Conc. Plant	3%	6%	10%	Av. Plant
Neem	30.00	39.45	100.00	56.48
Turmeric	30.00	37.88	42.56	36.81
Mint	35.00	45.43	100.00	60.14
Av. Conc.	31.67	40.92	80.85	—
LSD (0.05)	Plant (A) = 6.4*		Conc. (B) = 3.82*	A×B = 2.47*

Discussion

1. General Insecticidal Efficacy and Concentration Effects of aqueous extracts in *C. maculatus* larval and adult stages

The results of the present investigation unambiguously establish that aqueous extracts of neem, turmeric, and mint exert significant, concentration- and time-dependent insecticidal activity against both larval and adult stages of *Callosobruchus maculatus* on mung bean. The clear positive relationship between 3% and 10% concentrations with corrected mortality for three botanicals and life stages, it is corroborates that mortality increased by extract concentration increasing (Mustafa & Ghani, 2026; Muhammad, 2025) [17, 16].

The corrected mortality increasing with exposure time, it is

mechanistically compatible with the botanical insecticides mode of action (contact-toxicity) (Benyan & Khalaf, 2026) [4].

The sustained contact of bioactive compound leads to penetrate the insect cuticle, specifically in aqueous extracts where the concentration of bioactive molecule at the cuticle surface is lower than in organic solvent extracts (Oksari *et al.*, 2024) [19]. This effect pattern was particularly clearly for neem, where the mortality of larvae increased from 20.52% at 24 h to 59.89% at 96 h.

2. The Insecticidal Effect of plants aqueous extracts in *C. maculatus* larval and adult stages:

The highest larval mortality reached to 100% after 96 hours of treatment with 10% concentration of neem extract. These results are in similar with Ogbonnaya *et al.* (2025) [18], who recorded 100% mortality of *C. maculatus* after 96 h treatment using 0.0015 µg/mL azadirachtin, confirming the strong effect of neem's active constituents. The efficacy of neem against *C. maculatus* larvae reflects the primary mechanism of azadirachtin - interference with ecdysone signalling, disrupting the ecdysis process critical to larval moulting and development (Jenkins *et al.*, 2003; Kutcherov, 2020) [10, 11].

Turmeric exhibited intermediate efficacy in larval bioassays and relatively lower performance in adult bioassays compared to neem and mint. These results were consistent with what Lithi *et al.* (2019) [13] mentioned, as they confirmed that substances extracted from turmeric-derived materials as effective stored grain protectants at specific concentrations but generally of lower efficacy than neem-derived materials in direct insecticidal bioassays. The insecticidal mechanisms of turmeric against *C. maculatus* encompass both contact toxicity through curcuminoid activity and potential fumigant activity from volatile terpenoid constituents of the essential oil (Anas *et al.*, 2024; Revathy *et al.*, 2025) [3, 22].

The most notable finding in the adult bioassays was the superior performance of mint extract relative to both neem and turmeric at the 24- and 48-hour exposure periods, with mint consistently producing higher adult mortality at equivalent concentrations and time periods. At 96 h and 10% concentration, mint and neem co-achieved 100% adult mortality, yielding plant-averaged adult mortalities of 60.14% (mint) and 56.48% (neem). This stage-specific pattern - where mint performed less effectively against larvae than neem but outperformed neem against adults - points to differential susceptibility of larval versus adult cuticular composition and target-site sensitivity to mint bioactive constituents Rajkumar *et al.* (2019) [21]. Menthol and menthone, the principal bioactive terpenoids of *Mentha* essential oil, are well-characterised acetylcholinesterase inhibitors in arthropod systems. Adult *C. maculatus*, which possess a fully chitinised adult cuticle distinct in composition from larval cuticle, may present enhanced penetration accessibility to lipophilic menthol molecules through spiracular openings and thinner inter-segmental membranes (Wu *et al.*, 2023; Madrid *et al.*, 2026) [27, 14].

3. Practical Implications for Integrated Post-Harvest Management:

The achievement of 100% larval and adult mortality by

neem (10%, 96 h) and mint (10%, 96 h) establishes both botanicals as candidate grain protectants for integration into IPM programmes for mung bean storage. From a practical point of view, the 10% concentration represents available application rate for storage seed surface treatment by aqueous botanical extracts in small storage systems, requiring neither specialized equipment nor hazardous chemical handling.

