EFFECTS OF PLANT EXTRACTS ON THE LARGER GRAIN BORER, *PROSTEPHANUS TRUNCATUS* HORN (COLEOPTERA: BOSTRICHIDAE)

BY

MWESHI MUKANGA

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DECLARATION

I, MWESHI MUKANGA hereby declare that this dissertation represents my own work and that it has not been previously submitted for a degree at this or any other university.

....

Signature

10/05/2001

Date

APPROVAL

This dissertation of MWESHI MUKANGA is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy (Crop Science) of the University of Zambia.

Name and Signature of Examiners		Date
1.	Name: FELIX S. MWANGALA	3/4/2001
	Signature: [signature]	
2.	Name: YAKUB JEEDAT	10/5/2001
	Signature: [signature]	
3.	Name: Davies M. Lungu	10/5/2001
	Signature: [signature]	

DEDICATION

To Nomvuyo Dadirai Tembo, a great friend. I also dedicate this work to my parents, Mukaya and Juliet for their patience, love and care during the crucial time of my studies, and to the memory of my beloved kid sister, Patricia Gillian Muyembe.

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ABSTRACT

This study was conducted to assess the insecticidal activity of selected plant extracts: Eucalyptus *Eucalyptus globulus* L., Guava, *Psidium guajava* L., Neem, *Azadirachta indica* A. Juss., Tephrosia, *Tephrosia vogelii* F (Hook) and Water Hyacinth *Erchhornia crassipes* (Martius) Solms-Laubach, against the Larger grain borer, *Prostephanus truncatus* (Horn). The effects of plant extracts were determined in two ways: dry leaf powder trials and petroleum ether leaf extracts experiments. Split plot design with three replications was used for all the experiments. The bioassays were conducted at a temperature of 27 ° C and 70 + 5% relative humidity.

The dry leaf powders were applied in six doses: 0.1, 0.5,0.25, 0.5, 1.0, 2.5 and 5 grams per 100g dried cassava chips or flour to determine the reproduction inhibition, repellency, food preference and anti-feeding deterrence of the extracts on *P. truncatus*. Quantification of the reproduction inhibition was made at 14, 28, 42, 56 and 70 days after infestation. The results of reproduction inhibition study showed that the leaf powders partially suppressed reproduction of parent adult population. The numbers of larvae, pupae and adult in leaf powder treated cassava were significantly (P<0.01) fewer compared to the untreated cassava. Significantly low numbers were produced in Neem treatment, followed by Tephrosia and Water Hyacinth whereas Guava had a comparably higher numbers of *P. truncatus*. Dry leaf powder application at 2.5 and 5.0g per 100g dried cassava were superior to the lower doses, 0.1, 0.25 and 0.5g/100g. No larvae or pupae was produced in Actellic Super (1.6 % *Pirimphos methyl* and 0.3% *Permethrin*) treated cassava (applied at 50 g /90 kg dried cassava) as the adults were killed soon after introduction.

The mean percent weight loss due to *P. truncatus* feeding on leaf powder treated cassava was between 13 – 18% compared to 39 % in untreated cassava, after 70 days of storage. Actellic super treated cassava incurred 0.23% weight loss during the same period.

Repellency effect and food preferences were assessed for five days consecutively, while the anti-feeding effect was assessed 7 days after introducing the insects in the treatment vials. Tephrosia, Neem and Water hyacinth extracts had strong repellent and anti-feeding effects on *P. truncatus* while Eucalyptus and Guava were moderate. Negative orientation in response to treated cassava was observed. *Prostephanus truncatus* preferred the untreated cassava more than leaf powder treated cassava.

Mortality due to the petroleum ether leaf extracts was compared in the vapour, residual surface film exposure, topical application and *P. truncatus* larval dipping methods. The petroleum ether leaf extracts were applied at the rate of 0.1, 0.25, 0.5 and 1 % concentration. Mortality was assessed after 24 hours in the vapour method, 72 hrs in the residual film surface exposure method and 120 hrs in the topical application method while the larval dipping experiment was conducted over 20 days. Toxicity of petroleum ether leaf extracts was plant specific and dose –dependent. In the vapour test, Neem extracts were highly toxic to *P. truncatus,* followed by Tephrosia and Water hyacinth. When the insects were exposed to the residual surface film, it was found that Eucalyptus was more effective against the insects. Insect mortality increased with increased exposure time. In the topical application, Tephrosia and Water hyacinth extracts were highly toxic. When *P. truncatus* larvae was dipped in the petroleum ether leaf extract, mortality was highest in Tephrosia, followed by

Neem and Water hyacinth. It is likely that these materials could be used as storage protectants.

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1.0. INTRODUCTION

The larger grain borer, *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae), is a serious pest of farm-stored maize (Wright, 1984) and dried cassava (Hodges *et al.*, 1985). Losses to dried cassava caused by this pest could be as high as 70 -80% over a period of 4 months of storage (Golob, 1988; Roux, 1999). Damage of this magnitude is extraordinarily high and demonstrates the destructive nature of this pest, which can threaten food security at both household and national levels (Mallya, 1992).

Cassava or tapioca (*Manihot esculenta* Crantz) is a major staple food in sub-Saharan Africa (Hahn *et al.,* 1993). In Zambia, it is a major crop in four of the nine provinces, Luapula, Northern, Northwestern and Western provinces (Soenarjio, 1995). *Prostephanus truncatus* like many other storage pests belonging to the insect families Bostrichidae and Tenebrionidae (Haines, 1991) make dried cassava chips unmarketable by converting them into powder (GASGA, 1993). Due to contamination with egg deposits, faecal matter and insect parts, cassava like maize is rendered unfit for human consumption (Mallya, 1992).

The recent introduction and spread of the larger grain borer into Africa, Zambia included, has increased dried cassava storage problems (Schulten, 1996). Hence, effective storage protection strategies are urgently required. Current control measures for the *P. truncatus* include fumigants (Hashem and Reichmuth, 1993), contact insecticides (Dales and Golob, 1997) and biological control (Richter *et al.*, 1997); for the latter a predator, *Teretrius nigrescens* Lewis (Coleoptera: Histeridae) (Mazur, 1997) is used. These methods are expensive and can not be afforded by the small-scale farmers in developing countries. Plants with insecticidal properties however may offer a cheaper sustainable alternative to these methods. They could be an abundant source of locally available pest control agents that can be grown at the village level. The insecticidal specificity of some of the plant extracts and their lack of negative impacts on the food and the environment make them ideal candidates for incorporation into an integrated pest management strategy. Obeng-ofori and co-workers (1996) have indicated that the use of locally available plant materials for medicinal and agricultural purposes is a common practice in traditional African communities. However, the scientific basis for this practice is not clearly known.

