

Biology, damage, and integrated approaches of pulse beetle (*Callosobruchus chinensis* L.) in storage condition: A review

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Abstract

Pulse beetle belonging to the genus *Callosobruchus* which is categorized as a group of destructive pests of storage ingredients globally. Among them species namely *Callosobruchus chinensis* (L.) is a key primary storage pest causing severe quantitative and qualitative losses in stored pulses. The pest infestation occurs by laying eggs on the surface of the seeds which further develop into larvae inside the seeds by feeding on the cotyledons. This internal feeding activity of the pulse beetle larvae leads to a decline in weight, quality of the grains and a significant loss of germination potential. Under favourable environmental conditions, several generations of the pest are developing in stored pulses causing a sharp increase in population and leading to severe losses. Conventional methods of controlling pulse beetle infestation in stored pulses are largely based on using the chemical fumigants and insecticides. However, overdependence on such methods has led to concerns over insecticide resistance, pesticide residues, and environmental risks. Hence, there is a vital need in developing nature friendly and sustainable approaches in managing pulse beetle infestation in stored pulses. Recent studies have indicated the potential of botanical insecticides, plant oils, inert dusts, hermetic storage methods, and biological control agents in managing bruchids effectively. The present review aims to summarize the taxonomy, morphology, biology, host range, symptoms of damage, and integrated management of *Callosobruchus chinensis* with special emphasis on recent advances in developing eco-friendly methods of controlling pulse beetle infestation in stored pulses

Keywords: Bruchids, botanical insecticides, hermetic storage, integrated pest management

Introduction

Pulses are at the heart of food security worldwide and are a major source of plant-based proteins particularly for vegetarians. It is ranked 2nd after cereal crops in terms of their importance in food production owing to their well-balanced composition of proteins, essential amino acids, minerals, and vitamins. Pulses are also important in sustainable agriculture because of their contribution to healthy soils through nitrogen fixation and reduced dependence on chemical fertilizers (Singh *et al.*, 2022) [52]. Globally, pulses occupy an area of 68.32 million hectares and sharing 57.51 metric tonnes (Chaturvedi and Ali, 2002) [12]. India belongs at the top of pulse production and consumption worldwide accounting for a quarter to a little over a quarter of global production (Avinash & Patil, 2018) [7]. However, losses in pulses are a major challenge in pulse value chains. New studies indicate that losses in pulses are caused by a significant number of insect pests in storage, which impacts food availability and income for pulse growers (Chandel *et al.*, 2023) [10].

Additionally, pulses are the vital source of human diets and nutritional balance especially in developing countries which play a key role in agricultural economy. Pulses or legumes are termed as Poor man's meat due to vital source of nutrition and affordability. They are very nutrient rich food which play crucial role to fulfil the deficiency of protein diet on daily basis. On the other hand, pulses maintain the soil fertility by fixing biological nitrogen in soil which ultimately leads to sustainable agriculture. They are considered as a very good source of proteins (20-40%), carbohydrates (50-60%), and minerals like calcium and iron (Ofuya and Akhidue, 2005) [37]. Pulses are rich in essential amino acids like methionine, tryptophan, and cysteine,

along with micronutrients like iron, zinc, magnesium, and potassium.

Among all pulses, chickpea occupies a special place with respect to global production with India holding the first rank followed by Australia, Myanmar, and Ethiopia (FAO, 2023). In the midst of all insect infestation in stored pulses, bruchids (Coleoptera: Bruchidae) rank first in terms of damage potential. Within the whole bruchid groups which typically infests pulses, pulse beetle of the species *Callosobruchus chinensis* Linn. is identified as the major pest of stored pulses infesting in the field as well as stored conditions (Yadav *et al.*, 2022) [54]. Although *C. chinensis* has short life and does not feed in its adult stage, its larvae hollow out the endosperm of pulses and render them unfit for consumption and seed purpose. Their infestation causes 50-60% damage to seeds and causes a reduction of 90% in seed germinability (Meena *et al.*, 2021). Although infestation is low in the fields (1-2%) and in the other hand it causes 40-50% damage in stored grains depending upon the period of storage and conditions (Prasad *et al.*, 2023) [43]. *C. chinensis* infests various pulses including chickpea (*Cicer arietinum* L.), pigeon pea (*Cajanus cajan* L.), green gram (*Vigna radiata* L.), black gram (*Vigna mungo* L.), cowpea (*Vigna unguiculata* L.), pea (*Pisum sativum* L.), and soybean (*Glycine max* L.) etc. (Singh *et al.*, 2021) [51].

