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Evaluation of repellent and insecticidal effects of *Cymbopogon citratus* (Stapf.) on *Sitophilus granarius* (Linn.) (Coleoptera: Curculionidae) in cereal storage

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Abstract
Human civilization has advanced significantly over the last 10,000 years, which has resulted in improvements in resource management, food production, and storage methods. However, as more land is set aside for housing, industry, and transportation, the steady loss of farming over the past few centuries has been exacerbated by faster population growth, longer life expectancies, and industrial expansion. However, chemical pesticides are an efficient way to control pests in grains that are kept. Nonetheless, when grains are consumed, their residues enter the human body and might create physiological problems. Plant extracts include active compounds beneficial in plant defence against various insect pests. Assessing the impact of several solvent extracts from *Cymbopogon citratus* on the granary weevil (*Sitophilus granarius*) is the main goal of this study. The Entomology Research Unit's insectarium provided the weevils used in this investigation. Hexane, ethyl acetate, and ethanol were among the solvents used to extract *C. citratus*, and the granary weevils were used to assess the efficacy of each extract concentration. The research showed that as the concentration of leaf extract and time of exposure increased, so did the percentage of mortality. The current experiments revealed that the ethanol extract of *C. citratus* was more effective than the other solvents. In 72 hours, the highest repellent was 98.4%, and insecticidal was 89.5% against *S. granarius*. The study suggested using *C. citratus* as an alternative to synthetic pesticides and the demand for biopesticides as safer and biodegradable for effective control of *S. granarius*.

Keywords: *Cymbopogon citratus*, *Sitophilus granarius*, Insecticidal activity, plant extracts, repellent activity

Introduction

Stored grain pests are economically important because they infest a wide variety of stored goods and are common in many places across the globe. One of the fundamental reasons for the global food crisis is the loss of stored grains, which has occurred in significant numbers worldwide. Post-harvest losses caused by stored insect pests range from 9% in developed countries to 20% or more in developing countries (Zapata and Smagghe, 2010) [42].

A major contributing factor to the world food problem is the substantial loss of stored grains. Only four bug species can grow inside the endosperm's kernels, and only a small number of insect species may survive in stored grains. One of the most dangerous insects in the family Curculionidae (Coleoptera) is the granary weevil (*Sitophilus granarius*). The stored grains—wheat, oats, sorghum, barley, corn, rice, millet, and even manufactured pasta—are all known to sustain significant harm from this weevil. It causes damage that drastically lowers the amount and quality of these grains. Since the granary weevil likes colder climates, it is more prevalent in northern areas.

Using fumigation, low-toxicity pesticides, and pest management in stored products resulted in several issues, such as resistant insect strains, environmental pollution, and health hazards (Rahman *et al*., 2009) [35]. These bioinsecticides interrupt the activity of insect pests because they contain antifeedant, detrimental, and insect-repellent qualities and inhibit insect development (Chowanski, 2016). The biodegradability of plant-based formulations makes them an environmentally acceptable and sustainable substitute for synthetic pesticides. Scientists are putting much effort into developing a bioinsecticide source to manage insect populations.

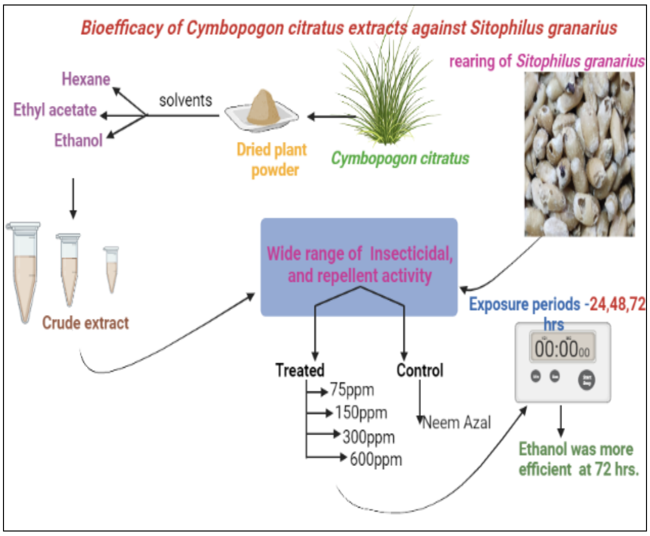
Cymbopogon citratus

The culinary herb lemongrass is mainly grown in India, Indonesia, Sri Lanka, and Southeast Asia. It is typically used to relieve pain, tension, and anxiety. Lemongrass extracts have antibacterial, antidandruff, anti-cancer, anti-inflammatory, and repellant properties due to the presence of limonene and citral (Khan, 2020) [19]. Fibres, carbohydrates, and vitamins A, B, and C are among the bioactive ingredients in lemongrass that support cell development, enhance the immune system, and heal damaged tissue (Nambiar and Matela, 2012 [13]; Abbas and El-Saeid, 2012) [1]. It also has magnesium, which is needed for protein synthesis, glycolysis, and muscle activity (Prasad *et al*., 1998 [34]; Alsogayer, 2018). Selenium is for cognitive function and fertility (Singh, 2012) [38], and zinc is needed for wound healing, expected growth, and development (Ranjah, 2019) [36].

