



Insecticidal activity of *Euphorbia ingens* latex against the saw-toothed beetle *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) under laboratory conditions

Mohale Mathole*, Pieter King

Department of Biology & Environmental Sciences, Sefako Makgatho Health Sciences University, Medunsa, Pretoria, South Africa

Article history

Received: June 20, 2026
Revised: August 29, 2026
Accepted: September 10, 2026
Published: October 5, 2026

*Correspondence

Mohale Mathole
E-mail: matholeclinton@gmail.com

License and copyright



Copyright: © 2026 by the authors. **Open-access** publication under the terms and conditions of the **Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA)** license

E-ISSN and DOI

E-ISSN: 3026-2461
<https://doi.org/10.25077/aijent.4.2.99-108.2026>

ABSTRACT

Plant-derived products are reported as potential eco-friendly alternatives to synthetic insecticides. *Euphorbia ingens* (Euphorbiaceae) is a latex-bearing species with reported insecticidal properties. Therefore, the present study aimed to evaluate the phytochemical composition of *E. ingens* latex and its insecticidal and repellent properties against *Oryzaephilus surinamensis*. The total terpenoid and alkaloid contents were estimated spectrophotometrically. Insecticidal activity was assessed using dipping and contact residual methods, whereas repellency was evaluated using a dual-choice apparatus. The total alkaloid and terpenoid content within *E. ingens* latex extracts were determined at 372.64 ± 80.76 mg atropine equivalents g^{-1} and 36.09 ± 1.08 mg linalool equivalents g^{-1} , respectively. The insecticidal and repellent properties of *E. ingens* latex against *O. surinamensis* increased with increasing concentrations and time. The LC_{50} values of *E. ingens* latex against *O. surinamensis* were determined at 2.67 and 3.39% (v/v) using dipping and contact residual methods, respectively. The corresponding standard errors were evaluated at 2.67 ± 0.729 and 3.39 ± 1.460 (v/v), respectively. Furthermore, the repellency percentage at an exposure time of 3 hr ranged from $15.00 \pm 5.77\%$ at 15% concentration to $76.67 \pm 8.82\%$ at 85%. At 6 hr, the repellent activity further increased, ranging from the $20.00 \pm 5.77\%$ to $83.33 \pm 8.82\%$ across the same concentrations. *E. ingens* latex has alkaloid and terpenoid content and insecticidal and repellent activity against *O. surinamensis*.

Keywords: Alkaloids; Botanical insecticides; *Euphorbia ingens*; *Oryzaephilus surinamensis*; Terpenoids.

INTRODUCTION

Storage insect pests, such as weevils, grain borers, and flour beetles, are among the

leading contributors to grain quality degradation and grain loss in storage facilities (Demis & Yenewa, 2022). These pests are responsible for approximately 10% of

economic losses to stored grain produce annually (Mutalov et al., 2025). They also pose a significant threat to food security by contributing to stored-grain waste through contamination by insect excreta, secretions, and body fragments (Kumar, 2017). Furthermore, these insects pose health concerns, as exposure to contaminated grain has been reported to trigger allergic reactions and lead to indirect bacterial and fungal contamination of food commodities (Phillips & Throne, 2010; Hubert et al., 2018). Lastly, storage insect pests reduce the yield of the next generation of crops through seed damage caused during feeding and by transmitting pathogens that hinder seed germination (Adesina & Aderibigbe, 2021).

Synthetic insecticides are commonly used to combat these beetles, and while effective, they are associated with a variety of adverse effects (Araújo et al., 2023). Residues of these chemicals are known to contaminate food stored in facilities, rendering it unsafe for human consumption (Lebelo et al., 2021). They also pose a significant risk to applicators when not handled with caution, leading to health complications (Tudi et al., 2022). Scientific studies reveal that constant exposure to synthetic insecticides such as organophosphates and organochlorides increases the risk of cancer and neurodegenerative disorders (Sarailoo et al., 2022). Furthermore, these products persist due to their non-biodegradable, cumulative nature, which can negatively affect various non-target organisms and disrupt ecological balance (Gill & Garg, 2014). Lastly, repeated application of synthetic insecticides is linked to the development of resistance in targeted pest insects (Siegwart et al., 2015).

