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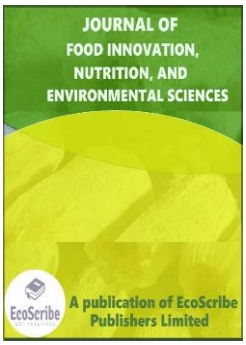

ORIGINAL RESEARCH ARTICLE

Chemical Composition and Insecticidal Activity of Ethanol Extracts of Clove Seed, Onion Peels and Bay Leaf on Adult ***Prostephanus truncatus*** of Stored Maize

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ABSTRACT

Prostephanus truncatus poses a significant threat to global food security, particularly in stored maize and cassava, due to substantial postharvest losses. Botanical insecticides offer a sustainable and environmentally protective option for stored products. This study investigated the chemical composition and insecticidal efficacy of ethanolic extracts from clove seed (*Syzygium aromaticum*), onion peel (*Allium cepa*), and bay leaf (*Laurus nobilis*) against adult *P. truncatus* infesting stored maize. Ethanolic extracts were prepared from clove seed, onion peels, and bay leaves. Their chemical compositions were characterized using GC-MS. Insecticidal activity was evaluated by assessing adult mortality, seed damage, and F1 progeny emergence in *P. truncatus* exposed to varying concentrations (5%, 10%, 15%) of the extracts over 96 hours. A synthetic insecticide (DDVP) served as a standard control. All extracts demonstrated concentration and exposure time dependent insecticidal effect. *Syzygium aromaticum* and *Allium cepa* showed strong insecticidal effects, achieving 100% mortality at 15% concentration within 72 hours, comparable to the synthetic standard. GC-MS analysis revealed high concentrations of phenolic compounds (e.g., Phenol-2-methoxy-3-(propenyl), Phenol, 2-methoxy-4-(2-propenyl)-, acetate) and terpenes (Caryophyllene) in *S. aromaticum* and Catechol and Ethyl alpha-d-glucopyranoside as major constituents in *Allium cepa*. *Laurus nobilis* demonstrated lower, but notable, insecticidal activity, with Andrographolide and Eucalyptol as primary compounds. *S. aromaticum* significantly reduced seed damage and suppressed F1 progeny emergence, proving most effective in protecting stored maize. These findings revealed the potential of these plant-based alternatives for developing sustainable and environmentally friendly strategies to manage stored product pests, thereby reducing reliance on synthetic chemicals and enhancing food security.

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1. INTRODUCTION

Prostephanus truncatus (Horn), commonly known as the Larger Grain Borer (LGB), is a highly destructive primary pest of stored maize (*Zea mays* L.) and dried cassava, particularly in tropical and subtropical regions (CABI Compendium, 2023; Hodges, 1986). Originating from Meso-America, this beetle has rapidly spread globally, becoming a significant threat to food security, especially in Africa where it causes substantial post-harvest losses (Quellhorst *et al*., 2021; Muatinte *et al*., 2014). Infestations by *P. truncatus* can lead to severe damage, with reports indicating up to 40% loss of stored maize within just three months if left uncontrolled (Boxall, 2002). The economic impact on smallholder farmers, who rely heavily on stored grain for sustenance and income, is particularly devastating.

Traditional pest management strategies for *P. truncatus* often involve the application of synthetic chemical insecticides, either as dusts mixed with grain or as residual sprays in storage structures (Quellhorst *et al*., 2021; Muatinte *et al*., 2019). While effective in the short term, the widespread and continuous use of these synthetic pesticides raises significant concerns regarding environmental contamination, human health risks due to residues in food, and the development of insecticide resistance in pest populations (Panagiotakis *et al*., 2023; Ngegba *et al*., 2022). The emergence of resistance to commonly used insecticides, coupled with increasing consumer demand for pesticide-free food products, necessitates the exploration of safer, more sustainable, and environmentally benign alternatives for stored grain protection (Isman, 2006).

Botanical insecticides, derived from plants, offer a promising alternative to synthetic chemicals due to their diverse modes of action, biodegradability, and lower environmental persistence (Regnault-Roger *et al*., 2012). Many plant species produce secondary metabolites that possess insecticidal, repellent, antifeedant, or growth-inhibitory properties against various insect pests (Kumar, 2025). The use of plant-based products for pest control aligns with integrated pest management (IPM) strategies, promoting ecological balance and reducing reliance on hazardous chemicals.

Among the numerous plants with documented insecticidal potential, clove (*Syzygium aromaticum L.*), onion peel (*Allium cepa L.*), and bay leaf (*Laurus nobilis L.*) are of particular interest. These plants are widely available, possess distinct aromatic compounds, and have been traditionally recognized for their medicinal and preservative properties. Previous research has identified various bioactive compounds in these plants, such as eugenol in clove (Yan *et al*., 2002), quercetin in onion (Joković *et al.,* 2024), and 1,8-cineole in bay leaf (Chintalchere *et al.,* 2020), which are known to exhibit biological activities, including insecticidal effects against a range of pests. However, specific studies focusing on the ethanol extracts of clove seed, onion peels, and bay leaf, and their direct efficacy against *Prostephanus truncatus* on stored maize, are less comprehensively documented.