Many chemically manufactured pesticides are used to manage pests in crops. The FAO reported that the amount of pesticide used worldwide in 2018 was 4.12 Mt, essentially the same as the previous year's amount of 4.15 Mt (FAO, 2020) [13]. Organochlorine, organophosphate, carbamate, and pyrethroid comprise a sizable number of synthetic insecticides. They may persist in various environmental mediums for a day to many years and have distinct modes of action on pests (Bilal *et al*., 2019) [7].

This study demonstrated the possibility for improving an integrated pest management approach that deviates from the accepted methods currently employed for farm-level stored grain insect pest control. The method is still economical, safe, and ecologically benign. The main goal of the study was to determine how well different solvent extracts from

Cymbopogon citratus, such as ethanol, hexane, and ethyl acetate, worked against the wheat weevil (*Sitophilus granarius*).



Materials and Techniques

1. ***Cymbopogon citratus* Collection:** The Salem district of the plant was the source of fresh leaves. The leaves were cleaned well and then allowed to dry at room temperature in the shade for five to ten days. After drying, the leaves were pulverized in an electric blender and then separately extracted using a soaking process with ethanol, hexane, and ethyl acetate. he extracts were stored in airtight glass containers.

2. **Crude extract preparation:** The gathered leaves were ground into a fine powder in a blender after being oven-dried for the entire night at 50°C. Each 5-gram sample was extracted twice using 250 milliliters of ethanol, ethyl acetate, and hexane at room temperature. Using Whatman No. 1 filter paper, the extracts were filtered, and rotary evaporation was used to dry the filtrates from the two extractions.

3. **Rearing of *Sitophilus granarius*:** 500 grams of sterilized wheat grains were placed in plastic jars to raise adult *S. granarius* weevils. For two weeks, the grains were frozen at -14°C to get rid of any bug contamination that might have existed beforehand. To lay eggs, about 300 adult weevils were added to the jars. The muslin covering the cloths was fastened using elastic bands.

4. **Insecticidal action of *S. granarius:*** Adult *S. granarius* weevils that had just emerged were used to test insecticidal action. Whatman Different plant extract concentrations (75, 150, 300, and 600 ppm) were applied to No. 1 filter paper, which was then allowed to dry for ten minutes. After that, 25 mature weevils were put in each jar, and the treated filter paper was attached to the inside of the lid. After 24, 48, and 72 hours, the insecticidal effects were assessed.

$$\mathrm{POD} = \frac{\mathrm{Ts} - \mathrm{Cs}}{\mathrm{Cs}} \mathrm{X100}$$

POD: Percentage of damage.
Ts: Insects in treated sample.
Cs: Insects in control samples.

1. **Repellent action of *S. granarius:*** Exposure of *S. granarius* to *C. citratus* was used to evaluate the extracts' repelling properties. Five plastic boxes, each joined by plastic tubing, made up the experimental arrangement. Grain treated with *C. citratus* extract at different quantities (75, 150, 300, and 600 ppm) was found in four of the boxes. Each box was filled with twenty adult weevils that were not sexed. There were no insects in the middle container, which contained unprocessed grain. Using Lwanda's method, the number of insects was determined after 72 hours. The following formula was used to determine the Excess Proportion Index:

$$\mathrm{EPI} = \frac{\mathrm{Nt} - \mathrm{Nc}}{\mathrm{Nt} + \mathrm{Nc}} \mathrm{X}\ 100$$

EPI = Excess Proportion Index
Nt = the number of insects in the treated box; Nc = the number of insects in the control box.

Results

Table 3.1-3.3 shows that *C. citratus* had exceptional insecticidal action against adult S. granaries weevils. Higher quantities of the ethanol extract showed statistically significant insecticidal efficacy. Similarly, experimental groups that received therapy for 72 hours exhibited the highest level of insecticidal action. This aligns with previous findings by several authors. According to the current investigation, plant extracts effectively reduced adult and offspring mortality from *S. granarius* in stored grains. The effectiveness of medicinal herbs against the *S. granarius* insect pest in stored grain with reference to F1 protein has been the subject of numerous published investigations.

