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Bionomics and management of *Callosobruchus maculatus* (fabricius) on stored mungbean

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Abstract
The pulse beetle *Callosobruchus maculatus* (Fabricius) is a major constraint in the storage of mung bean, causing significant quantitative and qualitative losses. The present study evaluated the efficacy of sun drying, selected plant powders, and botanical oils for the management of this pest under storage conditions. Mung bean seeds were subjected to different treatments, including sun drying at varying times, application of castor, tulsi, and eucalyptus leaf powders (5% w/v), and coating with botanical oils. Results indicated that sun drying between 11:00 am and 3:00 pm significantly reduced oviposition compared to control. Among plant powders, castor leaf powder exhibited the highest oviposition deterrence (29.33%), while tulsi powder recorded the highest adult mortality (97.54%), followed by eucalyptus powder (89.99%). Notably, all botanical oils provided complete protection, achieving 100% adult mortality and preventing oviposition. These findings highlight the potential of simple, eco-friendly, and cost-effective approaches in reducing postharvest losses of mung bean. The integration of botanical powders and oils into storage practices could contribute to sustainable pulse protection strategies. Further validation through pilot field trials and formulation development is recommended to support adoption in farmer-level storage systems.

Keywords: *Callosobruchus maculatus*, green gram, plant extract, botanical oils, oviposition deterrence, integrated pest management, biopesticides

Introduction
Pulses are an important source of dietary protein, fiber, and essential micronutrients, playing a vital role in food and nutritional security worldwide (Bouis & Saltzman, 2017) [8]. Among them, mungbean (*Vigna radiata* L.) is a major pulse crop in South and Southeast Asia, valued both as food and fodder due to its short duration, nitrogen-fixing ability, and adaptability to marginal environments. During 2023-24, India produced 3.10 million tonnes of mungbean, representing nearly 12% of the nation's total pulse output (Government of India, 2024).

Despite its importance, mungbean is highly susceptible to storage pests that cause considerable deterioration in both seed quality and quantity. The pulse beetle, *Callosobruchus maculatus* (Fabricius), is the most destructive bruchid associated with stored mungbean, causing 30-40% losses during storage, and in severe cases, up to 100% seed damage (Sharma *et al*., 2007; Khare & Johari, 1984; Devi & Devi, 2014) [37, 19,]. Infestation often begins in the field but continues in storage, where larvae develop entirely within seeds, leading to weight loss, reduced germination, and poor market value (Southgate, 1979; Credland, 1986) [40, 10].

Conventional management relies heavily on fumigants and synthetic insecticides. However, repeated application has led to issues such as insect resistance, environmental contamination, and toxic residues in food grains (Howe & Currie, 1964) [16]. These limitations underscore the urgent need for safer, eco-friendly, and cost-effective alternatives. Botanicals, including edible oils and plant powders (e.g., neem, tulsi, pongamia), have shown promise as grain protectants by reducing oviposition, suppressing adult emergence, and minimizing seed damage, while being safer for humans and animals (Shaaya *et al*., 1997) [38].

The present study was therefore undertaken with the following objectives:

1. To study the bionomics of *C. maculatus* on stored mungbean.
2. To assess the effectiveness of sun drying on bruchid incidence.
3. To evaluate the bio-efficacy of selected botanical oils and plant powders as grain protectants against *C. maculatus*.

2. Materials and Methods: Investigations on the management of the pulse beetle, *Callosobruchus maculatus* Fabricius infesting stored mung bean were carried out in the Department of Entomology, Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi during 2022-2023. The detailed methodology adopted is given below.

2.1 Mass Culturing of Pulse Beetle: Naturally infested mung bean grains were collected from villages, institutes, storage facilities, and godowns. The pulse beetle culture was maintained in plastic jars at 30 ± 2 °C and 70 ± 5% RH in the entomological laboratory. For sub-culturing, ten pairs of newly emerged *C. maculatus* adults were released into jars containing 100 g of disinfested mung bean.