This study aimed to characterize the major chemical constituents present in the ethanol extracts of clove seed, onion peels, and bay leaf, and to evaluate their insecticidal efficacy against adult *P. truncatus* under laboratory conditions, thereby assessing their potential as sustainable and effective biopesticides for the protection of stored maize.

This study seeks to provide scientific evidence supporting the use of these botanical resources as viable alternatives for managing *P. truncatus*, thereby contributing to enhanced food security and reduced reliance on synthetic pesticides in post-harvest maize storage.

2. MATERIALS AND METHODS

2.1 Study site and conditions

The study was conducted in the Entomology Laboratory, Nigerian Stored Products Research Institute, Ibadan Zonal office, at 27 ± 2 °C and 70 ± 5% RH under dark conditions (decreasing the light that penetrated through the windows) to simulate stored-grain environments (FAO, 2018).

2.2 Test insect colony

A laboratory colony of *Prostephanus truncatus* (Horn) was maintained on clean maize (*Zea mays* L.) in glass jars and reared at the above conditions. Mixed-sex adults aged 1–2 weeks were used for bioassays (Tapondjou *et al*., 2002).

2.3 Plant material and crude extraction

Dried clove (*Syzygium aromaticum*) seeds, onion (*Allium cepa*) outer peels, and bay (*Laurus nobilis*) leaves were sourced from Bodija market, Ibadan, cleaned and air-dried. The plants were identified taxonomically and authenticated in the Plant Sciences Department of University of Ibadan, Oyo State. Materials were milled to fine powder. Crude ethanol extracts were prepared by macerating 50 g of each powdered material in 500 mL of 70% ethanol (1:10 w/v) for 72 h with intermittent shaking, then filtered (Whatman No.1) and concentrated under reduced pressure at 40 °C using a rotary evaporator to yield crude extracts, the plant extracts were kept in a well-tight sterile bottle/container under refrigerated conditions until use (Adedire *et al*., 2011; Keita *et al*., 2001).

2.4 Grain preparation and application rate

The untreated maize grains were obtained from Bodija market, Ibadan. Maize grains were disinfested (using freezing) and cooled to room temperature (FAO, 2018). Twenty grams (20 g) of maize were placed into 250 mL plastic jars. Each jar assigned to a treatment appropriate concentration of 5%, 10%, and 15% (w/v), 0.2, 0.4 and 0.6mL respectively, was evenly sprayed onto the 20 g grain and mixed manually for uniform coating; treated

samples were air-dried for 1 h to allow solvent evaporation. Untreated control: no solvent or extract applied and a standard control (DDVP 1000G/L, EC) with the recommended rate of 0.5ml.

2.5 Bioassay design

Treatments: clove extract, onion peel extract, bay leaf extract at 5%, 10% and 15% (w/v). Each treatment × concentration combination was replicated three times in a Completely Randomized Design (CRD). Twenty (20) adult *P. truncatus* (1–2 weeks old, mixed sex) were introduced into each jar immediately after drying. Jars were sealed with Silveira lin cloth to permit ventilation.

Observations and measured parameters

- Adult mortality: recorded at 24 h, 48 h, 72 h, and 96 h post-treatment. Insects were probed gently; lack of movement indicated death (Ileke and Oni, 2011)

$$\%Mortality = \frac{Number\ of\ dead\ insects}{Total\ number\ of\ insects} * 100$$

- Progeny (F_1) emergence: assessed 30 days after initial infestation by counting emerged adults.

- Grain damage: determined by sorting the grains into holed and whole grain. The percentage is determined using the formula,

$$\%\ Seed\ damage = \frac{Number\ of\ holed\ grains}{Total\ number\ of\ counted\ grains} * 100$$

2.6 Phytochemical screening and GC-MS analysis

The phytochemical constituents of the plant extract were determined following the official methods described by the Association of Official Analytical Chemists, as described by Njoku and Obi (2009). Standard procedures were employed to quantitatively assess the presence of key bioactive compounds such as alkaloids, flavonoids, saponins, tannins, and phenolics. All analyses were performed in triplicates.

For chemical profiling, aliquots of each crude extract were subjected to GC-MS analysis (Agilent 7890A GC coupled to 5975C MSD) on an HP-5MS column (30 m × 0.25 mm × 0.25 µm). Oven program: 50 °C (2 min), ramp 10 °C/min to 250 °C (hold 10 min); helium carrier gas at 1 mL/min. Compounds were identified by matching spectra with the NIST library (Keita *et al*., 2001).

