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RESEARCH ARTICLE

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Comparative Evaluation of Botanical Oils against *Callosobruchus chinensis* L. in Stored Black Gram

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ABSTRACT

Background: The pulse beetle *Callosobruchus chinensis* (L.) is a major storage pest of black wgram (*Vigna mungo* L.), causing severe seed loss and reduced germination. While botanical oils have shown insecticidal potential, most studies focus only on adult mortality, overlooking reproductive suppression.

Methods: Seven commercially available oils (neem, eucalyptus, peppermint, castor, mustard, sesame and sunflower) were applied at 5/ mL/kg seed under laboratory conditions. Adult mortality and oviposition (eggs per 100/ g seeds) were recorded monthly for four months. Correlation analysis examined the relationship between mortality and oviposition suppression.

Result: Peppermint and eucalyptus oils consistently caused the highest mortality (93.33-80.00%) and reduced oviposition by 80.71% and 76.65%, respectively. Neem oil was also effective, whereas sesame and sunflower oils showed lower efficacy. A strong negative correlation ($r = -0.99$, $p<0.001$) indicated that treatments lethal to adults simultaneously suppressed reproduction. Peppermint, eucalyptus and neem oils offer long-lasting, dual-action protection against *C. chinensis* in stored black gram, combining adult mortality with oviposition deterrence. Using standardized commercial oils ensures reproducibility and provides a sustainable alternative to synthetic fumigants.

Key words: Black gram, Botanical oils, Mortality-reproduction correlation, Oviposition deterrence, Pulse beetle.

INTRODUCTION

Pulses are vital food crops globally, providing protein, dietary fiber, vitamins and minerals essential to combat malnutrition (Viguiliouk *et al*., 2019; Pearce *et al*., 2021). India is the largest producer, contributing over half of global pulse production, with black gram (*Vigna mungo* L.) as a key variety (FAOSTAT, 2021; DAC and FW, 2022). Beyond nutrition, black gram forms a symbiotic association with *Rhizobium* bacteria, enabling it to fix atmospheric nitrogen and thereby improve soil fertility (Sadiq *et al*., 2023).

Post-harvest losses due to storage pests are a major challenge. Among these, the pulse beetle (*Callosobruchus chinensis* L.) is particularly destructive, often causing 30-40% seed damage in traditional storage and, under severe infestations, complete seed loss (Gbaye *et al*., 2011). Infestation typically begins in the field and rapidly intensifies during storage, with damage often reaching 60-100% within just two to three months (Ragul and Manivannan, 2024). Of the various bruchid species, *C. chinensis* and the cowpea weevil (*C. maculatus* F.) are the most economically significant. Adult females lay eggs on seed surfaces; larvae bore into seeds, reducing weight, quality and germination potential (Sharma, 1984; Hasan *et al*., 2020).

Synthetic insecticides and fumigants are commonly used for storage protection, but their drawbacks include resistance, chemical residues and ecological hazards. Botanical oils offer a safer alternative, providing insecticidal, repellent and oviposition-deterrent effects (Isman, 2006).

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Oviposition is a key driver of population growth in *C. chinensis*, yet most studies focus only on adult mortality. Without controlling egg laying, population build-up and long-term seed protection remain uncertain. Botanicals can act via multiple mechanisms, including direct toxicity, repellence, oviposition deterrence and sub lethal effects on progeny (Shivanna *et al*., 1994; Meghwal *et al*., 2007; Ravi *et al*., 2008; Saiful *et al*., 2013).

This study evaluated seven commercially standardized oils-eucalyptus, neem, peppermint, castor, mustard, sesame and sunflower-against *C. chinensis* in stored black gram. It simultaneously assessed adult mortality and oviposition and analyzed their correlation to determine integrated protective efficacy, with direct practical relevance for pulse storage management.

MATERIALS AND METHODS

Experimental site and conditions

The research, titled "Comparative Evaluation of Different Botanical Oils against Pulse Beetle (*Callosobruchus chinensis*) in Stored Black Gram," was conducted in the Entomology Laboratory at the School of Agriculture, SR University, Warangal, between January and April of the 2024-25 academic year. Experiments were performed under controlled conditions, maintaining a temperature of 27±2°C and relative humidity of 65±5%.