Plants and plant-based products are reported to be safer, more environmentally friendly alternatives to synthetic insecticides. Furthermore, these products are reported to be biodegradable and to exhibit minimal bioaccumulation in ecosystems (Souto et al., 2021; Ngegba et al., 2022). Several plant species, such as *Plectranthus ornatus*, *Asparagus laricinus*, *Azadirachta indica*, *Acorus*

calamus, and *Cymbopogon citratus*, have been reported to have repellent, ovicidal, growth-inhibiting, and mortality-inducing properties against storage insect pests (Mathole & King, 2026; Kuppusamy et al., 2016; Iwuagwu et al., 2020). These plants have insecticidal properties against storage pests such as *Sitophilus maezias*, *Sitophilus oryzae*, *Tribolium castaneum*, and *Oryzaephilus surinamensis* (Quintero et al., 2025; Nikolaou et al., 2021). Additionally, studies reveal that these plants contain several phytochemicals, such as terpenoids, alkaloids, phenols, and tannins, that are responsible for these effects (Jaikishun et al., 2023). These phytochemical constituents have been shown to exert several modes of action against insect pests, which minimize the risk of resistance development (Dar et al., 2017). Plant species such as *Datura stramonium* have been shown to exhibit selective insecticidal properties, being effective against pest insects while being least harmful to beneficial species (Kumar et al., 2026).

Euphorbia ingens is a latex-bearing tree belonging to the family Euphorbiaceae. It is native to several Southern African countries and found growing in the wild on rocky, arid, and savanna landscapes. The plant exhibits various biological activities, including anticancer, antibacterial, antifungal, and anti-inflammatory activities, as well as traditional medicinal applications (Amtaghri et al., 2022). Mathole and King (2025) investigated the insecticidal properties of the plant latex against *Blatella germanica* and *Periplaneta americana* and found it to be effective. Despite these findings, a detailed review of the existing literature provides limited information regarding the insecticidal properties of *E. ingens* against *O. surinamensis*. Therefore, the current study was undertaken to investigate the insecticidal properties of *E. ingens* latex against *O. surinamensis*.

METHODS

Study area

This study was conducted at the Sefako Makgatho Health Sciences University (SMU), Ga-Rankuwa, Pretoria, South Africa (25°36'53"S; 28°1'25"E).

Chemicals

All chemicals were of the highest purity (≥ 90). Methanol, atropine, bromocresol green, diosgenin, chloroform, glacial acetic acid, and vanillin reagent were all purchased from Merck, USA.

Rearing of *Oryzaephilus surinamensis*

Oryzaephilus surinamensis were reared in a controlled environment at a room temperature of $28 \pm 2^\circ \text{C}$ and $70 \pm 5\%$ relative humidity in complete darkness. The insects were reared in white rice flour media and powdered milk, mixed with two teaspoons of yeast (Jian et al., 2012). *Oryzaephilus surinamensis* used in the bioassay were unsexed adults 2 weeks old. Also, all experiments were conducted in Petri dishes covered with mesh cloth to prevent insects from escaping.

Collection and Drying of *Euphorbia ingens* latex.

Latex of *Euphorbia ingens* was drawn from cut basal branches collected into 50 ml centrifuge tubes from a healthy and mature tree within the premises of Sefako Makgatho Health Sciences University (SMU), Pretoria, South Africa. The latex was stored in an ice box, transported to the biology and environmental sciences laboratory, and then placed in a refrigerator at 3°C . 20 ml of freshly collected latex was filtered, evenly spread in a thin layer on a heat-resistant glass dish, placed in a drying oven pre-set at 45°C , and allowed to dry for 12 hours. The dish was then removed from the oven, cooled in a desiccator for 30 minutes, and the latex was scraped off and stored in airtight vials for phytochemical analysis.

Preparation of *Euphorbia ingens* latex extracts.

The guidelines of Koffi et al. (2010) were followed for extracting latex from *E. ingens*, with slight modifications. The dried latex was ground into a powder using an electric blender, and the fine powder was sieved through a metal sieve (0.5-1.5mm), then soaked in 1000ml of methanol. The mixtures were shaken for 24 hours using an orbital shaker at 120rpm. The latex extracts were then filtered through 11 μm

filter paper (Whatman No. 1). A rotary evaporator at 45°C and 80 rpm was used to evaporate the filtrates, and the resulting substrates were stored in a clean, dry container.

Quantitative alkaloids test of *Euphorbia ingens* latex extracts.

The total alkaloid content in *E. ingens* latex extracts was quantified using an atropine calibration standard, following the guidelines of Madhu et al. (2016), with slight modifications. Concentrations of 50, 100, 150, 200, 250, 350, and 500 mg.ml^{-1} of atropine were each measured in triplicate using a spectrophotometer, and their absorbances were used to plot a standard curve. The standard curve showed a linear regression of $Y = 0.0009X + 0.9352$, $R^2 = 0.9671$ (Fig. 1) and was used to calculate the total alkaloid content, expressed as $\mu\text{g.ml}^{-1}$ of atropine per gram of extract.