Zambia like many other countries in Africa is endowed with abundant plant resources, many of which could be potential sources of plant products with insecticidal and mollusicidal properties (Berger, 1994). Examples of such plants include: Neem, *Azadirachta indica* A. Juss; Tephrosia, *Tephrosia vogelii*, Hook F.; Guava, *Psidium guajava* L.; Eucalyptus, *Eucalyptus globulus* Lab.; and Water Hyacinth *Erchhornia crassipes* (Martius) Solms-Laubach. However the exact quantities of botanicals that may give optimum insecticidal effects are unknown. Hence it is necessary to quantify the amount of plant derived materials that provide adequate protection against insect pests as well as to determine how these affect insect behaviour, growth and reproduction (Jilani, 1992).

Thus the objectives of the study were:

(1) To determine the effect of Neem, Tephrosia, Guava, Eucalyptus, and Water hyacinth leaf extracts on the reproduction and feeding behaviour of *P. truncatus*.

(2) To test the extracts for insecticidal properties and,

(3) To determine whether these extracts could be used as dried cassava protectants in storage.

2.0. LITERATURE REVIEW

2.1. Distribution of larger grain borer, *Prostephanus truncatus*

The larger grain borer, *Prostephanus truncatus*, is indigenous to Meso-America, as a major but localised pest of farm-stored maize (Watters, 1984). It occurs widely from Southern Texas, United States of America, through Mexico and Central America, extending to Panama and Columbia (Wright 1984).

Since the early 1980s, *P. truncatus* has spread uncontrollably in areas south of Sahara, having been brought in through imported maize from the tropical regions of America (Pierce and Schmidt, 1993). It has been known from East Africa (Mallya, 1992) since 1981, where it is a serious pest of stored maize and dried cassava. It has been observed to cause severe losses to farm-stored maize in the hot-dry Tabora region of Tanzania and in Southern Kenya (Golob, 1988). In 1984, it was reported in Togo, and more recently it has been identified from Ghana, Benin, Guinea-Conakry, Burkina Faso, Nigeria, Rwanda, Burundi, and Malawi (GASGA, 1993). Adda *et al.* (1996) speculates that the pest might invade all maize and cassava growing areas of tropical Africa.

The pest was first reported and recorded in Zambia, in Nakonde district, in 1993 (Sumani, 1997). The pest was restricted to that part of the country until September 1995. It's spread to the rest of the country was quickened through the importation of maize from America, via Tanzania, to offset the maize shortfall brought about by three years of drought (Sumani and Ngolwe, 1996). The pest has since been recorded in all the nine provinces of Zambia except Northwestern province (Semple, L, 1996; personal communication). Sumani and Ngolwe (1996) state that " though there are no reports of farm-stored maize being infested with *P. truncatus*, the pest has continued to be caught in pheromone traps near farmstead implying that the pest is becoming established in the wider environment; the bush and forests."

2.2. Biology of larger grain borer, *Prostephanus truncatus*

The genus *Prostephanus* was first erected in 1897 by Lesne for *Dinoderus truncatus* (Horn); using a specimen found on a plant imported from Central America (Wright, 1984). *Prostephanus truncatus* belong to the order Coleoptera (the Beetles) in the family Bostrichidae whose members are characterised principally as wood - borers (Haines, 1991). The other species belonging to this family known to infest stored grains include the Lesser Grain Borer, *Rhyzopertha dominica* (Fabricus) and *Dinoderus minutus* (Fabricus). Other species of *Dinoderus, Heterobostrychus, Bostrychoplites, Apate*, and *Sinoxylon* are occasionally found on dried cassava, and rarely on stored grains, bamboo and wood.

The adult *P. truncatus* have a typically cylindrical bostrichid shape (Hodges, 1986). The declivity is flattened and steep. Its surface has many tubercles. The antennae are straight and have a loose three-segmented club. The body is 3 - 4.5 mm long and dark brown in colour (GASGA, 1993), with the head ventral to the prothorax so that it is not visible from above. The larvae are white and parallel -sided, i.e., they do not taper. The legs are rather short and the head capsule is small relative to the size of the body. The thoracic segments are considerably larger than those of the abdomen. The first larval instar is distinctive in having a median posterior spine (Hashem, 1989; Helbig and Schulz, 1994) while the 3rd instar constructs a pupal case from frass bonded with a larval secretion either within the food source or in the surrounding dust (Roux, 1999).

The complete life cycle of *P. truncatus* from egg to adult stage takes 25 $\pm$ 2 days under optimum conditions of 30 °C temperature, 70% relative humidity and the food media at 13 % moisture content (Golob, 1988; Wright, 1984). The incubation period of the eggs is 3 - 7 days. The larval stage lasts 14 $\pm$ 2.8 days. The larval stage involves three larval instars (Watters, 1984). The pupa stage is 6.5 $\pm$ 0.7 days (Hashem, 1989). The immature stages of the insect develop entirely within the food source. Estimates for the intrinsic rate of increase for *P. truncatus* under ideal conditions of temperature and humidity on maize cobs or on stabilised maize grain, are in the order of 0.7 - 0.8 per week (Watters, 1984). The number of offspring of *P. truncatus* are on average 13 on dried cassava after 60 days (Helbig, 1995).

2.2.2. Host range, feeding habit and damage

Besides stored maize and dried cassava, the pest is also able to survive on other stored cereal products such as soft wheat and improved varieties of sorghum (Watters, 1984) and sweet potatoes (Golob, 1998). Unlike many other Bostrichids, *P.* is capable of developing and reproducing in dead wood (Hodges *et al.*, 1994). On wood from cassava, *P. truncatus* is able to breed and survive for 40 - 44 weeks (Detmers *et al.,* 1993).

Prostephanus truncatus reacts in general to odours from starchy commodities, which elicit short-range arrestment, though the stored products are only attacked facultatively (Hodges, 1994). The feeding on dried cassava chips depends on the high -starchy content (Detmers *et al.,* 1993). The presence of digestive proteins in the food substrate however increases the feeding intensity (Houseman and Thie, 1993). The food intake is greatest at 26 ° C and 85 % R.H. The feeding activity on dried cassava is characterised by the production of a large quantity of powder, as *P. truncatus* bores and tunnels through the chips (Helbig, 1995). In its lifetime, *P. truncatus* consumes on average 607 mg of cassava and produces 465 mg of cassava dust (Pradzynska, 1993).

