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Bio efficacy of various plant oils as grain protectants against the pulse beetle, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae)

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ABSTRACT

The pulse beetle, *Callosobruchus maculatus* (Fabricius), is a globally destructive pest of stored legumes, causing immense economic and nutritional losses. In the pursuit of sustainable and environmentally safe pest management strategies, this study evaluated the contact toxicity of nine botanical oils (sunflower, groundnut, mustard, mint, castor, coconut, cottonseed, tobacco seed, and neem 3000 ppm) against adult *C. maculatus*. Bioassays were conducted using oil concentrations ranging from 0.5 to 2.0 ml per 100g of seed, with mortality recorded 24 hours post-treatment. Neem oil demonstrated the highest toxicity, yielding the lowest median lethal concentration (LC50 = 1.25 ml/100g seed) and achieving 67.33% mortality at the highest dose. Mustard, castor, and cottonseed oils also exhibited potent insecticidal properties. In contrast, coconut oil was the least effective (LC50 = 2.00 ml/100g). These findings underscore the potential of botanical oils, particularly neem and mustard, as viable, eco-friendly alternatives to synthetic fumigants in integrated stored-product pest management.

Keywords: *Bioassay, Contact toxicity, Ic50,Mortality and Pulse beetle*

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops cultivated worldwide and serves as a major source of plant protein. It is grown in more than 50 countries across Asia, Africa, Europe, Australia, and the Americas. Global chickpea production reached about 16 million tonnes in recent years, with India contributing nearly 70–75% of the world's production. India is the largest producer of chickpea, producing about 11–12 million tonnes annually. Major chickpea-producing states in India include Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, and Andhra Pradesh. Chickpea seeds contain about (18–24%) protein and play a vital role in human nutrition as well as in improving soil fertility through biological nitrogen fixation. Due to its nutritional value and adaptability, chickpea is considered an important crop for food security and sustainable agriculture. Despite its importance, chickpea production and storage are greatly affected by insect pests. In India, more than 200 species of insect pests have been reported to infest pulse crops. Among them, pulse beetles belonging to the family Chrysomelidae (Bruchinae) cause severe losses in both the quantity and quality of stored pulses. The important species recorded in India include *Callosobruchus maculatus* (Fabricius), *Callosobruchus chinensis* (Linnaeus), *Callosobruchus analis* (Fabricius), *Callosobruchus phaseoli* (Gyllenhal), and *Callosobruchus theobromae* (Linnaeus) (Balikai and Neenu, 2018).

More than 50 insect species are known to infest chickpea both in the field and during storage. Among the stored grain pests of pulses, the pulse beetle *Callosobruchus chinensis* is considered one of the most destructive and economically important pests (*Ahmed et al.,* 2003). Severe infestation by pulse beetles may result in up to 99.33% seed damage after 120 days of storage *(*Venkatesham *et al.,* 2015).

Some insect pests initiate infestation in the field and continue their development during storage. Post-harvest damage caused by insects is therefore a major constraint in pulse production (Khaire *et al.,* 1992). Pulse beetles are notorious pests of several pulse crops including chickpea, pigeon pea, green gram, cowpea, peas, and lentil (Aslam *et al.,* 2002). During storage, bruchid beetles cause considerable losses by damaging the grains.

The pulse beetle not only causes quantitative losses through seed damage and weight reduction but also leads to qualitative losses by reducing nutritional value and seed germination, thereby making the grains unsuitable for consumption (Raghvani and Kapadia, 2003). The infestation of pulse beetles often begins in the field and becomes evident during storage. The earliest sign of infestation is the presence of white eggs attached to the seed surface. After hatching, the larvae bore into the seed and feed on the internal contents during their development. The adults emerge by cutting circular exit holes on the seed surface, which are the most visible symptoms of damage. Adult beetles do not feed on the grains; instead, they mate and lay eggs on the seed surface (Sharma, 1984).

MATERIAL AND METHODS

Insect Rearing and Culture

A biologically pure stock culture of *C. maculatus* was established under controlled 4. o f seeds served as the experimental control. Into each treated and control container, thirty freshly emerged adult beetles (15 males and 15 females) were introduced. The containers were sealed with perforated lids. All treatments, including the controls, were replicated to ensure statistical validity.

Data Collection and Statistical Analysis

Insect mortality was evaluated exactly 24 hours post-treatment. Beetles were classified as dead if they exhibited no movement of their appendages (legs or antennae) when gently probed with a fine camel-hair brush. Where control mortality occurred (kept below 5%), the observed treatment mortality was corrected using Abbott's formula (Abbott, 1925). The corrected dose-mortality data were subsequently subjected to Probit analysis (Finney, 1971) to compute the median lethal concentration (LC50), the 90% lethal concentration (LC90), fiducial limits, regression equations, and Chi-square values.

RESULTS AND DISCUSSION

Concentration-Mortality Response

The bioassays demonstrated a clear dose-dependent mortality response across all tested plant oils within 24 hours of exposure. No mortality was recorded in the control groups, confirming that the observed beetle mortality was strictly attributable to the oil treatments. The detailed corrected mortality percentages for each oil across the four concentrations are summarized in Table 1.

