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RESEARCH PAPER

Field assessment of the potentials of some plant-derived insecticide against damage caused by *Leucinodes orbonalis* on eggplant (*Solanum gilo*) at Umudike, Nigeria

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ABSTRACT

The efficacy of plant-derived insecticides was compared with a synthetic insecticide, Lambda-cyhalothrin over two cropping seasons (2015 and 2016) against *Leucinodes orbonalis*, the eggplant fruit and shoot borer (EFSB) infesting eggplant, *Solanum gilo*. The plant materials included oil palm (*Elaeis guineensis*) bunch ash, soursop (*Annona muricata*) seeds, and goat weed (*Ageratum conyzoides*) leaves. These plant materials were formulated into aqueous extracts of 150 g/L (w/v), while Lambda-cyhalothrin was applied at the rate of 5 mL/L (v/v). The experimental design was a Randomized Complete Block Design (RCBD). There were 5 treatments with 3 replications applied on 2 cultivars of eggplants (*Afufa Ukwu* and *Ngwa Large*). Percentage fruit damage varied significantly ($P < 0.05$) with various treatments. The lowest mean percentage fruit damage was observed in the plot treated with Lambda-cyhalothrin (20.38%), followed by goat weed (29.03%), soursop (40.69%), palm bunch ash (43.30%) and the control (67.08%) for 2015 and 2016. Other parameters measured followed the same trend. Mean yield was significantly affected by the treatments. The highest mean yield was obtained from the plots treated with Lambda-cyhalothrin (12,346.6 g), followed by plots treated with goat weed (11,295.0 g), soursop (9877.2 g), palm bunch ash (8729.4 g) and control was the least (6583.0 g). Among the plant extracts, *A. conyzoides* that recorded low mean percentage damage had very high yield. Therefore, it can be used as insecticides in the control of EFSB.

Key words: eggplant, eggplant fruit and stem borer, insecticides, *Leucinodes orbonalis*, plant extracts

INTRODUCTION

Eggplant (*Solanum gilo*) (Family: Solanaceae) commonly called aubergine, brinjal or guinea squash in some parts of the world is an important crop thought to have originated from tropical Africa (PROTA, 2021). Eggplants are popular and important vegetable crop grown year round in most countries of Asia, The Pacific, Europe and Africa (Pugalendhi et al., 2010; Gautam et al., 2019; Nusra et al., 2020). In Nigeria, the crop is identified with many names amongst various ethnic groups; being called *Yalo* in the North, *Igbagba* in the Southwest and *Anara* or *Afufa* in the Southeast (Ebiringa, 2020). In Southeast Nigeria, immature fresh fruits are eaten raw, and used to welcome visitors into the family (PROTA, 2021). In most other African cultures however, fresh fruit and leaves of the crop serve as vegetables for making soups, porridge and salads (Davidson & Monulu, 2018). Ethno-medicinally, the roots, leaves and twigs of the plant are used for treating various diseases in most parts of Africa (Han et al., 2021).

One hundred grams of eggplant delivers 25 calories of energy, carbohydrates (6.0 g), protein (1.0 g), fat (0.2 g), sodium (2.0 mg), potassium (229 mg), magnesium (3%), vitamin C (3%) and B-vitamins (5%) (Shukilar & Nalk, 1993; USDA, 2021). Being low in calories (25 Cal/100 g) and fats (0.2 g/100 g), and high in potassium content (229 mg/100 g), studies have shown that eggplant could positively help with reduction of cardiac and liver problems, and to facilitate weight reduction (Oyebade, 2011). Hence, eggplant are suitable for diabetics, hypertensive and obese patients (Prabhu et al., 2009; Pugalendhi et al., 2010, Horna et al., 2007; Gopalan et al., 2007). In some studies in Africa, it was found that eggplant is anticholesterolomic, and protects from glaucoma (Igwe et al., 2003) due in part to certain vitamins and mineral salts thought to help in maintaining the functions of the heart and blood pressure (Oyebade, 2011). Some studies also have associated eggplants with anti-ulcerogenic properties (Chioma et al., 2011). Besides contributing to improved human nutrition, eggplant hold strong potentials to generate income for farmers (Alam

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et al., 2003).

