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A review on bruchid management in pulses

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Abstract
Bruchids (*Callosobruchus* spp) are important pests of pulses found commonly infesting pulses like chick pea, pigeon pea, green gram, cowpea, black gram and moth bean in storages. The estimated post-harvest losses caused by bruchids to the pulses ranged from 30-40% within 6 months of storage and when left unattended losses could be upto 100 percent. Small farmers do not use insecticides for storage of pulses. For effective and sustainable preventive measures of bruchids, different compatible options like sun drying, use of botanicals, use of bruchid resistant varieties, use of biopesticides are recommended. Botanicals are easily available, ecofriendly and simple to apply. The present review article has given detailed review of bruchid management by using botanicals, varietal resistance and biopesticides. For curative control of bruchids fumigation by Aluminum phosphide is proven effective for large size pulse storages.

Keywords: Bruchid management, pulses, *Callosobruchus* spp

Introduction
Pulses, the "wonderful gift of nature" play an important role in Indian economy and are a rich source of supplementary protein of daily diets of vegetarian population. Pulses are the rich source of protein, several amino acids, minerals and certain vitamins, and are available to the poor people at a responsible price. Pulses are also known as "poor man's meat". Pulses are consumed all over the world. Consumption is higher in those parts of the world, where animal proteins are scarce and expensive.

Pests of Stored Pulses
Many grani-vorous pest species are unable to develop on legume seeds due to their high content of digestion inhibitors and most of the insect pests infesting stored pulses are from the Coleoptera subfamily Bruchidae. At present main storage pest of pulses is bruchids i.e. *Callosobruchus* spp. which begins the seed infestation not only in storages but also in the field. (Thambhare, 2007) [35] There is historical documentation of high seed infestation (50%) (Sharma *et al.* 2017) [29] and dramatic germination losses (60–90%) in many pulse crops. It is recorded that 55- 60 percent loss in seed weight and 45.50 to 66.30 percent loss in protein content of pulses is due to infestation caused by the pulse beetle in *Pisum sativum* (pea) (Hosamani *et al.* 2018) [18]. The estimated post-harvest losses caused by bruchids to the pulses ranged from 30-40% within 6 months of storage and when left unattended losses could be upto 100 percent. (Govindan *et al.*, 2020) [7]. Field level infestation accounts to only 1-2% damage. (Srinivasan *et al.* 2008) [26] This species still remains major concern because of uncertainty about its control, even with novel insecticides.
It is, therefore, very essential to protect the pulses from *Callosobruchus* spp. during storage. The objective of this study is to review the different safe, effective and sustainable management options of *C. chinensis* on pulses and to reduce the population of pulse beetle below economic threshold level in the storages.

Taxonomical Position of Pulse beetle
C. chinensis was first described by Linnaeus. It belongs to the Kingdom: *Animalia*, Phylum: *Arthropoda*, Class: *Insecta*, Order: *Coleoptera*, Family: *Chrysomelidae*, Genus: *Callosobruchus*, Species: *Callosobruchus chinensis*. (Asela K, 2019) [45]. Pulse beetle belongs to the family *Bruchidae* that comprises more than 1700 species of 62 genera worldwide. The most important species include *Callosobruchus chinensis*, *C. analis* and *C. maculatus*.

Life cycle and ecology of bruchids

The life cycle and ecology of both *C. maculatus* and *C. chinensis* are similar. The initial infestation originates in the field. The eggs are firmly glued to pods and seeds. In the field, eggs are laid on pods and in storage directly on the seeds. Bruchids lay 1–3 eggs/seed, and larger seed size accommodates a larger number of eggs. Hatching of the eggs takes place after 6 days of oviposition. The larvae penetrates into the seed and develop inside it. Larvae excavate an emergence tunnel to the seed surface, forming a translucent window in the seed coat for the adult emergence. Larval duration varies from 18-22 days. Although adults do not feed on seeds, they may feed on pollen and flower nectar in the field. The adult males and females both have an average life span of 7 days under laboratory conditions and only a few can survive more than 2 weeks. The oviposition by *C. maculatus* reaches a peak within 2 days after the commencement of oviposition and declines over time. Each female lays about 100 eggs. The life cycle of both species is about 28–30 days at 30 °C and 70% relative humidity. The bruchids use vibrations from the egg laying substrates for oviposition. (Singha and Rajkumari, 2021) [23] Bruchids do not feed during the brief adult stage and reproduction depends mainly on the resources the insect accesses during larval stages from a single seed, with severe competition from other larvae.

