RESEARCH PAPER

A Review on Biology of Pulse Beetle (Callosobruchus chinensis Linn) and their Management through botanicals on stored green grams (Vigna radiata)

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ABSTRACT
Green gram (Vigna radiata) is one of the most important pulse crops and serves as a major source of dietary protein for a large portion of the population, particularly in developing countries. However, during storage, green gram seeds are highly vulnerable to infestation by storage pests, among which the pulse beetle (Callosobruchus chinensis) is considered one of the most destructive. The pest causes serious quantitative and qualitative losses by feeding inside the seeds during its larval stage, leading to weight loss, reduction in seed quality, and decreased germination capacity. The concealed development of larvae within the grains makes early detection and management of the pest difficult. Traditionally, chemical fumigants and synthetic insecticides have been used to control pulse beetles in storage. Although effective, their continuous use has raised concerns regarding pesticide residues, environmental pollution, insect resistance, and risks to human health. In recent years, increasing attention has been given to eco-friendly and sustainable pest management methods. Botanical products, particularly plant-derived essential oils, have shown promising potential as alternatives to synthetic chemicals for managing storage pests. Essential oils obtained from aromatic plants possess various bioactive compounds that exhibit insecticidal, repellent, fumigant, and oviposition-deterring properties. This review focuses on the biology of the pulse beetle and highlights the efficacy of several essential oils, including citronella, camphor, sesame, clove, eucalyptus, mustard, and basil oils, in controlling Callosobruchus chinensis in stored green gram. These oils have been reported to cause significant adult mortality, reduce egg laying and progeny development, and minimize seed damage while maintaining acceptable seed germination. Therefore, the use of botanical essential oils represents a safer and environmentally sustainable approach for protecting stored green gram from pulse beetle infestation..

Keywords: Pulse Beetle, Essential Oil, Green gram, Damage, Seed protection.
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INTRODUCTION

In human daily diet 50 % is full filled by legumes; For the reason, it provides 25% protein and enzymes needed for human Utilizations to secure their nutrition [1]. In the of 2024-25 the accountable pulses production in our India is 25 M t, Among the all-pulse green gram contributes 3.82 M t which 70 % of global contributions. During the cropping it enhance the soil nutrition through N fixation [2], In the spite of its production will be affected by abiotic and biotic stress especial a pest i.e. Pod fly, Pod borer, Aphids, Whitefly, Pulses Beetle, Thrips. Under the favorable condition C. chinensis will cause 68.9 % to 100% damage in storage period and it will be varied depend on the region such as temperate and tropical [1,4]. Nearly every farmer's store amount of pulses seeds in their farm house for next growing seasons [3]. In the global presents of twenty disparate *Callosobruchus* genus are alive in that species common species which create gram infit for consumption through their damages that are *Callosobruchus* maculatus Fab and *Callosobruchus chinensis* Linn [5]. As like a legume it makes unpredictable loss and damages in stored green grams. Conventional pulse beetle management systems predominantly depend on fumigants and synthetic chemical insecticides [12]. Non-chemical approaches to controlling C. maculatus populations are advantageous since they leave no chemical residues on the products and pose a low risk of the insects developing resistance [10]. From an several papers Suggested techniques include regularly introduced grains or pulses in the sun, mixing them with ash or sand, or applying cooking oil as a coating [7]. One of the pests causing huge problems at the of stored crop periods is C. maculatus. As methyl bromide disappears from use, limits may hit Pho's toxin too, while expenses climb - this pushes search toward options without synthetic chemicals for green gram treatment [12, 6]. When judging how well new pesticides work, plant-based liquids often play a key part because they offer real test grounds [8]. Nowadays, very hard challenges stack up alongside strict global trade limits - so scaling down outdated pesticides grows critically worldwide. Where hard poisons used to protect stored grains or seeds, gentler methods now need room to work. Even with changes unfolding, keeping beetle away stays a steady concern hiding just below the surface [9]. Due to the demand for environmentally friendly pest management in this modern era, botanical products derived from aromatic plants such as essential oil and powders are being utilized as potent, eco-safe insecticidal agents against the pulse beetle, *Callosobruchus chinensis*. Phytochemicals are derived from different parts of plants such as flowers, stems, roots, and leaves. Owing to their broad range of biological effects, plant-based products have been utilized for multiple purposes, including toxicity, repellent properties, cosmetic applications, natural treatments, and aromatherapy [8]. In the sense of hence, IPM (Integrated pest management) using of non-chemical, biorational and environmentally friendly strategy have been adopted for stored pest management and are deemed as an important result and alternatives [9, 15]. Among various biorational methods, plant essential oils have been shown to most effectively manage pests. Furthermore, when used on seeds and for consumption, they manifest lower toxicity effects [11].

