Original Research Article

Evaluation of the Insecticidal Potential of Six Plants Leaves Powders Against *Acanthoscelides obtectus* Say on Stored *Phaseolus vulgaris* L.

Abstract

Most plant powders possess insecticidal properties and can be used to control insect pests on stored products. This study was conducted to evaluate insecticidal properties of *Solanum melongena*, *Parkia biglobosa. Ipomoea batatas*, *Colocasia esculenta*, *Tridax procumbens* and *Terminalia catappa* against *Acanthoscelides obtectus* Say, an insect pest of stored *Phaseolus vulgaris* L. The leaves powder of these plants were assessed for aduticidal and reproduction inhibition potential as well as effect on seed weight in a completely randomized design at three treatment concentrations of 0.5%, 1.0%, 1.5% and 0 as the control. All the test plants investigated exhibited insecticidal activity against *A. obtectus*. Results showed a trend of variation in adult *A. obtectus* mortality according to post-treatment days and plants powder concentrations. Results analysis revealed that at 14 days after treatment, *T. catappa* at 1.5% had the highest significant (P=0.05) mortality of 40.21 ± 0.71^{i}. This was followed by *S. melongena* which had a similar effect of 39.41 ± 0.52^{i} at the same concentration (1.5%). The least significant mortality was observed in the control. At 0.5% *T. procumbens*, 0.5% *Parkia biglobosa*, 1.0% *I. batatas* and 1.0% *C. esculenta*, leaves powder had comparable effects. It was observed that the control had the highest number of progeny emergence of 181.33 ± 0.88^{g} after six weeks while *T. catappa* significantly (P=0.05) inhibited progeny at 1.5% followed by 1.5% *S. melongena* and 1.5% *C. esculenta*. Seeds of *P. vulgaris* treated with 1.5% *T. catappa* also had the least significant weight loss of 0.93 ± 0.17 g compared to the control which had the highest significant weight loss of 55.68 ± 0.79 g. Though all the plants studied caused significant increase in adult *A. obtectus* mortality, reduction in progeny emergence and *P. vulgaris* seed weight loss than the control. *Terminalia catappa* however, exhibited the best insecticidal potential. *Terminalia catappa and Solanum melongena* were very effective in inhibiting the reproduction and progeny emergence of *A. obtectus*, but increased adult mortality resulting in weight loss suggesting their potential in controlling *A. obtectus* on stored *P. vulgaris*.

Keywords: *Acanthoscelides obtectus*, stored *Phaseolus vulgaris*, leaves powder, Insecticidal potential.

:

1. Introduction

The protection of stored grains and seeds against insect pests is a major problem for agriculturists with attendant effect on food security and sustainability. Plants have been recognized as excellent sources of bioactive compounds or secondary metabolites that can serve as alternative substances for pest control. Plant insecticides are natural compounds with insecticidal properties and their use in crop and or grain protection is as old as agricultural practice. They are easily biodegradable, more reliable, environmental friendly [1], cheap, readily available [2], and target specific [3].

The potential and use of Indigenous plants extracts and powders in the control of insect pests in recent years has been recognized by scientist [4], [5]. Various types of plant preparations (solvent extracts, powders, essential oils and whole plants) have been assessed for their insecticidal activity, including their action as fumigants, repellents, anti-feedants, anti-oviposition and insect growth regulators [6].

Crop plants are grown for food production to meet the food security need of the people. The produce from crops need to be stored for later use. Stored products are faced with the problem of damage orchestrated by storage insect pests causing great losses to harvested crops hence, necessitating their control. *Solanum melongena*, *Parkia biglobosa. Ipomoea batatas*, *Colocasia esculenta*, *Tridax procumbens* and *Terminalia catappa* reported to possess medicinal and insecticidal properties are readily available and accessible to farmers in rural communities in Nigeria, hence can be use as grain protectants. The objective of this research is to evaluate the insecticidal potential of these plants leaves powders against *Acanthoscelides obtectus* Say on stored *Phaseolus vulgaris* L.

Solanum melongena L. (Family: Solanaceae) also known as eggplant is a species of night shade grown for its edible fruit. Eggplant is used for medicinal purposes. Various parts of the plant; powder or ash, decoction are used for curing diabetes, dysentery, cholera, bronchitis, toothache, asthenia, haemorrhoids and skin infections. *S. melongena* also possesses narcotic, anti-asthmatic and anti-rheumatic properties. In several countries eggplant has magical uses. It is used as a symbol of protection, good health and female fertility [7]. Ethanolic extract of *S. melongena* showed potent activity against *Sitophylus oryzae*, Carpenter ant Pantry weevil [8]. *Solanum melongena* leaves extract showed the presence of flavonoids, alkaloids, tannins and steroids [9].

Parkia biglobosa (Jacq.) R. Br. Ex G. Gon (Fabaceae) also called African locust bean, monkey cutlass tree, two ball nitta-tree, fern leaf is a multipurpose tree legume found in many African countries. The seeds, the fruit pulp and the leaves are used to prepare numerous foods and drinks, and to feed livestock and poultry [10]. Quantitative phytochemical analysis of *P. biglobosa* revealed that the leaves contained phenols, flavonoids, tannins, saponins, cardiac glycoside, steroid, terpenoid, alkaloid and anthrquinones in variable amounts. The fruit pods of *P. biglobosa* are used to produce an insecticide powder, which is added with water and sprayed on crops. Aqueous pod husk extract of *P. biglobosa* could serve as a biopesticide for sustainable and safety grain storage [11]. [12] reported that the leaves and seeds of *P. biglobosa* possess insecticidal activity against *Trogoderma granarium* Everts. Ethanol and petroleum ether seed extracts of African locust bean were found to possess the ability to protect the seeds of *Vigna unguiculata* from infestation damage caused by *Callosobruchus maculatus* [13].

