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REVIEW OF HEALTH HAZARDS OF CHEMICAL PESTICIDES AND EMERGING BOTANICAL SOLUTIONS AGAINST STORED GRAIN BRUCHIDS OF THE GENUS CALLOSOBRUCHUS (COLEOPTERA: CHRYSOMELIDAE)

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ABSTRACT
In India, a significant portion of the population frequently consumes pulses to meet their protein and vitamin needs. To maintain food security, Indians store vast amounts of food grains in both public and private warehouses. During storage, a variety of biotic and abiotic factors influence grain quality. Among biotic factors, the insect pests belonging to the genus *Callosubruchus* cause the most harm to stored grains or pulses. The major species of this genus include *Callosobruchus maculatus, Callosobruchus chinensis,* and *Callosobruchus analis.* Many strategies have been employed for post-harvest pest control of these bruchids in which chemical control is a popular strategy that involves the use of chemical insecticides to combat pests. However, using chemical pesticides to protect pulses is dangerous to the environment and also to human health, which raises concerns regarding both acute and chronic health effects like poisoning, neurological disorders, hormonal, reproductive disorders, carcinogenic effects, allergy, and respiratory problems. Therefore, nowadays more stress is being laid on the use of botanicals for the control and management of stored bruchids that serve as environment environment-friendly and economically feasible option. As the botanicals greatly lower the risk to human health, prevent harmful residues, and promote safer, sustainable grain storage, all of which are consistent with public health and food safety objectives. Hence, this review provides a comprehensive view of the various types of health risks caused by chemical insecticides, and a light will also be thrown on the possible botanicals that have been explored by various workers in India.

KEYWORDS: *Botanicals, chemical pesticides, Callosobruchus, health, disorders.*

INTRODUCTION
A significant amount of the global gross domestic product is derived from agriculture, and the majority of people rely on an agro-based economy for their existence. However, in the majority of developing nations, subsistence farming, limited access to agricultural technology, and inadequate pest management practices contribute to lower crop yields. The majority of storage losses, which result in significant annual losses, are due to poor storage facilities and infestations by insect pests. Among the stored grain insects, the bruchids are a major category of stored grain pests that infest pulses in both the field and storage. However, as these beetles persist throughout the storage period, the harm is mainly observable in warehouses and household storage of pulses. (Ramzan *et. al.*, 1990).

Bruchids are small insects (1-6 mm) from the subfamily Bruchinae (Chrysomelidae: Coleoptera), with approximately 1700 species classified into 62 genera. Among these, 20 species belonging to the genus *Callosobruchus*, which are the most common bruchid that infest stored pulses (Bano and Gupta, 2015). Out of these, three species are most commonly infesting different types of pulses in stores, namely, *Callosobruchus. maculatus*, *Callosobruchus chinensis, and Callosobruchus. analis*.

These species are cosmopolitan in distribution. Their major host are a variety of beans, viz., *Vigna unguiculata* L. (Cowpea), *Vigna radiata* L. (Moong), *Vigna mungo* L. (Urd), *Vigna aconitifolia* (Moth), *Lablab purpureus*, and leguminous plants such as *Cicer arietinum* L. (Chickpea), *Glycine max* (Linn.) *Merril* (Soyabean).

To control the damage caused by these bruchids, the synthetic pesticides are the mainstay of pest control technologies. Since the discovery of DDT in 1939, chemical insecticides have dominated pest management programs worldwide (Misra 2014). The grains held in

godowns and warehouses are treated with fumigants (carbon disulfide, methyl bromide, phosphine, carbon tetrachloride, EDCT, chloropicrin (tear gas), sulphur dioxide, and methyl formate), organophosphates (malathion, chlorpyrifos), and pyrethroids (delta malathion, cypermethrin) at varying amounts (Murali 2013). Pesticides can also be classified based on their mode of entry, and accordingly these are systemic, contact, stomach poisons, and repellents (Reddy and Guerrero 2010, Cheng et. al., 2021).

Pesticides are considered a quick, simple, and affordable method for controlling insect pests. However, these have contaminated practically every area of the world, with residues detectable in soil, water, and air. The release of pesticides into the environment can lead to both short-term and long-term impacts, potentially disrupting the normal functioning of ecosystems (Lal et. al, 2017).

Numerous pesticides have been linked to health and environmental problems, and their usage in agriculture has been discontinued. Pesticide exposure can occur by ingestion, inhalation, or skin contact. The potential health effects of pesticides are determined by the type of pesticide, the time and mode of exposure, and the individual's health status (Alewu et. al, 2000). Chemical pesticides have been linked to a wide range of severe health impacts, including gastrointestinal, neurological, respiratory, reproductive, carcinogenic, endocrine, and dermatological disorders (Sanborn et. al, 2007).