Table 3.1-3.3: Insecticidal activity of hexane, ethyl acetate and ethanol extract *Cymbopogon citratus* tested against adult granary weevil *Sitophilus granarius*

Concentrations	Exposure periods 72hrs		R^2 Linear
	Extract of Hexane		
	Mortality (%)	Lc90 (UBL-LBL)	
75ppm	19.41±2.87	584.45 (522.19 - 672.41)	0.997
150ppm	32.59±1.75		
300ppm	56.03±1.93		
600ppm	90.47±0.69		
Neem Azal	100.0±0.00		

Concentrations	Extract of Ethyl acetate		R^2 Linear
	Mortality (%)	Lc90 (UBL-LBL)	
75ppm	20.11±1.93	530.56 (474.72-609.05)	**0.992**
150ppm	35.73±1.25		
300ppm	63.38±0.78		
600ppm	93.22±0.63		
Neem Azal	100.0±0.00		

Concentrations	Extract of Ethanol		R^2 Linear
	Mortality (%)	Lc90 (UBL-LBL)	
75ppm	23.20±2.74	472.16 (422.06 - 542.95)	**0.986**
150ppm	37.16±2.16		
300ppm	72.09±0.99		
600ppm	95.74±0.34		
Neem Azal	100.0±0.00		

The mean mortality ± standard deviations of five replications (n = 25) are the values displayed. with the SPSS program, at a 95% confidence level.

Similarly, a similar pattern was observed with *C. citratus* repellent activity (Figures 3.1-3.3). Significant activities were observed because of the presence of many phytochemical compounds imbibed with ethanol. This aligns with previous findings by several authors. According to the current investigation, plant extracts effectively reduced adult and offspring mortality from *S. granarius* in stored grains. The effectiveness of medicinal herbs against the *S. granarius* insect pest in stored grain with reference to F1 protein has been the subject of numerous published investigations. (Tapondjou*et al*., 2002; Ketoh*et al*., 2005; Kestenholz*et al*., 2007 [18]; Iboudo *et al.*, 2010 [16]; Derbalah and Ahmed, 2011) [11].

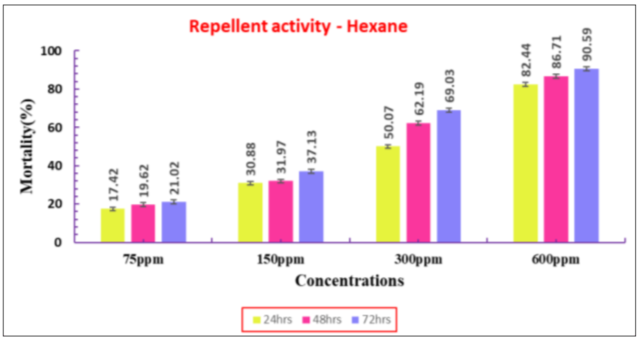


Fig 3.1: *Cymbopogon citratus* hexane extract's efficacy to repel *Sitophilus granarius*

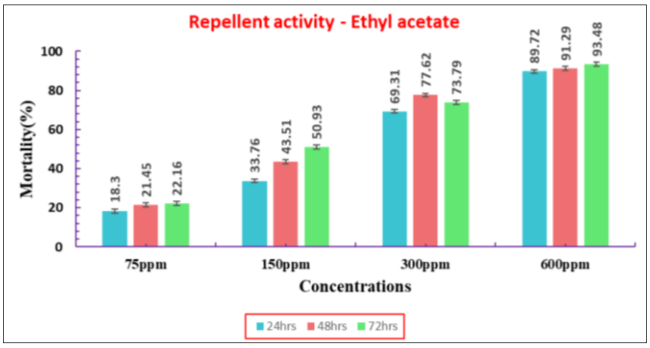


Fig 3.2: *Cymbopogon citratus* ethyl acetate extract's efficacy to repel *Sitophilus granarius*

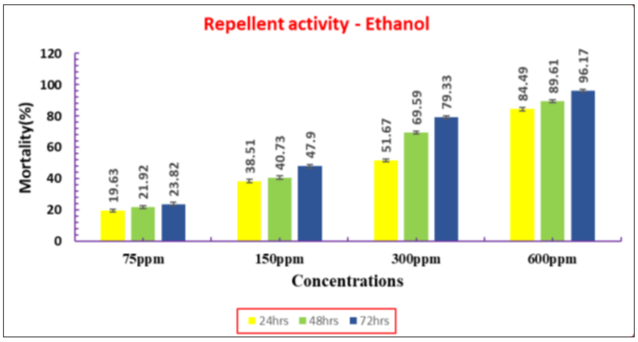


Fig 3.3: *Cymbopogon citratus* ethanol extract's efficacy to repel *Sitophilus granarius*