For sample analysis, *E. ingens* latex extracts of 1ml were dissolved in 10 mL of distilled water in a 100 mL volumetric flask, and the volume was made up to the mark with distilled water. Afterward, 5 ml of Bromocresol green (BCG) and 5 ml of the prepared buffer solution were slowly pipetted into the volumetric flask. The sample was then washed with 5 mL of chloroform. The aliquot was taken to the spectrophotometer, and the absorbance was measured at 470 nm.

Quantitative terpenoids test of *Euphorbia ingens* latex extracts.

The total terpenoid content in *E. ingens* latex extracts was estimated using a linalool calibration standard, following the guidelines of Madhu et al. (2016), with slight modifications. Concentrations of 50, 100, 150, 200, 250, 350, and 500 mg.ml^{-1} of linalool were each measured in triplicate using a spectrophotometer, and their absorbances were used to plot a standard curve. The standard curve exhibited a linear regression ($Y = 0.0029X + 0.01$; $R^2 = 0.9963$; Fig. 2) and was used to calculate the total terpenoid content, expressed as mg.ml^{-1} of linalool per gram of extract.

For sample analysis, 1ml of *E. ingens* latex extract was dissolved in 1ml of a 5% (w/v) vanillin solution prepared in glacial acetic acid.

To the mixture, 2.5 ml of concentrated sulphuric acid was carefully added, and the reaction was vortexed and incubated in a water bath at 60 °C for 15 min to develop color. The mixture was immediately cooled in an ice bath for approximately 5 min, and the absorbance was measured at 538 nm.

Insecticidal effects of Euphorbia ingens latex against Oryzaephilus surinamensis using the dipping method.

The insecticidal properties of *Euphorbia ingens* latex against *O. surinamensis* were determined using the dipping method described by Mashaba et al. (2025), with slight modifications. Twenty unsexed adult *O. surinamensis* of approximately the same size were placed in six plastic containers. The beetles in the first five containers served as the experimental group. They were exposed to *E. ingens* latex at 2, 4, 6, 8, and 10% (v/v), and the sixth container served as a negative control, exposed only to distilled water. The containers were sealed with perforated lids to prevent insects from escaping, and they were tested for 24 hours. The trials were carried out in triplicate, where each experimental concentration and the negative control were repeated three times. Post-trial, the insects were examined underneath a light dissection microscope and probed with a fine camel brush, and those that lacked motion were considered dead.

Insecticidal effects of Euphorbia ingens latex against Oryzaephilus surinamensis using the contact residual method.

Insecticidal effects of *E. ingens* latex against *O. surinamensis* were evaluated using the contact (residual) assay method, following the guidelines of Mathole and King (2026), with slight modifications. *E. ingens* latex at concentrations of 2, 4, 6, 8, and 10 % (v/v) and a negative control of distilled water were prepared. Subsequently, the various concentrations and a negative control of distilled water, each at a volume of 5 ml, were impregnated onto six separate filter papers, air-dried for 10 minutes, and placed into separate petri dishes. Thereafter, twenty adults of *O. surinamensis* were placed in each of the six 50 ml petri-dishes

and exposed to the various leaf extract concentrations of *E. ingens* latex. The experimental trials for each treatment were repeated three times, and the saw-toothed beetles were observed for 24 hours. *Oryzaephilus surinamensis* removed with a fine camel brush and did not show signs of movement were considered dead.

Insecticidal effects of Euphorbia ingens latex against Oryzaephilus surinamensis using repellent assay.

The repellent assay of *E. ingens* latex against *O. surinamensis* was performed using a dual-choice repellence apparatus, following the guidelines of Thavara et al. (2007), with slight modifications. The apparatus consisted of a central plastic chamber (50 ml) connected to two side containers, labeled A and B, through two polyvinyl chloride tubes. The central chamber served as a release point for the insects, while containers A and B represented treatment and control chambers, respectively. The treated chamber (A) was filled with cornflakes cereal mixed with 1 ml of varying concentrations ranging from 15, 25, 60, and 80 % (v/v) of the *E. ingens* latex extracts, and the cereal in chamber (B) served as a negative control and was mixed with 1 ml of distilled water. Twenty adult *O. surinamensis* were gently introduced into the central chamber and allowed to move freely between the two points. The number of saw-toothed beetles in the control and experimental groups was recorded after 3 hours and again after 6 hours of exposure. Each experimental trial was repeated three times.