Dried cassava is damaged more readily than maize (Golob, 1988; Hodges *et al.*, 1985) Besides cereals, dried cassava and pulse grains; *P. truncatus* causes damage to a wide range of farm-stored materials or products namely leather, wood, soap articles and the fabric of mud-plastered buildings (Golob 1988; Pierce and Schmidt, 1992; Helbig *et al.*, 1990). *Prostephanus truncatus* has been reported to cause nearly 80% losses in dried cassava over 8 weeks in a bioassay (Helbig, 1995). On-farm weight loss of dried cassava as a result of *P. truncatus* infestation has not been studied (Golob, 1988). However, in a simulated field study, Hodges *et al* (1985) found weight losses as high as 73.6% after 17 weeks of storage.

2.3. Use of botanicals in storage insect pest management

Leaves, roots, twigs, flowers or pulverised parts of certain plants have been mixed with various commodities in different parts of the world; particularly in India, China and Africa, for use as stored food protectants against pests (Dales, 1996). Golob and Webley (1980) produced a bibliography, which summarised the traditional use of plant parts as protectants of stored products. The most promising botanical pesticides reported by Jacobson (1989) are to be found in the plant families: Meliacea, Rutaceae, Asteraceae, Annonaceae, Labiatae and Camellacae. About 2400 plant species have been documented as possessing pest control properties (Rees *et al.,* 1993). The traditional use of plant derivatives or materials is based; simply on experience and understanding that comparatively less damage occurs in treated stored farm products. Dales (1996) has provided a review of over 120 plants and plant products used in the protection of stored products, together with a summary of the different methods used for assessing their insecticidal activities. A few plant species in the genera *Azadirachta, Acornus, Chenopodium, Eucalyptus, Metha, Ocimum, Piper* and *Tetradenia* have been tested in the laboratory to give an indication of their potential usefulness as stored products protectants. Jilani (1992) has suggested that plant species that are found to be effective and popular locally with the farmers need to be subjected to safety testing, at least involving basic toxicological studies. The principal advantage of botanicals is that farmers are able to provide their own protectants (Berger, 1994).

2.3.1. Neem

The Neem tree, *Azadirachta indica*, belongs to the Mahogany family, Meliacea. Neem is widely distributed throughout tropical Africa in both dry and humid areas (Saxena, 1989). There is immense documentation on the Neem tree including the pesticidal properties of Neem products (Dales, 1996; Rees *et al*; 1993, Schmutterer 1990). For stored product protection, Neem is usually used as a powder from crushed seeds which is admixed with the grain at various concentrations. This gives protection against many insect pests including weevils, *Sitophilus spp.*, Khapra beetles, *Trogoderma granarium* and Lesser grain borer, *Rhizopertha dominica* (Singh, 1993).Various Neem tree parts have been evaluated for insecticidal activity. These include: dried leaves, seed and seed kernel; oil cake from seeds; aqueous or organic solvent extracts of seed kernel; standardised Neem-rich extracts; partial fractions and azadiractin-rich formulations (Schmutterer, 1990).

The active constituents of Neem have been identified as limonds, a group of stereochemically homogenous steroid-like tetratriterpenoids. The most active constituent being Azadiractin (Saxena *et al.,* 1989), formed by a group of closely related isomers designated AZA, AZB, AZC, AZD, AZE, AZF and AZG (Dales, 1996). Azadiractin has been documented as a feeding deterrent; anti-ovipositional, growth-disrupting and fecundity- and fitness-reducing agent (Lowery and Isman, 1994).

More than 25 compounds that have been isolated from the Neem tree. Nine of these compounds including 22-23-dihydro-23β-methoxyazadirachtin, 3-tigloylazadirachtol and 1-tigloyl-3-acetyl-11-methoxyazadirachtin possess insect growth regulating properties (Dales, 1996). Salanin and meliantriol isolated from Neem seed kernels are active feeding deterrents (Schmutterer, 1990) while meliacarpin derivative, 1-tigloyl-3-acetyl-11-hydroxy-4-β--methylmelicarpin has strong anitfeeding, growth inhibition, and high insecticidal properties (Rojatkar and Nagasampagi, 1993).

Neem leaf powder mixed with common beans at the rate of 5g/100g is reported to be effective in controlling the Mexican bean weevils, *Epilachna varivestis* (Busungu and Mushobozy, 1991). Jilani and Su (1983) have reported that 680 ug/cm^3 of petroleum ether extract of Neem leaves applied to filter paper produced 81.5 and 42 % repellency against *Tribolium castaneum*, 1 and 8 weeks after treatment. Maredia *et al.* (1992) also reported that application of leaf ether extracts at 5 ml/kg to maize caused 97 % mortality in *Sitophilus zeamais* and 22 % mortality in *P. truncatus* when assessed 10 days after treatment application.

2.3.2. Tephrosia

The legume Tephrosia, *Tephrosia vogelii* is a shrubby plant indigenous to Africa, where it is well distributed in the tropics. It is locally used as shelter, cover crop, fish poison and as a pesticide. In Eastern and Southern Africa, *T .vogelii* and other related species have been grown in small plantations by small holders for their use in crop protection (Berger, 1994). The principle active ingredient is rotenone (Gaskins *et al.*, 1972) but there are also other rotenoids such as tephrosin, deguelin and 6a, 12a-dehydrodeguelin (Lambert *et al.*, 1993). The insecticidal effects of Tephrosia extracts have been tested on several insect pests (Berger, 1994; Dales, 1996). The powder from Tephrosia leaves for example, has been used to protect stored products. Tephrosia leaf powder admixed with unshelled groundnuts at 2.5% (w/w) induced 98.8% mortality of groundnut borer, *Caryedon serratus*, within 13 days (Delobel and Malonga, 1987).