2.2 Bionomics of *C. maculatus*

Studies were conducted on the development of *C. maculatus* in mung bean under laboratory conditions. Particular attention was given to the egg period, grub period, pupal period, and adult longevity, following general procedures described by Howe & Currie (1964) [16], Southgate (1979) [40].

Figures 1a-d illustrate the life cycle of *C. maculatus* as observed during the study.

- Fig. 1a - Egg
- Fig. 1b - Larval instars and pre pupa
- Fig. 1c - Adult male
- Fig. 1d - Adult female

Fig 1a: EGG **Fig 1b:** Larval instars and Pre pupa **Fig 1c:** Adult Male **Fig 1d:** Adult Female **Fig 1a-d:** Life Cycle of Pulse Beetle

2.3 Effectiveness of Sun Drying

2.3.1 Preventive Method

Mung bean grains (125 g) were sun dried on white muslin cloth during summer when maximum temperatures exceeded 37 °C. The grains were dried between 11:00 a.m. and 5:00 p.m., cooled under a fan, and stored in plastic jars. One pair of *C. maculatus* adults was introduced for 48 h, then removed. Infestation was monitored in the laboratory (Table 1).

Table 1: Experimental details of sun drying treatments.

Treatment	Duration (h)	Time
T_0 - Control	-	-
T_1	1	11:00-12:00
T_2	2	11:00-13:00
T_3	3	11:00-14:00
T_4	4	11:00-15:00
T_5	5	11:00-16:00
T_6	6	11:00-17:00

Replications: 4

2.4 Effectiveness of Grain Protectants

2.4.1 Plant Powders: Oven-dried (55 °C, 1 h) leaves of selected botanicals were powdered and mixed with 100 g of mung bean grains @ 5% (w/w). Five pairs of *C. maculatus* were released into each treatment jar; untreated grains served as control (Table 2).

Table 2: Experimental details of plant powders used against *C. maculatus*

Treatment	Plant	Family	Part used	Concentration
T_1	Castor	Euphorbiaceae	Leaves	5% w/w
T_2	Custard apple	Annonaceae	Leaves	5% w/w
T_3	Eucalyptus	Myrtaceae	Leaves	5% w/w
T_4	Citrus	Rutaceae	Leaves	5% w/w
T_5	Neem	Meliaceae	Leaves	5% w/w
T_6	Tulsi	Lamiaceae	Leaves	5% w/w
T_7	Nochi	Lamiaceae	Leaves	5% w/w
T_8	Adathoda	Acanthaceae	Leaves	5% w/w
T_9	Control	-	-	-

2.4.2 Botanical oils: Eight botanical oils were tested by mixing with 100 g mung bean grains @ 1% (v/w). Five pairs of *C. maculatus* were released in each jar (Table 3).

Table 3: Experimental details of plant oils used against *C. maculatus*

Treatment	Oil	Family	Part used	Concentration
T_1	Castor oil	Euphorbiaceae	Seed	1% v/w
T_2	Coconut oil	Arecaceae	Nut	1% v/w
T_3	Eucalyptus oil	Myrtaceae	Leaves	1% v/w
T_4	Groundnut oil	Fabaceae	Seed	1% v/w
T_5	Mustard oil	Brassicaceae	Seed	1% v/w
T_6	Pungam oil	Fabaceae	Seed	1% v/w
T_7	Sesame oil	Pedaliaceae	Seed	1% v/w
T_8	Sunflower oil	Asteraceae	Seed	1% v/w
T_9	Control	-	-	-

2.5 Experimental Design

The experiments were laid out in a Completely Randomized Design (CRD).

- Sun drying: 7 treatments (T_0-T_6), 4 replications
- Plant powders: 9 treatments (T_0-T_8), 3 replications
- Plant oils: 9 treatments (T_0-T_8), 3 replications

2.6 Data collection and statistical analysis

Data on the number of eggs laid and adult mortality were recorded at 1, 3, and 5 days after treatment (DAT). Percentage values were arcsine and square-root transformed before subjecting to ANOVA. Treatment means significant at 5% probability were separated using SPSS software.