Ipomoea batatas Lam. (Family: Convolvulaceae): *Ipomoea batatas* commonly called sweet potato is a major food crop in the subtropical regions of the world. It is an herbaceous perennial vine that has purplish flowers, large nutritious tuberous roots and heart-shaped lobed leaves. Sweet potato is a widely cultivated food plant native to tropical America. The leaves and shoots are used traditionally as medicine. The roots contain a toxic laxative ipomoein [14]. Essential oil from sweet potato vines inhibited the growth of some pathogenic bacteria and fungi [15]. Health-wise, *I. batatas* help prevent vitamin A deficiency, contains anti-diabetes, anti-cancer, anti-inflammatory and antimicrobial properties. *Ipomoea batatas* guard against ulcer, help in minimizing the risk of cardiovascular diseases, improve hair and skin, aid in digestion, blood pressure regulation, can boast fertility, improve good vision. It is a memory-enhancing food and help in weight management. It also helps in the management of stress [16]. Phytochemicals present in the leaves of *Ipomoea batatas* include tannins, alkaloids, steroids, glycosides, saponins, flavonoids, and soluble carbohydrates [17]; terpenes/steroids, coumarins, anthraquinones, alkaloids, flavonoids, saponins, tannins phenolic acids [18]

***Colocasia esculenta* (Taro)** (L.) Schott (Family: Araceae)**:** Is an annual herbaceous edible medicinal plant from tropical and sub-tropical regions [19], [20]. Its corms are rich in carbohydrates, protein, thiamine, riboflavin, niacin, oxalic acid, calcium oxalate, minerals, lipids, unsaturated fatty acids and anthocyanins [21]. Traditionally *C. esculenta* has been used as a medicinal plant for curative purposes. A wide variety of bioactive compounds can be extracted from all plant parts. These compounds have been reported to possess important pharmacological activities including anticancer [22], antihyperlipidaemic/antihypercholesterolaemic [23], anxiolytic [24], wound healing [25], antimelanogenic [26], anti-inflammatory [27] probiotic [28], antihypertensive [29], antidiabetic [30]; [31], antioxidant [32], hepatoprotective [33], anti-inflammatory and antimicrobial [34], anti-helminthic [35], proliferative [36] and hypolipidaemic properties. [37] reported the insecticidal efficacy of *Colocasia esculenta* tuber agglutinin (CEA) against two devastating hemipterans: *Bemisia tabaci* and *Lipaphis erysimi*. Phytochemical analysis of *C. esculenta* leaves revealed the presence of alkaloids, glycosides, flavonoids, terpenoids, saponins, tannins, phenols and oxalate [38], [39], [40].

***Tridax procumbens* L. (Asteraceae):** *Tridax procumbens* is a very promising species that produces secondary metabolites reported to have a variety of medicinal uses including among others, anti-anemic, anti-inflammatory, anti-diabetic and anesthetic properties [41]. Essential oils extracted from *T. procumbens* are reported to have insecticidal activity against *Musca domestica, Culex quinquefasciatus, Dysdercus similis and Supella* spp. [42]. A petroleum ether extract from flowers protects cowpea seeds from damage by the bruchid *Callosobruchus maculatus* [43]. The leaves of *T. procumbens* possess alkaloids, polyphenols, tannins, flavonoids (catechin and flavones), saponins, glycosides, carbohydrates, carotenoids, hydroxycinnamates, phytosterols, moderate benzoic acid derivatives and lignans, [44], [45], [46].

Terminalia catappa L. (Myrtales: Combretaceae): Compounds extracted from the leaves of *T. catapa* were potent insecticides, feeding deterrents and progeny production inhibitors against *Sitophilus oryzae* (L.), *Rhyzopertha dominica* (F.) and *Callosobruchus chinensis* (L.) three of the four major pests of stored grains [47]. Leaf extract of *T. catappa* is an effective herbal larvicidal and pupicidal agent against *Aedes aegypti* [48]. *Terminalia catappa* is used by traditional healer for the treatment for worm [49]. Alkaloids, flavonoids, and tannins reported in *T. catappa* are known for their anti-microbial properties [50]. Tannins are also known to reduce herbivory and decrease larval growth. Phytochemical screening of *T. catappa* leaf extract revealed the presence of tannins, saponins, flavonoids, alkaloids, anthraquinones, steroids, saponin glycosides and cardiac glycosides; resins, reducing sugars [51]; alkaloids, reducing sugar, resins and steroids [52].

2. Materials and Methods

2.1 Experimental site

The study was carried out in the Department of Zoology and Environmental Biology, University of Calabar, Cross River State, Nigeria. Cross River State is located at $5^{o}45^{1}$N and $8^{o}30^{1}$ and has an area of 2.156 km^2.

2.2 *Phaseolus vulgaris* Seeds

Seeds of *Phaseolus vulgaris* were bought from the Goldie Market in Calabar, Cross River State, Nigeria. The damaged seeds were sorted by hand-picking leaving the undamaged ones (unbroken seeds with no feeding holes). The undamaged seeds were kept in a refrigerator at -18^{o}C for one day for sterilization. These unbroken seeds were used for assessment.

2.3 Collection, preparation of plants powder

The fresh leaves of *S. melongena*, *P. biglobosa. I. batatas*, *C. esculenta*, *T. procumbens* and *T. catappa* were harvested from plants in Calabar Municipality Local Government Area of Cross River State, Nigeria in October 2015 and were authenticated in the Department of Plant and Ecological Studies, University of Calabar, Nigeria. The experiment lasted for three months. The leaves were shade-dried for one week and milled separately with the aid of an electric milling machine (Super Master, Model SMB2977, Japan) and sieve through a cloth-mesh of 0.25 mm to obtain a homogenous powder which were separately stored in air-tight containers and used for evaluation within two days.

2.4 Insecticidal Activity of Powders

To evaluate the insecticidal potential of the five plants powders against adult mortality of *A. obtectus* the beans were treated separately with each powder. The leaf powder of each plant was assessed at different concentrations of 0.5%, 1.0%, 1.5% and 0% w/w as the control and mixed separately 100 g of *P. vulgaris* in 125 ml plastic containers. Twenty unsexed adults *A. obtectus* (one-day old) were introduced into each of these containers and covered with perforated lid to promote aeration and prevent insects escape. The experiment was laid out in a completely randomized design. Adult mortality was assessed at 2, 4, 6, 8, 10, 12 and 14 days after treatment. The insects were considered dead if appendages did not move when prodded with a fine brush. Dead insects from the substrate were removed after sieving through a 5 mm sieve. The insects were allowed to stay for 5 minutes after prodding with a brush to assure if the individuals were dead or just paralyzed. If they moved, they were reintroduced on substrate.

2.5 Assessment of the First Filial Generation Inhibition Efficacy of the Plant Powders.

After mortality test assessment, all insects (dead and alive) were removed carefully and the experimental set-up kept undisturbed for six weeks. The number of adult progeny emergence was obtained by counting at fourth, fifth and sixth week. The number counted gave the cumulative progeny emergence at the seventh week revealing the reproduction inhibition potential of the plants studied.