The percentage repellency (PR) was calculated using the formula:

$$PR = (C - T) / (C + T) \times 100$$

where *C* = number of insects on the control half and *T* = number on the treated half.

Data analysis

Mortality percentages were recorded after 24 hours and corrected using Abbott's formula (Abbott, 1925). Also, the LC₅₀ values were estimated by probit analysis according to Finney and Stevens (1948) and performed in Microsoft Excel. Data were expressed as mean ± standard

error of the mean. Repellence data were subjected to one-way ANOVA followed by Tukey's HSD test at $p < 0.05$ using SPSS version 32.0.

RESULT

The total alkaloid and terpenoid content in *E. ingens* latex extracts was determined to be 372.64 ± 80.76 mg atropine g^{-1} and 36.09 ± 1.08 mg linalool g^{-1} , respectively (Table 1).

Table 1. Total alkaloid and terpenoid content of *E. ingens* latex extracts

Sample	Total alkaloid content	Total terpenoid content
<i>Euphorbia ingens</i>	372.64 ± 80.76	36.09 ± 1.08

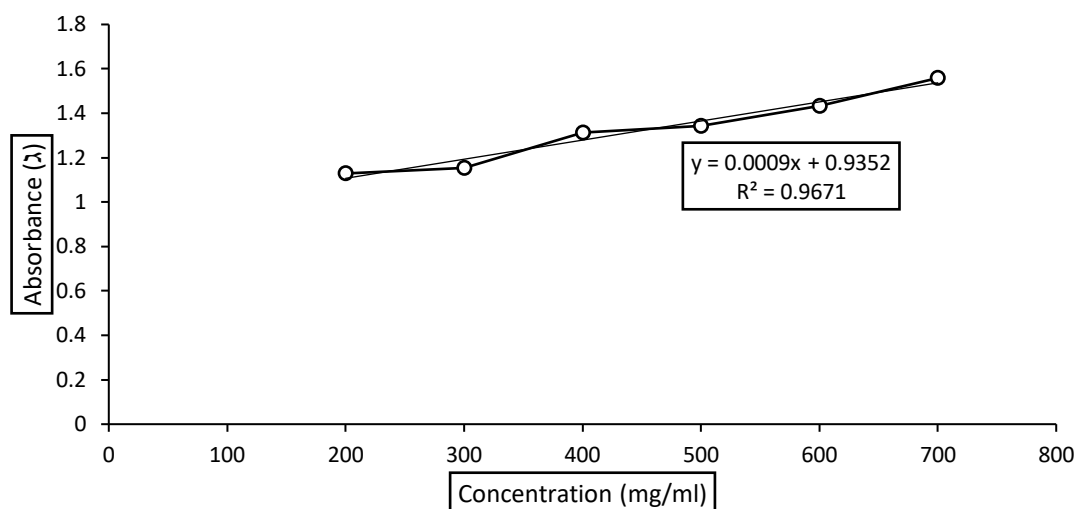


Figure 1. Standard calibration curve for estimation of total alkaloid content for standard atropine (Atropine/mg).

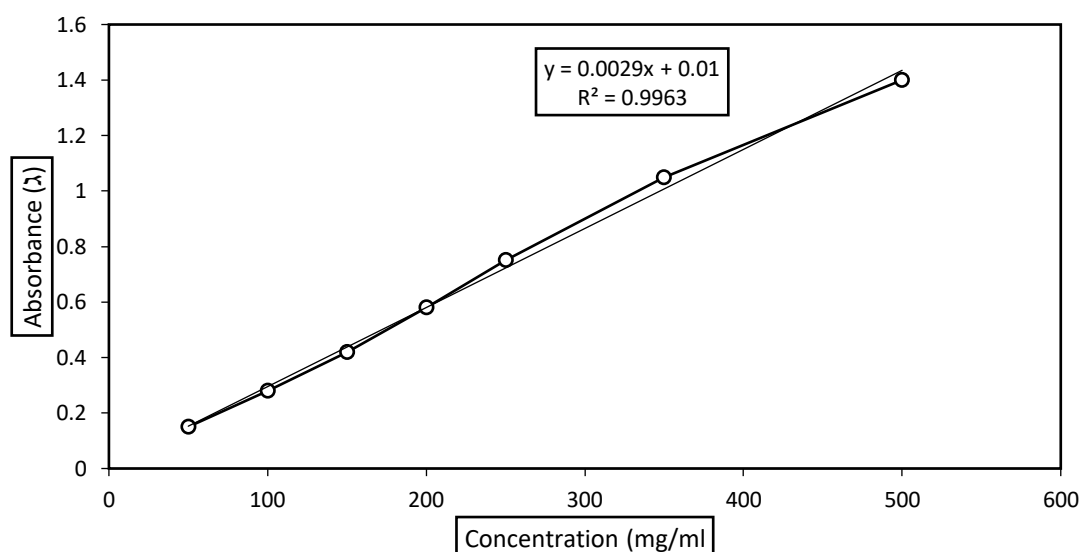


Figure 2. Standard calibration curve for estimation of total terpenoid content for standard linalool (Linalool/mg).