Nature and Extent of damage

Bruchids are cosmopolitian insect able to eat all kinds of food. Bruchid is primary pest of stored pulses (Chakraborty *et al* 2015) [24]. The adult bruchid female lay eggs on the seed surface and after hatching the eggs, the grubs bore into the seed. The grubs are developed inside a single seed and the adults emerge out by leaving behind seeds with holes. More than one larva can develop within a single seed. Damaged legume seeds thus reduce weight, become unsuitable for consumption and have poor germinating ability. Heavy infestation can lead to mouldiness and reduction in commercial value of the seeds. Seed losses due to pulse beetle are direct, as well as indirect. Apart from their direct damage to the stored seeds they also create conditions that bring secondary infestation mainly by fungi and subsequent mycotoxin contamination. Faruk *et al.*, 2011 [5] recorded that 55-60% loss in seed weight and 45.50 to 66.30% loss in protein content of pulses is due to infestation caused by this beetle. Bruchids cause overall seed weight loss, loss of seed viability and altered nutritional quality due to the presence of insect frass, excrement and dead insects in and on the seed. A single beetle is able to cause 3.5% weight loss in cowpea seeds (Tembo *et al*., 2016) [34]. Damage by bruchids is irreversible and direct on the grain (Kananji, 2007) [12]. Due to the bruchids' high fertility, ability to re-infest and short generation times, even low initial infestation rates can lead to tremendous damage (Yamane, 2013) [38]. Mookherjee *et al.*, 1970 [17] recorded 4 to 98% loss of pulse seeds may be observed due to the infestation by the pulse beetle in storage.

Management of Bruchids in storage

Preventive Measures

1) Drying and disinfestations

Sun drying is the common traditional practice followed by the farmers before grains and pulses storage. (Prakash *et al.* 2016) [19]. The process of heating grain in the sun to kill insects is called solarization. It is an old age practice by farmers before storing the grains and pulses in regions where the outdoor temperature reaches 20 °C or higher (Chua and Chou, 2003) [3]. Generally pulses need to be dried to safe moisture level, below 11-12%, prior to storage. Crops are usually harvested at high moisture content to avoid shattering losses. Solar drying of pulses can be done on cemented platform, mat, jute cloth or metal sheets. If grain temperature is increased up to 60 °C and maintained for 10-15 minutes, all live stages of pulse beetle present in pulses are killed.

2) Reducing intergranular space

Adult pulse beetles, being very weak and having a short life, cannot move in grain mass and are restricted to top 15 cm layer. Movement of adult pulse beetle can be prevented by placing a 7-10 cm layer of dry sand at the top of grain mass. (Vikaspedia, 2008) [37]

3) Use of botanicals

The toxicity of a large number of essential oils and their constituents has been evaluated against bruchids. Botanical pesticides are an alternative to chemical pesticides Essential oils and their constituents have been shown to be a potent source of botanical pesticides.

Table 1: Plant powders and oils tested against *Callosobruchus* spp. and their active ingredients

Plant Powders	Active ingradients	References
Sweet flag rhizome (*Acorus calamus*) powder	α- and β.-asarone.	Nandi *et al.* 2022 [18]
Turmeric (*Curcuma longa*)	Curcumin	Ali *et al.* 2006 [2]
Custard apple seed powder (*Anona squamosal* L.)	Cyclosquamosin B, Tocopherols, Carotenoids (µg of β-Carotene/100 m)	Sharma *et al.* 2010 [30]
Tulsi Leaf Dust (Ocimum Sasi Licum)	Caryophyllene, terpinene 4-ol, eugenol methyl ester, and 3-carene	Savita Verma and P.Anandi (2010) [36]
Nirgudi (*Vitex negundo*)	Casticin, isoorientin, chrysophenol D, luteolin, p–hydroxybenzoic acid and D-fructose.	Sathyaseelan *et al.* 2008 [32]
Chilli (*C. annum*)	Capsisin	Manju *et al.* (2019) [16]
Neem leaf powder (*Azadirachta indica*)	Nimbin, Nimbicidin and Azadirachtin	Tripathi *et al.* (2006) [33]
Edible seed oils		
Mustard (*Brassica juncea* L.)	Erucic acid and oleic acid, alpha-linolenic acid	Singhal and Singh (1990) [25]
Soyabean (Glycine max)	linoleic acid, α-linolenic acid, oleic acid, 1palmitic acid and stearic acid	Chaudhary *et al.* (2014) [4]
Ground nut oil	Palmitic acid, oleic acid, and linoleic acid. arachidic acid, arachidonic acid, behenic acid, lignoceric acid	Sahoo and Chandarkar (2013) [22]
Coconut oil	Lauric acid	
Non edible oils		