2.3.3. Water hyacinth

Water hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubauch (Pontederaceae) is among the most serious aquatic weeds (Parsons, 1976). It grows abundantly in lakes and ponds and has a high growth rate. Studies by Rani and Jamil (1989) have shown that 1% (w/w) of petroleum ether leaf extract when applied to rice caused 100 % mortality in the fourth (4th) larval instar of red flour beetle, *Tribolium castaneum* (Herbst) within 6 days. The effect persisted for 7 months. Topical application of 0.1% petroleum ether leaf extract to adult seed beetle, *Callosobruchus maculatus* F. caused 100% mortality within 2 days. At concentrations above 1%, the petiole acetone extract acted like a juvenile hormone mimic, inhibiting reproduction as well as inducing morphological abnormalities in *T castaneum* and *Dysdercus cingulatus* (F.). When the extract were applied to a diet of *T. castaneum* at 0.5 mg extract/ 5g of rice, it caused 100% larval mortality (Jamil *et al.*, 1984).

2.3.4. Eucalyptus

The Eucalyptus, *Eucalyptus globulus* Lab., is a member of the Myrtaceae family. Eucalyptus trees are grown worldwide mainly for timber and pulp. They are also used in medicine, perfumery and industry (Dakshinamurthy, 1988). According to Berger (1994), Eucalyptus is among the plants used in pest control either experimentally or traditionally in Eastern and Southern Africa. The main constituents of Eucalyptus spp. are terpenes and include α-pinene, cineole and limonene (Santos *et al.*, 1997).

Sharaby (1988) evaluated the toxicity of Eucalyptus globulus leaf powder against the rice weevil, *Sitophilus oryzae* L. and the granary weevil, *Sitophilus granarius* L. The median lethal dose causing 50% mortality (LD_{50}) after 7 days were 4.1g and 4.86g per 100g rice for *S. oryzae* and *S. granarius*, respectively. The leaves showed repellent activity against both species. When 0.4 % Eucalyptus oil was admixed with red gram, it prevented emergence of *Callosobruchus chinensis* F. (Srivastava *et al.*, 1988).

2.4.5. Guava

Guava, goyave, *Psidium guajava* L., belongs to the family Myrtaceae. The fruit is made into jam, while the leaves are used medicinally for treating wounds, as an astringent, toothache remedy and digestive disorders (Wilson, 1980). Beta-caryophyellene and alpha-pinene are the major active constituents of the guava leaves (Santos *et al.*, 1998). Sharaby (1988) reported the insecticidal effect of Guava leaf powder. The LD_{50} for *S. oryzae* and *S granarium* after 7 days were 2.251 % and 2.278 % (w/w), respectively. The admixture of 15% w/w with rice prevented the production of F1 adult of both species.

3.0. MATERIALS AND METHODS

Two sets of experiments, dry leaf powders studies and petroleum ether leaf extracts trials, were carried out to study the effects of plant extracts on the larger grain borer, *P. truncatus.* Dry leaf powder studies were conducted in the Plant Protection Insectary at Mount Makulu Central Research Station. The petroleum ether leaf extraction and experiments were performed in the Animal Science and Plant Protection Laboratories, School of Agricultural Sciences, University of Zambia.

Split-plot design with three replications was used for all the experiments. The data from the experiments were subjected to analysis of variance (ANOVA). The separation of means was done by Duncan's Multiple Range Test (DMRT). Significance was taken at 5% level (Steel and Torries, 1980).

3.1. Dry leaf powder trials

Plant species used for the experiments were Eucalyptus, *Eucalyptus globulus,* Guava *Psidium guajava*; Neem, *Azadirachta indica*, Vogel Tephrosia, *Tephrosia vogelii* and Water hyacinth, *Erchhornia crassipes*. Fresh young leaves from these plants were picked and washed with clean tap water. They were dried in the shade, to avoid direct sunlight which biodegrades the active ingredients. The leaves were ground to fine powder using 30mm-mesh sieve using the moliner grinder. The powder was packed in 500g plastic bags and stored in a refrigerator at 5 ^{o} C for later use.

The test insect, *P. truncatus* was reared on maize grains, MM 752, in the Plant Protection Insectary Unit at Mount Makulu Central Research Station. The insects were reared in 1-L glass jars at 28 $\pm$ 2^{o}C temperature and 70 $\pm$ 5 % relative humidity and with alternating light and dark periods of 12 hours. The adults and larvae were separated after sieving out the maize and placed in different vials for later use. The colony of *P. truncatus* was established with adult insects initially obtained from the Tanzania Zambia Railway Authority (TAZARA) warehouse, Kapiri Mposhi.

Dried cassava, "Bangweulu cultivar" was used as the food media for *P. truncatus* during the experiments. The cassava was obtained from Mansa Technical Agricultural Site, Ministry of Agriculture, Food and Fisheries. After harvesting, the cassava tubers were peeled and chipped manually using an ordinary knife. The cassava chips were sun-dried for 48 hrs thereafter soaked in water for 24 hrs, and then sun-dried again for the same period. The chips were sterilised before use, to kill off any insect forms that may present by exposure to 60 - 70°C temperature in an electric oven for 10 minutes and then cooled.

Dry leaf powders were applied as admixtures in six serial doses of 0.1, 0.25, 0.5, 1, 2.5 and 5g of ground leaves per 100 g of sterilised dried cassava chips. Dales (1996) suggests that dry powdered material may be added at the rate of 1 to 5 % weight for weight (w/w). However, lower rates than 1% (w/w) have been used by several scientists (Dakshinamurthy, 1988; Jilani *et al.*,1988) as storage product protectants. The dry leaf powder trials were conducted at same temperature and humidity conditions at which the insect colony was maintained.

3.1.1. Reproduction inhibition study

Assessment of the reproduction inhibition properties of the dry leaf powders was based on previous works by Jilani *et al* (1988). One hundred grams of treated cassava chips were placed in 1 litre glass jars. Actellic super (1.6% *Pirimphos-methyl* and 0.3% *permethrin*) was applied at 50g per 90 kg of dried cassava chips ((Mwaya, 1997). Untreated cassava chips served as control. Twenty, 1-week old, *P. truncatus* adults (10 male, 10 female) were introduced in each glass jar. After 10 days, the adults were removed. On the 14th, 28th, 42nd, 56th and 70th day after infesting the dried cassava chips. The number of live, dead and malformed *P. truncatus* larvae, pupae and adults in the ensuing progeny were counted. The response of the test insects in the treated cassava were corrected using the modified Abbott's formula:

$$\frac{100\,(\text{Number of insects in control} - \text{Number of insects in treatment})}{(\text{Number of insects in control})}$$

Henceforth, percentage reduction in the progeny was calculated. A treatment was judged to give complete protection against *P. truncatus* if no progeny was produced. Only the live and normal larvae and pupae were returned to the jars. Dead and malformed larvae and pupae, plus all the adults were removed. The cassava chips were weighed at each sampling date in order to determine the weight loss caused by the boring and tunnelling activity of *P. truncatus*.