The results of the current study revealed that the latex of *Euphorbia ingens* possesses insecticidal properties against *Oryzaephilus surinamensis*. The mortality percentages of *O. surinamensis* exposed to the latex of *E. ingens* increased with increasing concentrations in both dipping and contact residual methods. In addition, the

highest concentration, 10% (v/v), resulted in 100% and 80% mortality with the dipping and contact residual methods, respectively. Furthermore, the dipping method exhibited higher mortality rates than the contact residual method against saw-toothed beetles (Table 2).

Table 2. Insecticidal effects of *Euphorbia ingens* latex against *Oryzaephilus surinamensis* using dipping and residual contact methods.

Sample no	Concentration (%)	No of tested adults <i>O. surinamensis</i>	<i>Euphorbia ingens</i>	
			Dipping method Mortality %	Contact residual method Mortality %
0	0	20	0	0
1	2	20	45	35
2	4	20	55	55
3	6	20	85	65
4	8	20	90	75
5	10	20	100	80

The LC₅₀ values of *E. ingens* latex against *O. surinamensis* were determined at 2.67 and 3.39% (v/v) using dipping and contact residual methods, respectively. The corresponding standard errors were 2.67 ± 0.729% and 3.39 ±

1.460% (v/v), respectively. Furthermore, the 95% confidence intervals ranged from 1.941 to 3.399 for the dipping method, whereas for the contact residual method, they ranged from 1.9 to 4.82 against the saw-toothed beetle (Table 3).

Table 3. Insecticidal effects of *Euphorbia ingens* latex against *Oryzaephilus surinamensis* using dipping and residual contact methods in terms of LC₅₀, Standard error of LC₅₀ values, and 95% confidence interval.

Method type	LC ₅₀	Standard error of LC ₅₀	Confidence interval
Direct application method	2.67	2.67±0.729	1.941-3.399
Contact (residual) assay method	3.39	3.39 ± 1.460	1.9-4.82

The results of the current study revealed that *E. ingens* latex has a repellent effect against *O. surinamensis*. The repellency effect of *E. ingens* latex against *O. surinamensis* increased with increasing exposure time and concentration. The repellency percentage at an exposure time of 3 hr ranged from 15.00 ± 5.77% at 15% concentration to 76.67 ± 8.82% at 85%. At 6 hr, the repellent activity further increased, ranging

from the 20.00±5.77% to 83.33±8.82% across the same concentrations. Furthermore, the findings show a clear dose-dependent effect, with higher concentrations exhibiting greater repellent activity than lower concentrations (p<0.05). The lowest and highest repellent activities at exposure times of 3 and 6 hours were observed at concentrations of 15% and 85%, respectively (Table 4).

Table 4. Repellent activity of *Euphorbia ingens* latex against *Oryzaephilus surinamensis*.

Con (v/v %)	3 hr PR(%) (Mean± SE)	6 hr PR(%) (Mean± SE)
15	15.00 ± 5.77a	20.00±5.77a
25	43.33 ± 8.82b	53.33±8.82b
60	53.33± 8.82c	63.33±8.82c
85	76.67±8.82d	83.33±8.82d

*Means in column followed by different letters (a-d) are significantly different at ($p < 0.05$, Tukey's test)

DISCUSSION

The results of the current study revealed that the latex of *E. ingens* possesses alkaloids and terpenoids. These findings align with previous studies reporting the presence of these compounds in this plant. For instance, Mathole and King (2025) reported on the presence of alkaloids and terpenoids within the latex of *E. ingens*. Another study by Okpako et al. (2023) identified terpenoids in methanolic root extracts of *E. ingens*. Despite these reports, an extensive literature review reveals limited information on quantitative estimates of these compounds in the latex of *E. ingens*. Therefore, the findings of the present study are the first to report on the assessment of total alkaloids and terpenoids in *E. ingens* latex, estimated at 372.64 ± 80.76 mg atropine g^{-1} and 36.09 ± 1.08 mg linalool g^{-1} , respectively.