However, the production of this nutrient-rich and healthful vegetable suffers many biotic challenges including diseases and insect pest pressures (Nyeko et al., 2014). *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) is the most serious and widely distributed insect pest of eggplants (Chakraborti & Sarkar, 2011; Ashadul et al., 2014; Nawaz et al., 2020). It occurs throughout the year and attacks the crop at all stages of its growth (Pugalendhi et al., 2010). Yield losses ranging up to 85–92% have been attributed to attacks of the pest (Patnaik, 2000; Misra, 2008; Jagginavar et al., 2009; Sahu et al., 2020). The larvae could infest eggplants throughout the crop's lifespan (Cork et al., 2001). In the affected crops, the larvae bore into the young shoots, petioles, midribs of large leaves, flowers buds, fruits, and feed on the internal tissues (Singh et al., 2006). The infested flower buds drop and fruits oozed with larval frass through the holes made on the plant, which later becomes portals to secondary fungal infections (Korycinska & Cannon, 2010).

Attempts at curbing this constraint have been done through intercropping with *Tagetes* sp., crop rotation, use of resistant cultivars (or GM varieties where available), bio-control agents, phytochemicals including pheromones, and frequent sprays of synthetic insecticides (Satpathy & Mishra, 2011; Ashadul et al., 2014; Gautam et al., 2019; Shelton et al., 2019; Goldel et al., 2020). However, intensive applications of insecticide are required for killing the larvae before they bore inside shoots or fruits. Once in the shoots or fruits, EFSB larvae are inaccessible to the killing action of surface-applied chemicals (Alam et al., 2003). Since neonate larvae can enter fruits or shoots within only a few hours of hatching from eggs, pesticides have to be applied frequently in order to have sufficient toxic residues on the plant surface enough to kill the crawling larvae to get effective control effects (Prodhan et al., 2018). Against the backdrop of heavy insecticide application on this crop, indiscriminate use of pesticides, however, has a number of undesirable side effects such as the emergence of resistant species of insects, environmental pollution, and food safety concerns (Goldel et al., 2020; Enyiukwu et al., 2021).

In order to alleviate growing public concerns regarding the effects of synthetic pesticides on environmental and human health, much scientific attention has been geared towards bio-pesticides in recent decades. Bio-pesticides are cheap and environmentally non-disruptive. Therefore, this study was undertaken to determine and compare the effects of plant-derived insecticides (*Annona muricata* seed, *Elais guineensis* bunch, *Ageratum conyzoides* leaves) with a synthetic insecticide (Lambda-cyhalothrin) on damage by *L. orbonalis* on two varieties of *S. gilo* grown at Umudike, Abia State Nigeria.

MATERIALS AND METHODS

Research Site. The study was conducted in the Michael Okpara, University of Agriculture Teaching and Research Farm Umudike. Umudike is located within the tropical rainforest area of the Southeast Agricultural zone of Nigeria and lies within the latitude 05º29'N and longitude 07º32'E with altitude of about 122 m above sea level. The site has an average annual rainfall of 2200 mm and temperature of 23 ºC minimum and 32 ºC maximum (Agro-meteorological station of National Root Crops Research Institute, Umudike, NRCRI). The trials were laid out during the rainy seasons of the years 2015 and 2016.

Soil Analysis. Analysis of the physical (percentage silt, clay, and sand, texture) and chemical (pH, organic carbon, organic matter, available P, total nitrogen, etc.) characteristics of the Research Farm was carried out at the Soil Science Laboratory of NRCRI, Umudike, using standard protocols as adopted by Ikeogu & Nwofia (2013).

Eggplant Cultivar. Two cultivars of eggplants (*S. gilo*) were used for the study; they are Var. *Afufa* Ukwu obtained from Agwu, Enugu State, and Var. *Ngwa Large* from Ngwa, Abia State, Nigeria.

Field Preparation, Layout and Crop Establishment. The experimental field measuring 28 × 16 m^2 was slashed and ridged by hoeing during the 2015 and 2016 planting season (April–October). Two week old seedlings of these varieties raised from a nursery nearby were transplanted onto the ridges, and moisture was maintained by a natural rain-fed system. The field was laid out in a randomized complete block design (RCBD) arranged in a split plot with 3 replications. There were 30 plots for the trials, each plot measuring 3.6 × 3.6 m. The ridges were planted with 24 stands of eggplant/plot with planting spacing pegged at 1.0 × 0.6 m. The distance between plots and across replicates was maintained at 1 m.