Recent research has also pointed out the demerits of using only synthetic insecticides for controlling storage pests. Problems such as insecticide resistance, residue problems, and environmental and health concerns are pushing scientists to look for greener and more sustainable approaches for managing these pests. In this regard, eco-friendly approaches such as hermetic storage, botanical insecticides, inert dusts, and biorational insecticides are

gaining more attention. Hermetic storage has shown excellent results for controlling bruchids and for preserving seed quality over long storage periods. Similarly, botanical insecticides and inert dusts such as plant products and diatomaceous earth are also giving excellent results for controlling *Callosobruchus* species through mechanisms such as egg-deterrent activity, repellency, and contact toxicity. In view of the ongoing losses caused by *C. chinensis* and the increasing need for more safe storage approaches, there is a critical need for reviewing recent developments in managing pulse beetles. This research aims to review safe, effective, and more sustainable approaches for controlling *C. chinensis* in stored pulses to reduce the losses of post-harvest while preserving grain quality and protecting the environment.

Taxonomical characteristics and identification of bruchids

The pulse beetle belongs to the order Coleoptera and the family Bruchidae. Taxonomic classification of pulse beetle is as follows

1. **Kingdom:** Animalia
2. **Phylum:** Arthropoda
3. **Class:** Insecta (Hexapoda)
4. **Sub-class:** Metabola (Pterygota)
5. **Division:** Holometabola (Endopterygota)
6. **Order:** Coleoptera
7. **Family:** Bruchidae
8. **Genus:** *Callosobruchus*
9. **Species:** *chinensis*

Morphological study

As per report by FAO, 2009 that majority of pests mainly belongs to two orders namely coleoptera (60%) and lepidoptera (100%) (Atwal and Dhaliwal 2008) [5]. Pulse beetle adults are small insects that measure 2-4 mm and are compact with an oval body. They are brown or reddish

brown and are identified by particular markings on their wing covers. The head has two prominent compound eyes and serrated antennae which are significant sensory organs for these insects. The pronotum is broad, and the three pairs of legs are useful for movement on the stored grain material (Credland & Wright, 1989) [13]. A significant morphological feature of bruchid beetles is that they do not have elytra that cover their abdomen entirely, and the posterior abdominal segments are exposed. This is used to identify the genus *Callosobruchus* (Giga & Smith, 1983) [19]. Bruchids are commonly referred to as seed beetles/cowpea beetle/bean beetle because their immature stages develop inside seeds of legumes (Onyido *et al.* 2001). Several species within this genus attack stored pulses, but *C. chinensis* and *C. maculatus* are vital due to their significant effect in global economy (Southgate, 1979) [55]. In Cowpea, there are severe damage which is caused by *C. maculatus* that keep it to the category of significant pest (Kergoat *et al.* 2008) [26]. It has been reported by Augustine and Balikai, 2019 [6] that 1st instar larva of *C. maculatus* was identified by pro-thoracic plates in pairs which was capable to make an entry to the hard type seed coat and larva able to penetrate inside the embryo to destroy it fully and pulses became unfit and unhealthy for consumption. Damage leads to loss of seed weight and adults follow the growth life cycle from egg to pupa through holometamorphosis or complete metamorphosis (egg-larva-pupa-adult). One of the best examples which cause significant loss in cowpea i.e., *C. maculatus* in post-harvest storage (Adedire *et al.*, 2011, Park *et al.*, 2003, Sanon *et al.*, 2010) [2, 39, 47]. Pulses infested by both of the species directly or indirectly causes severe damage rate. Commercially and domestically, main focus is maintaining only the storage portion and keeping the infestation as negligible which ultimately cause contamination for a long time by secondary pest attacks and hence deterioration occurs which leads to quality and quantity of stored pulses.

Types of bruchids and their identification characteristics

Particulars	<i>Callosobruchus chinensis</i>	<i>Callosobruchus maculatus</i>	<i>Callosobruchus analis</i>
Common name	Asian pulse beetle	Cowpea weevil	Red eyed pulse beetle
Size of body	Small and about 2.5 to 4 mm long	Near about 3 to 4 mm in length	About 3 to 4 mm long
Colour	Reddish brown with metallic body	Reddish brown or dark brown with black markings or spots on the elytra	Light brown to tan with smooth and shiny appearance.
Shape of body	Oval and a little flattened	The body is oval and slightly flattened	Oval and slightly flattened
Prominent markings	Series of dark colour spots on the elytra	Presence of irregular black spots or patches on the wing covers is the most prominent identifying characteristic.	Distinctive red or orange spot near eyes.