Biology of beetle on stored grain

Egg & Incubation

It is the initial stage of every insect life cycle. Here, it crucial because in the storage period the eggs transfer into the field (Matured Pod) to Storage bag or area, the find of eggs laid on the seed surface is not possible to see with naked eye [18, 16]. The female laid egg on the grains is like white dot present, During the oviposition colour of fresh egg were transparent then turned into white to creamish brown because the frass accumulation in inside the egg (Fig.1) [18]. The egg shape plausibly Oval or Cigar shape [17]. According to the (Sangitha lamina et, al 2022) a beetle can lay 3 - 6 eggs in single green grain in the average of 4 eggs. In other hand laid eggs by C. chinensis on 100g of green gram seed was 93.67 with an average of 9.69[18]. As per studies the beetle eggs measured length were ranges from 0.48 to 0.58 mm varied and an average of 0.52 mm. It was broad up to 0.30 to 0.34 mm and with an average of 0.32 mm [19]. The past

studies on the various developmental stages of C. chinensis detected incubation period was ranging from 3 to 6 days and a with a means of 4.3 ± 1.03 days under lab conditions on green gram [18, 22]. As per study by A Shinde Pranjali et, al (2023) the shortest incubation period observed on mung bean was 2.67 days. So, in this condition the incubation duration could differ from locality to locality just because the abiotic factors and storage places inside factors [36]. At the time of hatching an egg were becoming milky whitish colour and a cloudy like appearance due to accumulation of bored material in the albumen (Fig. 2) [18].

Fig.1: Newly Laid egg of C. chinensis

Fig 2: Appearance of hatched egg C. chinensis

Larval and pupal stage

The larval and pupal development of *Callosobruchus chinensis* on green gram (*Vigna radiata*) takes place entirely inside the seed. The newly hatched larvae penetrate inside the seed coat and feeds inner cotyledonary tissues; the egg shell was left outside [20]. The infestation detected only after the adult emergence time because the larval and pupal period remain vieled the grains. The apodous grub is 'C'-shaped and creamy white, with a distinct brown head capsule (Fig.3) [21][22]. It will cross three moults, resulting in four larval instars, The first instar larvae were 0.63 ± 0.12 mm in length and 0.34 ± 0.03 mm in width and second instar larvae were 0.97 ± 0.07 mm in length and 0.56 ± 0.05 mm in width and third instar larvae were 1.20 ± 0.10 mm in length and 0.75 ± 0.07 mm in width and the final fourth instar larvae were 2.55 ± 0.18 mm in length and 1.40 ± 0.10 mm in width of C. chinensis [40]. which can be differentiated on size based and head capsule castings. The total larval duration on green gram generally ranges from 15 to 18 days under laboratory conditions, depending on temperature and relative humidity [18]. A short pre-pupal stage of about 2–3 days precedes pupation. The beetle as exarate type of pupa, initially cream coloured, and once adult emerged turn into dark brown. The pupal period typically from 6 - 8 days [18][19].

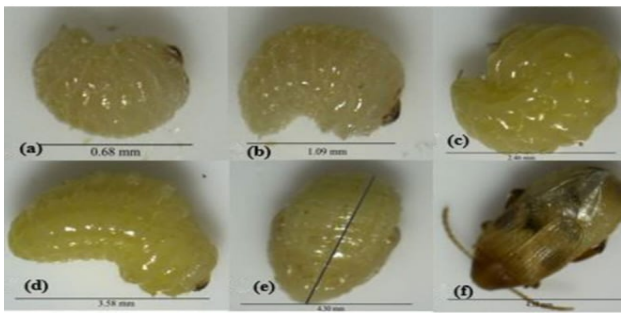

Fig.3: Grub - Instars and Pupal period of C. chinensis

Adult emergence and Longevity

Prior to adult emergence, the last instar larvae prepare a thin indirect exit window on the seed coat [20]. During emergence, the adult beetle pushes its head outward first and chews through this window with its mandibles, leaving a characteristic round hole that serves as a clear sign of bruchid infestation (Fig 4) [36]. Lately surfaced grown-ups are small, round, brownish beetles with black and slate markings. The species exhibits clear sexual dimorphism [20]. Females are generally larger and heavier than males. In females, the elytra are comparatively shorter, exposing the whitish terminal portion of the abdomen

marked with two black round spots [17 , 19]. Antennal differences are also apparent, with males bearing pectinate antennae and females have serrate antennae under normal storehouse conditions, adult life generally ranges between 6 to11 days [21]. Females generally survive slightly longer than males, with reported pars of about 6-9 days for females and 7-11 days for males. On green gram, Females fecundity has been reported to vary from 78 to 102 egg per female, with a normal of roughly 90 eggs [18]. Variations in adult survival and reproductive eventuality are explosively told by environmental factors similar as temperature, relative humidity, host seed quality, and food availability [22]. A clear understanding of adult emergence patterns and life is essential for assessing population build up and for assessing the effectiveness of botanical protectants used in stored green gram operation [36].