Crop Establishment and Treatment. Treatments formulated and used for the study were oil palm (*E. guineensis*) bunch ash, goat weed (*A. conyzoides*) leaf extract, soursop (*A. muricata*) seed extract at concentration of 150 g/L of water, and a synthetic insecticide (Lambda-cyhalothrin). The procedure for their preparation and concentration are given in Table 1. At 4 weeks after planting (WAP), the seedlings were spray-inoculated at sunset with aqueous formulations of the bio-insecticides and lambda-cyhalothrin; and repeat applications were carried out at flowering.

Data Collection. Data were collected once a week for six weeks in 2015 and 2016 trials on the population of *L. orbonalis* larvae per pod/10 stands, number of holes per pod/10 stands, weight of fruits per plant/plot, and number of fruits damaged/10 pods/10 stands/ plot which was calculated as:

$$FD\ (\%) = \frac{n}{N} \times 100\%$$

FD = fruit damage;
n = number of damage fruit;
N = total number of fruit sampled.

Data Analysis. Data obtained were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS version 9 (SAS, 2005).

Table 1. Treatment formulations and rates of application

Treatments	Formulation	Concentration
Palm bunch ash	150 g of palm bunch ash mixed in a litre of hot water and left for 12 hours and sieved to obtain a uniform solution	150 g/L
Annona muricata	150 g of *Annona muricata* crushed seed is mixed in a litre of hot water, left for 12 hours and further sieved to obtain an aqueous solution	150 g/L
Ageratum conyzoides	150 g of *Ageratum conyzoides* crushed leaves was soaked in a litre of hot water and left for 12 hours and sieved to obtain an aqueous solution	150 g/L
Lambda-cyhalothrin E.C.	5 mL	5 mL/L

Table 2. Physico-chemical properties of the experimental site before planting

Parameter	Years	
	2015	2016
Physical properties		
Sand (%)	67.80	64.80
Silt (%)	11.40	11.80
Clay (%)	20.80	23.40
Texture	Sandy clay loam	Sandy loam
Chemical properties		
pH (H_2O)	5.90	5.80
Organic carbon (%)	1.02	1.56
Organic matter (%)	1.76	2.68
Available phosphorus (cmol/kg)	39.60	68.20
Total nitrogen (%)	0.09	0.25
Exchangeable calcium (cmol/kg)	4.00	4.40
Exchangeable magnesium (cmol/kg)	1.60	1.20
Exchangeable potassium (cmol/kg)	0.12	0.19
Exchangeable sodium (cmol/kg)	0.35	0.21
Exchangeable acidity (cmol/kg)	1.12	1.20
Exchangeable CEC (cmol/kg)	7.19	7.20
Base saturation (%)	84.42	83.33

Separation of significant treatment means was carried out with the least significant difference (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Results presented in Table 3 showed the response of the two eggplant cultivars during the 2015 and 2016 cropping seasons to attacks of *L. orbonalis*. It indicated that the number of larvae/pod recorded on *Afufa Ukwu* and *Ngwa Large* were (0.40) and (0.44), respectively in 2015. In 2016, the mean number of larvae/pod in *Afufa Ukwu* and *Ngwa Large* was 0.39 apiece. Whereas the values of this variable occasioned by attacks of EFSB on the two varieties were statistically (P< 0.05) not at par in the first year, they were however at par in 2016 (Table 3). The mean number of tunnels per pod due to EFSB attacks recorded on *Ngwa Large* and *Afufa Ukwu* were 1.15 and 1.00, respectively in 2015; and 0.97 per pod irrespective of cultivar in 2016. Whereas the number of holes per pod observed on *Ngwa Large* variety differed significantly from those on *Afufa Ukwu*, the opposite was statistically (P< 0.05) the case in the 2016 cropping season (Table 3).

