



Botanical Extracts as Eco-friendly Alternatives for Insect Pest Management in Stored Products: A Review

Shelly¹, Bindu Bala¹, Amandeep Kaur¹, Harpreet Kaur², Pardeep Kaur Sandhu³

10.18805/ag.R-2845

ABSTRACT

The persistent use of synthetic insecticides in stored grain pest management has raised several concerns, including the emergence of pest resistance, environmental contamination and human health hazards. Consequently, there is an increasing interest in the use of botanical extracts as sustainable and environmentally benign alternatives. This review consolidates research findings on various plant-based insecticides that exhibit toxic, repellent, antifeedant and growth-disrupting effects against key storage pests such as *Tribolium castaneum*, *Sitophilus zeamais*, *Rhyzopertha dominica*, *Trogoderma granarium* and others. Extracts and essential oils from plants like *Azadirachta indica*, *Curcuma longa*, *Murraya koenigii* and *Lantana camara* have demonstrated high efficacy in mortality, repellency and feeding inhibition. The accumulated evidence highlights the potential role of botanicals in integrated pest management (IPM) strategies, promoting safe and effective pest control in stored products.

Key words: Environmental contamination, Insecticides, Plant-based insecticides, Repellency, Stored grain pest.

Stored product pests are a major challenge in agricultural systems, especially in tropical and subtropical regions. These pests damage grains, reduce nutritional quality and cause significant economic losses. The cowpea weevil, scientifically designated as *Callosobruchus maculatus*, serves as a salient illustration of this predicament, as it infests stored legumes, resulting in a reduction of mass and diminished seed viability (Katoo *et al.* 2025). Historically, chemical insecticides have been the primary method for controlling these pests. However, over-reliance on synthetic pesticides has led to serious problems such as pest resistance, residues in food products, environmental toxicity and adverse health effects on humans and non-target organisms. The ongoing application of synthetic pesticides has resulted in the emergence of resistance among target pest populations, thereby diminishing their vulnerability to these chemical agents (Khan and Ahmad, 2019). Such resistance compels the utilization of increased dosages or more hazardous alternatives, thereby exacerbating the existing issue (Kumari, 2023). It is estimated that approximately 80% of the pesticides that are applied lead to environmental contamination, significantly compromising soil and water quality (Ali *et al.*, 2021). Biodiversity is profoundly affected, with evidence suggesting a 70% decrease in insect biomass and a 50% decline in farmland avian populations across Europe. In this context, plant-derived insecticides or botanicals have emerged as viable alternatives due to their biodegradability, target specificity and low environmental persistence. Plant-derived insecticides are presented as eco-friendly alternatives to synthetic insecticides. Plants contain alkaloids, flavonoids, triterpenoids, saponins, steroids, glycosides and tannins (Shunmugadevi and Radhika, 2020). The wide array of

¹PG Department of Zoology, Sri Guru Teg Bahadur Khalsa College, Sri Anandpur Sahib-140 118, Punjab, India.

²Department of Zoology, Government Mohindra College, Patiala-140 407, Punjab, India.

³PG Department of Zoology, Mata Gujari College, Fatehgarh Sahib-147 007, Punjab, India.

Corresponding Author: Bindu Bala, PG Department of Zoology, Sri Guru Teg Bahadur Khalsa College, Sri Anandpur Sahib-140 118, Punjab, India. Email: binduwardhan21@gmail.com

How to cite this article: Shelly, Bala, B., Kaur, A., Kaur, H. and Sandhu, P.K. (2026). Botanical Extracts as Eco-friendly Alternatives for Insect Pest Management in Stored Products: A Review. *Agricultural Reviews*. **47(5)**: 855-858. doi: 10.18805/ag.R-2845.

Submitted: 19-02-2026 **Accepted:** 22-07-2026 **Online:** 21-09-2026

bioactive compounds can act as insecticides, repellents, antifeedants, or growth regulators. This review explores the use of botanical extracts in managing stored product pests, compiling results from multiple studies to demonstrate their effectiveness and potential application in IPM programs.