Plant material and treatments

Black gram seeds (var. Mash-114) were used to evaluate the efficacy of seven botanical oils: eucalyptus, neem, peppermint, castor, mustard, sesame and sunflower. Oils were applied at a rate of 5/ mL/kg of seeds, while untreated seeds served as the control.

Insect culture

A continuous laboratory culture of *C. chinensis* was established using naturally infested black gram seeds collected from the godown at Elkathurthy. Infested seeds containing both eggs and adults were placed in clean plastic containers with healthy black gram seeds (var. Mash-114). Containers were covered with muslin cloth and secured with rubber bands to allow ventilation while preventing insect escape. Newly emerged adults were transferred regularly to fresh containers containing healthy seeds to maintain successive generations. The culture was maintained under standard laboratory conditions (27 ±2°C, 65±5% RH).Males and females were distinguished based on morphological traits: males have distinctly serrate antennae and a pygidium lacking dark patches, while females have more subtly serrate antennae and a pygidium with two dark midline patches. Females were slightly larger than males, averaging 3.60±0.08 mm in length versus 3.25 ±0.23 mm for males and breadths of 2.02±0.04 mm versus 2.16±0.05 mm, respectively (Devi and Devi, 2013).

Experimental setup

High-germination black gram seeds with moisture content below 10% were selected. For each treatment, 1.5 kg of seeds were coated with one of the seven botanical oils. Seeds were thoroughly mixed in high-density polyethylene (HDPE) containers and air-dried for one hour at room temperature. Untreated seeds served as the control. From each batch, 100/ g of seeds were placed in 250/ mL ventilated plastic containers, with three replicates per treatment. Five pairs of 24-48-hour-old adults (5 males + 5 females) were introduced into each container. All containers were maintained under controlled laboratory conditions (27±2°C, 65±/5% RH, natural light cycles).Adult mortality was recorded after 48 hours of exposure using the formula:

$$\text{Mortality (\%)} = \frac{\text{No. of insect dead}}{\text{Total no. of insect released}} \times 100$$

Observations were conducted monthly over four months to assess the residual efficacy of the botanical oils under storage conditions.

Number of eggs laid on seeds

Each 250/ mL container containing 100/ g of treated seeds was examined using a hand-held magnifying lens. All visible eggs laid by female *C. chinensis* on the seed coat were counted carefully to avoid damage to seeds or eggs.

Statistical analysis

Data were analyzed following Gomez and Gomez (1984). Percentage data were transformed using the arc-sine method when necessary. Significant differences between treatments were determined using the critical difference (CD) at a 5% probability level.

RESULTS AND DISCUSSION

Effect of botanicals on adult mortality

All seven botanical oils significantly influenced the adult mortality of *C. chinensis* compared to the untreated control

Table 1: Adult mortality (%) of *Callosobruchus chinensis* in black gram seeds treated with botanical oils over four months.

Treatment	Dosage	1 Month	2 Month	3 Month	4 Month
Neem oil	5 ml/kg	83.33 (66.15)	76.66 (61.22)	73.33 (59.00)	66.66 (54.78)
Eucalyptus oil	5 ml/kg	91.66 (73.40)	86.66 (68.86)	80.00 (63.44)	70.00 (56.79)
Peppermint oil	5 ml/kg	93.33 (77.71)	90.00 (71.57)	86.66 (68.86)	80.00 (63.44)
Castor oil	5 ml/kg	73.33 (59.00)	66.66 (54.78)	63.33 (52.78)	56.66 (48.85)
Mustard oil	5 ml/kg	71.66 (57.86)	63.33 (52.78)	56.66 (48.85)	50.00 (45.00)
Sesame oil	5 ml/kg	63.33 (52.78)	53.33 (48.87)	46.66 (45.00)	43.33 (41.15)
Sunflower oil	5 ml/kg	43.33 (41.15)	33.33 (35.22)	23.33 (28.78)	20.00 (26.57)
Control	-	23.33 (28.78)	23.33 (28.78)	20.00 (26.57)	20.00 (26.57)
F-test		Sig	Sig	Sig	Sig
SEm ±		2.90	2.02	1.72	1.39
CD at 5%		8.69	6.05	5.16	4.17
CV (%)		8.68	6.51	5.88	5.18

Figures in parentheses are corresponding arc sine transformation values.