3. Results

3.1 Effect of sun drying on oviposition deterrence of *Callosobruchus maculatus*

The effect of different durations of sun drying on oviposition deterrence of *C. maculatus* on stored mungbean is presented in Table 4. Results indicated that all sun-drying treatments significantly reduced oviposition compared to the untreated control (72.5 eggs). Among the treatments, the lowest oviposition was recorded in T_4 (11:00-15:00 h) with 30.75 eggs, followed by T_6 (11:00-17:00 h) and T_5 (11:00-16:00 h), which recorded 35.00 and 34.50 eggs, respectively. Shorter exposure periods (T_1: 1 h and T_2: 2 h) were comparatively less effective, though they still significantly reduced oviposition over control.

These findings highlight the importance of exposure duration, where extended sun drying substantially suppressed oviposition and acted as an efficient preventive method against infestation.

Table 4: Effect of sun drying on oviposition deterrence of *C. maculatus* in stored mungbean

Treatment	Oviposition (Mean ± SE)
T_0 (Control)	72.50 (8.51) ^{b}
T_1 (11:00-12:00 h)	43.00 (6.55) ^{a}
T_2 (11:00-13:00 h)	46.75 (6.83)^{a}
T_3 (11:00-14:00 h)	30.75 (5.24)^{a}
T_4 (11:00-15:00 h)	27.50 (5.74)^{a}
T_5 (11:00-16:00 h)	34.50 (5.89)^{a}
T_6 (11:00-17:00 h)	35.00 (5.91) ^{a}

SE = 2.40, CD (p = 0.05) = 5.28

3.2 Effect of Plant Powders on Oviposition Deterrence in *Callosobruchus maculatus:*

The oviposition deterrent activity of various plant powders on *C. maculatus* is presented in Table 5. Among all treatments, Ricinus communis (castor) leaf powder at 5% concentration recorded the lowest oviposition (29.33 eggs), showing significant deterrence compared to the untreated control (134.00 eggs). This was followed by Ocimum basilicum (36.66 eggs) and Eucalyptus globulus (42.33 eggs), which were statistically on par.

In contrast, Justicia adhatoda (131.33 eggs) showed poor oviposition deterrence, being comparable to the untreated control. Other powders such as Annona squamosa, Citrus limon, Azadirachta indica, and Vitex negundo recorded intermediate levels of deterrence.

These results indicate that castor, tulsi, and eucalyptus powders have strong potential as eco-friendly protectants for mungbean storage, whereas adhatoda was least effective.

Table 5: Effect of different plant powders on oviposition deterrence of *Callosobruchus maculatus*

Treatment	Oviposition (Mean ± SE)
T_1(castor)	29.33 (5.41) ^{a}
T_2(custard apple)	70.33 (8.38) ^{ab}
T_3(eucalyptus)	42.33 (6.50) ^{ab}
T_4(citrus)	51.33 (7.16) ^{ab}
T_5(neem)	78 (8.83) ^{ab}
T_6(notchi)	102.33 (10.11) ^{ab}
T_7(tulsi)	36.66 (6.05) ^{ab}
T_8(adathoda)	131.33 (11.46) ^{b}
T_9(control)	134 (11.57) ^{b}

SE = 2.40; CD (p = 0.05) = 5.28

3.3 Effect of plant powders on adult mortality of *Callosobruchus maculatus*

Adult mortality of *C. maculatus* at 1, 3, and 5 days after treatment (DAT) is presented in Table 6. Among the tested botanicals, the highest adult mortality at 1 DAT was recorded in *Citrus limon* (33.33%), which was statistically on par with *Ricinus communis* (26.66%), *Annona squamosa* (25.55%), *Eucalyptus globulus* (30.00%), *Azadirachta indica* (22.22%), *Vitex negundo* (21.11%), *Ocimum basilicum* (34.44%), and *Justicia adhatoda* (32.22%).