The results of the percentage of fruit damaged by EFSB, *L. orbonalis* on the test crop in 2015 and 2016 are presented in Table 3. The results showed that the pest-inflicted fruit profile was generally lower in 2015 than in 2016 for the two varieties. *Ngwa Large* had percentage damage of 38.28% while *Afufa Ukwu* had 39.67%. Similarly, 39.33% and 42.56% fruit damage were recorded respectively on the test cultivars in 2016. Though no significant (P> 0.05) difference was observed between the percentage of fruit damage on *Afufa Ukwu* and *Ngwa Large* due to infestation and activities of *L. orbonalis* in 2015, however, the damage observed on *Afufa Ukwu* was statistically superior to that recorded on *Ngwa Large* in 2016 cropping season.

Leucinodes orbonalis Guenee the eggplant fruit and shoot borer (EFSB) has been rated as a very serious pest of eggplant in eggplant growing regions of The Pacific, Asia and Africa (Ashadul et al., 2014; Prodhan et al., 2018; Nawaz et al., 2020). Screening for and use of resistant (or at least tolerant) varieties is adjudged one of the most important steps to pest management (Chukwu & Enyiukwu, 2021). Findings from this study indicated that *L. orbonalis* successfully attacked and sufficiently damaged both cultivars of eggplant. However, the damage was higher on the Vars. *Afufa Ukwu* than *Ngwa Large*. Data in Table 3, therefore suggest that Var. *Ngwa Large* is comparatively tolerant to infestation and onslaught by EFSB, *L. orbonalis* than Var. *Afufa Ukwu*.

Genetically influenced biochemical factors are reported to play immense roles in cultivar pest susceptibility or resistance. High contents of certain amino acids, ash, and reducing sugars encourage and promote susceptibility of a cultivar to insect attacks. Conversely, the high presence of certain enzymes such as peroxidases, polyphenol oxidase (PPO), phenyalanine ammonium lyase (PAL), silica, lignin and glyco-alkaloids strongly increase the resistance of a cultivar to pest onslaught (Khorsheduzzaman et al., 2010; Davidson & Monulu, 2018). Therefore the better performance of Var. *Ngwa Large* over *Afufa Ukwu* (Table 3) may have been due to higher presence of resistance-promoting compounds in it than in *Afufa Ukwu*. Findings in this study where *Ngwa Large* eggplant cultivar out-performed *Afufa Ukwu* in reducing the level of EFSB infestation and fruit damage is consistent with the report of Kassi et al. (2019) in which eggplant Var. Round Brinjal 86602 showed less susceptibility to infestation and tissue or fruit damage by *L. orbonalis* than Vars. Round White and Singhnath 656 in a trial.

The results of the mean number of larvae/pod on the eggplant treated with different plant-derived insecticides in 2015 and 2016 are presented in Table 4. The mean number of *L. orbonalis* larvae/pod varied significantly (P< 0.05) among the treatments. The mean number of larvae/pod amongst phyto-pesticides was significantly (P< 0.05) lowest in plots treated with goat weed (0.30), followed by *A. muricata* (0.40), and highest in plots exposed to palm bunch ash which had 0.41; though the later was not statically different from effects of *A. muricata*. On the other hand, Lambda-cyhalothrin had out-performed all the botanical treatments reducing the number of larvae per pod from 0.75 to 0.22. However, all the treatments were superior to the effects observed on the plants in the control experiments.

Regarding the mean number of holes on fruits of the eggplant treated with different plant-derived insecticides in 2015 and 2016, the observed entomotoxic effects varied significantly as presented in Table 4. The number of holes/pod recorded on the treated plants was statistically (P< 0.05) highest in the control (2.06), followed by those treated with Palm bunch ash (1.16), and then *A. muricata* (1.03) and goat weed (0.79) whereas 0.36 was recorded on Lambda-cyhalothrin treated plant in 2015 (Table 4). All the botanical insecticides reduced the number of holes per pod than the effects (2.06) recorded on plants in the control. The results of percentage damage to the eggplant (*S. gilo*) by EFSB, *L. orbonalis* after treatment with plant-derived insecticides in 2015 and 2016 are presented in Table

Table 3. Response of eggplant varieties *Afufa ukwu* and *Ngwa Large* (mean number of larvae/holes per pod and mean percentage fruit damage) to attacks by eggplant fruit and stem borer (EFSB) in 2015 and 2016 cropping seasons