Square root (x + 0.5) transformations were made of the data to compensate for skewness and to stabilise variance before the analysis by ANOVA was done. The total insect counts at each dosage were regressed against the time (days) at which insect counts were made, to determine the residual persistence of the leaf powders. Correlation of the destructive stages of the *P. truncatus* progeny (Hodges, 1986) to weight loss of cassava was performed to assess the influence of each stage on the weight loss of dried cassava.

Significance of correlation was determined by the 2-tailed studentized *t*- test (Hoshmand, 1998).

3.1.2. Repellency study

The experiment was a modification of the repellency test described by Sharaby (1988). Two and a half grams of treated and untreated cassava were placed on opposite ends of filter paper, with 10 cm space in between on a plastic Petri dish (14 cm diameter, 2 cm height), which served as an arena. Ten, 1-2 weeks old, unsexed *P. truncatus* adults starved for 48 hrs were introduced in the centre of the arena. The number of insects found on the treated cassava was recorded at 09:00hrs and 16:00hrs, for five (5) consecutive days (Dales, 1996). Average insect counts for each day were converted to per cent repellency (Jilani, 1992; Saxena *et al.,* 1989), which was calculated after Gillenwater and McDonald (1975):

$$\textbf{\% Repellency} = \frac{\textbf{Number of insects on control half - Number on treated half}}{\textbf{Number of insects on control half + Number on treated half}} \times 100$$

3.1.3. Anti-feeding study

The potency of antifeedant effect of the dry leaf powders was determined using filter paper bioassay method described by Dales (1996). The leaf powder was dusted evenly on both sides of the filter paper (113.1 cm^2), in which 1.0g cassava flour was placed. The leaf powder was applied on the filter paper as a proportion of the dose per 100g to that per 1.0g dried cassava, i.e. 0.001, 0.0025, 0.005, 0.01, 0.025 and 0.05g. The wrapped cassava was placed in 35ml vial. Cassava flour wrapped in the untreated filter paper served as control. Five, 1-week old *P. truncatus* adults, starved previously for 24 hours were introduced in each vial and left for 7 days. The wrapped cassava served as sole food source. The number of holes in filter paper produced by boring insects were recorded at end of the 7 – day exposure period.

3.1.4. Food Preference study

A modification of the method described by Jilani (1992) was used in this experiment. Treated cassava was sub-divided into 1.00g lots, placed on a Petri dish at 3cm distance from each other and 6 cm from the centre. The untreated cassava served as the control. Ten , 1-2 weeks old *P. truncatus* adults were introduced in 5 mm radius centre circle marked by a pencil on the no. 542 Whatman filter paper that covered the floor of the glass Petri dish (14 cm diameter, 1 cm height). The number of insects found on or within a 1 cm-radius of treated and untreated cassava on Petri dish, was recorded as showing preference. Observations were made twice daily at 09:00 hrs and 16:00 for five consecutive days. Average number of insects for each 24-hour period was then taken.

3.2. Petroleum ether leaf extract experiments

Dales (1996) and Jilani (1992) reported that petroleum ether is one of the most common solvents for plant material extraction. Thus petroleum ether leaf extracts of the selected plants were prepared. Five grams of leaf powder was extracted in a soxhlet apparatus with Petroleum ether (Bp. 40 - 60° C) for 8 hours. After which, the solvent was evaporated in a rotary evaporator at 30° C to dryness and the weight of the crude extract determined. Three extractions were done out for each of the selected plants. Guava leaf powder yielded 251mg, Tephrosia 477.3mg , Eucalyptus 719.7mg, Water hyacinth 196.8 mg and Neem 260.4mg of extract.

Petroleum ether leaf extracts were applied at 0.1%, 0.25%, 0.5% and 1% concentrations. A 1 % concentration stock solution was obtained by dissolving 100 mg of petroleum ether leaf extract from each plant in 10 ml of acetone. Lower concentrations of 0.1, 0.25 and 0.5 % were prepared by further dilution of the stock solution with acetone (Rani and

Jamil, 1989). The experiments were conducted at same temperature and humidity conditions at which the insect colony was maintained. Insect mortality data were analysed using the probit analysis (Finney, 1971), POLO PC (Le Ora Software Inc., 1987) to obtain the median lethal concentration of the petroleum ether leaf extracts at 50% kill (LC_{50}).

3.2.1. Vapour method

The experiment was set up as described by Dales (1996). Ten *P. truncatus* adults, of unknown sex and age, were placed inside a 35 ml vial which acted as a gas chamber with a plastic lid in which minute slits were made. A filter paper disc (15.9 cm^2) impregnated with the petroleum ether leaf extract, was suspended from the plastic lid. *Prostephanus truncatus* exposed to the acetone impregnated filter paper disc served as control. Mortality was recorded after 24 hours of exposure. Mortality was confirmed by exposing the insects to a light source. Those that did not move were considered dead.

3.2.2. Residual surface film exposure

According to Rani and Jamil (1989), a residual film of petroleum ether leaf extract was prepared by pouring 1 ml of the test solutions into glass Petri dish (10 cm diameter, 1 cm height) which was dried uniformly by gentle shaking. Ten *P. truncatus* adults of unknown age and sex were released on each of the treated surfaces and covered with untreated Petri-dishes covers. Petri dishes dried with the solvent alone, served as the control. Mortality was recorded every 24 hrs for three days.

3.2.3 Topical application method

The experiment was conducted using the method described by McDonald *et al.*, (1970) and Su (1991), with slight modifications. Using a micro-syringe applicator, 1 μl of the test solution was applied to the dorsum of thorax of each insect. Ten, unsexed, 1 - 2 weeks old *P. truncatus* adults were treated with each dose. After treatment, insects were transferred to glass Petri-dishes (9 cm diameter, 1 cm height) containing untreated cassava flour. The insects were examined daily for five days. Those that did not move or respond to the gentle touch were considered dead. Percentage kill of the insects was recorded every 24 hours.