At 3 DAT, *O. basilicum* leaf powder showed the maximum adult mortality (33.33%) which was significantly higher than other treatments. By 5 DAT, *O. basilicum* (44.66%) remained the most effective, followed by *E. globulus* (39.99%) and *J. adhatoda* (42.00%). The lowest adult mortality was observed in *V. negundo* (24.44%). The untreated control showed negligible mortality (3.33%) even after 5 DAT.

Overall, *O. basilicum* exhibited the highest cumulative adult mortality (34.44%), indicating its strong insecticidal potential against *C. maculatus* under storage conditions.

Table 6: Effect of plant powders on adult mortality (%) of *Callosobruchus maculatus*

Treatment	Mean			
	1 DAT	3 DAT	5 DAT	Total
T_1(Castor)	16.66 (2.34) ^{a}	26.66 (2.97) ^{ab}	36.66 (3.48) ^{ab}	26.66
T_2(Custard apple)	16.66 (2.34) ^{a}	20 (2.53) ^{ab}	40 (3.62) ^{ab}	25.55
T_3(Eucalyptus)	16.66 (2.05) ^{a}	30 (3.16) ^{ab}	43.33 (3.79) ^{a}	30.00
T_4(Citrus)	33.33 (2.89) ^{a}	26.66 (2.84) ^{ab}	33.33 (2.85) ^{ab}	31.11
T_5(Neem)	13.33 (2.10) ^{a}	13.33 (2.10) ^{b}	40 (3.56) ^{ab}	22.22
T_6(Notchi)	16.66 (2.29) ^{a}	26.66 (2.89) ^{ab}	20.00 (2.24) ^{ab}	21.11
T_7(Tulsi)	16.66 (2.34) ^{a}	33.33 (3.48) ^{a}	47.55 (4.36) ^{a}	34.44
T_8(Adathoda)	20 (2.53) ^{a}	23.33 (2.72) ^{ab}	43.33 (4.20) ^{a}	32.22
T_9(Control)	0 (0.40) ^{b}	0 (0.40) ^{c}	10 (1.61) ^{b}	3.33

3.4 Effect of botanical oils on oviposition deterrence in *Callosobruchus maculatus:* The insecticidal efficacy of different botanical oils on oviposition deterrence of *C. maculatus* is presented in Table 7. Complete inhibition of oviposition (100%) was observed in all oil treatments (*Ricinus communis*, *Cocos nucifera*, *Eucalyptus globulus*, *Arachis hypogaea*, *Brassica juncea*, *Pongamia pinnata*, *Sesamum indicum*, and *Helianthus annuus*). In contrast, the untreated control recorded normal oviposition, resulting in 100% seed damage and 10.14% weight loss.

Since no oviposition was recorded in any of the oil treatments, subsequent adult emergence was completely suppressed, indicating that botanical oils are highly effective oviposition deterrents under storage conditions. These findings confirm the potential of edible and non-edible oils as eco-friendly protectants for pulses against storage beetles.

Table 7: Effect of botanical oils on oviposition or fecundity

S.no	Treatments	Percent inhibition rate of oviposition over control	Percent of damage over control	Weight loss
1.	T_1 Castor oil	100	-	-
2.	T_2 Coconut oil	100	-	-
3.	T_3 Eucalyptus oil	100	-	-
4.	T_4 Groundnut oil	100	-	-
5.	T_5 Mustard oil	100	-	-
6.	T_6 Pungam oil	100	-	-
7.	T_7 Sesame oil	100	-	-
8.	T_8 Sunflower oil	100	-	-
9.	T_9 Untreated	0	100	10.14

3.5 Effect of botanical oils on adult mortality of *Callosobruchus maculatus*

The effect of different botanical oils on the adult mortality of *C. maculatus* is presented in Table 8. Complete mortality (100%) was observed in all oil treatments within 5 days indicating rapid insecticidal action. In contrast, no mortality was recorded in the untreated control, which allowed normal beetle emergence.