Variety	Year		Mean	Year		Mean	Year		Mean
	2015	2016		2015	2016		2015	2016	
	Mean number of larvae/pod			Mean number of holes/pod			Mean percentage of fruit damage (%)		
Afufa ukwu	0.40	0.39	0.40	1.00	0.97	0.99	39.67	42.56	41.12
Ngwa Large	0.44	0.39	0.42	1.15	0.97	1.06	38.78	39.33	39.06
Mean	0.42	0.39		1.08	0.97		39.23	40.95	
	LSD $_{(0.05)}$ Mean number of larvae/pod = 0.02			LSD $_{(0.05)}$ Mean number of holes/pod = 0.08			LSD $_{(0.05)}$ Mean percentage damage = 2.01		
	LSD $_{(0.05)}$ Year × Variety = 0.25			LSD $_{(0.05)}$ Year × Variety = 0.14			LSD $_{(0.05)}$ Year × Variety = 3.89		

Table 4. Effects (mean number of larvae/larvae, percentage fruit damage and fruit yield) of botanical insecticides (palm bunch ash, soursop, goat weed) and Lambda-Cyhalothrin on eggplants naturally infested by EFSB - Leucinodes orbinalis in 2015 and 2016 cropping seasons

Treatment	Year		Mean	Year		Mean	Year		Mean	Year		Mean
	2015	2016		2015	2016		2015	2016		2015	2016	
	Mean number of larvae/pod			Mean number of holes/pod			Mean percentage of fruit damage (%)			Fruit yield (g)		
Control	0.75	0.63	0.69	2.06	1.67	1.87	70.28	63.89	67.08	4550.0	8616.0	6583.0
Palm bunch ash	0.41	0.44	0.43	1.16	1.25	1.20	41.67	43.00	43.3	6645.0	10,804.8	8729.4
Soursop	0.40	0.41	0.41	1.03	0.96	0.99	40.83	40.56	40.69	8068.4	11,686.0	9877.2
Goat weed	0.30	0.28	0.29	0.79	0.60	0.70	30.56	27.50	29.03	8952.0	13,638.0	11,295.0
Lambda-cyhalothrin	0.22	0.19	0.21	0.36	0.36	0.36	22.22	18.33	20.28	10,106.0	14,587.2	12,346.6
Mean	0.42	0.39		1.08	0.97		41.11	38.67		7666.1	11866.4	
	LSD $_{(0.05)}$ Mean number of larvae/pod = 0.04			LSD $_{(0.05)}$ Mean number of holes/pod = 0.13			LSD $_{(0.05)\ \%}$ damage = 3.18			LSD $_{(0.05)}$ Treatment = 667.2		
	LSD $_{(0.05)}$ Year			= 421.96								

4. Percentage fruit damage varied significantly (P< 0.05) amongst the botanical insecticidal treatments. The profile of activity was goat weed extract (30.6%) followed by *A. muricata* extract (40.8%) ≥ palm bunch ash (41.7%) and control (70.3%) in 2015. Similarly, Lambda-cyhalothrin recording 22.22% outperformed all the botanical treatments and control in reducing the damage due to the insect pest on the test crop.

This work showed that the botanical insecticides significantly reduced the population, attacks, and damage caused by EFSB, *L. orbonalis* on the test crop in varying degrees (Table 4). Goat weed demonstrated higher insecticidal activity than the other extracts. Type and concentration of active ingredient(s), and the kind and position of side chains (methyl, hydroxyl, halides etc.) contained on its carbon skeleton affect insecticidal activity of plant extracts (Echeverrigaray et al., 2010; Enyiukwu & Awurum, 2013). The concentration of an active ingredient is influenced by solubility in the extracting solvent (Enyiukwu et al., 2014; Enyiukwu et al., 2016). The higher insect killing potential demonstrated by goat weed in this study may have been due to higher solubility of its active principles in water than those of *A. muricata* and *E. guineensis*. It also suggests that the type of active ingredient or its substituents contained in goat weed differed greatly from those in *A. muricata* and *E. guineensis*.