Life stages and ecology of bruchids

The life cycle of *Callosobruchus chinensis* consists of four developmental stages: egg, larva, pupa, and adult.

Egg Stage

Female beetles deposit their eggs as progenies individually on the surface of pulse grains. Eggs are oval in shape and translucent which are firmly attached to the seed coat. A female beetle is capable of laying 50 to 100 eggs in her lifetime, depending on environmental conditions and host availability (Messina, 1991) [29].

Larval Stage

As soon as egg hatches it emerges into the seed coat and then moves into the cotyledon to feed on the tissues of the seeds. At this stage, the larvae are most destructive since

they consume all the internal content of the grain, thus causing significant damage (Ofuya, 2001) [36].

Pupal Stage

Pupation occurs inside the cavity made inside the seeds as a result of larval feeding. At this stage, the insect undergoes complete metamorphosis and gradually transforms into an adult beetle. If temperatures and humidity are right, the entire life cycle can be completed within 25-35 days, allowing multiple pest generations to develop during storage.

Adult Stage

The adult beetle comes out of grains by gnawing a circular hole on the outer coat. These adult beetles live for only a short time, approximately 7-10 days. They do not eat and

spend most of their time mating and laying eggs (Ahmed *et al.*, 2003)^[3].

Host range and distribution

The pulse beetles are known to feed on a wider range of store legumes. The main stored products infested are chickpea, pigeon pea, green gram, black gram, cowpea, lentil, and pea, and the infestation has also been recorded on soybean and wild legumes (Singh *et al.*, 2021)^[51]. They are distributed over tropical and subtropical parts of the globe particularly in Asia, Africa,

and Latin America. The high temperature and high humidity conditions favour their development and multiplication, causing significant infestations in stored pulses (Keneni *et al.*, 2011)^[25]. Pulse beetle initiates their damage in field conditions and during harvesting it can cause 1-5% infestation. Bruchids can maintain their decreased population most of the time through developing larval and pupal population. The most attacking stage is larva which ultimately consumes the grains and affect the weight and germination percentage (Murdock *et al.*, 2003; Deshpande *et al.*, 2011)^[16, 33].

Table 1: Major Host Plants of Pulse Beetle (*Callosobruchus chinensis*)

Crop	Scientific name	Susceptibility level	Remarks
Chickpea	<i>Cicer arietinum</i> L.	High	Most preferred host for oviposition and larval development
Pigeon pea	<i>Cajanus cajan</i> L.	High	Commonly infested during storage
Green gram	<i>Vigna radiata</i> L.	Very high	Highly susceptible due to softer seed coat
Black gram	<i>Vigna mungo</i> L.	High	Supports rapid pest multiplication
Cowpea	<i>Vigna unguiculata</i> L.	Very high	Primary hosts of bruchids
Lentil	<i>Lens culinaris</i> L.	Moderate	Infestation depends on seed coat hardness
Field pea	<i>Pisum sativum</i> L.	Moderate	Susceptibility varies among varieties
Soybean	<i>Glycine max</i> L.	Low-moderate	Occasionally attacked during long storage

Damage symptoms and nature of damage

Infestation of pulses by pulse beetle results in a reduction in quantity and quality of pulses. One of the major indicators of pulse beetle infestation is the presence of round exit holes on the surface of seeds, indicating that adult beetles have emerged from the seeds (Jood *et al.*, 1993)^[23]. Infestation of seeds also results in a reduction in weight and value of seeds. Moreover, there is also a reduction in germinability and nutritional value of seeds. In severe cases of infestation, the entire quantity of pulses is rendered unfit for human consumption in a matter of a few months of storage (Prasad *et al.*, 2023)^[43]. *C. maculatus* are the primary destructor of the pulse grains and losses reaches up to 10–20% in storage (Phillips and Throne, 2009)^[41]. Approximately 600 insect species belonging to the order coleoptera which are the key pests of stored materials and significantly creates damage rate to the high (Rajendran and Sriranjini, 2008)^[44]. The stored grain pests start damaging from field but at storage it became more active due to establishment of larva and micro climatic conditions (Hagstrum and Phillips, 2017)^[21]. Initially post-harvest losses are managed by proper handling, harvesting, and drying of grains. It has ability to move from one pulse stored bag to another due to their flight habit (Mahroof *et al.*, 2010)^[27]. It has been reported that yearly crop damage occurs ranging from 10-30% out of which around 26% is due to insect pests (Ridley *et al.*, 2011)^[46].