Discussion

Sitophilus granarius, the granary weevil, is the world's most dangerous pest of stored products. The effects of 25 essential oils used to suppress adult granary weevils were examined by Demeter *et al.* in 2021 [10]. The study discovered that *Allium sativum* had the highest mortality rate and that Mentha arvensis and eucalyptus oils were the most efficient against the weevils. According to Tajidin *et al.* (2012) [39], citral is the main constituent of lemongrass oil, and the results of the chromatographic study for exotic lemongrass are consistent with their findings. Citral was the most prevalent component in volatile oil, with a presence varying from 61.2% to 76.46% depending on the production location, according to separate research by Trang *et al.* (2020) [40] that assessed the chemical composition of lemongrass essential oil cultivated in various parts of Vietnam. According to Plata-Rueda *et al.* (2020) [33], the main constituents of lemongrass essential oil are citral and neral. The mixture also contained neral (34.1%) and geranial (46.83%) citral isomers, according to Alves *et al.* (2019).

Both native and exotic lemon types of grass can create odours repulsive to insects because volatile molecules enter the air and are inhaled by insects through their spiracles (Plata-Rueda *et al*., 2020 [33]; Martnez *et al*., 2018). Because of their harmful effects on the neurological system, lemongrass's essential oil and terpenoids also affect behavioural responses, changing displacement patterns and promoting or impeding insect movement. Houghton *et al.* (2006) ascribe the repellent function to the presence of monoterpenes and sesquiterpenes, which kill insects by inhibiting AChE activity in the nervous system.

Every element in a plant extract contributes differently to the metabolic impact it has on the intended insects. For instance, tiny levels of loliolide, which has a number of biological characteristics, including the ability to repel insects, were found (Gordon *et al*., 1982) [14]. (Miyazawa *et al*., 1997 [27]; Lee *et al*., 2000 [20]; Derbalah and Ahmed, 2011) [11] Bioactive monoterpenoids (e.g., alcohols, ketones, and hydrocarbons) that are derived from plant materials and oils are thought to inhibit acetylcholinesterase. The most effective monoterpene that inhibits AChE in insect brains is 1,8-cineole, according to Lee *et al.* (2000) [20]. Natural chemicals and monoterpenes may be able to prevent insect infestations of stored grains by this mode of action.

Essential oils from lemon grass have a greater chance of maize weevil mortality and react favorably to increases in applied dose and exposure duration. According to several authors (Mishra *et al.*, 2012 [26]; Jumbo *et al.*, 2014 [17]; Bett *et al.*, 2016 [6]; Bounoua-Fraoucene *et al.*, 2019 [8]; Lazzaretti *et al.*, 2020) [21], mortality rose as exposure time and dose increased. According to Oyedeji *et al.* (2020) [32], who evaluated the effects of fumigation and contact with *Citrus sinensis* essential oil and its isolated components, the compounds show substantial toxicity against adult *C. maculatus* and *S. zeamais* insects. This suggests insect mortality rises as the concentration range of *C. sinensis* or its isolated components increases. Adel *et al.* (2015) [3] investigated the effect of acetone extracts of geranium, basil, and fennel seed oils on *S. oryzae* and *C. macullatus* in similar studies. Geranium oil was effective against *S. oryzae* and *C. maculatus* in the absence of rice grains.

Insect pests that carry dangerous illnesses are effectively controlled by bio-insecticides, mainly those derived from plants. Due to their rich bioactive compounds, these plants and their derivatives are the best substitutes for chemical pesticides. According to specific research, plant extracts effectively kill Dipterans (Morey and Khandagle, 2012) [28]. Several individuals were utilizing the synthetic pesticide organophosphate Malathion before using environmentally benign bio-insecticides. However, its usage may harm the environment, animals, and people. Consequently, a new application was needed, and bio-insecticides were employed. It was shown that the moisture-absorbing properties of lemon grass stems and leaves may effectively substitute malathion (Aditama *et al.*, 2019) [4].

Conclusion

Due to the insect *Sitophilus g*ranarius, farmers are suffering large financial losses in their fields and during storage. Three distinct organic solvents—ethanol, ethyl acetate, and hexane—were used in this investigation to extract *Cymbopogon citratus*. Each solvent extract's efficacy was evaluated at different concentrations. Notably, the plant's promise was validated by the ethanol extract. According to our research, *Cymbopogon citratus* is a natural pesticide that is becoming more and more popular and advantageous. It has been shown to be a successful and environmentally responsible pest control solution when compared to synthetic alternatives.

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