However, the marginal difference in insecticidal activity of *A. muricata* and *E. guineensis* suggests that compounds contained in these botanicals may have similar structure, substituent or solubility in water; as a result, they may compete for the same binding site or process on the target insect (Enyiukwu et al., 2016). The differential toxicity and higher efficacy of Lambda-cyhalothrin (a semi-pyrethroid that acts by elevating sodium channels leading to paralysis and death of affected insects) over goat weed compounds (precocene I and II an anti-juvenile hormone and possible acetylcholenesterase inhibitor) and *A. muricata* (lipid disrupting acetogenins) may be due to longer persistence on the test crop than goat weed and soursop extracts which are easily degraded by heat and UV-radiation (Dim et al., 2004; Isman & Reffrin, 2014; Lu et al., 2014; Kumar et al., 2018; Hildago et al., 2018; Chahal et al., 2021; Enyiukwu et al., 2021).

Besides directly killing target pests (Ramos et al., 2006), several workers are of the opinion that these natural products prime host tissues to produce phenolic substances that repel or ward-off pest species (Awurum et al., 2016; Nawaz et al., 2020). Findings in this work in which extracts of *A. conzoides* and *A. muricata* successfully reduced infestation, attacks, and damage on eggplant by *L. orbonalis* is in conformity with reports of Moreira et al. (2007), Kavitha et al. (2008), Mochaiah et al. (2011), and Owusu (2012) who reported ovicidal and insecticidal activities of soursop, papaya and neem leaf and kernel extracts against *L. orbonalis* Guenee in okro and eggplant.

The results of the fruit yield of the test eggplants exposed to the botanical insecticides and Lambda-cyhalothrin in the 2015 and 2016 cropping seasons are presented in Table 4. Whereas Lambda-cyhalothrin had the highest yield of all treatments (10.106 kg), goat weed extract recording (8.982 kg) was next, followed by *A. muricata* extract (8.068 kg), and lastly palm bunch ash (6.645 kg). The control experiment recording a yield value of 4.550 kg was the least in the 2015 cropping season. The indices of trend of insecticidal activity for all the treatments (botanical and Lambda-cyhalothrin) followed exactly the patterns observed for number of larvae, number of holes and percentage tissue damage per plant observed on the test crop in the 2015 cropping season than in 2016. Generally the pest pressure was higher in 2015 cropping season than 2016 whereas the fruit yield of the crop was lower in the cropping season of the former year than in the latter (Table 4).

Data obtained from this study also showed higher number of larvae, holes and percentage damage of fruit per pod per plant on *Afufa Ukwu* than *Ngwa Large* especially in 2016. High ambient temperatures and humidity encourage fecundity of EFSB (Amana & Omoloye, 2012) may be the reason for higher population, attacks and damage by *L. orbonalis* on the crop in 2015 than in 2016. Certain mineral elements in plant tissues affect its resistance or otherwise to disease and pest attacks (Enyiukwu et al., 2021). Phosphorus and calcium are involved in fostering strength, rigidity and development of strong interlocking cross-walls in plant tissues (Okpara, 2014; Amadioha & Nwazuo, 2019) which translates to improved resistance to pests and diseases. Higher available P and Ca in the eggplant rhizospere of 2016, coupled probably with higher ability of *Ngwa Large* to utilize these growth factors (Han et al., 2021) may explain the better performance of *Ngwa Large* over *Afufa Ukwu*. Furthermore the higher reduction of pest pressure and damage by *L. orbonalis* by the test extracts translated to higher fruit yields of the plant (Table 4), a view also held by other workers (Satpathy & Mishra, 2011; Sahu et al., 2020).

CONCLUSION

This study has revealed that the use of bio-insecticides from *A. muricata* and *A. conyzoides* extracts hold strong and effective potentials for reduction of damage by EFSB and to improve the yield of eggplant. Therefore these plant extracts especially leaf extract of *A. conyzoides* is recommended as a suitable alternative to the synthetic insecticides for the management of *L. orbonalis* and improvement of eggplant productivity in the field.

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AUTHORS' CONTRIBUTIONS

KCE and NFN planned and designed the field experiment. KCE interpreted the data on insect population and plant damage. NFN carried out the experiment in the field, collected relevant data from the field and analyzed them. All the authors played roles in preparing the manuscript. DNE interpreted phytochemical and mode of action aspects of the work and also arranged and edited the manuscript. All the authors have read and approved the manuscript.

COMPETING INTEREST

All authors declare that we have no conflicts of interest related to the publication of this manuscript.

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