Fig 4: Emergence of beetle through circular hole on grain

Fig 5: Adult of Callosobruchus chinensis

Table: 1- Developmental period of different stages of Callosobruchus chinensis on pulses under laboratory condition [39]

Developmental Stages of C. chinensis	Minimum	Maximum	Average developmental period of C. chinensis
Egg period	3	6	4.3 ± 1.03
Larval – Pupal period	21	26	24.25 ± 1.65
Adult period	6	11	8.15 ± 1.66
Adult (Female)	6	9	7.10 ± 1.02
Adult (Male)	7	11	8.75 ± 1.33

Total life cycle	31	42	36.3 ± 3.65
Pre oviposition period	0	1	0.25 ± 0.44
Oviposition period	6	8	7.05 ± 0.75
post oviposition period	1	2	1.55 ± 0.51

Efficacy of Essential oils

In the part of Efficacy that result much be the percent of oil need to create the beetle's mortality, decreasing of oviposition percentage and in the case of efficient of essential oil cannot affect the germination percent of the stored seed [13]. According to the antimicrobial, antifungal, insecticidal, larvicidal, and antioxidant capabilities of essential oils, they are leveraged to alleviate costs and adverse effects as substitutes to synthetic chemical solutions. Essential oils have become more crucial in recent years because of their approachability and biological characteristics [28].

Efficacy of basil oil

Essential oil of Ocimum basilicum has demonstrated strong insecticidal activity against *Callosobruchus maculatus* under laboratory conditions [16]. Contact toxicity increased with concentration, with 1% oil causing up to 93% adult mortality, while lower concentrations produced comparatively limited effects. The oil also showed a low LC_{50} value, indicating high potency against the bruchid beetle [29]. In addition to adult mortality, basil oil significantly reduced oviposition and feeding damage, resulting in minimal seed weight loss without affecting germination [29]. The bioactivity of basil oil is mainly attributed to its major constituents, particularly linalool and 1,8-cineole, which are known for their toxic and repellent effects against stored-grain insects [16]. These findings support the potential of basil essential oil as an eco-friendly alternative for managing C. maculatus in stored pulses.

Efficacy of Citronella Oil *Callosobruchus chinensis*

Citronella oil was found to have good insecticidal and repellent activities against *Callosobruchus chinensis* in stored pulses. In laboratory tests, citronella oil was found to have caused mortality of 72-96% within 72 hours of exposure to C. chinensis. Higher concentrations of citronella oil caused mortality of over 90%. In addition, the oil was found to have good repellent activities against C. chinensis [33]. The repellent activities of citronella oil ranged between 70-88%, indicating good repellent activities. This indicates that the treated grains were avoided by the adults. In addition, the damage to the seeds was reduced to below 10-15% in treated seeds. This indicates a reduction of around 60-75% in damage to the seeds. Furthermore, the emergence of adults was reduced by 65-85%, indicating good inhibition of the development of the progeny. However, the oil was found to have no effect on the viability of the seeds [33, 34]. The seeds treated with citronella oil showed good viability of around 80-92%, which was similar to the seeds of the control plants. Which was similar to untreated, healthy seeds. Based on these results, citronella oil successfully avoids pulse beetle infestation while preserving seed quality.

Efficacy of Camphor Oil on *Callosobruchus chinensis*

In addition, both contact and fumigant toxicity for camphor oil against C. chinensis is being evaluated. The assessment of the study on botanical oils found that camphor oil induced 65 - 90% adult death, with the greatest mortality occurring at higher doses after 72 hours of exposure. With the repellent properties values ranging from 60 to 82%, the oil exhibited great repellent impact, indicating strong avoidance reactions by adult beetles [33, 37]. Grain protection was demonstrated by the reduction of seed damage to 12 - 18% as opposed to 38 - 50% in the untreated control, or roughly 55 - 70% less damage. Additionally, progeny development was severely impeded resulting in a 60 - 80% reduction in adult emergence [33]. Camphor oil did not significantly reduce seed viability at the measured concentrations, as evidenced by the fact that seed germination in treated grains remained between 78 and 88%. Overall,

while maintaining acceptable germination percentages, both citronella and camphor oils showed notable insecticidal, repellent, and protective effects against C. chinensis in stored pulses, indicating their potential inclusion in botanical-based management strategies for stored green gram [37].