(Table 1 and Fig 1). Among the tested oils, peppermint caused the highest mortality throughout the study period, recording 93.33% in the first month and 80.00% in the fourth month. Eucalyptus oil closely followed, with mortality values ranging from 91.66% to 80.00% over four months. Neem oil also demonstrated high efficacy, producing 83.33% mortality in the first month and maintaining 80.00% by the fourth month. Moderate activity was observed in castor and mustard oils, with mortality decreasing gradually from 73.33% to 56.66% and 71.66% to 50.00%, respectively. Sesame and sunflower oils were comparatively less effective, with mortality declining from 63.33% to 43.33% and 53.33% to 33.33%, respectively. The untreated control consistently recorded the lowest mortality, ranging from 20.00% to 23.33%, confirming that the observed effects were due to the treatments.

A general trend observed across all treatments was a gradual decline in adult mortality over the four-month period, which may be attributed to the reduction in residual activity of the oils with storage duration. Nevertheless, the relative efficacy of peppermint, eucalyptus and neem remained superior throughout the experiment.

These results are supported by Lalsingh Rathod *et al.* (2017), who reported that plant-based powders and oils significantly increased adult mortality of *C. chinensis* in stored legumes, highlighting the effectiveness of botanicals for pulse beetle management.

Effect of botanicals on oviposition

The application of botanical oils significantly reduced oviposition by *C. chinensis* on stored black gram seeds compared to the control (Table 2 and Fig 2). Peppermint and eucalyptus oils consistently resulted in the lowest number of eggs laid, indicating strong oviposition-deterrent properties. Peppermint oil reduced egg laying to 40 eggs 100 g seeds in the first month and 80 eggs 100 g seeds by the fourth month, whereas eucalyptus oil allowed 40-70 eggs over the same period. Neem oil also demonstrated substantial suppression of egg laying, ranging from 60-90 eggs 100 g seeds over four months. Moderate oviposition

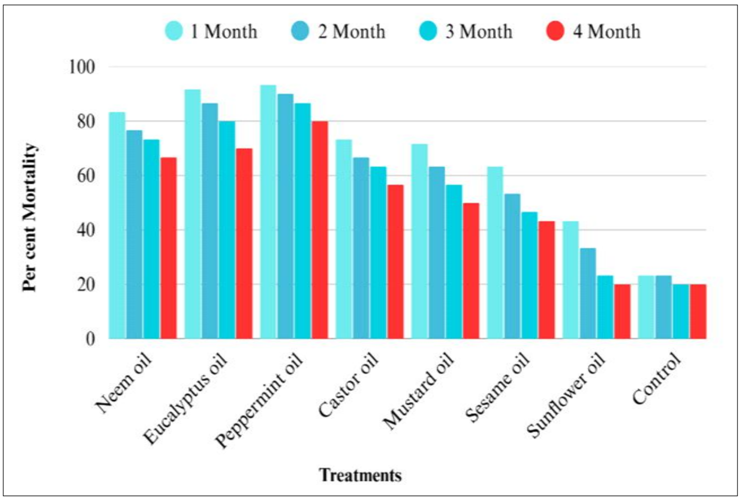

Fig 1: Effect of different botanical oils on per cent mortality of *Callosobruchus chinensis* in stored black gram seeds.

Table 2: Monthly oviposition (eggs per 100 g seeds) of *C. chinensis* on black gram seeds treated with botanical oils.