2.7 Data analysis

Experimental data (mortality, seed damage and F1 progeny) were analyzed using ANOVA and it was performed using SPSS v26, and means separated by Turkey's HSD at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Phytochemical screening and GC-MS of plant extracts

Phytochemical screening of the ethanol extracts revealed the presence of multiple bioactive classes **(Table 1).** The clove seed extract tested positive for alkaloids, flavonoids, steroids, terpenoids, phenolic compounds, tannins, glycosides including saponins and coumarin glycosides, along with proteins and carbohydrates. Volatile oils and anthraquinones were absent in this extract. The onion peel extract showed abundant phenols, flavonoids especially quercetin derivatives such as quercetin 3, 4′-diglucoside and quercetin 4′-monoglucoside saponins, tannins, carbohydrates, steroids, and reducing sugars. The bay leaf extract similarly contained alkaloids, flavonoids, phenols, terpenoids, glycosides, steroids, saponins, tannins, and carbohydrates. This broad phytochemical diversity suggests multifunctional bioactivities such as antioxidant, antimicrobial, and anti-inflammatory effects (Idu *et al.,* 2021; Momoh *et al*., 2022).

Table 2 shows Chemical composition of the ethanol extracts of three botanicals (clove seed, onion peel and bay leaf). Gas Chromatography-Mass Spectrometry (GC-MS) analysis of the Clove (*Syzygium aromaticum*) seed extract revealed Phenol-2-methoxy-3-(propenyl) (30.05%), Caryophyllene (22.14%), and Phenol, 2-methoxy-4-(2-propenyl)-, acetate (25.21%) as major components. Other significant compounds include Estragole (13.55%). The high concentration of these phenolic compounds and terpenes, particularly eugenol derivatives isoeugenol (implied by Phenol-2-methoxy-3-(propenyl) and eugenol acetate (Phenol, 2-methoxy-4-(2-propenyl)-, acetate) **(Table 2)**, is well-known for its insecticidal properties often acting through membrane disruption and enzyme inhibition, and likely contributes to the observed high efficacy of *S. aromaticum* (Zeng *et al*., 2010). Ho *et al*. (1994) highlighted the promising results of clove against stored product beetles.

The GC-MS analysis of the onion (*Allium sepa*) peel extract revealed several key compounds, with Catechol (21.95%), Ethyl alpha-d-glucopyranoside (18.18%), and beta-D-Glucopyranoside, methyl (8.60%) being the most abundant. Other notable compounds include dl-alpha-Tocopherol (3.34%) and 2, 2′-Ethylenediphenol (4.79%) (**Table 3**). The presence of these compounds, particularly phenolic compounds like Catechol and 2, 2′-Ethylenediphenol, may contribute to the observed insecticidal activity through mechanisms such as oxidative stress and disruption of cellular functions (Saha *et al*.,

2020; Idu *et al*., 2021). Research by Ogbonna *et al*. (2016) specifically investigated the bioefficacy of *Allium cepa* against *Prostephanus truncatus* infesting maize, showing its potential as a natural control agent. Other studies have also demonstrated the insecticidal activity of Allium sativum (garlic) against stored product pests (Nikolaou *et al*., 2021; Yang *et al.,* 2010). Importantly, although phytochemical screening indicated the presence of abundant quercetin derivatives (e.g., quercetin 3,4′-diglucoside and quercetin 4′-monoglucoside), these flavonoids were not detected in the GC-MS output. This discrepancy is attributed to the non-volatile and thermolabile nature of glycosylated flavonoids, which prevents their detection under GC-MS conditions without prior derivatization.

The GC-MS analysis of the bay (*Laurus nobilis*) leaf extract identified Andrographolide (53.07% and 1.15% across two peaks) (**Figure 3),** Aromadendrene oxide-(1) as the second most abundant peak (21.12%) and Eucalyptol (5.80%) as major components (**Table 4**). While Andrographolide is known for various biological activities, its direct insecticidal efficacy against *P. truncatus* might be less pronounced compared to the phenolic compounds found in *S. aromaticum* and *A. sepa*. Eucalyptol is a known insect repellent and fumigant, which could contribute to the observed effects (El Baghazaoui *et al*., 2024).

Table 1: The results of phytochemical screening of plant extracts

Phytochemical components	Clove Seed (*Syzygium aromaticum*)	Onion Peels (*Allium cepa*)	Bay Leaf (*Laurus nobilis)*
Alkaloids	P	A	P
Flavonoids	P	P	P
Steroids	P	P	P
Terpenoids	P	A	P
Phenols	P	P	P
Tannins	P	P	P
Glycosides	P (including saponins & coumarin glycosides)	P (saponins)	P (including saponins)
Proteins	P	A	A
Carbohydrates	P	P	P
Reducing Sugars	A	P	A
Volatile Oils	A	A	A