Neem (*Azadirachta indica*)	Tetranortriterpenoids (Azadirachtin, melantriol, salannin, nimbin, nimbidin,	Sharma *et al* (2016) [31]
Karanj (*Pongamia pinnatta*)	Liminoid karanjin.	(Khaire *et al* 1992) [14]

4. Varietal Resistance

Borthakur (1992) [46] reported that foods on which the pulse beetle was bred influence the number of eggs laid, presumably better foods enabled the larvae to yield adults with a greater potential for egg production.

Table 2: Resistant cultivars of pulses against pulse beetle

Crop	Resistant cultivars	Reference
Pigeonpea	ICP 89049, IPA 37 and Dholi dwarf DB	Naik *et al*. 2021 [39]
	ICPW 130 and ICPW 66	Jadhav *et al*. (2012) [40]
Chickpea	PI 599066	Sathish *et al*. 2020 [27]
Cowpea	Aswany	Fawki *et al*. (2012) [40]
	GC 3	Senthilraja N and PS Patel 2021 [41]
	DCP 92-3	Singh *et al* 2016 [28]
Green gram	LM 131, V 1123, LM 371 and STY 2633	Punnysamy *et al* 2014 [21].
	Km-12-5 and P-S-16	Soumia P.S. and Chitra
Black gram	UH 82-5,IC 8219 and SPS 143	Punnysamy *et al* 2014 [21].

5. Biopesticides for te control of pulse beetle

Biological control is the use of predatory or insect-parasitic insects or microbes to control pests. Several species of beneficial insects that attack the pulse beetle in stored seeds

Table 3: Effective biopesticides tested against pulse beetle

Sr. No.	Biopesticides	Reference
1.	*B. thuringiensis* (4×10^8 cells/mL)	Malaikozhundan and J. Vinodini (2018) [42]
2.	*B. thuringiensis*	Javad (2014) [43]
3.	Entomopathogenic fungi and bacteria	Mohsan *et al*. (2019) [47]
4.	*Metarhizium anisopliae*	Javid, *et al*. (2018) [11]
5.	*Beauveria bassiana*	Islam and Biswas (2017) [44]
6.	*B. bassiana*	Shaheen *et al*. (2017) [44]

B) Curative Treatment

Fumigation

A fumigant is a chemical vapour or gas that, when released, penetrates objects or enclosed areas in concentrations that are lethal to pest. Commonly used fumigant is aluminium phosphide (ALP).

Some researchers claim that phosphine does not impair the pulse grains nor leave residues that could be hazardous to the consumer when correctly applied and the pulses are aerated (Ahmad 1976; Rangaswamy and Gunasekaran 1996) [1, 20]. It was observed that after the application of 6 phosphine tablets/ tonne to grains for the stipulated time and then airing, some food legumes desorbed the residual phosphine more rapidly than others and within 1 day of aeration the residues were significantly reduced. Based on this observation Rangaswamy and Gunasekaran (1996) [20] recommended use of phosphine as a suitable fumigant for pulses. On the flip side, there are growing reports of insects developing resistance to phosphine

Conclusion

Pulses have high nutritional value in human diet. Pulses in storage are attacked by bruchids i.e. *Callosobruchus* spp. Many nonchemical methods are widely adapted to mange bruchids. Fumigation with ALP is used for large size storage but its application has negative effect on environment and threat to develop insecticide resistance. Insecticides with plant origin could be exploited for development of novel molecules against bruchids.

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