Treatment	Dosage	1 Month	2 Month	3 Month	4 Month
Neem oil	5 ml/kg	60.00 (4.08)	70.00 (4.24)	80.00 (4.38)	90.00 (4.50)
Eucalyptus oil	5 ml/kg	40.00 (3.67)	50.00 (3.90)	60.00 (4.08)	70.00 (4.24)
Peppermint oil	5 ml/kg	40.00 (3.67)	60.00 (4.08)	70.00 (4.24)	80.00 (4.38)
Castor oil	5 ml/kg	103.33 (4.63)	90.00 (4.50)	100.00 (4.60)	110.00 (4.70)
Mustard oil	5 ml/kg	70.00 (4.24)	70.00 (4.24)	80.00 (4.38)	90.00 (4.50)
Sesame oil	5 ml/kg	103.00 (4.63)	120.00 (4.79)	140.00 (4.94)	160.00 (5.07)
Sunflower oil	5 ml/kg	180.00 (5.19)	190.00 (5.25)	210.00 (5.35)	230.00 (5.44)
Control	-	273.33 (5.61)	290.00 (5.67)	310.00 (5.74)	330.00 (5.80)
F-test		Sig	Sig	Sig	Sig
SEm ±		0.10	0.07	0.06	0.06
CD at 5%		0.30	0.22	0.19	0.17
CV (%)		3.91	2.82	0.36	2.03

Figures in parentheses are corresponding logarithmic transformation values.

reduction was observed in castor and mustard oils, while sesame and sunflower oils were less effective. Sunflower-treated seeds recorded the highest number of eggs among treated groups (180-230 eggs 100 g seeds), although still lower than the untreated control, which recorded the maximum oviposition (273-330 eggs 100 g seeds).

These findings are consistent with earlier reports demonstrating the oviposition-deterrent activity of plant extracts against *C. chinensis* and related bruchids. In black gram, Azadirachtin-treated seeds exhibited the highest oviposition deterrence (92.18%), followed by *Cassia angustifolia* (68.56%) and *Pongamia* (57.01%), whereas *Calotropis* showed the least effect (40.30%) (Vijayalakshmi *et al*., 2021). Vanmathi *et al*. (2010) reported that aqueous extracts of *C. gigantea* and *V. negundo* significantly reduced oviposition of *C. maculatus* in black gram seeds.

Similar trends were reported by Sharma *et al*. (2013), who observed that plant products such as neem, mustard and groundnut oils significantly increased adult mortality and reduced oviposition and seed damage caused by *C. chinensis* in chickpea.

The oviposition-deterrent activity of these botanical oils and extracts is likely due to the presence of repellent compounds or chemicals that interfere with the physiology and behavior of adult bruchids, thereby reducing their egg-laying capacity. The current study reinforces the potential of botanicals as eco-friendly alternatives for the management of *C. chinensis* in stored pulses, particularly black gram.

Overall reduction in egg laying

Analysis of cumulative oviposition reduction showed that peppermint oil achieved the maximum suppression (80.71%), followed by eucalyptus (76.65%) and neem (72.58%). Castor and mustard oils provided moderate reduction (56.35% and 50.73%, respectively), while sesame and sunflower were comparatively less effective (41.12% and 35.53%). This pattern mirrors the adult mortality results, highlighting the dual protective role of these oils in reducing both adult populations and reproduction (Table 3).

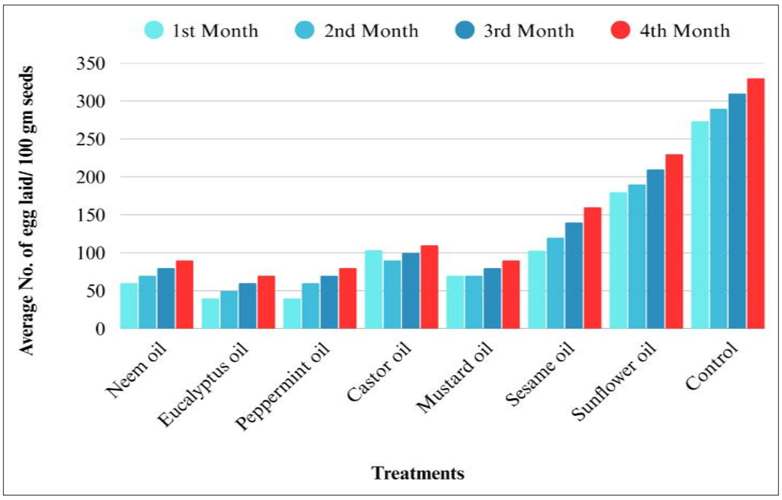

Fig 2: Effect of different botanical oils on oviposition of *Callosobruchus chinensis* in stored black gram seeds.