Neem oil achieved the highest maximum mortality (67.33% at 2.0 ml), closely followed by mustard and castor oils, while coconut oil failed to surpass 50 per cent mortality even at the maximum dose.

Probit Analysis and Toxicity Parameters

The data demonstrated excellent homogeneity and good fit to the probit model, evidenced by the low Chi-square values and high R-squared values across all treatments Table 2.

Based on the derived LC_{50} values, the relative toxicity of the oils can be ranked as follows: Neem (1.25) > Mustard (1.31) > Castor (1.35) > Groundnut (1.40) > Tobacco seed (1.44) > Mint (1.49) > Cottonseed (1.52) > Sunflower (1.54) > Coconut (2.00).

The empirical data from this study align with the broader entomological consensus that plant oils serve as highly effective, multi-modal grain protectants. The fundamental mechanism of mortality observed within the 24-hour period is largely attributed to physical asphyxiation. As noted by Schoonhoven *et al.* (2005), when seeds are uniformly coated with oil, the fluid severely obstructs the spiracles (respiratory

Table 1. Corrected 24-hour mortality (%) of adult *C. maculatus* exposed to varying concentrations of plant oils

Treatment	0.5 ml/100g	1.0 ml/100g	1.5 ml/100g	2.0 ml/100g
Neem oil (3000 ppm)	11.33%	31.00%	58.78%	67.33%
Mustard oil	10.00%	30.00%	58.31%	66.00%
Castor oil	16.67%	25.00%	51.68%	65.00%
Tobacco seed oil	18.34%	26.66%	55.00%	65.00%
Mint oil	16.66%	25.66%	51.66%	65.00%
Cottonseed oil	22.33%	39.85%	53.55%	64.33%
Sunflower oil	19.29%	38.59%	52.63%	63.16%
Groundnut oil	20.00%	40.00%	53.22%	58.33%
Coconut oil	4.83%	14.77%	29.33%	47.33%

Table 2. Probit analysis of different oils against adults of *C. maculatus*

Treatments	LC50 (ml/100g)	95% Fiducial Limits	Chi-square (χ^2)	R^2 Value	Regression Equation (Y = a+bx)
Sunflower oil	1.54	1.31 – 2.13	0.014	0.999	Y = 4.60 + 2.30X
Groundnut oil	1.4	1.22 – 1.98	0.01	0.991	Y = 4.60 + 2.30X
Mustard oil	1.31	1.11 – 1.84	0.007	0.985	Y = 4.62 + 3.24X
Mint oil	1.49	1.27 – 2.21	0.52	0.914	Y = 4.48 + 2.84X
Castor oil	1.35	1.16 – 1.92	0.52	0.914	Y = 4.48 + 2.84X
Coconut oil	2	1.62 – 2.98	0.31	0.981	Y = 4.21 + 2.62X
Cottonseed oil	1.52	1.29 – 2.09	0.88	0.996	Y = 4.15 + 2.61X
Tobacco seed oil	1.44	1.19 – 2.06	0.41	0.91	Y = 4.57 + 2.71X
Neem oil 3000ppm	1.25	1.05 – 1.76	0.22	0.985	Y = 4.83 + 2.05X

pores) of the bruchids, leading to rapid suffocation. Neem oil (3000 ppm) exhibited the most potent insecticidal properties (LC_{50} = 1.25 ml/100g; 67.33 per cent mortality at 2.0 ml). This exceptional efficacy is not solely due to physical asphyxiation but is heavily augmented by its rich biochemical profile. Neem derivatives contain azadirachtin and other complex triterpenoids, which possess formidable contact toxicity, disrupt insect neuroendocrine systems, and act as severe antifeedants (Prakash & Rao, 1997) Among the purely edible and common industrial oils, mustard (LC_{50} = 1.31 ml/100g) and castor (LC50 = 1.35 ml/100g) demonstrated excellent bio efficacy. The success of these specific oils is frequently linked to their higher viscosity and specific fatty acid compositions. Heavily viscous oils provide a more persistent and stable coating on the seed testa, ensuring a prolonged physical barrier that prevents gas exchange in the insect, compared to more volatile or easily absorbed oils (Hill, 2002).Conversely, coconut oil proved to be the least effective protectant in this trial, requiring the highest concentration (LC50 = 2.00 ml/100g) to achieve 50 per cent mortality.

CONCLUSION

This study conclusively demonstrates that botanical oils possess robust contact toxicity against the pulse beetle, *C. maculatus*. Neem oil (3000 ppm), mustard oil, and castor oil provided the most rapid and effective insecticidal control at the lowest concentrations. Given their high efficacy, biodegradability, and safety profile compared to synthetic pesticides, the integration of these plant oils into post-harvest pest management protocols presents a highly viable, sustainable, and economically accessible strategy for the protection of stored legumes.

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