Note: P = Present A = Absent

Table 2. Chemical composition of the ethanol extract of *S. aromaticum* seed

Peak	R Time	Area	Area%	Height	Height %	A/H	Name
1	15.368	67885527	30.05	55821081	53.45	1.22	Phenol-2-methoxy-3-(propenyl
2	16.213	50016635	22.14	18221172	17.45	2.74	Caryophyllene
3	16.673	6607433	2.92	2511825	2.41	2.63	Humulene
4	17.204	56944742	25.21	19443764	18.62	2.93	Phenol, 2-methoxy-4-(2-propenyl)-, acetate
5	18.174	2008210	0.89	453949	0.43	4.42	2-Undecene, 9-methyl-, (Z)-
6	18.793	1700766	0.75	586573	0.56	2.90	Carpophyllene oxide
7	19.524	2393687	1.06	809783	0.78	2.96	2', 3', 4' Trimethoxyacetophenone
8	22.650	4701431	2.08	933657	0.89	5.04	Di-n-ocytl phthalate
9	22.782	30616849	13.55	5002125	4.79	6.12	Estragole
10	25.560	3050143	1.35	644267	0.62	4.73	Estragole
		225925423	100.00	104428756	100		

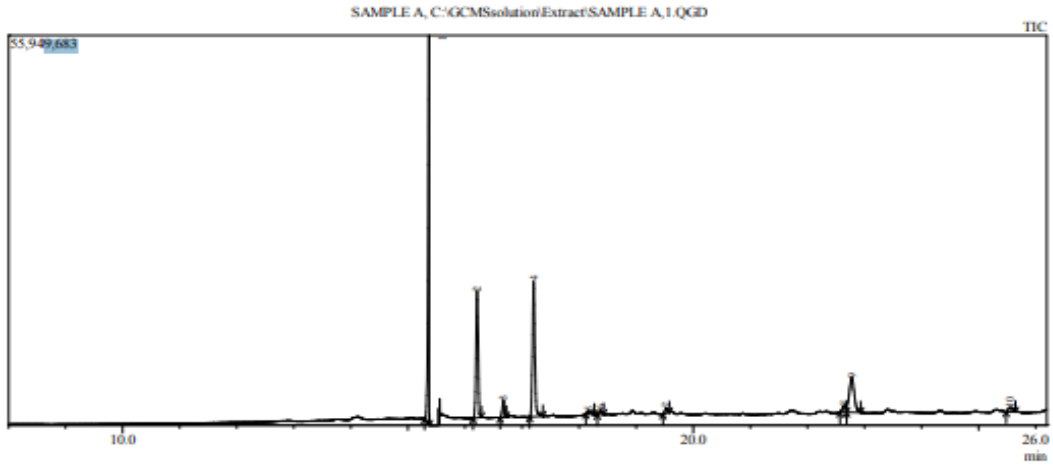

Fig. 1: GC-MS chromatogram of Clove seed ethanol extract

Table 3. Chemical composition of Onion peel ethanol extract

Peak	R Time	Area	Area%	Height	Height %	A/H	Name
1	11.236	2519497	0.93	607466	1.26	4.15	Decane, 2,3,5,8-tetramethyl
2	12.261	7793237	2.88	1606174	3.34	4.85	1-Butanol, 3-methyl-, acetate
3	13.311	59368768	21.95	7693036	15.99	7.72	Catechol
4	13.618	4307953	1.59	1203128	2.50	3.58	Phosphonic acid, methyl-, bis(trimethyl)
5	14.936	4685311	1.73	1327743	2.76	3.53	2-Methoxy-4-vinylphenol
6	15.361	2514064	0.93	755686	1.57	3.33	Phenol, 2-methoxy-3-(2-propenyl)-
7	16.301	4017704	1.49	1559217	3.24	2.58	3(2H)-Furanone, 2-hexyl-5-methyl
8	17.039	2452587	0.91	861829	1.79	2.85	3-Furanacetic acid, hexyl-2,5-dihydro-2
9	17.411	16508639	6.10	2596581	5.40	6.36	. beta-D-Glucopyranose, 1,6-anhydro
10	18.002	2415003	0.89	375172	0.78	6.44	2', 4'-Dimethoxyacetophenone
11	18.452	23253863	8.60	2925494	6.08	7.95	. beta-D-Glucopyranoside, methyl
12	18.586	5745936	2.12	1402912	2.92	4.10	3(2H)-Furanone, 5-methyl-2-octyl
13	18.938	49174155	18.18	5790007	12.04	8.49	Ethyl.alpha-d-glucopyranoside
14	19.170	5644042	2.09	831576	1.73	6.79	Ethanone, 1-(3,4,5-trimethoxyphenyl)-
15	19.277	9022147	3.34	1203845	2.50	7.49	dl-alpha-Tocopherol
16	20.077	10442741	3.86	2170923	4.51	4.81	Bis(tridecyl)phthalate
17	20.731	5866617	2.17	1113774	2.32	5.27	2,3-Dimethyl-8-oxo-non-2-enal
18	20.868	2626110	0.97	826212	1.72	3.18	1,2-Benzenedicarboxylic acid, bis(2-
19	21.131	6179913	2.28	2114492	4.40	2.92	Hexadecanoic acid, methyl esther
20	21.293	2184896	0.81	532361	1.11	4.10	Acetamide, N-(2-piperidin-4-ylethyl)-
21	21.623	3208759	1.19	967645	2.01	3.32	7,9-Di-tert-butyl-oxaspiro(4,5)deca-6
22	21.831	3915271	1.45	1313587	2.73	2.98	Hexadecanoic acid, ethyl ester
23	22.250	1700689	0.63	560610	1.17	3.03	Hexadecanoic acid, 2-oxo-, methyl
24	23.198	6298744	2.33	1762601	3.66	3.57	9-Octadecenoic acid (Z)-, methyl ester
25	23.145	3400292	1.26	729674	1.52	4.66	1-Allyl(dimethyl)silyloxymethyl-4-me
26	23.739	3082487	1.14	691945	1.44	4.45	N,N-bis (2-Trimethylsiloxyl) ethamine
27	23.839	4072728	1.51	1003848	2.09	4.06	4-Oxazolecarboxylic acid,
28	23.982	3532475	1.31	1018975	2.12	3.47	17-Octadecynoic acid
29	25.204	1634926	0.60	452677	0.94	3.61	Dimethylamine, N-(diisopropylpho
30	25.489	12945219	4.79	2097905	4.36	6.17	2,2'-Ethylenediphenol
		270514773	100.00	48097095	100.00		