Treating seeds before storage, instead of treating them after pest infestation in the storage, provides sufficient concentration of biologically active compounds on the seed surface during the early durations of insect infestation (Muhammad & Rashid, 2024) [15].

Conclusion

The current study finding, that aqueous extracts of neem, turmeric and mint have significant effects, concentration- and time-dependent insecticidal activity against *Callosobruchus maculatus* larvae and adult stages. The conclusions including:

1. The neem and mint aqueous extracts were the highest effective botanical treatments, both leading to 100% of *C. maculatus* larvae and adults mortality at 10% concentration after 96 hours, whereas turmeric showed moderate efficacy. In addition, a differences was observed between the two leading extracts, as neem was more affect against larvae whereas mint was more activity against adults, indicating stage-specific responses that can guide targeted application strategies.
2. These findings emphasizes the use of neem and mint extracts as safe and available alternatives to synthetic insecticides in post-harvest mung bean protection.

References

1. Akbar R, Khan IA, Ali A, Faheem B, Usman A, Farid A, *et al.* Evaluating the efficacy of plant extracts in managing the bruchid beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Insects*. 2024;15(9):691. doi:10.3390/insects15090691.
2. Alhoqail WA. Bio-efficacy of plant extracts against a major stored grain insect pest bruchid beetle *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*. 2025;53(1):14327. doi:10.15835/nbha53114327.
3. Anas M, Falak A, Khan A, Khattak WA, Nisa SG, Aslam Q, *et al.* Therapeutic potential and agricultural benefits of curcumin: A comprehensive review of health and sustainability applications. *Journal of Umm Al-Qura University for Applied Sciences*. 2024. Advance online publication. doi:10.1007/s43994-024-00200-7.
4. Benyan LA, Khalaf JM. Effect of some vegetable oils and biological factors on the control of southern cowpea beetle, *Callosobruchus maculatus*. *Arab Journal of Plant Protection*. 2026;44(1). doi:10.22268/AJPP-001399.
5. Ebadi A, Naseri B, Besheli BA, Razmjou J, Ebadollahi A, Pourabad RF, *et al.* Resistance of some lentil cultivars against the cowpea beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). *Journal of Stored Products Research*. 2025;111:102546.
6. Fan GW, Wang P, Liu YS, Sang YL, Liu N, Hao YJ.