In order to protect pulses from infestation by *Callosobruchus* spp. and attain better storage results, it is of prime importance to organize the existing research results in a systemic manner. This helps in better understanding the management of the infestation by various methods. Thus, the review is focused here on assessing the potential of various management options for infestation by *Callosobruchus* spp., thereby highlighting the efficiency of the options in pulse storage.

Notable characteristics of legumes

Pulses, which fall under the family Fabaceae, are grown all over the world for their seed material that is rich in proteins and are an essential component in food and nutritional security globally. They are a rich source of plant-based proteins and make a considerable contribution to human

nutrition by providing dietary fibres, carbohydrates, starch, and essential vitamins and minerals. In addition to their contribution to human nutrition, pulse by-products also find their way as low-grade animal feed and fuelwood.

Agronomically, pulses have been found to be highly beneficial as they can fix nitrogen from the atmosphere through symbiotic associations, thus enriching the soil fertility with nitrogen as well as phosphorus (Patterson *et al.*, 2009; Sardana *et al.*, 2010)^[40, 48]. Pulses have been observed to have positive contributions to the biotic as well as abiotic components of the agro-ecosystem. Pulses have been considered to be the primary source of protein supply to the vegetarian population with a balanced composition of essential amino acids, especially when consumed along with cereals (Reddy, 2010; Saxena *et al.*, 2010; Asif *et al.*, 2013)^[4, 45, 50]. Due to their high biological value and nutritional significance, pulses have been considered to be a part of a healthy and balanced diet with high energy value.

In the last few decades, the demand for pulses has risen manifold with the rise in population and the rise of nutritional awareness. However, the production of pulses is unable to meet the demand, resulting in a substantial supply-demand gap. Bruchid beetles of the family Bruchidae have been identified as a problem in the storage of pulses, as they are closely associated with leguminous crops and are considered the primary pests of stored grains. Cowpeas are the most vulnerable to bruchid infestation as they have less natural resistance to bruchid attack during storage.

Management options of bruchids

Cultural and preventive methods

Storage practices are of vital importance in controlling bruchid infestations. Dry storage of grains to safe moisture levels (which are below 10%), storage facility cleanliness, and maintenance of hygienic conditions in storage are all important in controlling pest development (Golob & Webley, 1980)^[20].

Traditional methods

It includes many strategies like sealed containers, harvesting time, alternate host, intercropping, cleanliness, smoulders, effects of gas and vegetable oil.

Strategies for pest management	Mode of action & Affected stage
Sealed containers (Plastic/polythene/iron)	Asphyxiation (Adult)
Inert materials (Sand/Ash/Silica gel/Diatomaceous earth)	Asphyxiation (Egg, larva & adult)
Adjusting harvesting time	Disruption of pest cycle & growth
Alternate host	Prevent continuous infestation by eliminating wild hosts (Egg and larva)
Inter-cropping	With non-host plant which gives lethal effects (Egg & larva)
Cleanliness (DDT or other chemicals)	Asphyxiation (All stages are affected)
Smoulders (Smoke)	Fumigation (Adult)
Effects of gas	Fumigation (Eggs & Adult)
Vegetable oils	Ovicidal property (Eggs)
Store unthreshed pulses	Barrier to eggs development

Botanical insecticides

Botanical ingredients include neem seed powder, neem oil, mustard oil, eucalyptus oil, and garlic extracts that display significant repellent and lethal activity against pulse beetles. Their mechanism of action is to deter egg laying and interfere with their developmental processes (Isman, 2006) ^[22].

Inert dusts

Inert powders, e.g., diatomaceous earth, ash, and sand, are grain protectants. The powders scratch and wear away the insect's outer layer, causing desiccation and death (Murdock *et al.*, 2012) ^[32].

Hermetic storage technologies

Hermetic storage methods such as stored bags (PICS bags) and containers work by creating

low-oxygen environments that inhibit insect breathing and reproduction. These methods have proven to be highly effective in protecting stored pulses (De Groote *et al.*, 2013) ^[14].