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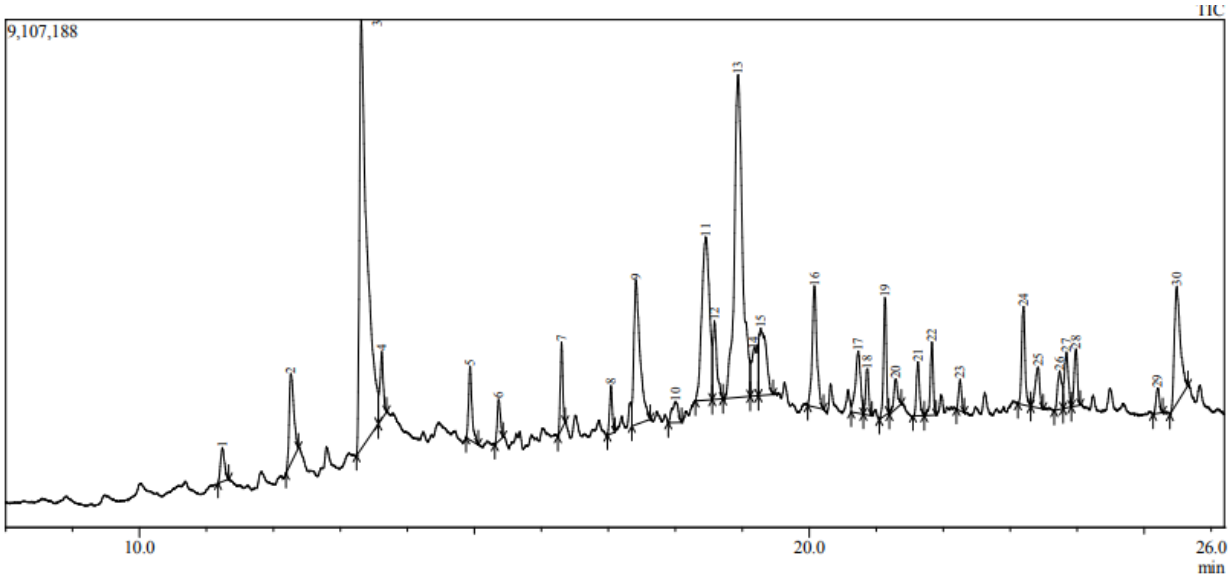

Fig.2: GC-MS chromatogram of Onion peel ethanol extract

Table 4. Chemical composition of Bay Leaf ethanol extract

Peak	R Time	Area	Area%	Height	Height%	A/H	Name
1	10.711	35636980	5.80	14792186	14.90	2.41	Ecalyptol
2	12.926	4197144	0.68	495863	0.50	8.46	3,3,6-Trimethyl-1
3	15.085	16466567	2.68	6387117	6.43	2.58	3-Cyclohexane-1-methanol
4	15.377	4177270	0.68	1301646	1.31	3.21	Phenol, 2-methoxy-3
5	16.282	2804372	0.46	857728	0.86	3.27	1-Methyl-4-(1-acetoxy-
6	16.731	6464488	1.05	1286914	1.30	5.02	1,3-Propanediol, 2-(hydr
7	17.203	5573564	0.91	1157341	1.17	4.82	.beta-Guaiene
8	18.072	129745163	21.12	22497401	22.66	5.77	Aromadendrene oxide-(1)
9	18.275	7059928	1.15	1593787	1.61	4.43	Andrographolide
10	19.017	326048948	53.07	37120679	37.39	8.78	Andrographolide
11	19.791	14950970	2.43	2268978	2.29	6.59	1,8-Cyclopentadecadiyne
12	20.686	4784821	0.78	1017147	1.02	4.71	2-methyltetracosane
13	21.194	38724071	6.30	5735767	5.78	6.75	Cedran-diol,)8S,14)-
14	21.626	3532963	0.58	645736	0.65	5.47	Pregnan-20-one, 3-hyroxy-
15	23.421	14234167	2.32	2115781	2.13	6.73	9-Butyltricyclo (4.2.1.1(2,5)
		614411416	100.00	99274071	100.00		