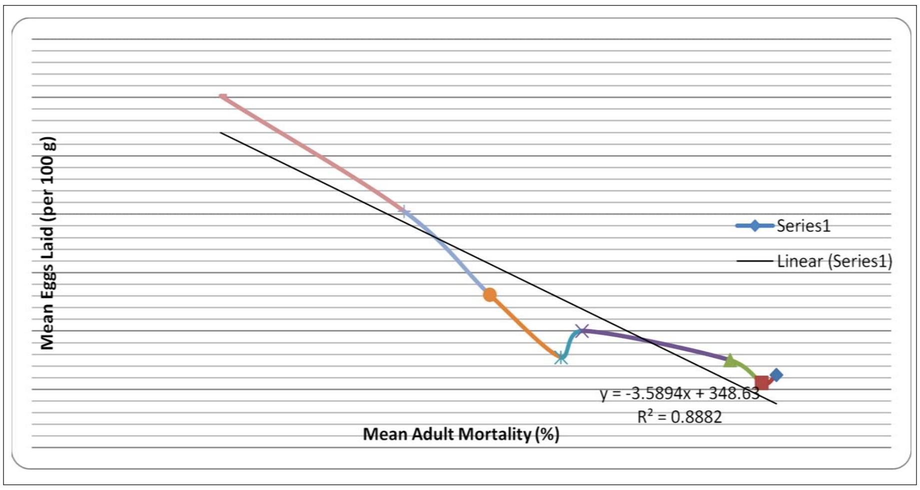

Fig 3: Correlation between mean adult mortality (%) and mean egg laying (per 100 g seeds) of *Callosobruchus chinensis* in black gram treated with botanical oils.

Table 3: Overall oviposition reduction (%) of *C. chinensis* due to botanical oils.

Treatment	Eggs laid (per 100/ g)	% Reduction over control
Peppermint	12.66	80.71
Eucalyptus	15.33	76.65
Neem	18.00	72.58
Castor	28.66	56.35
Mustard	32.33	50.73
Sesame	38.66	41.12
Sunflower	42.33	35.53
Control	65.66	-

Correlation between adult mortality and oviposition

Correlation analysis revealed a strong negative relationship between mean adult mortality and mean egg laying ($r = -0.99$, $p<0.001$) (Fig 3). Treatments causing higher mortality, such as peppermint, eucalyptus and neem oils, also exhibited the strongest oviposition deterrence. Conversely, sunflower and sesame oils, which were less lethal to adults, allowed significantly higher egg deposition. This relationship indicates that botanical oils provide dual protection, reducing both adult populations and reproductive potential, thereby ensuring effective long-term storage management.Peppermint, eucalyptus and neem oils were most effective against *C. chinensis*, likely due to bioactive compounds such as menthol, eucalyptol and azadirachtin with insecticidal and repellent properties. Castor and mustard oils provided moderate protection; sesame and sunflower were less effective but still better than control.The strong negative correlation ($r = -0.99$) indicates dual action: direct adult toxicity and oviposition suppression, ensuring immediate and long-term protection. Residual efficacy over four months supports the practical use of these oils for storage protection. Using commercially standardized oils enhances reproducibility and overcomes limitations of crude extracts reported in previous studies.

CONCLUSION

Peppermint, eucalyptus and neem oils are effective, sustainable protectants against *C. chinensis* in stored black gram. Their dual action-adult mortality and oviposition inhibition-provides both immediate and long-term protection. Commercially standardized oils ensure reproducibility and practical applicability, offering a safe and eco-friendly alternative to chemical fumigants for integrated pulse storage management.

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Disclaimers

The views expressed in this paper are solely those of the authors and do not necessarily reflect the opinions of their affiliated institutions. The authors are solely responsible for the accuracy of the information provided.

Informed consent

All experimental procedures involving insects and plant materials were conducted responsibly under laboratory conditions at SR University, School of Agriculture, Warangal. No human participants or vertebrate animals were involved.

Conflict of interest

The authors declare no competing interests.

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