3.2.4 Larval dipping method

Treatments were selectively confined to third instar *P. truncatus* larvae. The experiment was performed using the technique described by Rani and Jamil (1989). One millilitre of each test solution was put in a 35ml vial. Ten larvae were dipped individually for 5 seconds only, to avoid death due to suffocation, in each test solution. Control larvae were dipped in the same quantity of acetone. Treated larvae were then transferred to 10 grams untreated cassava flour on the glass Petri dish (10cm diameter, 2cm height). The larvae were observed for 20 days and daily mortality recorded. Any morphological and behavioural defects such as abnormal wing formation, colour, failed pupation and adult emergence, during the metamorphosis from larvae to adult stage were observed. These characters were selected arbitrarily (Table 1).

Table 1. Morphological and behaviour characters used for observing *Prostephanus truncatus* larvae dipped in petroleum ether leaf extracts.

Character	**Classes under each character**		
Activity	High	Slight	No movement
Size	Normal	Small	Enlarged
Colour	Whitish/cream	Purplish	Brown/Black
Shape	Normal	Curled	Round
Pupating	Normal	Failed	
Adult emergence	Normal	Failed	

4.0. RESULTS

4.1. Dry leaf powders studies

4.1.1. Reproduction inhibition study

No larvae were recorded from Actellic super treated cassava hence the 100% reduction observed in this treatment throughout the storage period (Table 2). Significantly ($P<0.01$) less numbers of the larvae of *P. truncatus* were produced in the leaf powder treatments compared to control – untreated cassava.

When the treatment effects on the number of *P. truncatus* larvae were compared over time; the 100 % reduction in larval numbers recorded in the leaf powder treatments at 14 days after treatment (DAT), indicates that no larvae were produced in these treatments at this time (Table 2). However, between 14 and 42 DAT, there was a significant larval population increase. The peak larval population was reached at 42 DAT, with lower doses i.e., 0.10 and 0.25 g/100 g dried cassava, producing between 6.6 and 56.8 % more than the control. Eucalyptus treated cassava had significantly more larvae, followed by Guava. Fewer larvae were produced in Neem treated cassava. At 56 DAT the mean numbers of *P. truncatus* larvae were reduced considerably. The biggest reduction of 69.1% was in Tephrosia , while Guava had the smallest reduction (44.6%) in larval population at this date. Thereafter the reduction in the number of larvae was highly significant ($P<0.01$). At last sampling date i.e., 70 DAT, the leaf powder treatments produced 90 – 97% reduction in the numbers of larvae over the control however, were not significant difference between the treatments. Leaf powder treatments provided the same larval reduction as Actellic super.

Table 2. Mean percent reduction in the number of *Prostephanus truncatus* larvae in dried cassava treated with different doses of leaf powders during 70 days of storage .

Dose (g/100g)	Days after treatment					Mean
	14	28	42	56	70	
Eucalyptus						
0.1	100.0	82.7	-51.4	-45.8	100.0	37.2 d
0.25	100.0	62.5	-56.9	64.6	100.0	54.0 cd
0.5	100.0	81.3	14.2	37.8	100.0	66.7 bcd
1	100.0	96.3	17.0	67.6	100.0	76.2 abcd
2.5	100.0	100.0	75.0	93.9	100.0	86.1 ab
5	100.0	100.0	100.0	79.6	100.0	93.3 ab
Mean	100.0 a	87.1 ab	16.3 h	46.6 cde	96.9 a	
Guava						
0.1	100.0	90.5	-6.6	-41.7	86.7	45.7 cd
0.25	100.0	54.2	-12.3	18.2	96.1	51.2 d
0.5	100.0	100.0	32.9	-18.9	100.0	49.6 cd
1	100.0	81.5	-19.9	-12.9	93.7	49.5 d
2.5	100.0	-41.7	84.4	94.4	91.7	65.7 abc
5	100.0	98.9	85.7	100.0	74.1	91.7 ab
Mean	100.0 a	60.9 abc	17.3 gh	23.2 fgh	90.4 ab	
Neem						
0.1	100.0	97.6	-8.2	-50.0	88.1	45.6 d
0.25	100.0	100.0	-0.6	72.4	92.2	72.8 abcd
0.5	100.0	77.8	28.7	68.3	94.4	73.8 abcd
1	100.0	98.1	55.4	47.6	96.8	79.9 abcd
2.5	100.0	100.0	97.8	100.0	90.6	97.6 a
5	100.0	97.9	100.0	98.2	100.0	99.2 a
Mean	100.0 a	95.2 a	45.5 defg	56.1 cd	93.8 a	
Tephrosia						
0.1	100.0	89.9	-62.3	25	100.00	50.5 d
0.25	100.0	100.0	15.4	62.2	100.0	75.5 abcd
0.5	100.0	91.7	20.4	57.2	98.3	73.5 abcd
1	100.0	98.0	-29.8	65.4	100.0	66.7 abcd
2.5	100.0	100.0	100.0	93.1	81.8	94.9 ab
5	100.0	100.0	97.6	93.7	92.6	96.8 a
Mean	100.0 a	96.6 a	23.5 efgh	66.1 bcd	95.5 a	
Water hyacinth						
0.1	100.0	90.1	0.8	-9.2	100.0	56.3 d
0.25	100.0	96.3	-35.6	75.5	100.0	67.3 abcd
0.5	100.0	68.3	24.6	18.9	100.0	62.4 cd
1	100.0	86.7	51.0	28.4	100.0	73.2 abcd
2.5	100.0	94.4	93.3	100.0	82.9	87.5 ab
5	100.0	98.9	100.0	98.1	96.3	98.7 a
Mean	100.0 a	89.1 ab	39.0 e-h	51.9 a	96.5 a	
Actellic	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Unntreated	0.0 i	0.0 I	0.0 I	0.0 i	0.0 i	0.0 I
C.V	34.1					
Time effect ** (SEm = 8.46) ; Dose effect ** (SEM=8.78)						

Figures followed by the same letter(s) within rows or columns do not differ significantly (P<0.05), ns - not significant (P<0.05); ** Significant (P< 0.01); Duncan' Multiple Range Test on square root(X + 0.5). SEm - Standard error of the mean.

Larval numbers decreased with increasing dosages in all the leaf powder treatments (Table 2), however the differences were not significant ($P<0.05$). The leaf powders exhibited absolute reduction in the numbers of larvae even at the lowest dose of 0.1g/100g. The two higher doses (2.5 and 5.0/g 100g) were significantly superior to lower dosages (0.1 - 1.0g/100g). The higher doses were however, not significant different from Actellic super treated cassava. On average, Neem treated cassava produced 78.15% less larvae than the control, followed by Tephrosia, 76.35%. Guava leaf powders were least effective, 58.73%.