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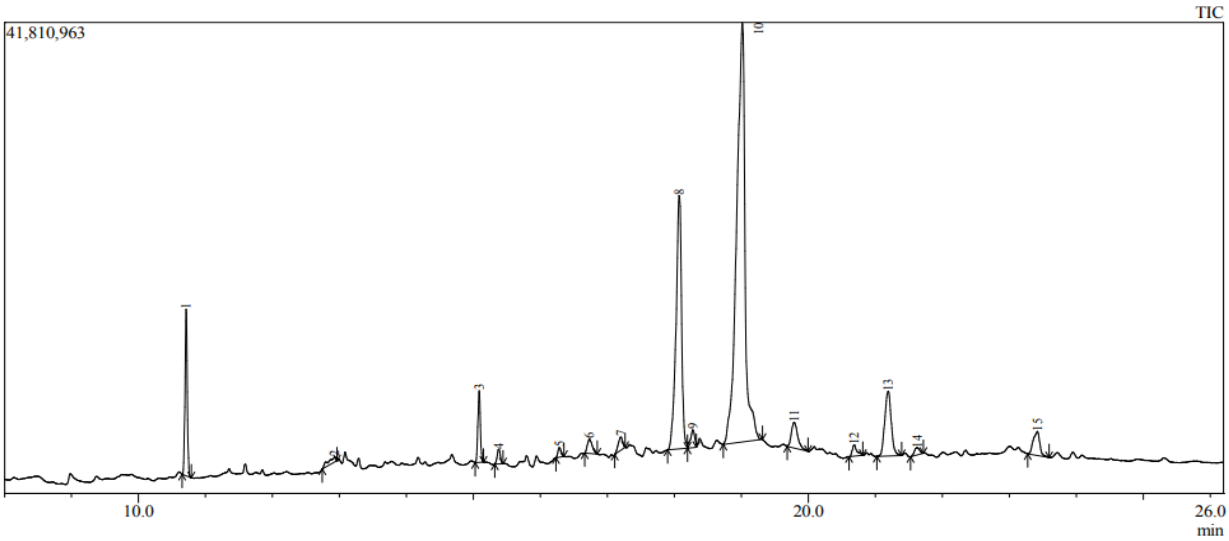

Fig. 3: GC-MS chromatogram of Bay ethanol extract

3.2 Effect of plant extracts on mortality of *Prostephanus truncatus*

The percentage mortality of *Prostephanus truncatus* exposed to ethanolic extracts of *Allium sepa, Syzygium aromaticum,* and *Laurus nobilis* at varying concentrations (5%, 10%, and 15%) and exposure times (24, 48, 72, and 96 hours) as shown in **Table 3**. The standard control (0.5ml DDVP) consistently achieved 100% mortality across all exposure times, while the untreated control (0.00%) showed negligible mortality, reaching only 3.33% after 96 hours. mortality increased with higher concentrations of the plant extracts and longer exposure times. At 5% concentration, *S. aromaticum* exhibited the highest mortality, reaching 86.67% after 96 hours, followed by *A. sepa* (73.33%). *L. nobilis* showed the lowest efficacy at this concentration, with only 36.67% mortality after 96 hours. Significant differences ($p<0.05$) were observed among the treatments at each exposure time. These findings are consistent with previous research highlighting the efficacy of botanical insecticides as sustainable alternatives to synthetic pesticides for stored product protection (Nikolaou *et al*., 2021; Dubey *et al.,* 2008).

At 10% concentration, *S. aromaticum* continued to demonstrate superior insecticidal activity, achieving 98.33% mortality after 96 hours. *A. sepa* also showed improved efficacy at this concentration, reaching 80.0% mortality. *L. nobilis* again had the lowest mortality, reaching 45.0% after 96 hours. Significant differences ($p<0.05$) were observed among the treatments at each exposure time. The highest concentration of 15% yielded the most significant results. Both *A. sepa* and *S. aromaticum* achieved 100% mortality after 72 hours and maintained it at 96 hours, indicating their potent insecticidal properties at higher concentrations. *L. nobilis* also showed a substantial increase in mortality at 15%, reaching 65.0% after 96 hours, though it remained less effective than the other two extracts. At 72 and 96 hours, *A. sepa* and *S. aromaticum* were not significantly different from the standard control ($p>0.05$), both achieving 100% mortality. These findings suggest a concentration and exposure time dependent insecticidal effect for all tested plant extracts against *P. truncatus*. This high efficacy aligns with numerous studies reporting the potent insecticidal properties of *S. aromaticum* (clove) essential oil and its main component, eugenol, against various stored product pests (Zeng *et al*. 2010; Wuttiwong *et al*., 2019; Ho *et al*., 1994)