At the end of seventh week, all insect and the frass were removed and the seeds of *P. vulgaris* were reweighed.

2.6 Statistical Analysis

Data obtained were subject one-way analysis of ANOVA to check for significant differences among the various treatments using SPSS version 17.0 software for probability level.

3 Results

Table 1: Effect of different concentrations of six plants leaves powder on the cumulative percentage mortality of *Acanthoscelides obectus* on *Phaseolus vulgaris*

Plant	Treatment	Days after treatment (DAT)						
		2 DAT	4 DAT	6 DAT	8 DAT	10 DAT	12 DAT	14 DAT
Solanum melongena	0.5%	1.03 ± 0.09^{b}	3.33 ± 0.01^{c}	4.45 ± 0.11^{b}	13.27 ± 0.22^{e}	13.92 ± 0.72^{f}	15.52 ± 0.55^{e}	18.27 ± 0.37^{d}
	1.0%	3.03 ± 0.04^{d}	5.67 ± 0.01^{de}	8.44 ± 0.24^{d}	16.29 ± 0.47^{g}	16.97 ± 0.21^{e}	19.56 ± 0.47^{gh}	35.18 ± 0.68^{h}
	1.5%	6.34 ± 0.06^{f}	9.29 ± 0.80^{h}	11.19 ± 0.18^{g}	17.57 ± 0.39^{g}	17.70 ± 0.37^{g}	27.31 ± 0.68^{k}	39.41 ± 0.52^{i}
Parkia biglobosa	0.5%	2.93 ± 0.08^{c}	3.97 ± 0.17^{c}	5.92 ± 0.16^{c}	6.73 ± 0.58^{b}	7.08 ± 0.09^{h}	7.94 ± 0.51^{b}	11.49 ± 0.54^{c}
	1.0%	4.66 ± 0.01^{e}	5.89 ± 0.29^{de}	8.09 ± 0.08^{d}	9.08 ± 0.65^{c}	11.30 ± 0.57^{b}	12.00 ± 0.58^{d}	20.38 ± 0.42^{d}
	1.5%	6.98 ± 0.05^{f}	7.66 ± 0.02^{ef}	8.77 ± 0.06^{d}	9.57 ± 0.16^{c}	11.90 ± 0.70^{e}	18.98 ± 0.41^{f}	28.00 ±0.58f

Ipomoea batatas	0.5% 1.0% 1.5%	1.34 ± 0.01^{b} 3.34 ± 0.01^{d} 7.90 ± 0.16^{g}	8.38 ± 0.09^{g} 10.60 ± 0.33^{i} 13.26 ± 0.36^{l}	9.59 ± 0.19^{e} 11.45 ± 0.49^{g} 14.92 ± 0.39^{i}	9.63 ± 0.49^{c} 11.62 ± 0.16^{d} 17.28 ± 0.55^{g}	9.09 ± 0.31^{d} 12.01± 0.19^{d} 17.68 ± 0.37^{h}	9.19 ±0.24^{c} 12.51±0.54^{d} 17.48 ± 0.51^{f}	10.87±0.48^{b} 13.44±0.72^{c} 19.77±0.60^{d}
Colocasia esculenta	0.5% 1.0% 1.5%	0.33 ± 0.01^{a} 4.67 ± 0.01^{e} 7.66 ± 0.01^{g}	4.96 ± 0.39^{d} 7.40 ± 0.13^{ef} 9.65 ± 0.38^{h}	6.56 ± 0.18^{d} 8.31 ± 0.11^{d} 13.44 ± 0.29^{h}	7.09 ± 0.23^{b} 9.28 ± 0.22^{c} 14.19 ± 0.34^{f}	7.54 ± 0.30^{b} 10.31 ± 0.48^{cd} 15.44 ± 0.25^{c}	7.48 ±0.36^{b} 11.77 ±0.34^{d} 18.33 ±0.51^{fg}	8.31 ±0.52^{b} 13.65 ±0.62^{c} 25.71±0.54^{ef}
Tridax procumbens	0.5% 1.0% 1.5%	1.00 ± 0.01^{b} 1.50 ± 0.03^{b} 2.99 ± 0.02^{c}	3.59 ± 0.16^{c} 5.30 ± 0.35^{de} 6.20 ± 0.18^{e}	7.05 ± 0.82^{e} 7.33 ± 0.88^{e} 7.59 ± 0.83^{e}	10.52 ± 0.37^{d} 12.55 ± 0.23^{e} 16.65 ± 0.69^{g}	13.99 ± 0.54^{f} 18.30 ± 0.74^{e} 21.60 ± 0.46^{i}	20.77±0.40^{f} 23.41 ±1.20^{g} 25.41 ±0.39^{h}	11.41±0.49^{c} 24.60 ±0.64^{e} 31.24 ±0.60^{g}
Terminalia catappa	0.5% 1.0% 1.5%	0.00 ± 0.00^{a} 0.00 ± 0.00^{a} 0.00 ± 0.00^{a}	2.50 ± 0.06^{b} 5.58 ± 0.20^{de} 6.64 ± 0.22^{f}	5.74 ± 0.08^{e} 8.37 ± 0.28^{d} 10.54 ± 0.36^{jf}	20.03 ± 0.96^{h} 21.08 ± 0.65^{hj} 22.21 ± 1.02^{i}	21.92 ± 0.45^{i} 24.29 ± 0.98^{j} 25.98 ± 0.49^{k}	25.83±0.75^{l} 29.20±0.59^{i} 30.10±0.05^{l}	31.82±3.45^{g} 36.24±0.79^{h} 40.21±0.71^{i}
Control		0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.33 ± 0.01^{a}	0.33 ± 0.01^{a}	1.25 ± 0.04^{a}	1.30 ±0.05^{a}	2.99±0.01^{a}

- Values are means of three replicates ± SEM
- Means followed by same superscript letters in each column are not significantly different, while means followed by different superscript letters are significantly different at (P=0.05) according to Duncan Multiple Range Test.
- DAT = Days after treatment.