Botanical extracts and their insecticidal potential Efficacy of plant extracts

Plant-derived products provide eco-friendly and low-cost pest-management options (Gahukar, 2019). Numerous studies have investigated the insecticidal potential of plant extracts against *T. castaneum*, a major pest of stored grains. Ethanolic and chloroform extracts of pomegranate peel (*Punica granatum*) showed 100% mortality at 2.0% concentration after 7 days whereas *Cucumis sativus* showed 80% mortality with hexane extract (Ismail *et al.*, 2025) against red flour beetle (*T. castaneum*). *Ricinus*

communis showed significant mortality with methanol extract against *T. castaneum* (Jbilou *et al.*, 2006). Amel *et al.* (2014) reported that the ethanol extract of pomegranate (*Punica granatum*) peel caused 56% larval mortality in *T. castaneum*. Similarly, Bhoje and Bhiram (2021) demonstrated that mortality and repellency against *T. castaneum* increased with rising concentrations of *Bergera koenigii* extract. Ali *et al.* (2019) found that the methanol extract of *Ricinus communis* induced the highest mortality, followed by the chloroform extract, while the n-hexane extract was least effective.

Although these plant extracts exhibit strong insecticidal qualities, their inconsistent efficacy raises the possibility that combining extracts or creating synergistic formulations could improve pest management tactics against *T. castaneum*. This strategy may result in more long-lasting pest control solutions. In addition to *T. castaneum*, several plant extracts were found effective against *Rhyzopertha dominica*.

Enzyme inhibition by botanical extracts

Thymus vulgaris inhibits alpha-amylase in *T. granarium*, with optimal inhibition at 10% concentration and pH 7 (Shaker *et al.*, 2023). *Eucalyptus globulus* and *Allium sativum* found to decrease digestive enzyme activity in *Ephestia kuehniella*, affecting metabolic processes (Mehrabadi *et al.*, 2011; Shahriari, 2020). The extracts' inhibitory effects are attributed to the presence of active substances like flavonoids, saponins and tannins (Shaker *et al.*, 2023). Concentration and environmental factors like pH and temperature affect how effective these extracts are (Mehrabadi *et al.*, 2011).

Even though these plant extracts have potential as environmentally friendly pest control techniques, their effectiveness can be impacted by variables and the surrounding environment, indicating the need for more study to maximise its application in farming systems. Various studies have emphasized the enzymatic and physiological impacts of botanical extracts on pest insects. Shaker *et al.* (2023) found that aqueous leaf extract of *T. vulgaris* inhibited alpha-amylase enzyme production in *T. granarium* larvae.

Toxic and repellent effects

Plant extracts' repellent and antifeedant qualities are used in botanical pest control to successfully control insect pests. Plant extracts such as essential oils as eco-friendly and have insecticidal activities including repellency, ovicidal activity, larvicidal activity and antifeedant activity (Singh *et al.*, 2012). According to research, a variety of botanical extracts have strong poisonous and repellent properties against important pests, increasing their potential as environmentally benign substitutes for synthetic pesticides.

Karakas (2016) found that extracts of *Anethum graveolens* and *Ocimum basilicum* had both toxic and repellent effects on *Sitophilus granarius*, with dill leaf extract showing the highest antifeedant activity. Epidi and Odili

(2009) concluded that *Dracaena arborea* and *Vitex grandifolia* powders were more protective of groundnuts from *T. castaneum* than ginger and pumpkin powders highlighting their antifeedant properties (Chugh *et al.*, 2023).

Moon *et al.* (2021) reported increased mortality and repellency in *R. dominica* with rising concentrations of *Jatropha curcas* and *Linum usitatissimum* extracts. According to Alkan and Ertürk (2020), trans-anethole was very efficient against *T. castaneum* and showed diverse degrees of mortality and repellency against various stored product pests. Many plants with strong antifeedant qualities were found by Pavela *et al.* (2025), indicating a wide range of possibilities for creating botanical insecticides. Although botanical pest management has potential, there are still issues with its consistency of effectiveness and the need for more study to improve application techniques and comprehend the underlying mechanisms.

Broader-spectrum efficacy

Broader-spectrum efficacy has also been recorded. Gariba *et al.* (2021) found that dried powders and aqueous extracts of *Lantana camara*, *Moringa oleifera*, *Citrus sinensis* and *Hyptis suaveolens* significantly reduced grain damage and insect survivorship in *Sitophilus zeamais* and *Prostephanus truncatus*. Atta *et al.* (2020) compared several botanicals and concluded that *Zingiber officinale* was more effective in repelling and killing *T. castaneum* than neem, clove, or tobacco. Joel (2015) supported the insecticidal potential of various plants such as *A. indica*, *Lawsonia inermis* and *Annona senegalensis* against *T. castaneum*, reinforcing their post-harvest utility.