Efficacy of Sesamum oil on *Callosobruchus chinensis*

Sesamum (sesame) oil is recognized as an effective against seed protectant against the bruchid infestation in stored pulses. Studies evaluating the plant oils against *Callosobruchus chinensis* on green gram revealed that sesame oil significantly reduced the oviposition, adult emergence, and seed damage at the period of storage [38]. Application of the sesame oil at recommended doses produced adult mortality ranging between 70 - 85%, along with substantial decline in the egg laying and larval development inside the grains [28]. The oil forms a thin coating on seed surfaces which interferes with respiration of eggs and larvae, thereby reducing survival of the pest [31]. In addition, sesame oil treatments resulted in lower seed damage percentages and maintained high seed germination, indicating its suitability for long-term storage of green gram. These findings highlight sesame oil as a practical botanical method for controlling pulse beetle infestation in stored pulses

Efficacy of clove oil on *Callosobruchus chinensis*

The Strong insecticidal activity and repellent effects against storage pests, such as pulse beetles, have been shown using clove oil [14]. According to the laboratory research, depending on the dose used, clove oil treatments might be result in extremely high adult mortality rates, frequently surpassing 85 - 95% [32]. The oil minimizes a seed damage during the storage by drastically reducing *Callosobruchus* species egg laying and adult emergence in grains that have been stored. Clove oil's aromatic scent and the bioactive substances, like eugenol, add to toxicity and insect-repelling properties [38]. Additionally, a studies show that the treated seeds maintain as a high germination potential, indicating that, when applied at the correct dosages, clove oil does not negatively impact seed viability [32]. Clove oil is therefore regarded as a very successful botanical solution for controlling pulse beetles in green gram that has been kept.

Efficacy of Eucalyptus oil on *Callosobruchus chinensis*

Another plant-based compound that has been extensively investigated for its ability to shield stored pulses against insect infestations is eucalyptus oil. According to experimental results, eucalyptus oil has potent fumigant and repellent qualities that have a major impact on *Callosobruchus chinensis* survival and reproductive behaviour [14, 28]. In alongside reducing egg laying and adult emergence in the stored seeds, treatments with a eucalyptus oil were found to result in the adult mortality levels ranging from approximately 70 to 90% [28]. As a consequence, compared with untreated seeds, the volume of seed damage during storage is significantly decreased [38]. Furthermore, studies have shown the applying eucalyptus oil to the seed grains intended for sowing does not adversely impact the percentage of germination [14]. Because of these qualities, eucalyptus oil is a viable environmentally friendly substitute for preventing pulse beetle infestation of stored green gram.,

Efficacy of Mustard oil on *Callosobruchus chinensis*

Additionally, mustard oil has been studied for the ability to protect a stored pulses from pulse beetles. An Egg adhesion and larvae entry into the stored grains were hindered by the oil's formation of a protective layer on the surface of seed [28, 38]. According to research, treatments with mustard oil can result in 65 - 80% adult mortality while drastically lowering *Callosobruchus* species oviposition and adult emergence [30]. In addition, it has been observed that the mustard oil treatments are lower the percentage of damaged seeds and maintains at appropriate germination levels all through storage [28]. Mustard oil is regarded as a useful botanical control method for controlling pulse beetle infestation in stored green gram because of its accessibility, affordability, and relative safety.

Limitations of Botanical Essential Oils

Botanical essential oils have validated promising efficacy against *Callosobruchus chinensis*; however, the several limitations were restricting their large-scale application to mitigate the losses in storage

condition. Essential oils possess the characters of high volatility leads to rapid evaporation, resulting in reduced persistence and shorter protection during storage. The effectiveness of these oils is also influenced by environmental conditions such as temperature and humidity, which may cause inconsistent results under field conditions. In addition, the absence of standardized formulations and recommended dosages creates variability in outcomes across studies. At higher concentrations, certain oils might exhibit phytotoxic effects, potentially affection of seed viability. Practical adoption is further constrained by issues related to cost, limited availability, and lack of commercially stable formulations. These challenges indicate that, despite their potential, essential oils require further refinement before being widely adopted as reliable alternatives to synthetic insecticides.