3.1 Effect Plants Leaves Powder on the Cumulative Percentage Mortality of *Acanthoscelides obectus* on *Phaseolus vulgaris*

Results in Table 1 revealed that at 14 days after treatment (DAT), significant (P=0.05) differences in the cumulative mean mortality of adult *A. obectus* were observed among different concentrations of test plants leaves powder of *S. melongena*, *P. biglobosa*., *I. batatas*, *C. esculenta*, *T. procumbens* and *T. catappa* and the control on stored *P. vulgaris*. Leaves powder of *T. catappa* at concentrations of 0.5%, 1.0% and 1.5% had the highest significant (P=0.05) mean mortality of 31.82±3.45^{g}, 36.24±0.79^{h} and 40.21±0.71^{i} followed by *S. melongena* 18.27±0.37^{d}, 35.18± 0.68^{h} and 39.41± 0.52^{i}, followed by *T. procumbens* 11.41±0.49^{c}, 24.60 ±0.64^{e} and 31.24 ±0.60^{g} respectively. Mean mortality values for *C. esculenta* at 1.0%, *I. batatas* at 1.0%, *P. biglobosa.* at 0.5% and *T. procumbens* at 0.5% had comparable effects on mortality. *Terminalia catappa* at 1.0% and 1.5% had similar effects as *S. melongena* at 1.0% and 1.5%. The control however, showed the least significant mortality.

Table 2: Effect of six plants leaves powder on the cumulative progeny emergence and reproduction

Plant	Treatment	Weeks after Treatment (WAT)		
		4 WAT	5 WAT	6 WAT
Solanum melongena	0.5% 1.0% 1.5%	11.11 ± 0.78^{f} 7.81 ± 0.54^{b} 7.07 ± 0.45^{b}	14.39 ± 0.61^{g} 9.24 ± 0.50^{c} 8.75 ± 0.45^{b}	18.81 ± 0.26^{d} 17.31 ± 0.76^{c} 13.17 ± 0.25^{b}
Parkia biglobosa.	0.5% 1.0% 1.5%	13.18 ± 0.59^{h} 10.97 ± 0.31^{e} 10.98 ± 0.18^{e}	18.36 ± 0.51^{k} 13.13 ± 0.33^{f} 9.93 ± 0.30b^{b}	19.43 ± 0.43^{d} 21.71± 0.30^{e} 21.78 ± 1.13^{e}
Ipomoea batatas	0.5% 1.0% 1.5%	17.52 ± 0.44^{j} 15.58 ± 0.90^{j} 12.88 ± 0.45^{g}	19.41 ± 0.46^{c} 18.32 ± 0.71^{k} 14.86 ± 0.58^{h}	15.75 ± 0.79^{c} 21.54 ± 0.63^{e} 18.61 ± 0.55^{d}
Colocasia esculenta	0.5% 1.0% 1.5%	16.87 ± 0.53^{k} 14.94 ± 0.18^{i} 13.24 ± 0.32^{h}	18.74 ± 0.51^{k} 15.56 ± 0.50^{j} 10.96 ± 0.43^{d}	11.40 ± 0.60^{b} 18.71 ± 0.47^{c} 12.34 ± 0.77^{b}
Tridax procumbens	0.5% 1.0% 1.5%	15.86 ± 0.52^{ij} 9.70 ± 0.62^{d} 8.88 ± 0.45^{c}	18.11 ± 0.49^{k} 11.00 ± 0.58^{e} 11.10 ± 0.65^{e}	18.38 ± 0.57^{d} 17.74 ± 0.30^{c} 16.54 ± 0.72^{c}

Terminalia catappa	0.5% 1.0% 1.5%	11.71 ± 0.85^{f} 7.71 ± 0.56^{b} 6.50 ± 0.35^{a}	14.95 ± 0.84^{h} 9.51 ± 0.50^{c} 7.17 ± 0.40^{a}	18.02 ± 1.02^{d} 13.42 ± 0.58^{b} 9.06 ± 0.69^{a}
Control		88.00 ± 0.58^{m}	148 00 ± 0.5^{l}	181.33 ± 0.88^{g}

- Values are means of three replicates ± SEM
- Means followed by same superscript letters in each column are not significantly different, while means followed by different superscript letters are significantly different at (P=0.05) according to Duncan Multiple Range Test.
- DAT = Days after treatment.

3.2 Effect of leaves powder on the cumulative progeny emergence and reproduction

At six weeks after treatment, the powders of all the plants studied depicted significant (P=0.05) effect individually on progeny emergence relative to the control. The control gave the highest mean cumulative emergence of *A. obtectus* of 181.33 ± 0.88^{g} which differed significantly (P=0.05) from the progeny emergence in all the treatments. At concentration 1.5% *T. catappa* had the lowest number of progeny emergence of 9.06 ± 0.69^{a} followed by 1.0% (13.42 ± 0.58^{b}) and 0.5% (18.02 ± 1.02^{d}) when compared to the control. Statistically, *T. catappa* at 1.0%, *S. melongena* at 1.5%, *C. esculenta* at 0.5% and 1.5% had comparable effects. *Colocasia esculenta* at 1.0%, *I. batatas* at 0.5% had similar effects.

Table 3: Effect of six plants leaves powder on weight loss

Plant	Treatment	Weeks after Treatment (WAT)		
		4 WAT	5 WAT	6 WAT
Solanum melongena	0.5% 1.0% 1.5%	6.08 ± 0.51^{g} 5.25 ± 0.67^{ef} 3.07 ± 0.51^{b}	9.11 ± 0.34^{f} 5.14 ± 0.24^{d} 4.92 ± 0.54^{c}	9.27 ± 0.50^{g} 7.69 ± 0.55^{efg} 5.57 ±1.61^{c}
Parkia biglobosa	0.5% 1.0% 1.5%	7.78 ± 0.64^{hi} 5.40 ± 0.59^{ef} 4.39 ±1.31^{be}	7.15 ±1.12^{def} 6.60 ± 0.61^{e} 4.20 ± 0.29^{ab}	7.42 ± .05^{efg} 7.27 ±1.28^{efg} 6.66 ± 0.30^{d}
Ipomoea batatas	0.5% 1.0% 1.5%	6.40 ± 0.89^{efg} 6.00 ± 0.58^{g} 5.39 ± 0.36^{ef}	7.81 ± 1.15^{ef} 6.59 ± 0.42^{e} 6.43 ± 0.38^{be}	8.22 ± 0.56^{f} 8.10 ± 0.59^{df} 8.28 ± 0.55^{f}
Colocasia esculenta	0.5% 1.0% 1.5%	7.44 ± 0.23^{h} 6.56 ± 0.27^{ghi} 6.27 ± 1.08^{gh}	6.86 ± 1.12^{f} 7.10 ± 1.02^{def} 6.15 ± 0.82^{e}	9.14 ± 0.64^{g} 8.00 ± 0.15^{fg} 5.74 ± 0.53^{c}
Tridax procumbens	0.5% 1.0% 1.5%	6.26 ± 0.63^{gh} 5.70 ± 0.54^{g} 5.48 ± 1.48^{ef}	7.32 ± 1.06^{g} 6.67 ± 0.60^{f} 4.33 ± 0.40^{ab}	8.51 ± 0.12^{f} 6.54 ± 0.17^{def} 5.89 ± 0.58^{ce}
Terminalia catappa	0.5% 1.0% 1.5%	3.51 ± 0.04^{bcd} 3.14 ± 0.74^{bc} 0.93 ± 0.17^{a}	6.67 ± 0.88^{f} 4.23 ± 0.39^{ab} 2.81 ± 0.45^{a}	7.74 ± 0.63^{cfg} 4.44 ± 0.83^{b} 3.35 ± 0.36^{a}
Control		24.78 ± 0.66^{j}	39.44 ± 0.55^{g}	55.68 ± 0.79^{h}