Allium sepa also exhibited strong insecticidal effects, particularly at the 15% concentration, where it achieved 100% mortality after 72 hours. This supports existing literature on the insecticidal properties of *Allium species*. Research by Ogbonna *et al*. (2016) specifically investigated the bioefficacy of *Allium cepa* against *Prostephanus* truncatus infesting maize, showing its potential as a natural control agent. Other studies have also demonstrated the insecticidal activity of *Allium sativum* (garlic) against stored product pests (Nikolaou *et al*., 2021, Yang *et al*., 2010)

Laurus nobilis showed comparatively lower insecticidal activity, although its efficacy improved with increasing concentration and exposure time. While *L. nobilis* has been reported to possess insecticidal properties against various stored product pests (El Baghazaoui *et al*., 2024; Jemâa *et al*., 2012) its effectiveness in this study was not as pronounced as *S. aromaticum* or *A. sepa*. Jemâa *et al*. (2012) found that *Laurus nobilis* essential oils had insecticidal activities against *Rhyzopertha dominica* and *Tribolium confusum*, suggesting its potential as an insecticide and repellent. The variations in efficacy among the plant extracts could be attributed to differences in their chemical compositions and the concentration of active compounds responsible for insecticidal action (Isikber, 2006)

Table 3: Percentage mortality of *Prostephanus truncatus* exposed to ethanolic extracts of *Allium sepa* peel, *Syzygium aromaticum* seed and *Laurus nobilis* leaf at different concentrations and exposure times.

Concentration	Treatment	Exposure Time 24hrs	48hrs	72hrs	96hrs
5%	*A. sepa*	10.00±2.89^{de}	25.00±2.89^{f}	38.33±1.67^{d}	73.33±1.67^{cd}
	S. aromaticum	20.00±2.89^{cde}	36.67±1.67^{e}	61.67±1.67^{c}	86.67±1.67^{b}
	L. nobilis	3.33±3.33^{b}	1.67±1.67^{g}	21.67±1.67^{e}	36.67±8.00^{e}
10%	*A. sepa*	28.30±1.67^{cd}	55.00±2.89^{cd}	66.67±4.41^{c}	80.00±2.89^{bc}
	S. aromaticum	45.00±2.87^{c}	63.33±3.33^{c}	86.67±1.67^{b}	98.33±1.67^{a}
	L. nobilis	11.67±1.67^{de}	26.67±1.67^{f}	33.33±1.67^{d}	45.00±2.89^{e}
15%	*A. sepa*	91.67±16.4^{ab}	78.33±1.67^{b}	100.00±0.00^{a}	100.00±0.00^{a}
	S. aromaticum	70.00±5.0^{b}	91.67±4.41^{a}	100.00±0.00^{a}	100.00±0.00^{a}
	L. nobilis	25.00±2.87^{cde}	46.67±1.67^{d}	61.67±1.67^{c}	65.00±2.89^{d}
0.5	Standard	100.00±0.00^{a}	100.0±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}
0.00	Control	0.00±0.00^{e}	0.00±0.00^{g}	0.00±0.00^{f}	3.33±1.67^{e}

Means±SE (n=3). Means for each treatment in the same column with the same superscripts are not significantly different ($p<0.05$).

3.3 Effect of plant extracts on seed damage

The percentage seed damage after exposure to different concentrations of the plant extracts shown in **Table 4**. The control group (0.00%) showed high seed damage of 90.0±3.06%, indicating significant damage in the absence of treatment. The standard treatment (0.5ml DDVP) effectively minimized seed damage to 2.67±0.67%, demonstrating its high efficacy. The control group was significantly different from all other treatments ($p<0.05$). Among the plant extracts, *S. aromaticum* consistently showed the lowest seed damage across all concentrations. At 5%, *S. aromaticum* resulted in 22.67±1.33% seed damage, which was lower than *A. sepa* (28.67±2.40%) and significantly lower than *L. nobilis* (51.33±3.71%). Significant differences ($p<0.05$) were observed among the treatments at this concentration. At 10% concentration, *S. aromaticum* further reduced seed damage to 10.67±0.67%, while *A.* sepa showed 16.67±0.67%. *L. nobilis* at 10% resulted in 35.33±1.76% seed damage. Significant differences ($p<0.05$) were observed among the treatments. At 15% concentration, *S. aromaticum* achieved the lowest seed damage of 7.33±0.67%, which was not significantly different from the standard ($p<0.05$). *A. sepa* at 15% showed 15.3±0.67% damage, while *L. nobilis* resulted in 30.0±1.15% damage.