Table:2 - Botanical Essential Oils Used for Management of Pulse Beetle (*Callosobruchus chinensis*) in Stored Green Gram

Essential oil & Dosage	**Botanical source**	**Major active compounds**	**Mode of action**	**Adult mortality (%)**	**Repellency (%)**	**Seed damage reduction (%)**	**Seed germination (%)**	**Reference**
Citronella oil 5ml	*Cymbopogon nardus*	Citronellal, citronellol, geraniol	Fumigant, repellent, oviposition deterrent	80–90	75–85	70–80	88–95	Khandaitaray *et al*., 2024
Camphor oil 5ml	*Cinnamomum camphora*	Camphor, cineole	Toxic vapour action, repellency	75–85	70–80	65–75	85–92	Pal & Katiyar, 2013
Sesamum oil 5ml	*Sesamum indicum*	Sesamin, sesamolin	Seed coating effect, egg suffocation	70–85	65–78	68–80	87–94	Pal & Katiyar, 2013
Clove oil 5ml	*Syzygium aromaticum*	Eugenol, eugenyl acetate	Contact toxicity, fumigant, strong repellent	85–95	80–92	75–88	85–93	Swamy & Wesley, 2021

Eucalyptus oil 5ml	*Eucalyptus globulus*	1,8-cineole, limonene	Fumigant toxicity, repellency	70–90	72–86	70–82	86–94	Kumar *et al*., 2017
Mustard oil 5ml	*Brassica juncea*	Allyl isothiocyanate	Toxic vapours, oviposition deterrent	65–80	60–75	60–72	84–92	Miah *et al*., 2013
Basil oil 5ml	*Ocimum basilicum*	Linalool, methyl chavicol	Repellent, fumigant toxicity	80–92	78–88	72–85	86–94	Khandaitaray *et al*., 2024

Research Gaps and Future Prospects

Despite significant progress in the study of botanical essential oils for the management of *Callosobruchus chinensis*, some crucial research domains require further attention. The majority of studies have been conducted in controlled laboratory settings, with validation in real storage conditions being significantly limited. The creation of standardized formulations is necessary to improve stability and prolong efficacy, especially using sophisticated techniques like encapsulation and nano-formulations. Investigations should also study the synergistic effects resulting from the mixing of various essential oils and their incorporation with other non-chemical techniques, particularly within an integrated pest management paradigm. The available literature still lacks thorough long-term examinations evaluating their influence on seed quality, safety criteria, and economic viability. Future endeavors should emphasize on translating laboratory discoveries into scalable, practical solutions, addressing both economic feasibility and application in field settings, thus allowing the incorporation of plant oils in sustainable grain storage.

CONCLUSION

Arguably the most damaging storage pests for pulses, especially green gram (Vigna radiata), is the pulse beetle (*Callosobruchus chinensis* L.). During the larval feeding, the beetle damages seeds, resulting in reduced grain weight, poor market value, and decreased seed viability, which causes the severe quantitative and qualitative losses during storage period. Establishing the effective approaches to manage the beetle to needs an understanding the biology of beetle and life cycle of the beetle. Eliminating the pulse beetles under the storage conditions can be particularly difficult due to short life period, a high reproductive Capability(fecundity), and concealed a larval development within the seeds. The application of botanical products - particularly the plant-derived essential oils has attracted a lot of attention lately as a sustainable substitute for the synthetic insecticides and its impacts. A number of essential oils have shown encouraging insecticidal and repellent properties against pulse beetles in stored pulses, including citronella, camphor, sesame, clove, eucalyptus, mustard, and basil oils. Fumigant toxicity, repellence, and oviposition prevention are merely some of the methods that these essential oils perform. In the end the result, this leads to higher adult mortality, decreased egg laying, and less seed damage, it will depend oil which we choose. Numerous of these oils have been shown in studies to be able to preserve adequate seed germination and viability while also causing substantial beetle mortality. Among them, clove, basil, and citronella oils have shown particularly strong efficacy due to the presence of

bioactive compounds such as eugenol, linalool, and citronellal. Have demonstrated especially effective efficacy. All things taken into account, using botanical oils to prevent pulse beetle infestation of stored green gram is a safer and more environmentally friendly method. They are appropriate parts of integrated pest management systems for stored grain protection because of their biodegradable nature, reduced toxicity to non-target organisms, and low environmental impact. To improve their practical adoption by farmers and store managers, more research is required on uniform administration techniques, ideal doses, and long-term storage performance. Using botanical oils in conjunction with better storage techniques could greatly lower post-harvest losses and increase pulse grain preservation.

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