DISEASES CAUSED BY CHEMICAL PESTICIDE EXPOSURE

Employees who handle pesticides may have acute health issues. Consuming fruits and vegetables that have been grown in soil and water contaminated with pesticides over a long time, or the regular absorption of these chemicals by laborers and farmers, leads to the accumulation of toxins in the body. This accumulation increases the risk of chronic ailments by raising toxin concentrations in vital organs (Figure 1).

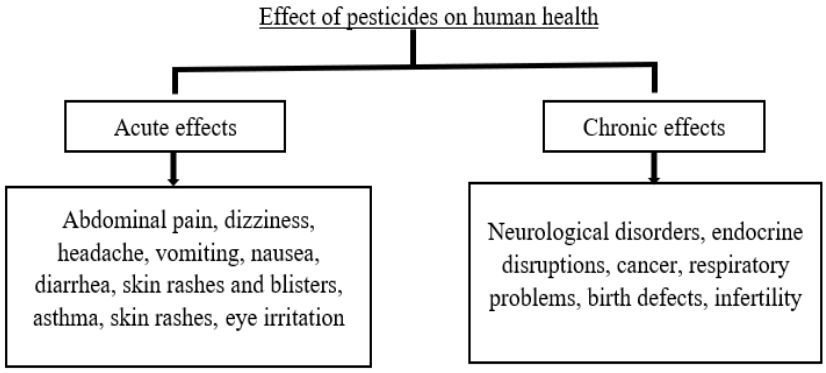

Figure 1: Effects of chemical pesticides on human health.

1. Neurological disorders

The carbamates and organophosphates are categories of chemical pesticides used on stored grains that can affect the neurological system of the body. They block the enzyme acetylcholine esterase (AChE), which stops the neurotransmitter acetylcholine (Ach) from being broken down in the synaptic cleft (Figure 2). When AChE is inhibited, ACh accumulates, causing cholinergic receptors to become overexcited, which results in symptoms such as respiratory failure, muscle jerks, and paralysis.

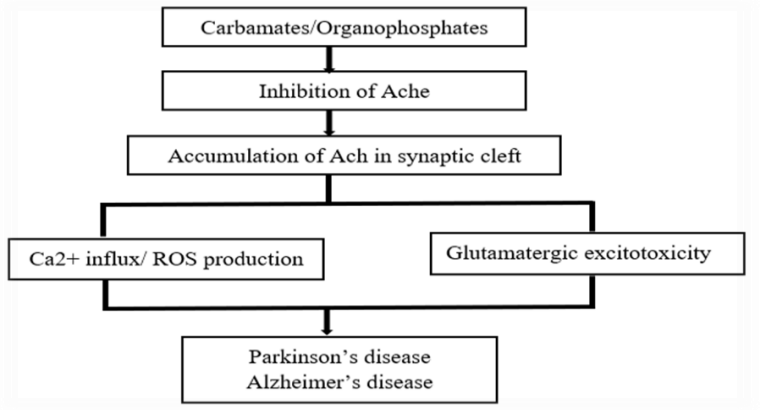

Figure 2: Mechanism of pesticide toxicity on the nervous system.

2. Respiratory problems

The different types of chemical pesticides such as methyl bromide, organophosphates, phosphine, and malathion used on stored grains for control of various pests are found to cause a high risk of developing respiratory disorders including chronic cough, dyspnea grades 3 and 4, throat irritation, nasal catarrh, and nasal dryness (Zuskin *et, al.*, 2008).

3. Endocrine disruptions

Pesticides interfere with the activity of endocrine glands, release timing of hormones, or mimic these hormones, which can lead to immune system compromise, decreased fertility, and abnormalities of the male and female genital tracts (Tabb and Blumberg, 2006, Kabir *et al.*, 2015). Endocrine-disrupting chemicals (EDCs) are hazardous because they interfere with normal hormonal homeostatic functions that promote tissue formation and growth (Table 1). They may cause an aggressive response depending on the receptor they target, they can have an antagonistic impact (Mrema *et al.*, 2015).

Table 1: Various endocrine disruptions caused by chemical pesticides.