Other significant contributions include Adjou (2019), who demonstrated that essential oil from *Hyptis suaveolens* caused 100% mortality in *Tenebroides mauritanicus* at low concentrations. Bossoua *et al.* (2015) emphasized that essential oils from *Cymbopogon schoenanthus* and *Eucalyptus citriodora* could be employed to counteract resistance to synthetic insecticides in *T. castaneum*. In another study, Bouayad *et al.* (2013) found that extracts of *Rosmarinus officinalis* and *Centaurium erythraea* reduced pupation and adult emergence and even induced cannibalism in *Plodia interpunctella* larvae.

Other valuable findings include Osipitan *et al.* (2014), who observed that botanical extracts exhibited strong contact toxicity against *Prostephanus truncatus*, particularly at 5-10% concentrations. Jadhav (2009) recorded that *Annona squamosa*, *Tephrosia purpurea* and *Acorus calamus* extracts were highly effective against *Corcyra cephalonica*, with larvae darkening and dying post-treatment. Nazari (2022) highlighted the antifeedant and growth-inhibiting effects of *Murraya paniculata* on *Cadra cautella* and *Spodoptera litura*. Finally, Yooboon *et al.* (2019) demonstrated that ethanolic crude extracts from *Piper retrofractum* and *Acorus calamus* exerted strong pesticidal effects against *Spodoptera litura*.

Although they present a number of real-world difficulties, botanical insecticides provide a sustainable substitute for synthetic pesticides in grain storage systems. Plant extract composition fluctuation, stability during storage, formulation problems and limitations in large-scale use are some of these difficulties. For botanical insecticides to be used effectively in grain storage management, certain issues must be resolved.

Variability in plant extract composition

Plant species, growing circumstances and extraction techniques can all have a substantial impact on the phytochemical makeup of plant-based insecticides. The uniformity and effectiveness of the pesticides may be impacted by this variability (Chugh *et al.*, 2023; Uikey, 2024). For instance, depending on their concentration and the particular pest they are intended to kill, neem and eucalyptus extracts have demonstrated differing degrees of insecticidal activity (Kousar *et al.*, 2025).

Formulation issues

A major difficulty is creating efficient formulations that guarantee the steady distribution of active chemicals. Formulations must be created to minimise degradation and maximise the insecticides' bioavailability and effectiveness (Vijayan *et al.*, 2023; Uikey, 2024).

The compatibility of botanicals with other control techniques must be carefully considered before including them into current pest management systems (Vijayan *et al.*, 2023).

Constraints in large-scale application

Cost, availability and the requirement for specialised equipment are some of the barriers to the widespread use of botanical insecticides in grain storage systems (Chugh *et al.*, 2023).

Environmental factors, which might fluctuate between storage facilities, can affect how effective botanical insecticides are (Vijayan *et al.*, 2023). Although there are drawbacks to using botanical pesticides, there are also many advantages, like less toxicity to non-target organisms and less of an influence on the environment. To overcome these obstacles and improve the usefulness of botanical pesticides in grain storage systems, more research and development is required (Uikey, 2024).

CONCLUSION

The reviewed literature provides compelling evidence of the efficacy of botanical extracts against a variety of stored product pests. These natural agents offer a promising alternative to conventional insecticides, exhibiting diverse modes of action such as direct toxicity, enzyme inhibition, growth regulation, repellency and feeding deterrence. Many plant extracts have shown potential not only against *T. castaneum* but also against pests like *S. zeamais*, *R. dominica* and *C. chinensis*, indicating their broad-spectrum applicability. While laboratory studies have established their

effectiveness, challenges remain in translating these results to field conditions. Standardization of extraction methods, formulation techniques and dosage regulation are essential for large-scale application. Further research into synergistic plant interactions, long-term efficacy and safety assessments will help integrate botanical insecticides into sustainable IPM strategies, offering environmentally friendly and effective pest control solutions for stored grains.

ACKNOWLEDGEMENT

The Authors are grateful to the SGPC management. Principal of Sri Guru Teg Bahadur Khalsa College, Sri Anandpur Sahib, for providing the essential facilities for the present review paper.

Conflict of Interest

This study does not require ethical approval. Authors declare no conflict of interest.