- Values are means of three replicates ± SEM
- Means followed by same superscript letters in each column are not significantly different, while means followed by different superscript letters are significantly different at (P=0.05) according to Duncan Multiple Range Test.
- DAT = Days after treatment.

3.3 Effect of Leaves Powders on Weight Loss and Seed Damage

At six weeks post-treatment the least significant (P=0.05) weight loss was observed with *P. vulgaris* seed treated with *T. catappa* at 0.5% (7.74 ± 0.63^{cfg}), 1.0% (4.44 ± 0.83^{b}) and 1.5% (3.35 ± 0.36^{a}). This is followed by *S. melongena* at 0.5%, 1.0% and 1.5% with weight reduction values of 9.27 ± 0.50^{g}, 7.69 ± 0.55^{cfg} and 5.57 ±1.61 ^{c} respectively as against the control which had the highest weight loss of 55.68 ± 0.79^{h}. 1.0% and 1.5% *T. catappa* had comparable effect, 0.5% *C. esculenta* and 0. 5% *S. melongena* had similar effects on weight loss of *P. vulgaris* seed.

4 Discussion

Insecticidal potential of six plants leaves powders against *A. obtectus* Say on stored *P. vulgaris* L. was evaluated. Results of this investigation revealed that the leaves powders of the *S. melongena*, *P. biglobosa, I. batatas*, C. *esculenta*, *T. procumbens* and *T. catappa* had different levels of insecticidal activity against *A. obtectus*. It was observed that though all treatment levels of the different plants used in this study were effective in decreasing *A. obtectus* population under laboratory conditions, their effectiveness were directly proportional to concentration and exposure period as seen with highest adult mortality at highest concentration of 1.5% and at six days after treatment. Our finding agrees to earlier reports of insecticidal properties and the use of plants in the control of insect pests. [53] evaluated the bioactivity of powders from 18 plant species on *Acanthoscelides obtectus* (Say) and reported that powder from aerial part of *Chenopodium ambrosioides* d.2 derivation caused the most efficient repellence, total adult mortality and no oviposition, followed by rinds of fruits of *Citrus sinensis* (cv. Pera) and leaves of *Lafoensia glyptocarpa*. Leaves of *Coriandrum sativum* were non repellent but caused total adult mortality and no oviposition. Also powders from aerial part of *C. ambrosioides* d. 1, from leaves of *Eucalyptus citriodora*, *Mentha pulegium*, *Ocimum basilicum*, *O. minimum* and *Ruta graveolens*, from rinds of fruits of *Citrus reticulate* (cv. Murcote) and from fruits of *Melia azedarach* and *L. glyptocarpa* were all repellent to *A. obtectus.* Extracts of *Urtica dioica* L. and *Taraxacum officinale* L. exhibited significant insecticidal activity against *Acanthoscelides obtectus* [54]. Gums extracted from the bark of *Anacardium occidentale* are effective insecticide [55]. Powders from the plant parts (leaf, stem and root) of *Chromolaena odorata* exhibited insecticidal activity against the cowpea beetle, *Callosobruchus maculatus* [56]. [57] reported on the insecticidal ability of *Telfairia occidentalis*, *Piper guineensis*, *Gmelina arborea*, *Bryophyllum pinnate*, *Amaranthus viridis* and *Musanga ceropolides* with *P. guineensis* and *G. arborea* exhibiting the highest insecticidal activity in the management of *Acanthoscelides obtectus on stored Phaseolus lunatus*.

Results of this study also showed a reduction in the number of progeny that emerged from all the treated seeds of *P. vulgaris* relative to the control. This result indicated that prevention of progeny emergence was exclusively due to treatment since the insects in control samples were higher than in the treated samples meaning that the tested insects were capable of effective oviposition. Thus the powders of the test plants either suppressed oviposition or killed the larvae hatching from eggs laid. One of the basic characteristics of an effective grain protectant is the ability to reduced progeny production in the treated grain. This is in consonance with previous reports by [58] who studied the insecticidal potential of two medicinal plants *Verbascum cheiranthifolium* (Boiss) and *Verbascum speciosum* (Scrophulariaceae) on mortality and progeny production against adult *Sitophilus oryzae* L. and found that extract of *V. cheiranthifolium* was more effective than *V. speciosum* against adult *S. oryzae* thus, could be used for the protection of stored grains from infestation of insect pests. [59] evaluated the insecticidal potential of n-hexane leaf extract of *Solanum tuberosum*, *Annona muricata*, *Cymbopogon citrates*, *Vernonia amygddalina*, *Caesalpina pulcherima* and *Lantana camara* and reported that all test plants extracts at high concentration of 3 and 5% caused significant increase in repellant and mortality, but a significant (P≤0.05) reduction in oviposition, fecundity, progeny emergence and seed damage relative to control. These results suggest the presence of different phytochemical compounds in these plants.