These results indicate that *S. aromaticum* is proving the most effective among the tested plant extracts in protecting seeds from *P. truncatus* damage, with its efficacy increasing with concentration. This aligns with the understanding that botanical insecticides can affect various physiological processes in insects, including reproduction and development (Regnault-Roger *et al*., 1994). *A sepa* also demonstrated a notable reduction in seed damage supporting its potential as a biopesticide. *L nobilis*, while less effective showed some protective effects against seed damage, particularly at higher concentrations. This suggests that even at lower insecticidal potency, it may contribute to pest management through repellent or anti-feedant properties, which can reduce damage and reproduction over time (Papanikolaou *et al*., 2022). The observed effects on seed damage are critical indicators of the overall protective capacity of these plant extracts in stored product environments.

Table 4: Effect of plant extracts at different concentrations on Seed Damage

Concentration	Treatment	Seed Damage (%)
5%	*A. sepa*	28.67±2.40^{cd}
	S. aromaticum	22.67±1.33^{de}
	L. nobilis	51.33±3.71^{b}
10%	*A. sepa*	16.67±0.67^{ef}
	S. aromaticum	10.67±0.67^{fg}
	L. nobilis	35.33±1.76^{c}
15%	*A. sepa*	15.3±0.67^{ef}
	S. aromaticum	7.33±0.67^{gh}
	L. nobilis	30.0±1.15^{cd}
0.5	DDVP	2.67±0.67^{h}
0.00	Control	90.0±3.06^{a}

Means±SE (n=3). Means for each treatment in the same column with the same superscripts are not significantly different ($p<0.05$).

3.4 Effect of plant extracts on F1 adults of *P. truncatus*

Table 5 showed the F1 progeny count of *P. truncatus* after 30 days of treatment with different concentrations of plant extracts. The control group (0.00%) exhibited a high F1 progeny count of 56.3±4.37, indicating significant reproduction in the absence of treatment. In contrast, the standard treatment (0.5ml DDVP) resulted in no F1 progeny (0.00±0.00), highlighting its complete proving effectiveness in suppressing reproduction. The control group was significantly different from all other treatments ($p<0.05$).

The F1 progeny count generally decreased with increasing concentration of the plant extracts. At 5% concentration, *S. aromaticum* had the lowest F1 progeny count (26.67±0.88), followed by *A. sepa* (42.33±0.67) and *L. nobilis* (43.0±1.15). Significant differences ($p<0.05$) were observed among the treatments. At 10% concentration, *S. aromaticum* reduced the F1 progeny count to 16.67±0.88, while *A. sepa* showed 31.33±1.20 progeny. *L. nobilis* had a progeny count of 42.67±0.88 at this concentration. Significant differences ($p<0.05$) were observed among the treatments. At the highest concentration of 15%, *S. aromaticum* was proving the most effective, reducing the F1 progeny count to 12.0±0.58, which was significantly lower than the other extracts. *A. sepa* at 15% had 19.67±1.33 progeny, and *L. nobilis* had 39.0±1.15 progeny.

These results confirm that *S. aromaticum* is proving the most effective among the tested plant extracts in suppressing the reproduction of *P. truncatus*, with its efficacy improving with increased concentration. This study showed that treatments with low F1 progeny are traced to those with high mortality and this is similar to previous research findings (Ibitoye *et al.*, 2025; Abdulbaki *et al.*, 2022).

Table 5: Effect of plant extracts at different concentrations on F1 adults of *P truncatus* after 30 days of treatment

Concentration	Treatment	F1 Progeny Count
	Allium sepa	42.33 ± 0.67^{cd}
5%	*S.aromaticum*	26.67 ± 0.88^{de}
	L. nobilis	43.0 ± 1.15^{b}
	Allium sepa	31.33 ± 1.20^{ef}
10%	*S.aromaticum*	16.67 ± 0.88^{fg}
	L. nobilis	42.67 ± 0.88^{c}
	Allium sepa	19.67 ± 1.33^{f}
15%	*S.aromaticum*	12.0 ± 0.58^{gh}
	L. nobilis	39.0 ± 1.15^{cd}
0.5	DDVP	0.00 ± 0.00^{h}
0.00	Control	56.3 ± 4.37^{a}

Means±SE (n=3). Means for each treatment in the same column with the same superscripts are not significantly different ($p<0.05$).

CONCLUSION

This study characterized the chemical compositions and evaluated the insecticidal efficacy of ethanolic extracts from *Syzygium aromaticum, Allium sepa,* and *Laurus nobilis* against *Prostephanus truncatus*. All extracts demonstrated concentration and exposure time dependent insecticidal effect, reduced seed damage, and suppressed F1 progeny. *Syzygium aromaticum* consistently exhibited the highest efficacy, comparable to the synthetic standard, and this may primarily associate to its rich phenolic and terpene content. *Allium sepa* also showed strong insecticidal properties, maybe associated with compounds like Catechol. While less potent, *Laurus nobilis* offered protective effects. These findings confirm the significant potential of these plant-derived extracts as effective, sustainable biopesticides for *P. truncatus* management in stored maize, offering viable alternatives to synthetic chemicals.

CONFLICT OF INTEREST

All authors declare that they do not have any conflicts of interest that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

The data used to support the findings of this study are available upon reasonable request from the corresponding author.

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