REFERENCES

- Adjou, E.S., Chougourou, D. and Soumanou, M.M. (2019). Insecticidal and repellent effects of essential oils from leaves of *Hyptis suaveolens* and *Ocimum canum* against *Tenebroides mauritanicus* (L.) isolated from peanut in post-harvest. *Journal of Consumer Protection and Food Safety*. **14**(1): 25-30.
- Ali, A., Khan, M. and Shah, F. (2019). Efficacy of methanol, chloroform and n-hexane extracts of *Ricinus communis* against *Tribolium castaneum*. *Pakistan Entomologist*. **41**(1): 51-55.
- Ali, S., Ullah, M.I., Sajjad, A., Shakeel, Q. and Hussain, A. (2021). In: Environmental and health effects of pesticide residues. Springer, Cham. pp. 311-336. https://doi.org/10.1007/978-3-030-54719-6_8.
- Alkan, M. and Ertürk, S. (2020). Insecticidal efficacy and repellency of trans-anethole against four stored-product insect pests. *Journal of Agricultural Sciences*. **26**(1): 64-70. <https://doi.org/10.15832/ANKUTBD.445671>.
- Amel, M., Riaz, S. and Khan, M. (2014). Toxicity of ethanol extract of pomegranate peel against *Tribolium castaneum*. *Pakistan Entomologist*. **41**(1): 51-55.
- Atta, B.M., Ismail, S.M. and Hamed, M.A. (2020). Repellency and toxicity of Zingiber officinale against *Tribolium castaneum*. *Journal of Innovative Sciences*. **6**(1): 1-11.
- Bhoye, V.S. and Bhiram, D. (2021). Concentration-dependent mortality and repellency of Bergera koenigii extract against *Tribolium castaneum*. *International Journal of Scientific Research in Science and Technology*. **9**(6): 483-487.
- Bossoua, K.M., Tofel, H. and Djoulde, D. (2015). Use of essential oils from Cymbopogon schoenanthus and Eucalyptus citriodora to combat insecticide resistance in *Tribolium castaneum*. *Industrial Crops and Products*. **76**: 306-317.
- Bouayad, N., Boutiti, R. and Hassikou, R. (2013). Effect of *Rosmarinus officinalis* and *Centaureum erythraea* extracts on *Plodia interpunctella* larvae cannibalism and development. *Spanish Journal of Agricultural Research*. **11**(1): 189-198.