The fact that the leaves powders of *S. melongena*, *P. biglobosa. I. batatas*, *C. esculenta*, *T. procumbens* and *T. catappa* in this study exhibited insecticidal activity against *A. obtectus* may be due to the presence of toxic phytochemicals or secondary metabolites such as saponins, tannins, alkaloids, steroids, cardiac glycosides, flavonoids and phenolics [60], [61]. These phytochemicals have been reported to possess insecticidal potentials against insect pests. They affect various aspects of insect larval fitness, such as survivorship, growth, and development. Saponins have obvious insecticidal properties. [62] reported that saponins causes increase in mortality levels, decrease in reproduction, reduced level of food intake and weight reduction in insects. These effects may be attributed to saponins making the food less attractive for eating, causing digestive problems, causing moulting defects or having toxic effects on cells. [63] reported that saponins interacts with cholesterol disturbing the synthesis of ecdysteroid; saponins also inhibits protease enzyme and is toxic to insect cells. The innate protective abilities of phenolic compounds against invading organisms has been reported [64]; as signal and plant defense molecules. Flavonoids, a class of phenolic compounds has been reported [65] to possess anti-feeding and attracting deterrent properties, thus are toxic to insects, fungi, nematodes and weeds. Tannins are another group of phytochemical that are toxic to small mammals [66]. They act as a defense mechanism in plants against pathogens and herbivores [67]. Alkaloids are naturally occurring complex compounds in plants that are toxic to insects [66]. Alkaloids (1,2-dehydropyrrolizidine) are a class of metabolites well-known feeding deterrents against herbivores and are toxic to a wide range of non-adapted animals [68], indicating their potential for pest management.

The highest adult mortality and lowest progeny emergence observed in this study with *T. catappa* and *S. melongena* powders may be attributed to the presence of bioactive compounds in these plants. *T. catappa* has a wide range of metabolites, including alkaloids, reducing sugars, saponins, tannins, resins, steroids, flavonoids and glycosides [69], [70]. The high level of toxicities in *T. catappa* explains the reduction in adult population of *A. obtectus* on stored *P. vulgaris* induced by treatment with this plant. The same toxic properties are responsible for anti-microbial activity and anti-herbivory [71]. *Terminalia catappa*'s toxicity is related to its insecticidal properties. The plant mimicked properties of commercial insecticide, with toxic effects on *Drosophila melanogaster* larvae.

Conclusion

The findings of our study revealed that our native plants investigated have insecticidal properties in decreasing *A. obtectus* population in a decreasing order *T. catappa* > *S. melongena* >*T. procumbens* > *P. biglobosa* > *C. esculenta* > *I. batatas* on stored *P. vulgaris*. This results implicate their use in the control of *A. obtectus* on stored *P. vulgaris*.

Conflicting Interest

Authors have declared that there is no conflicting interest.

References

[1] Koul O, Walia S, Dhaliwal GS. Essential oils as green pesticides; Potential and constraints. Biopesticide International. 2008; 62: 21-23.

[2] Fayinminnu OO, Chiro OO. The pesticidal potential of *Alternanthera brasiliana* (L.) O. Kuntze in solving pest problem in organic agriculture. Proceedings of the 4th ISOFAR Scientific Conference. 'Building Organic Bridges', at the Organic World Congress Istanbul, Turkey, 2014.

[3] Senthil NS, Kalaivani K. Efficacy of nucleo polyhedron virus (NPV) and azadirachtin and *Spodoptera litura* Fabricius (Lepidoptera). Noctuidae Biology Control. 2005; 34: 93-98.

[4] Onunkun O. Studies on the repellent activities of four common Asteracea in Nigeria against red flour beetle, *Tribolium castaneum*. The International Journal of Engineering and Science. 2013; 2(12): 90-93.

[5] Lawal OA, Opoku AR, Ogunwandle IA. Phytoconstituents and insecticidal activity of different solvent leaf extracts of *Chromolaena odorata* L. against *Sitophilus zeamais* (Coleoptera: Curculionidae). European Journal of Medicinal Plants. 2015; 5(3): 237-247.

[6] Negahban M, Moharramipour S, Sefidkon F. Fumigant toxicity of oil from *Artemisia* Besser against three stored product insects. Journal of Stored Product Research. 43: 123-128.

[7] Daunay MC, Chadha ML. *Solanum melongena* L. [Internet] Record from PROTA4U. Grubben GJH & Denton OA. (Editors). PROTA (Plant Resources of Tropical Africa/Resources vegetales de l'Afrique tropicale), Wageningen, Netherlands. 2004. Http://www.prota4u.org/search.asp. Accessed 5th February, 2019.

[8] Tribhuvan S, Kumar VR, Bhavani NL, Pravallika D, Roja K, Pravallika V. In vitro insecticidal activity of *Solanum melongena*. European Journal of Pharmaceutical and Medicinal Research. 2016; 3(5): 420-422.

[9] Mulalik S, Pridhavi K, Rao CM, Udupa N. Antipyretic and analgesic effect of leaves of *Solanum* melongena Linn. In rodents. Indian Journal Pharmacology. 2003, 35: 312-315

[10] USDA. Grin-germplasm resources information network. National germplasm resources laboratory, Beltsvile, Maryland, (2017).

[11] Fayinminnu OO, Adeniyi OO, Alabi OY, Omobusuyi DO. Potential of aqueous extract of pod husk *Parkia biglobosa* (Jacq.) Benth as a biopesticide in okra (*Abelmoschus esculentus* (L) Moench) production. Journal of Agriculture and Ecology Research International. 2017; 12(1): 1-12.

[12] Musa AK, Lawal MT. Insecticidal activity of *Citrus sineensis* (L.) and *Parkia biglobosa* (Jacq.) extracts against *Trogoderma granarium* Everts. Agriculture and Forestry. 2016; 62(3):197-206.

[13] Umar MS. Phytochemical screening and antifeedant activity of the seed extracts of *Parkia biglobosa* against cowpea bean (*Vigna unguiculata*) storage pest

(*Callosobruchus maculatus*). International Journal of Innovative Research in Science, Engineering and Technology. 2014, 3(9): 15991-15995.

[14] James AD. Handbook of energy crops. Unpublished 1983.

[15] Bo Y, Ling-wei X, Qiu-yue Z, Wan-wan K, Jun P, Meng K, Ji-hong J. Essential oil from sweet potato vines, a potential new natural preservative and an antioxidant on sweet potato tubers: Assessment of the activity and the constitution. Journal of Agriculture and Food Chemistry. 2016; 64(40): 7481-7491.

[16] Littlieton Care and Rehabilitation Centre (LCRC). Hpptps://littletoncare.com/2017/03/18/15-health benefits of sweet-potato-according to science, 2017.

[17] Mbaeyi-Nwaoha IE, Emejulu VN. Evaluation of phytochemical composition and antimicrobial activities of sweet potato (*Ipomomoea batatas*) leaf. Pakistan Journal of Nutrition. 2011, 12(6); 575-586.