The current study also documents the insecticidal activity of *E. ingens* latex against the storage insect pest *O. surinamensis*. Based on an extensive literature investigation, our findings are the first to report on the mortality effects of *E. ingens* against *O. surinamensis*. The latex exhibited LC_{50} values of 2.67% (v/v) and 3.39% (v/v) against *O. surinamensis* using the dipping and contact residual methods, respectively. *O. surinamensis* exhibited greater susceptibility to the dipping method as compared to the contact residual method, as indicated by the significantly lower LC_{50} value obtained in the assay. The observed discrepancy suggests that the dipping method enhances toxicity, likely due to direct, more uniform exposure of insects to the active compounds, in contrast to the contact residual method, which is indirect and associated with volatilization.

Furthermore, our findings are consistent with previous studies reporting insecticidal properties against storage insect pests exhibited by plants of the genus *Euphorbia*. A study by Diniz et al. (2014), for instance, revealed that *Euphorbia heterophylla* has insecticidal properties against *Sitophilus zeamais*. The plant induced 17.5% mortality against *S. zeamais* using the residual contact assay. Similarly, Imene and Naama (2021) reported that the latex of *Euphorbia bupleuroides* exhibited insecticidal properties against *Tribolium castaneum* and *Trogoderma granarium*, with LC_{50} values of 14.2 μ l and 14.7 μ l, respectively, when applied topically. The activity of *E. ingens* in this study suggests comparable bioefficacy, further substantiating the insecticidal potential of the genus *Euphorbia*.

In addition to its toxic effects, *E. ingens* latex also exhibited repellent properties against *O. surinamensis*. The latex of the plant at a concentration of 85% (v/v) exhibited the highest repellent activity of 76.67 ± 8.82 and $83.33 \pm 8.82\%$ against the saw-toothed beetle at 3 and 6 hr intervals, respectively. The significant increase in repellency over time suggests a time-dependent behavioral response, in which prolonged exposure periods enhance the beetles' ability to detect and avoid treated areas.

These findings corroborate scientific studies reporting the repellent and feeding-deterrent properties of plants in the genus *Euphorbia*. A study by Geng et al. (2011) investigated the feeding deterrent properties of *Euphorbia fischeriana* against *T. castaneum* and *Sitophilus zeamais*. The authors revealed that the *E. fischeriana* has anti-feeding properties against the two storage insect pests. Another study by Suleiman et al. (2018) also revealed that *Euphorbia balsamifera* has repellent properties

against *S. zeamais*. The authors report that the powder and solvent extracts of *E. balsamifera* exhibited repellent properties against the weevil, with methanol extracts achieving the highest repellency, $82.22 \pm 2.22\%$, at a concentration of 10.0×10^{-4} ppm.

Lastly, the presence of alkaloids and terpenoids in the latex of *E. ingens* may underscore its insecticidal and repellent properties against *O. surinamensis*. These classes of phytochemicals are associated with insecticidal and repellent properties against various pest insects (War et al., 2012). In addition, these biological activities may be attributed to the inherent properties of plant latex, which enables direct contact with insects and comprises a complex mixture of bioactive phytochemical constituents.

CONCLUSIONS

The results of the current study provide evidence that *E. ingens* has alkaloid and terpenoid compounds. Additionally, the study also documents insecticidal and repellent properties of the species against *O. surinamensis*. Therefore, it can be concluded that the plant has the potential to be a source of alkaloid and terpenoid compounds in phytochemical studies and can also be explored for its pharmaceutical and medicinal applications. Furthermore, *E. ingens* latex can be explored as a potential insecticidal agent against *O. surinamensis*, provided it is evaluated for mammalian toxicity, environmental persistence, and biodegradability.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Department of Biology and Environmental Sciences and Sefako Makgatho Health Sciences University for their facilities and resources that made this research possible.