Chemical control

Fumigants, e.g., phosphine, are often applied in large storage facilities to control storage pests. However, overuse has led to problems, e.g., pests have developed resistance and there are pesticide residues (Nayak *et al.*, 2022) ^[35].

Biological control

Natural enemies, e.g., parasitoids and fungi attacking insects, have also been considered as means of controlling bruchids. These biological control methods have shown promise as environmentally friendly measures, which can be integrated with other pest control methods (Ofuya, 2001) ^[36].

Table 2: Eco-friendly management methods against pulse beetle

Management method	Materials used	Mode of action	Key advantages
Botanical insecticides	Neem oil, garlic extract, eucalyptus oil	Repellent, oviposition deterrent	Eco-friendly and biodegradable
Plant powders	Neem seed powder, turmeric powder	Toxic and repellent effect	Easily available to farmers
Vegetable oils	Mustard oil, coconut oil	Coating on seed surface prevents egg laying	Safe for small storage systems
Inert dusts	Diatomaceous earth, ash	Cuticle abrasion and desiccation	Long residual activity
Hermetic storage	Triple-layer bags (PICS), airtight containers	Low oxygen environment suppresses insects	Chemical-free protection
Biological control	Parasitoids, entomopathogenic fungi	Natural mortality of pests	Sustainable approach

Recent advances in pulse beetle management

Recent research has pointed to greener options for managing pests. Advances in plant-based formulations, storage technologies, and resistant host plants are promising

alternatives to conventional chemical pesticides. These options, used collectively through integrated pest management, promise reductions in storage losses and increases in the sustainability of pulse storage.

Modern strategies for pest management	Mode of action & Affected stage
Physical control (Temperature, freezing and heating)	Growth & development disrupt (All life stages)
Radioactive control (Radiations such as beta and gamma)	Prevention of moulting process (All life stages)
Resistant varieties	Inhibit pests to develop into the host (Eggs)
Biological control (Bio-agents like parasites & parasitoids)	Lethal in nature (Egg, larva & pupa)
Phyto-chemical control (Powders/oils/extraction of botanicals)	Repellent, deterrent which is lethal in action (All stages)
Chemical control	Lethal action (All stages)
Transgenic approach (DNA alteration, Gene mapping)	Arcelins, phyto-hemagglutinins and α -amylase act as bruchid inhibitors (Larva)
Microbial control	Lethal in nature (All developing stages)
Cold plasma treatments	Reduces respiration rate and cause asphyxiation and lethal in nature (All stages)

Future perspectives:

Since time immemorial, the management of bruchid pests has been an important aspect in the storage and protection of pulses. In the past, pulse grains have been protected using different methods. Among the methods used was the application of artificial insecticides to manage different bruchid species that attack different pulse seeds. However,

the prolonged and indiscriminate use of artificial insecticides has been a great concern owing to the hazardous impacts on the environment, non-target organisms, insect resistance, and the risk they pose to human health.

Although conventional methods have their own importance, the limitations associated with the methods have led to the need to explore new alternatives that are safe for the

environment and human health. In this regard, the application of plant-based botanicals, individually or in combination, has been identified as a promising tool for managing *Callosobruchus* spp. and other pulse grain insects. This is because the botanicals are generally cheaper, readily available, environmentally friendly, and safe for human health, especially for the farming community.

Moreover, the integration of traditional practices, botanical preparations, microbial control agents, and other eco-friendly measures is also important for the efficient management of pests. This integration of traditional practices with the framework of Integrated Pest Management (IPM) may also be helpful in the efficient management of pulses, reduction of chemical residues, and protection of pulses from insect pests.

Conclusion

Amongst them, pulse beetles especially *Callosobruchus chinensis*, are some of the worst troublemakers for stored pulses, resulting in significant post-harvest losses worldwide. They reproduce quickly, and their mode of feeding is such that it evades detection, thereby becoming difficult to control once the grains are stored. There has been an increasing trend of using chemical control methods, but this has come under severe criticism owing to environmental issues, thereby forcing people to adopt green methods of control. A holistic approach to pest control, including the use of good storage practices, plant-based insecticides, inert products, hermetic storage, and biologicals, appears to be the answer to the safe storage of pulses. Adoption of these green methods can help in reducing post-harvest losses while ensuring the quality of the grain

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