- Chugh, P., Singh, R.K., Mishra, S., Levy, M.J., Hazarika, S., Haokip, S.W. and Nengparmoi, T. (2023). Recent development and review on botanicals from plants to stored grains. *International Journal of Plant and Soil Science*. **35(19)**: 929-936. <https://doi.org/10.9734/ijpss/2023/v35i193627>.
- Epidi, T.N. and Odili, C.S. (2009). Effectiveness of dracaena arborea and vitex grandifolia powders in protecting groundnuts from *Tribolium castaneum*. *African Journal of Environmental Science and Technology*. **3(1)**: 1-5.
- Gahukar, R.T. (2019). Utilization of indigenous plant species in tobacco crop protection in India-A review. *Agricultural Reviews*. **35(2)**: 142-147. doi: 10.5958/0976-0741.2014.00092.0.
- Gariba, F.K., Mensah, A.Y. and Owusu, E. (2021). Impact of dried powders and aqueous extracts of *Lantana camara*, *Moringa oleifera*, *Citrus sinensis* and *Hyptis suaveolens* on grain damage by *Sitophilus zeamais* and *Prostephanus truncatus*. *Cogent Food and Agriculture*. **7(1)**: 1-5.
- Ismail, H., El-Delimy, R., Ismail, H. and El-Delimy, R. (2025). Evaluation of the bioefficacy and toxicity of pomegranate peel (*Punica granatum* L.) extracts against adults of the red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Journal of Pure and Applied Sciences*. **24(3)**: 127-133. <https://doi.org/10.51984/jopas.v24i3.4334>.
- Jadhav, J.P. (2009). Effect of *Annona squamosa*, *Tephrosia purpurea* and *Acorus calamus* extracts against *Corcyra cephalonica*. *Journal of Applied Biosciences*. **35(1)**: 89-90.
- Jbilou, R., Ennabili, A. and Sayah, F. (2006). Insecticidal activity of four medicinal plant extracts against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *African Journal of Biotechnology*. **5(10)**: 936-940. <https://doi.org/10.5897/AJB06.164>.
- Joel, A. (2015). Toxic effects of *Azadirachta indica*, *Lawsonia inermis* and *Annona senegalensis* on *Tribolium castaneum*. *African Journal of Plant Science*. **9(2)**: 90-96.
- Karakas, M. (2016). Repellent and toxic effects of *Anethum graveolens* and *Ocimum basilicum* extracts on *Sitophilus granarius*. *Journal of Entomology and Zoology Studies*. **4(5)**: 870-874.
- Katoo, A.A., Ngugi, M. and Gitahi, S. (2025). *Callosobruchus maculatus*: A biotic enemy to pigeon pea productivity. *International Journal of Scientific Research and Technology*.
- Khan, M.A. and Ahmad, W. (2019). Synthetic chemical insecticides: Environmental and agro contaminants. In: Synthetic chemical insecticides: Environmental and agro contaminants Springer, Cham. pp. 1-22. https://doi.org/10.1007/978-3-030-23045-6_1.
- Kousar, T., Memon, Z.N., Abro, S. and Bhatti, Q.B. (2025). Evaluation of plant extracts as sustainable alternatives against the saw-toothed grain beetles (*Oryzaephilus surinamensis* L.) infesting stored grains in Khairpur, Sindh, Pakistan. *Planta Animalia*. **4(5)**: 243-247. <https://doi.org/10.71454/pa.004.05.0227>.
- Kumari, A. (2023). Pests and pathogens in stored seeds. <https://doi.org/10.5281/zenodo.16417265>.
- Mehrabadi, M., Bandani, A.R., Saadati, F.S. and Mahmudvand, M. (2011). α -Amylase activity of stored products insects and its inhibition by medicinal plant extracts. *Journal of Agricultural Science and Technology*. **13(1)**: 1173-1182. https://jast.modares.ac.ir/browse.php?a_id=1808andsid=23andslc_lang=fa.
- Moon, H.J., Kim, J.H. and Lee, H.S. (2021). Effects of *Jatropha curcas* and *Linum usitatissimum* extracts on mortality and repellency in *Rhyzopertha dominica*. *GSC Biological and Pharmaceutical Sciences*. **17(3)**: 137-143.
- Nazari, M. (2022). Antifeedant and growth regulatory effects of *Murraya paniculata* against *Cadra cautella* and *Spodoptera litura*. *National Academy Science Letters*. **45**: 25-30. <https://doi.org/10.1007/s40009-021-01083-6>.
- Osipitan, O.A., Oladimeji, A.T. and Ogunwande, I.A. (2014). Contact toxicity of botanicals against *Prostephanus truncatus*. *Archives of Phytopathology and Plant Protection*. **47(9)**: 1072-1081.
- Pavela, R., Kováčiková, K. and Novák, M. (2025). Botanical antifeedants: An alternative approach to pest control. *Insects*. **16(2)**: 136. <https://doi.org/10.3390/insects16020136>.
- Shahriari, M. (2020). Impact of *Eucalyptus globulus* and *Allium sativum* extracts on digestive enzymes of *Ephestia kuehniella*. *Toxin Reviews*. **39(4)**: 422-433.
- Shaker, M.A., El-Mergawy, R.E. and El-Sheikh, M.A. (2023). Inhibition of alpha-amylase enzyme in *Trogoderma granarium* larvae by aqueous leaf extract of *Thymus vulgaris*. *Revista Bionatura*. **8(2)**: 63-70.
- Shaker, S.R., Hakeem, I.M. and Lilo, H.M. (2023). Study of the inhibitory effect of aqueous extract of thyme leaf powder on alpha-amylase enzyme produced by insect larvae (*Trogoderma granarium*). *Bionatura (Ibarra-Impresa)*. **8(CSS 4)**: 1-11. <https://doi.org/10.21931/rb/css/2023.08.04.70>.
- Shunmugadevi, C., Radhika, A.S. (2020). Bioactivity of plant extracts against cowpea bruchid *Callosobruchus maculatus* (Fab): A review. *Agricultural Reviews*. **41(3)**: 185-200. doi: 10.18805/ag.R-1970.
- Singh, P., Pandey, A.K. and Tripathi, N.N. (2012). Essential oils: A renewable source for the management of stored product insects-A review. *Agricultural Reviews*. **33(3)**: 226-236.
- Uikey, J. (2024). Effect of plant based pesticides in grain storage management. *International Journal for Multidisciplinary Research*. **6(4)**: 1-8. <https://doi.org/10.36948/ijfmr.2024.v06i04.24964>.
- Vijayan, R., Vidhya, C.S., Ramkumar, S., Sarkar, N., Maheshwari, S., Rashwin, A.A. and Brajendra, B. (2023). Use of botanicals plant for stored grain pest management: A critical review. *International Journal of Plant and Soil Science*. **35(21)**: 801-809. <https://doi.org/10.9734/ijpss/2023/v35i214047>.
- Yoooon, T., Bansiddhi, A. and Promboon, A. (2019). Pesticidal effects of ethanolic crude extracts of *Piper retrofractum* and *Acorus calamus* on *Spodoptera litura*. *Chemical and Biological Technologies in Agriculture*. **6**: 5-10.