- Insecticidal activity of two *Pelargonium* essential oils and head transcriptome analysis of stored-product pest *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in response to citronellyl formate fumigation. *Pesticide Biochemistry and Physiology*. 2025;208:106278.
7. Farhadi B, Amiri A, Pourabad RF, Bandani AR. Transgenerational effects of peppermint essential oil on life table parameters and antioxidant enzymes in *Callosobruchus maculatus*. *Scientific Reports*. 2025;15:20721. doi:10.1038/s41598-025-08563-5.
 8. Hajam YA, Kumar R. Management of stored grain pest with special reference to *Callosobruchus maculatus*, a major pest of cowpea: A review. *Heliyon*. 2022;8(1):e08703. doi:10.1016/j.heliyon.2021.e08703.
 9. Hanus A. Legumes: Your ally in cardiovascular wellness. *American Journal of Lifestyle Medicine*. 2025;20(1). doi:10.1177/15598276251379302.
 10. Jenkins DA, Dunkel FV, Gamby KT. Storage temperature of neem kernel extract: Differential effects on oviposition deterrence and larval toxicity of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Environmental Entomology*. 2003;32(6):1283-1289.
 11. Kutcherov D. Staggered resolution of temperature-dependent embryonic and postembryonic development in the cowpea seed beetle *Callosobruchus maculatus* (F.). *BMC Ecology*. 2020;20:50. doi:10.1186/s12898-020-00318-2.
 12. Li WZD, Liu C, Geng Z, Zhang J, Pang X. A novel sesquiterpene alkaloid from *Zanthoxylum piasezkii* as a promising antifeedant against *Tribolium castaneum*. *Industrial Crops and Products*. 2025;236:122053.
 13. Lithi UJ, Faridullah M, Roy VC, Roy KC, Alam AK. Efficiency of organic pesticides, turmeric (*Curcuma longa*) and neem (*Azadirachta indica*) against dry fish beetle (*Dermostes* sp.) during storage condition. *Journal of the Bangladesh Agricultural University*. 2019;17(1):110-116. doi:10.3329/jbau.v17i1.40672.
 14. Madrid A, Fernández-Godoy R, Contreras-Morales T, Muñoz-Torres C. Insecticidal potential of *Mentha pulegium* essential oil and its main monoterpenes in *Drosophila melanogaster*. *Insects*. 2026;17(4):391. doi:10.3390/insects17040391.
 15. Muhammad MN, Rashid MUR. Insecticidal efficacy of diatomaceous earth and botanical powders against pulse beetle, *Callosobruchus analis* F. in stored mung bean (*Vigna radiata* L.). *Proceedings of the Pakistan Academy of Sciences B: Life and Environmental Sciences*. 2024;61(2):45-55. doi:10.53560/PPASB.
 16. Muhammad NAG. The effect of some alcoholic and aqueous plant extracts on the adults of the southern cowpea beetle *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae). *South Asian Research Journal of Biology and Applied Biosciences*. 2025;7(2):58-66. doi:10.36346/sarjbab.2025.v07i02.002.
 17. Mustafa AA, Ghani MYS. Evaluation of the efficiency of some aqueous and alcoholic plant extracts in controlling the southern cowpea beetle *Callosobruchus maculatus* F. *Mesopotamia Journal of Agriculture*. 2026;54(1):120-131. doi:10.33899/mja.2026.160372.1594.
 18. Ogbonnaya E, Oluchukwu IU, Precious E. Repellency activity and the effectiveness of lower concentrations of certain botanical insecticides (azadirachtin, α -humulene, and myristicin) against *Callosobruchus maculatus* Fab. *Nigerian Journal of Biochemistry and Molecular Biology*. 2025;40(2):160-164. doi:10.5897/NJBMB2025.
 19. Oksari AA, Susanty D, Rizki FH, Wanda IF, Arinana A, Dadang D. The effectiveness of the combination of *Dioscorea bulbifera* L. extract and leri water as a bio-insecticide. *BIO Web of Conferences*. 2024;117:01034. doi:10.1051/bioconf/202411701034.
 20. Püntener W. Manual for field trials in plant protection. 2nd ed. Agricultural Division, Ciba-Geigy Limited; 1981. p. 205.
 21. Rajkumar V, Gunasekaran C, Christy IK, Dharmaraj J, Chinnaraj P, Paul CA. Toxicity, antifeedant and biochemical efficacy of *Mentha piperita* L. essential oil and its major constituents against stored grain pest. *Pesticide Biochemistry and Physiology*. 2019;156:138-144. doi:10.1016/j.pestbp.2019.02.016.
 22. Revathy VS, Jacob AM, Binu N. Insecticidal efficiency of selected essential oils against stored pests *Sitophilus oryzae* and *Callosobruchus maculatus* by using GC-MS analysis. *Scientific Reports*. 2025;15:45477. doi:10.1038/s41598-025-29149-1.
 23. Shahbazi F, Shahbazi S, Nadimi M, Paliwal J. Losses in agricultural produce: A review of causes and solutions, with a specific focus on grain crops. *Journal of Stored Products Research*. 2025;111:102547.
 24. Singh S, Tiwari B, Pandey R. Comparative study on morphometrics of *Callosobruchus maculatus* and *Callosobruchus chinensis* developed on mung bean. *Discover Agriculture*. 2024;2:105. doi:10.1007/s44279-024-00126-y.
 25. Stathers T, Holcroft D, Engelbert M, Ravat Z, Marion P. Crop postharvest loss reduction interventions in sub-Saharan Africa and South Asia: Systematic scoping review update 2024. UK Foreign, Commonwealth and Development Office (FCDO); 2024. p. 81.
 26. Vutula N. The reduction of post-harvest losses is crucial for a successful cassava value chain and food security in Africa. *Open Agriculture Journal*. 2024;18:e18743315333391. doi:10.2174/0118743315333391241205114914.
 27. Wu Z, Jin C, Chen Y, Yang S, Yang X, Zhang D, Xie Y. *Mentha* spp. essential oils: A potential toxic fumigant with inhibition of acetylcholinesterase activity on *Reticulitermes dabieshanensis*. *Plants*. 2023;12(23):4034. doi:10.3390/plants12234034.