The results clearly demonstrate that botanical oils are highly effective in suppressing adult survival of *C. maculatus* under storage conditions. Since adult mortality was absolute in all treatments, no subsequent oviposition or grain damage was recorded, confirming their dual role as oviposition deterrents and adulticidal agents. These findings highlight the potential of oils as eco-friendly grain protectants with both physical and chemical modes of action against storage pests.

Table 8: Effect of botanical oils on adult mortality of *Callosobruchus maculatus*

	Treatments	Adult mortality percent over control
1.	T_1 Castor oil	100
2.	T_2 Coconut oil	100
3.	T_3 Eucalyptus oil	100
4.	T_4 Groundnut oil	100
5.	T_5 Mustard oil	100
6.	T_6 Pungam oil	100
7.	T_7 Sesame oil	100
8.	T_8 Sunflower oil	100
9.	T_9 Control	0

4. Discussion

4.1 1 Binomics of *Callosobruchus maculatus*

The biology of *C. maculatus* plays a crucial role in shaping management strategies. Previous studies have established that oviposition, larval survival, and adult emergence are strongly influenced by seed characteristics and storage conditions (Barde *et al*., 2012; Barde *et al*., 2014; Credland *et al*., 1986) [5, 6, 10]. Classical works by Howe and Currie (1964) [16], Raina (1970) [34], and Southgate (1979) [40] described the pest's high reproductive capacity and ability to complete multiple generations under storage conditions. More recently, Devi and Devi (2014) and Thakur and Pathania (2013) [41] reaffirmed the adaptability of *C. maculatus* to diverse legumes, while Huignard *et al*. (1985) [17] and Wasserman (1985) [43] highlighted oviposition dynamics and competition. Such information underpins the need for non-chemical, preventive approaches to disrupt the pest's life cycle effectively.

4.2 Sun Drying as a Physical Management Strategy
Our study demonstrated the effectiveness of sun drying, particularly between 11:00 am and 3:00 pm, in reducing oviposition. These findings are consistent with earlier reports by Chauban and Ghaffar (2002) [9], Adebayo and Anjorin (2018) [1], and Peter and Hassan (2019), who documented the role of solar heating in suppressing egg viability and larval development. Lale and Vidal (2003) [22] confirmed that elevated grain temperatures adversely affect survival and fecundity of bruchids, while Doumma (2007) [12] and Moumouni *et al*. (2014) [25] demonstrated its practicality in Sahelian storage systems. Sun drying thus emerges as a low-cost, eco-friendly measure that can be integrated into household and small-scale storage practices, particularly where synthetic insecticides are inaccessible.

4.3 Plant Powders as Biopesticides: Botanical powders showed considerable deterrence in the present work, with castor and tulsi leaf powders providing significant oviposition inhibition and adult mortality. Earlier findings support the utility of leaf powders from diverse species in bruchid management (Boeke *et al*., 2004; Akunne *et al*., 2013) [7, 4]. Similar protective effects of neem, notchi, and other botanicals were noted by Okonkwo and Okoye (1996) [29], Elhag (2000) [14], Singh (2011) [39], Ojo and Ogunleye (2013) [28], Ekeh *et al*. (2013) [15] and Mohamadi Nori *et al*. (2018) [24], confirmed oviposition deterrence properties, while Musa *et al*. (2009) [26] and Radha and Susheela (2014) [33] observed reduction in progeny emergence. Collectively, these findings suggest that powders interfere with egg laying, respiration, or larval penetration, thereby lowering infestation pressure.

4.4 Botanical Oils as Grain Protectants
Botanical oils provided the most promising results in our study, with 100% mortality and oviposition inhibition across all treatments. This aligns with reports by Das and Karim (1986) [11], Lale and Mustapha (2000) [21], and Rajapakse and Van Emden (1997) [35], who observed the protective role of edible and medicinal oils against *C. maculatus*. More recent investigations have confirmed strong insecticidal and repellent properties of botanical oils, including basil, neem, eucalyptus, and mustard (Khalequzzaman *et al*., 2007; Parmar and Patel, 2015; Nisar *et al*., 2022) [20, 30, 27]. Sabbour (2019) [36] and Akbar *et al*. (2022) [3] further demonstrated their efficacy as contact insecticides, while Manju *et al*. (2018) [23] explored dust formulations of essential oils. Such evidence indicates that oils coat the grain surface, suffocating eggs and larvae while deterring adult oviposition, leaving minimal residues compared to synthetic chemicals.