The mean values indicated no significant differences among leaf powder treatments for the number of deformed and dead larvae (Table 3). The highest deformity and mortality was recorded in Neem, followed by Guava. The lowest deformity was in Eucalyptus and lowest larval mortality was in Tephrosia. No deformed larvae were observed in Actellic super treatment because no larvae were produced. The mean values for dose versus deformity and mortality were very insignificant for any meaningful trend to be observed. See Appendix 1 - 4 for the larval numbers recorded in each treatment.

Table 3. Mean number of dead and deformed *Prostephanus truncatus* larvae in dried cassava treated with leaf powders

Treatment	Mean number/100 g dried cassava	
	Larvae	
	Deformed	**Dead**
Eucalyptus	0.222 a	0.356 a
Guava	0.311 a	0.367 a
Neem	0.344 a	0.389 a
Tephrosia	0.233 a	0.267 a
Water hyacinth	0.256 a	0.367 a
Actellic super	0.00 b	0.00 b
Control	0.00 b	0.00 b
Mean	0.195	0.249
C.V%	29.6	33.7

Figures followed by the same letter within a column are not significant different at P<0.05; Duncan Multiple Range Test on square root (x + 0.5).

No pupae were recorded in Actellic super treatment throughout the storage period. In leaf powder treatments, pupae were observed from 28 DAT (Table 4). There was a significant increase in the pupal population in all leaf powder treatments between 28 and 56 DAT. Significantly ($P<0.01$) more pupae were produced in Eucalyptus, followed by Guava. The smallest increase was recorded in Neem treated cassava. At 70 DAT, the number of pupae was at par with that recorded at 28 DAT. It was observed that the reduction in pupal population in the Neem and Tephrosia treatments was sustained throughout the storage period.

There was a significant ($P<0.01$) decrease in the numbers of pupae produced in the leaf powder treated cassava, with increasing dose (Table 3), except where 5g/100g was applied, whose mean percent reduction in pupal population was consistently lower than the results for 1.0 and 2.5g/100g. Between 75-80% reduction in the numbers of pupae were recorded in all leaf powder treatment when 2.5g/100g applied. When comparing the effectiveness of the different leaf powders, Neem, Tephrosia and Water hyacinth were highly effective in reducing the number of pupation even at the lowest dose of 0.1g/100g

Table 4. Mean percent reduction in the number of *Prostephanus truncatus* pupae in dried cassava treated with different doses of leaf powders during 70 days of storage.

Dose (g/100g)	Days after treatment 14	28	42	56	70	Mean
Eucalyptus						
0.10	0.00	100.0	-30.3	44.4	66.7	36.1 de
0.25	0.00	100.0	-27.8	-3.2	100.0	33.8 cde
0.50	0.00	100.0	-33.3	50.0	100.0	43.3 e
1.00	0.00	100.0	100.0	100.0	66.7	73.3 abcd
2.50	0.00	100.0	100.0	100.0	100.0	80.0 a
5.00	0.00	33.3	66.7	66.7	100.0	53.3 cde
Mean	0.00 g	88.9 ab	29.2 f	59.7 b-f	88.9 ab	
Guava						
0.10	0.00	100.0	-41.7	27.8	66.7	30.6 de
0.25	0.00	100.0	66.7	-42.1	100.0	44.6 bcde
0.50	0.00	100.0	33.3	44.4	100.0	55.6 bcde
1.00	0.00	100.0	66.7	70.9	66.7	60.8 a-e
2.50	0.00	100.0	100.0	100.0	100.0	80.0 a
5.00	0.00	33.3	66.7	66.7	100.0	53.3 cde
Mean	0.00 g	88.9 ab	48.6 cdef	44.6 ef	88.9 ab	
Neem						
0.10	0.00	100.0	77.8	66.7	66.7	62.2 a-e
0.25	0.00	91.7	100.0	83.3	100.0	75.0 ab
0.50	0.00	100.0	-33.3	66.7	100.0	46.7 de
1.00	0.00	100.0	100.0	100.0	66.7	73.3 abcd
2.50	0.00	100.0	100.0	100.0	100.0	80.0 a
5.00	0.00	33.3	66.7	66.7	100.0	53.3 cde
Mean	0.00 g	87.5 ab	68.5 bcde	80.0 abc	88.9 ab	
Tephrosia						
0.10	0.00	100.0	91.7	44.4	66.7	60.6 a-e
0.25	0.00	100.0	75.0	88.9	100.0	72.8 abc
0.50	0.00	100.0	33.3	51.4	100.0	56.9 a-e
1.00	0.00	100.0	83.3	79.6	66.7	65.9 a-e
2.50	0.00	100.0	100.0	83.3	100.0	76.7 ab
5.00	0.00	33.3	66.7	66.7	100.0	53.3 cde
Mean	0.00 g	88.9 ab	75.0 bcd	69.1 bcde	88.9 ab	
Water hyacinth						
0.10	0.00	100.0	80.6	27.8	66.7	55.0 b-e
0.25	0.00	66.7	38.9	40.5	100.0	49.2 cde
0.50	0.00	100.0	33.3	44.4	100.0	55.6 b-f
1.00	0.00	83.3	100.0	59.3	66.7	61.9 a-e
2.50	0.00	100.0	100.0	100.0	100.0	80.0 a
5.00	0.00	33.3	66.7	66.7	100.0	53.3 cde
Mean	0.00 g	80.6 a	69.9 b-f	56.4 def	88.9 ab	
Actellic super	0.00 g	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Control	0.00 g	0.00 g	0.00 g	0.00 g	0.00 g	0.00 g
C.V	30.2					

Time effect ** (SEm = 9.34) ; Rate effect** (Sem=8.90)

Figures followed by the same letter(s) within rows or columns do not differ significantly (P<0.05) ; * Significant at P< 0.05; * * Significant at P< 0.01 Duncan' Multiple Range Test on square root (X + 0.5). SEm - Standard error of the mean.