S.No.	Chemical pesticides	Diseases	Reference
1	Organochlorines	Type 2 diabetes	Mrema *et.al* 2013
2	Chlorpyrifos/ malathion	Interfere with the hypothalamic pituitary adrenal (HPA) axis, and alter thyroid hormone activity.	Cecconi *et.al* 2007
3	Carbamates	Alter steroid hormone production	Jacobson *et.al* 2010
4	Pyrethroids	Weakens estrogenic and anti-androgenic activity	Tolson and Wang 2010

4. Reproductive disorders

Researchers have reported that exposure to chemical pesticides can result in a range of reproductive issues that can equally impact men, women, and children (Garcia, 2003). The possibility of issues with reproduction and development, including exposure to chemical pesticides used on stored grain products, can increase the risk of birth defects, decreased fertility, and abnormal sperm (Frazier 2007).

5. Cancer

Exposure to pesticides has been linked to an increased risk of leukemia, a disease characterized by abnormal production of white blood cells that can hinder the body's ability to fight off infections and other health disorders. The studies also reveal that there is a significant increase in risks between either childhood pesticide exposure or parental occupational exposure and childhood cancer. (Infante-Rivard and Weichenthal, 2007; Turner et al., 2010). People who are closely associated with pesticides exposure were found to be at greater risk to various malignancies such as leukemia, Burkitt lymphoma, neuroblastoma, Wilm's tumor Non-Hodgkin lymphoma, soft tissue sarcoma, ovarian cancer, cancers of lung, stomach, colon, bladder, and rectum (Schinasi and Leon, 2014; Xu *et al*., 2010). Lerro et al (2015) observed that there is an increased risk of several hormonally-related cancers, including breast, thyroid, and ovarian cancer, due to the extensive use of organophosphate pesticides. Various studies have also reported the presence of high amounts of carcinogenic organochlorides in foods of animal origin, which may be due to the bioaccumulation of these pesticides (Sadighara et al. 2023). The mechanism by which these carcinogenic pesticides affect human physiology is shown in Figure 3.

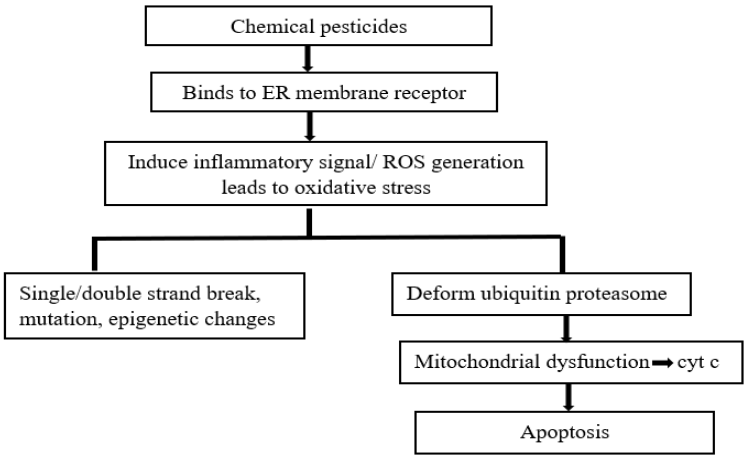

Figure 3: Mechanism of pesticides causing cancer.

Hence, the problems associated with pesticides include health issues, environmental damage, and the development of pesticide-resistant organisms. To ensure the safety of both people and the environment, governments, research institutions, and private companies should invest in the development of safer alternatives to chemical pesticides. Therefore, the scientific community has taken an initiative to explore safer alternatives to chemical pesticides.

USE OF PLANT-BASED ALTERNATIVES FOR CHEMICAL PESTICIDES

The foundation of Integrated Pest Management (IPM) is one of the initiatives that aims at controlling pest populations in stored grains. Therefore, to effectively manage insect pests, the IPM technique incorporates the judicious use of all pest management strategies, such as cultural, physical, mechanical, biological, and chemical methods, systematically. This technique has emerged as the most recognized and a strong concept in modern agricultural science (Kogan, 1998).

The utilization of botanicals for grain preservation from pests is considered a promising alternative to chemical insecticides. Plant material may produce volatile chemicals that repel or confuse the adult beetles, eventually preventing invasion from treated grains (Belmain and Stevenson, 2001).

The plants contain secondary metabolites that directly affect the development and reproduction of bruchids (Suteu et al. 2020). One of the essential conditions for such a program to succeed is that the material used should not be toxic to human beings, as these toxicants need to be mixed with the stored legumes. The plant toxicants are used in three types of formulations on stored grains, namely, extracts, powders, and oils. The different formulations aim to reduce oviposition by bruchids and cause their death due to the action of volatile fumes (Fig. 4).