REFERENCES

- Abbott, W.S. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economy and Entomology*, 18(2):265–267.
- Adesina, J.M. & Aderibigbe, A.T.B. (2021). Seed preservatives properties of *Secamone afzelii* (Schult) K. Schum extracts on wheat grains damage and germination capability—*Bulletin of the National Research Center*, 45(1):52.
- Amtaghri, S., Akdad, M., Slaoui, M. & Eddouks, M. (2022). Traditional uses, pharmacological, and phytochemical studies of *Euphorbia*: A review. *Current Topics in Medicinal Chemistry*, 22(19):1553–1570.
- Araújo, M.F., Castanheira, E.M. & Sousa, S.F. (2023). The buzz on insecticides: a review of uses, molecular structures, targets, adverse effects, and alternatives. *Molecules*, 28(8):3641.
- Dar, S.A., Rather, B.A., Wani, A.R. & Ganie, M.A. (2017). Resistance against insect pests by plant phenolics and their derivative compounds. *Chemical Science Review Letters*, 6(22): 1073–1081.
- Demis, E. & Yenewa, W. (2022). Review on major storage insect pests of cereals and pulses. *Asian Journal of Advances in Research*, 5(1):41–56.
- Diniz, J.F.S., da Silva, P.R., dos Reis, M.R., Endo, R.T., Ramos, R.S., Fernandes, F.L. & da Silva, Í.W. (2014). Insecticide activity of weeds on pests of stored products and crops. *Journal of Agricultural Science*, 6(7):194.
- Finney, D.J. & Stevens, W.L. (1948). A table for the calculation of working probits and weights in probit analysis. *Biometrika*, 35(1/2):191–201.
- Geng, Z.F., Liu, Z.L., Wang, C.F., Liu, Q.Z., Shen, S.M., Liu, Z.M., Du, S.S., & Deng, Z.W. (2011). Feeding deterrents against two grain storage insects from *Euphorbia fischeriana*. *Molecules*, 16(1):466–476.
- Gill, H.K. & Garg, H. (2014). Pesticide: environmental impacts and management strategies. *Pesticides-toxic aspects*, 8(187):10–5772.
- Hubert, J., Stejskal, V., Athanassiou, C.G. & Throne, J.E. (2018). Health hazards

associated with arthropod infestation of stored products. *Annual review of entomology*, 63: 553-573.

- Imene, B.R.I.K. and Naama, F.R.A.H. (2021). *Euphorbia bupleuroides* Desf. latex as biopesticide against the red flour beetle (*Tribolium castaneum* [Herbst, 1797]) and khapra beetle (*Trogoderma granarium* Everts, 1898). *Acta agriculturae Slovenica*, 117(2):1-6.
- Iwuagwu, M.O., Etusim, P.E., Emmanuel, N.C., Igwe, J.C., Nwaugo, V.O. & Onyeagba, R.A. (2020). Exploitation of plant herbs in the control of disease vectors: A review. *Pharmaceutical and Biosciences Journal*, ():07-21.
- Jaikishun, S., Ansari, A.A., Maldonado, D., Guerra, F., Subramanian, G., Kurup, R. & Ansari, M.K.A. (2023). Medicinal Characterization and Phytochemical Constituents of Selected Native Plants of Guyana, South America: A Review. *Plants As Medicine and Aromatics*, ():1-12.
- Jian, F., Larson, R., Jayas, D.S. & White, N.D. (2012). Three-dimensional temporal and spatial distribution of adult *Oryzaephilus surinamensis* and *Sitophilus oryzae* in stored wheat under different temperatures, moisture contents, and adult densities. *Journal of Stored Products Research*, 49:155-165.
- Koffi, E., Sea, T., Dodehe, Y. & Soro, S. (2010). Effect of solvent type on the extraction of polyphenols from twenty-three Ivorian plants. *Journal of Animal and Plant Sciences*, 5(3): 550-558.
- Kumar, A., Arya, S., Deoli, S., Joshi, M., Kumar, R., Kumar, R.R., Rawat, D.S. & Prakash, O. (2026). A holistic review on phytochemical insights with ethnomedicinal and insecticidal applications of *Xanthium strumarium* L. *Discover Chemistry*, 3(1):9.
- Kumar, R. (2017). *Insect pests of stored grain: Biology, behavior, and management strategies*. Apple Academic Press.
- Kuppusamy, E., Dhamodharan, K. & Jayakumar, S. (2016). Role of plants and plant-based products towards the control of insect pests and vectors: A novel review. *Journal of Coastal Life Medicine*, 4(11): 902-917.
- Lebelo, K., Malebo, N., Mochane, M.J. & Masinde, M. (2021). Chemical contamination pathways and the food safety implications along the various stages of food production: a review. *International journal of environmental research and public health*, 18(11): 5795.
- Madhu, M., Sailaja, V., Satyadev, T. & Satyanarayana, M.V. (2016). Quantitative phytochemical analysis of selected medicinal plant species by using various organic solvents. *Journal of Pharmacognosy and Phytochemistry*, 5(2):25-29.
- Mashaba, K.S., King, P.H. & Mathole, C.M. (2025). Insecticidal Properties of *Euphorbia tirucalli* Latex against Selected Household Pests (*Blattella germanica*, *Periplaneta americana*, and *Acheta domesticus*) under Laboratory Settings. *Egyptian Academic Journal of Biological Sciences, F. Toxicology & Pest Control*, 17(2):179-190.
- Mathole, C.M. & King, P.H. (2026). Insecticidal Effects of *Plectranthus ornatus* and *Asparagus larycinus* against *Tribolium castaneum* and *Oryzaephilus surinamensis* under Laboratory Settings. *Egyptian Academic Journal of Biological Sciences, F. Toxicology & Pest Control*, 18(1):31-40.
- Mathole, M. & King, P. (2025). Investigating insecticidal properties of *Euphorbia ingens* (E. Mey. Ex Boiss, 1862) latex against common household cockroach pests, namely *Blattella germanica* (Linnaeus, 1767) and *Periplaneta americana* (Linnaeus, 1758), under laboratory settings. *Entomology Beginners*, 6: e095-e095.