[18] Pochapski MT, Fosquiera EC, Esmerino LA, dos Santo EB, Faragg PV, Santo FA, Groppo FC. Lam. Pharmacognosy Magazine. Apr-Jun 2011, 7(25); 165-170.

[19] Tarak D, Namsa ND, Tangjang S, Arya SC Rajbonshi B, Samal PK, Mandal M. An inventory of the ethnobotanicals used as anti-diabetic by a rural community of Dhemaji district of Assam, Northeast India. Journal of Ethnopharmacology. 2011; 138 (2): 345-350.

[20] Lim TM. *Colocasia esculenta*. (1st ed.), Edible medicinal and non-medicinal plants. Springer Netherlands, Netherlands. 2015; 9: 454-492

[21] Subhash C, Sarla S, Jaybardhan S. Phytochemical screening of garhwal himalaya wild edible tuber *Clocasia esculenta*. International Research Journal of Pharmacy. 2012; 3 (3):181-186.

[22] Brown AC, Valiere A. The medicinal uses of poi. Nutrition in Clinical Care: An Official Publication of Tufts University, 2004; 7 (2): 69-74.

[23] Sakano Y, Mutsuga M, Tanaka R, Suganuma H, Inakuma T, Toyoda M, Goda Y, Shibuya M, Ebizuka Y. Inhibition of human lanosterol synthase by the constituents of *Colocasia esculenta* (taro). Biological and Pharmaceutical Bulletin. 2005; 28 (2): 299-304.

[24] Kalariya M, Parmar S, Sheth N. Pharmaceutical Biology. 2010; 48 (11): 1207-1212.

[25] Gonçalves RF, Silva AM, Silva AM, Valentão P, Ferreres F, Gil-Izquierdo A, Silva JB, Santo D, Andrade PB. Influence of taro (*Colocasia esculenta* L. Food Chemistry. 2013; 141 (4): 3480-3485.

[26] Kim KH, Moon E, Kim SY, Lee KR. Anti-melanogenic fatty acid derivatives from the tuber- barks of *Colocasia antiquorum* var. esculenta. Bulletin of the Korean Chemical Society. 2010; 31 (7): 2051-2053.

[27] Biren NS, Nayak B, Bhatt S, Jalalpure S, Seth A. Saudi Pharmaceutical Journal. 2007; 15 (3/4): 228-232.

[28] Brown AC, Valiere A. Probiotics and medicinal nutrition therapy. Nutritind and Clinical Care. 2004; 9(1): 52-63.

[29] Vasant OK, Vijay BG, Virbhadrappa SR, Dilip NT, Ramahari MV, Laxamanrao BS. Antihypertensive and diuretic effects of the aqueous extract of *Colocasia esculenta* Linn. leaves in experimental paradigms. Iranian Journal Pharmaceutical Research. 2012; 11 (2): 621-634

[30] Eleazu CO, Iroaganachi M, Eleazu KC. Ameliorative potentials of cocoyam (*Colocasia esculenta* L.) and unripe plantain (*Musa paradisiaca* L.) on the relative tissue weights of streptozotocin-induced diabetic rats. Journal of Diabetes Research, 2013: 1-8.

[31] Li HM, Hwang SH, Kang BG, Hong JS, Lim SS. Inhibitory effects of *Colocasia esculenta* (L.) Schott constituents on aldose reductase. Molecules. 2014; 19 (9): 13212-13224.

[32] Lee S, Wee W, Yong J, Syamsumir D. Antimicrobial, antioxidant, anticancer property and chemical composition of different parts (corm, stem and leave) of *Colocasia esculenta* extract. Annales Universitatis Mariae Curie-Sklodowska, Sectio DDD. 2 0112; 4 (3): 9-16.

[33] Patil BR, Ageely HM. Antihepatotoxic activity of *Colocasia esculenta* leaf juice. International Journal of Advanced Biotechnology and Research 2011; 2 (2): 296-304

[34] Dhanraj N, Kadam M, Patil K, Mane V. Phytochemical screening and antibacterial activity of western region wild leaf *Colocasia esculenta*. International Journal of Biological Sciences. 2013; 2 (10): 18-23.

[35] Kubde MS, Khadabadi IA, Farooqui SLD. In-vitro anthelmintic activity of *Colocasia esculenta*. Scholars Research Library. 2010; 2(2): 82-85.

[36] Pereira PR, Silva JT, Vericimo MA, Paschoalin VMF Teixeira GPB. Crude extract from taro (*Colocasia esculenta*) as a natural source of bioactive proteins able to stimulate haematopoietic cells in two murine models. Journal of Functional Foods 2015; 18: 333-343.

[37] Roy A, Gupta S, Hess D, Kali Pada Das KP, Das S. Binding of insecticidal lectin *Colocasia esculenta* tuber agglutinin (CEA) to midgut receptors of *Bemisia tabaci* and *Lipaphis erysimi* provides clues to its insecticidal potential. Proteomics 2014; 14: 1646–1659.

[38] Kumawat NS, Chaudhari SP, Wani NS, Deshmukh TA, Patil VR. Antidiabetic activity of ethanol extract of *Colocasia esculenta* leaves in alloxan induced diabetic rats.International Journal of PharmTech Research. 2010, 2(2), 1246-1249.

[39] Krishnapriya TV, Suganthi A. Biochemical and phytochemical analysis of *Colocasia esculenta* (L.) Schott tubers. International Journal of Research in Pharmacy and Pharmaceutical Sciences. 2017, 2(3), 21-25.

[40] Keshav A, Sharma A, Mazumdar B. Phytochemical analysis and antioxidant activity of *Colocasia esculenta*. International Journal of Chemical and Molecular Engineering. 2019, 13(1), 20-23.

[41] Beck S, Mathison H, Todorov T, Calderón-Juárez E-A, Kopp OR. A review of medicinal uses and pharmacological activities of *Tridax procumbens* (L.). Journal of Plant Studies. 2018; 7(1): 19-35.

[42] Pathak AK, Dixit VK. Insecticidal and insect repellent activity of essential oils of Tridax procumbens and Cyathocline lyrata. Fitoterapia. 1988; 59(3):211-214.

[43] Alam MM, Anis M. Ethno-medicinal uses of plants growing in the Bulandshahr district of northern India. Journal of Ethnopharmacology. 1987; 19(1):85-88

[44] Jude CI,Catherine CI, Ngozi Mi. Chemical profile of *Tridax procumbens* Linn. Pakistan Journal of Nutrition, 2009; 548-550.