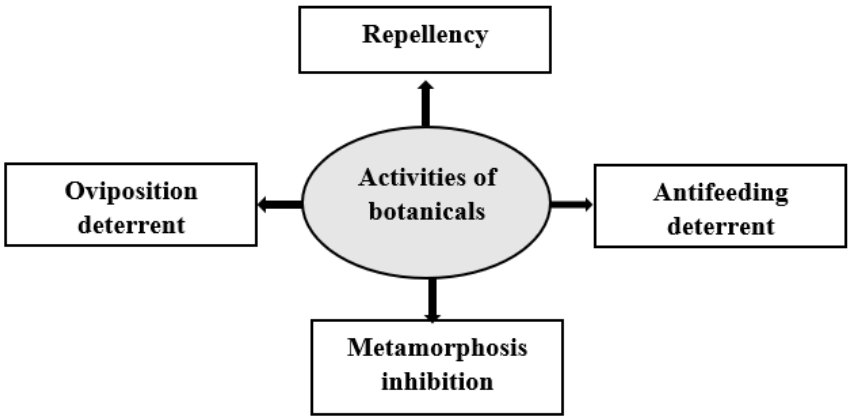

Figure 4: Types of actions shown by Botanicals on stored grain pests.

A plethora of literature shows that plants or plant constituents contain various types of secondary metabolites (alkaloids, tannins, terpenoids, flavonoids, saponins) that help to prevent the pre-harvest and post-harvest losses caused by insect pests or bruchids. The researchers have worked on different formulations against the three species of *Callosobruchus*, as described below (Table 2).

Table 2: Effect of plant products on *Callosobruchus* species.

Host grain	Plant species tested	Host pest	Part used	Formulation	Activities	Reference
Vigna unguiculta	*Momordica charantia*	*C. maculatus*	Leaves	Extract	Adult mortality and seed germination	Bagamala *et. al* 2024
Cicer arietinum (chick pea)	*Azadirachta indica* (Neem)	*C. maculatus*	leaves	Extract	Adult mortality	Saxena
Vigna radiata	*Ocimum sanctum, Pongamia pinnata, Vitex negundo, Adhatoda sp., Zingiber officinale, Capsicum annum, Piper nigrum,* and neem seed kernel powder	*C. maculatus*	Leaves, rhizome pods, bulbs, and seeds	Powder	Mortality, adult emergence, and seed germination	Manju *et. al*, 2019
Vigna unguiculta	*Capsicum frutescens*	*C. maculatus*	Chilli pepper whole	Powder	Oviposition and weight loss of	Rosulu *et. al* 2022

					grains	
Vigna aconitifolia	*Coleus amboinicus*	*C. chinensis*	Leaves	Extract	Adult mortality	Jadhav and Pradeshi 2024
Vigna radiata	*Ocimum sanctum*	*C. chinensis*	Leaves	Extract	Adult mortality and the developmental period	Dey *et. al* 2024
Cicer arietinum	Mint, Garlic, and Onion	*C. chinensis*	Leaves	Powder	Mortality and adult emergence	Thapliyal *et. al* 2024
Cicer arietinum	Neem, castor, and pongam	*C. chinensis*	Seeds	Oil	Oviposition and weight loss of grains	Herald and Tayde (2024)
Vigna radiata	*Sapindus mukrossi, Moringa oleifera, Cassia fistula, Rosa indica*	*C. analis*	Leave, flower	Powder	Adult mortality, oviposition, and adult emergence	Airi *et. al* 2025
Vigna radiata	*Cocos, Syzygium, Eucalyptus,* and *Nigella*	*C. analis*	Fruit, buds, and leaves	oil	Adult mortality, oviposition, and adult emergence	Airi *et. al* 2024
Vigna unguiculate	*Synzgium aromaticum, Azadirachta indica, Allium sativum,*	*C. analis*	Buds, leaves, bulbs, hizomes	Extract	Mortality and developmental biology	Verma *et. al* 2024
Vigna radiata	*Annona muricata*	*C. analis*	Leaves	Powder	Mortality	Harnita and Setyorni 2020

CONCLUSION

A review of the literature indicates that plant components may help control the *Callosobruchus* population on stored grains. Therefore, nowadays, the synthetic insecticides have been replaced by botanicals, which have been used for hundreds of years to ensure food safety by reducing the number of bruchids. Due to their easy availability from the local biodiversity, the majority of the botanical formulations would be suitable for farmers. Therefore, in developing nations where farmers cannot afford synthetic insecticides, the use of botanical insecticides is more advantageous. Because these plant-based formulations undergo short-term toxicity testing before being formulated as insecticides, they are a less expensive and healthier option than synthetic insecticides.

STATEMENTS AND DECLARATIONS

The authors declare that the manuscript is original and has not been published or submitted elsewhere. All authors have read and approved the manuscript for publication.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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