- Mutalov, A., Kalandarov, P., Kannazarova, Z., Gazieva, R. & Shavazov, K. (2025). Comprehensive strategies for managing stored grains: Tackling insect infestation and quality loss: A review. *Journal of Stored Products Research*, 112:102624.
- Ngegba, P.M., Cui, G., Khalid, M.Z. & Zhong, G. (2022). Use of botanical pesticides in agriculture as an alternative to synthetic pesticides. *Agriculture*, 12(5): 600.
- Nikolaou, P., Marciniak, P., Adamski, Z. & Ntalli, N. (2021). Controlling stored products' pests with plant secondary metabolites: A review. *Agriculture*, 11(9): 879.
- Okpako, I.O., Kyama, M.C. & Njeru, S.N. (2023). Phytochemical screening and gas chromatography-mass spectrometry analysis of *Euphorbia ingens* organic root extract. *Journal of Medicinal Plants Research*, 17(3):100-105.
- Phillips, T.W. & Throne, J.E. (2010). Biorational approaches to managing stored-product insects. *Annual review of entomology*, 55(1):375-397.
- Quintero, H., Quintero Cortes, J., Plata-Rueda, A. and Martínez, L.C., (2025). Azadirachtin-mediated responses in the maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae). *Insects*, 16 (3):294.
- Sarailoo, M., Afshari, S., Asghariazar, V., Safarzadeh, E. & Dadkhah, M. (2022). Cognitive impairment and neurodegenerative diseases development associated with organophosphate pesticide exposure: a review study. *Neurotoxicity Research*, 40(5):1624-1643.
- Sieglwart, M., Graillot, B., Blachere Lopez, C., Besse, S., Bardin, M., Nicot, P.C. & Lopez-Ferber, M. (2015). Resistance to bio-insecticides or how to enhance their sustainability: a review. *Frontiers in Plant Science*, 6:381.
- Souto, A.L., Sylvestre, M., Tölke, E.D., Tavares, J.F., Barbosa-Filho, J.M. & Cebrián-Torrejón, G. (2021). Plant-derived pesticides as an alternative to pest management and sustainable agricultural production: Prospects, applications, and challenges. *Molecules*, 26(16):4835.
- Suleiman, M., Rugumamu, C.P. & Ibrahim, N.D. (2018). Repellency potential of some botanicals against the maize weevil, *Sitophilus zeamais* (Motschulsky, 1855)(Coleoptera: Curculionidae) in stored sorghum. *Polish Journal of Entomology*, 87(1):85.
- Thavara, U., Tawatsin, A., Bhakdeenuan, P., Wongsinkongman, P., Boonruad, T., Bansiddhi, J., Chavalittumrong, P., Komalamisra, N., Siriyasatien, P., & Mulla, M.S. (2007). Repellent activity of essential oils against cockroaches (Dictyoptera: Blattidae, Blattellidae, and Blaberidae) in Thailand. *Southeast Asian J Trop Med Public Health*, 38(4):663-673.
- Tudi, M., Li, H., Li, H., Wang, L., Lyu, J., Yang, L., Tong, S., Yu, Q.J., Ruan, H.D., Atabila, A. & Phung, D.T. (2022). Exposure routes and health risks associated with pesticide application. *Toxics*, 10(6):335.
- War, A.R., Paulraj, M.G., Ahmad, T., Buhroo, A.A., Hussain, B., Ignacimuthu, S. & Sharma, H.C. (2012). Mechanisms of plant defense against insect herbivores. *Plant signaling & behavior*, 7(10):1306-1320.