[45] Singh P, Jain K, Khare S, Shrivastav P. Evaluation of phytochemical and antioxidant activity of *Tridax procumbens* extract. Pharmaceutical and Biosciences Journal (UKJPB). 5(6); 41-47.

[46] Catherine CI, Jude CI, Mercy OI. Phytochemical composition of *Tridax procumbens* Linn leaves: Potential as a functional food. Food and Nutrition Sciences. 2015, 6; 992-1004.

[47] Rani PU, Venkateshwaramma T, Devanand P. Bioactivities of *Cocos nucifera* L. (Arecales: Areceae) and *Terminalia catapa* L. (Myrtales: Combretaceae) leaf extracts as post-harvest grain protectants against four major stored product pests. Journal of Pest Science. 2011; 84(2): 235-247.

[48] Unnikrishnan G. Larvicidal and pupicidal activity of *Terminalia catapa* leaf extracts on *Aedes aegypti* mosquito: A vector Intervention. IOSR Journal of Pharmacy and Biological Sciences. 2014; 9(Ver. II): 58-63.

[49] Olukotun AB, Bell IA, Oyewale OA. Phytochemical and anthelmintic activity of *Terminalia catapa* (Linn) leaves. Journal of Applied Sciences and Environmental Management. 2018; 22(8): 1343-1347.

[50] Akharaiyi FC, Ilori RM, Adesida JA. Antibacterial effect of *Terminalia catappa* on some selected pathogenic bacteria. International Journal of Pharmaceutical and Biomedical Research 2011; 2: 64-67.

[51] Kankia HI. Phytochemical screening and antibacterial activities of leaf extracts of *Terminalia catappa* (Umbrella Tree). International Journal of Sciences and Research, 2012; 3(12); 2658=2661.

[52] Muhammad A, Mudi SY. Nigeria Society for Experimental Biology. 2011, 23(1); 33-39.

[53] Fabio M, Jose DV. Effect of powders from vegetal species on *Acanthoscelides obtectus* (Say) (Coleoptera: Brudidae) in stored bean. Neotropical Entomology. 2003; 31(1): 145-149.

[54] Jovanovic Z, Kostic M, Popovic Z. Grain-protective properties of herbal extracts against the bean weevil *Acanthoscelides obtectus* Say. Industrial Crops and Products. 2007; 26: 100-104.

[55] Ashvin GG, Rajaram SS, Shobha DJ. Comparative screening of acetonic extract of fruits of *Terminalia catapa* Linn. And *Anacardium occidentale* Linn. Asian Journal of Plant Science and Research. 2013; 3(2): 150-153.

[56] Osariyekemwen OU, Benedicta NO. Evaluation of the repellent and insecticidal activities of the leaf, stem and root powders of Siam weed (*Chromolaena odorata*) against the cowpea beetle *Callosobruchus maculatus*. Journal of Applied Science, Environment and Management. 2017; 21(3): 511-518.

[57] Mofunanya AAJ, Nta AI. Managing *Acanthoscelides obtectus* Say on stored *Phaselous lunatus* L. with six indigenous botanical powders. Annual Research & Review in Biology. 2018; 27(5): 1-8.

[58] Hojat K, Mahdi G, Reza A, Shiva SF, Mehdi T, Hojat S, Parisa A. The potential of using insecticidal properties of medicinal plants against insect pests. Pakistan Journal of Biological Sciences. 2008, 11(10): 1380-1384.

[59] Mofunanya AAJ, Nta AI. Entomotoxicity of six indigenous plants extracts in controlling *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) infestation in stored *Vigna unguiculata* L. Walp. IOSR Journal of Pharmacy and Biological Sciences. 2016; 11(6 Ver.VI): 45-49.

[60] Omokhua AG, Mcgaw IJ, Finnie JF, Van Staden J. *Chromolaena odorata* (L.) R. M. King & Rob. (Asteraceae) in sub-Saharan Africa: A synthesis and review of its medical potential. Journal of Ethnopharmacology. 2016; 183: 112-122.

[61] Musa AK, Lawal MT. Insecticidal activity of *Citrus sinensis* (L.) and *Parkia biglobosa* (Jacq.) extracts against *Trogoderma granarium* Everts. Agriculture and Forestry. 2016; 62(3): 197-206.

[62] De Geyter E. Toxicity and mode of action of steroid and terpenoid secondary plant metabolites against economically important pest insects in agriculture. PhD dissertation, Faculty of Bioscience Engineering, Ghent University, Ghent. 2012.

[63] Chaieb I. Saponins as insecticides: a review. Tunisian Journal of Plant protection. 2010; 5; 39-50.

[64] Joachim H, Makoi JR, Ndakidemi PA. Biological, ecological and agronomic significance of plant phenolic compounds in the rhizosphere of the symbiotic legumes-Review. African Journal of Biotechnology. 2007; 16(12): 1358-1368.

[65] Calsen SC, Fomsgaard IS. Biologically active secondary metabolites in white clover (*Trifolium repens* L.). A review focusing on contents in the plant, plant-pest interactions and transformations. Chemoecology. 2008; 18: 129-170.

[66] Fatoki OK, Fawole B. Identification of nematicidal ingredients from leaves, siam weed leaves and roots. African Journal of Plant Protection. 2000; 33-38.

[67] Kumbasli M, Bauce E, Rochefort S, Crepin M. Effects of tree age and stand thinning related variations in balsam fir secondary compounds on spruce budworm *Choristoneura fumiferana* development, growth and food utilization. Agricultural and Forestry Entomology. 2011; 13(3): 131-141.

[68] Agaba TA, Fawole B. Phytochemical constituents of siam weed (*Chromolaena odorata*) and African custard apple (*Annona senegalensis*). International Journal of Food, Agriculture and Veterinary. 2014; 6(1): 50-42.

[69] Muhammad A., Mudi SY. Phytochemical screening and antimicrobial activities of Terminalia catappa, leaf extracts. Biokemistri. 2011; 23:35-39.

[70] Packirisamy V, Kishnamorthi V. Evaluation of proximate composition and phytochemical analysis of Terminalia catappa from Nagapattinam Region. International Journal of Science and Research. 2012; 3: 877-880.

[71] Cornell HV, Hawkins BA. Herbivore responses to plant secondary compounds: a test of phytochemical coevolution theory. The American Naturalist. 2003; 161:507-522.