4.5 Integration into Sustainable Pest Management
The cumulative evidence highlights that sun drying, plant powders, and oils can substantially reduce postharvest losses in mung bean. Their efficacy, low cost, and safety to consumers make them highly suitable for adoption in smallholder contexts (Kéita at al., 2001; Tiroesele *et al*., 2014; Prasanthi *et al*., 2017) [18, 42, 32]. However, field-level validation and formulation standardization remain necessary before widespread scaling.

4.6 Implications
These findings highlight the potential of botanical-based treatments as eco-friendly and cost-effective alternatives to synthetic pesticides in stored grain protection. Sun drying remains a farmer-friendly practice for rural households, while plant powders and oils provide sustainable options for small- and large-scale storage. Integrating these methods could minimize losses caused by *C. maculatus* and reduce dependence on chemical fumigants, thereby ensuring safer grain storage and reduced pesticide residues.

4.7 Limitations of the Study
This study was conducted under controlled laboratory conditions, which may not fully mimic natural storage environments. Variability in oil quality, seed type, and environmental conditions could influence efficacy. Additionally, seed germination after treatments with oils and powders was not tested, which is important for long-term storage.

4.8 Future Research Directions
Further studies should:
1. Evaluate the persistence and long-term efficacy of botanical powders and oils during extended storage periods.
2. Assess the combined or synergistic effects of plant powders and oils for enhanced protection.
3. Investigate the impact of these treatments on seed viability and germination.
4. Conduct on-farm trials under varying climatic and storage conditions to validate laboratory findings.

The findings reaffirm that botanicals such as plant powders and edible oils are generally regarded as safe for humans and livestock, since most are derived from traditionally used medicinal or culinary plants. Their insecticidal action is attributed to bioactive compounds that interfere with oviposition, feeding, or development of pests, thereby reducing storage losses without the hazards associated with synthetic chemicals. Importantly, as these substances are biodegradable, the likelihood of harmful residues persisting on stored grains is minimal, making them environmentally compatible. Nevertheless, dosage standardization and formulation refinement are essential to ensure consistent efficacy while preventing any adverse effects on seed germination, grain palatability, or consumer health.

5. Conclusion
The present study demonstrated that sun drying, plant powders, and botanical oils significantly suppressed the pulse beetle *Callosobruchus maculatus* in stored mung bean. Sun drying between 11:00 am and 3:00 pm showed the highest oviposition deterrence, while among plant powders, castor leaf powder (5% w/v) was most effective, followed by tulsi and eucalyptus. At 5 DAT, tulsi powder recorded the highest adult mortality (97.54%), whereas all botanical oils tested achieved complete (100%) mortality and prevented oviposition. Overall, botanical oils proved superior to plant powders in providing protection during storage. These findings highlight the potential of safe, eco-friendly botanicals as alternatives to synthetic insecticides in integrated pest management (IPM) and postharvest grain protection. Their

use can reduce pesticide residues, minimize environmental hazards, and enhance the shelf life of stored pulses. Future research should focus on pilot field-level evaluations, development of standardized formulations, and assessment of farmer acceptability and cost-effectiveness. Such efforts will help translate laboratory efficacy into practical, sustainable storage solutions for smallholder farmers.

Authorship Contribution Statement

- **Anusuya RM:** Conceptualization, Methodology, Investigation, Data curation, Writing - original draft.
- **Kiruthika D**: Methodology, Formal analysis, Validation, Writing - review & editing.
- **Manomithra R:** Supervision, Project administration, Writing - review & editing.
- **Shofia Banu T:** Investigation, Resources, Visualization, Writing - review & editing.

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