No *P. truncatus* adults were recovered from the Actellic super treated cassava. The reproduction of the *P. truncatus* was not affected by the leaf powders to the same extent as indicated by the mean percentage reduction in number of adult progeny. No adults were recovered at 14 DAT in all treatments including control (Table 5). At 28 DAT, significantly ($P<0.01$) lower numbers of adults were recovered from leaf powder treatments compared to the control. The percent reduction in adult progeny in the leaf powder treatments was from 43.5 to 68.8 %. The mean percent reduction values revealed that the highest and lowest numbers of adults were produced in Tephrosia and Water hyacinth treated cassava, respectively. At 42 DAT, the adult population was considerably reduced in the Neem treated cassava. At 56 DAT, Eucalyptus leaf powders significantly reduced the emergence of adults than other leaf powder treatments, followed by Tephrosia. Guava was the least. At 70 DAT, there was significant reduction in the number of adults recovered in all the leaf powder except Guava, the mean percent reduction over the control was between 36 and 50%. Eucalyptus had biggest reduction, followed by Water hyacinth treated cassava. On the other hand, Guava treatment exhibited a 6% increase in adult population.

There was a reduced number of adults with increasing dose in all the leaf powder treated cassava (Table 5), however the differences were not significant ($P<0.05$). The mean for the dose effect revealed that the three lower doses (0.10, 0.25 and 0.50g /100g) were significantly inferior to the higher doses (1.0, 2.5 and 5.0g /100g) in reducing adult population. Neem and Guava applied at 5g/100g produced highest percentage control of the adult progeny.

Table 5. Mean percent reduction in the number of *Prostephanus truncatus* adults in dried cassava treated with different doses of leaf powder during 70 days of storage.

Dose (g/100g)	Days after treatment 14	28	42	56	70	Mean
Eucalyptus						
0.10	0.00	48.6	63.3	51.6	50.9	42.9
0.25	0.00	87.1	62.5	53.1	0.3	40.6
0.50	0.00	50.5	37.0	79.1	39.2	41.2
1.00	0.00	68.1	61.9	83.0	59.9	54.6
2.50	0.00	-20.0	25.6	81.3	66.1	30.6
5.00	0.00	26.7	74.9	96.8	80.7	55.8
Mean	0.00 h	43.5 defg	54.2 b-g	74.1 abc	49.5 b-f	
Guava						
0.10	0.00	43.1	56.3	13.1	31.3	28.7
0.25	0.00	64.6	59.9	-97.8	44.7	14.3
0.50	0.00	58.8	37.7	40.1	-26.8	42.0
1.00	0.00	68.6	71.3	75.6	32.8	49.7
2.50	0.00	57.8	83.3	81.3	48.9	54.3
5.00	0.00	76.9	86.8	69.5	86.2	63.9
Mean	0.00 H	61.6 b-f	65.9 a-e	30.3 g	36.2 FG	
Neem						
0.10	0.00	77.8	89.4	19.8	28.7	43.2
0.25	0.00	87.2	74.4	78.9	49.8	58.1
0.50	0.00	15.7	45.9	67.5	-54.0	15.0
1.00	0.00	73.2	83.4	79.2	65.4	60.2
2.50	0.00	44.4	83.9	84.7	69.5	56.5
5.00	0.00	74.7	87.9	86.9	67.1	63.3
Mean	0.00 h	62.2 b-f	77.5 ab	69.5 abcd	37.8 fg	
Tephrosia						
0.10	0.00	-11.1	47.7	65.5	49.1	30.2
0.25	0.00	32.1	33.0	59.0	15.9	28.0
0.50	0.00	48.6	5.5	83.7	-57.0	16.2
1.00	0.00	77.1	63.3	67.2	62.0	53.9
2.50	0.00	88.0	92.2	71.4	66.1	61.9
5.00	0.00	24.7	82.8	89.2	81.9	55.7
Mean	0.00 h	41.9 efg	54.1 a-f	72.7 abc	36.3 fg	
Water hyacinth						
0.10	0.00	63.9	60.2	-13.5	63.2	34.8
0.25	0.00	87.7	66.7	-30.8	11.4	39.3
0.50	0.00	61.1	59.6	69.4	10.0	40.0
1.00	0.00	90.8	81.6	78.0	38.1	57.7
2.50	0.00	53.3	33.6	75.0	71.2	46.6
5.00	0.00	55.8	58.8	89.3	83.3	57.5
Mean	0.00 h	68.8 a-e	60.1 b-f	54.8 b-g	46.2 c-g	
Actellic super	0.00 h	100.0 a	100.0 a	100.0 a	100.0 a	100.0
Control	0.00 h	0.00 h	0.00 h	0.00 h	0.00 h	0.00
C.V	34.1					
Time effect ** (SEm = 10.64) ; Rate effect ns						

Figures followed by the same letter(s) within rows or columns do not differ significantly (P<0.05); ns - not significant different ; * Significant at P<0.05; * * Significant at P< 0.01. Duncan' Multiple Range Test on square root (X + 0.5). SEm - Standard error of the mean.

The highest adult mortality was recovered from the Eucalyptus followed by Tephrosia (Table 6). Water hyacinth produced the lowest adult mortality, however this was not significantly different ($P<0.05$) from the control. Adult mortality was highest in Eucalyptus treatment followed by Water hyacinth. The highest and lowest numbers of dead adults were recovered from Guava and Neem, respectively. Except for Guava and Neem, which had a significant increase in adult mortality, the number of dead adults reduced considerably in other three leaf powder treatments. The highest mortality at 70 DAT, was recorded in Water hyacinth while lowest was in Eucalyptus, which was not significantly different from that in Guava treated cassava.

The various doses of leaf powders were significant different ($P<0.05$) for adult mortality (Table 6). Increased adult mortality was recorded with an increase in dose. The highest was when Guava leaf powder was applied at 5g/100g. The lowest were in 0.1 and 0.5g Neem applications.

No adult deformities were recorded in Actellic super treated cassava and the control (Table 7). Guava had significantly ($P<0.01$) higher number of deformed adults, followed by Eucalyptus and Water hyacinth. The lowest number of deformed adults were recovered from Neem treated cassava. On average 27 times more deformed adults were recovered from Guava than Neem treatment.

Table 6. Mean number of dead *Prostephanus truncatus* adults in dried cassava treated with different doses of leaf powder during 70 days of storage

Dose (g/100g)	Days after treatment					Mean
	14	28	42	56	70	
Eucalyptus						
0.1	0.000	0.000	0.000	0.667	0.000	0.133 de
0.25	0.000	0.000	1.000	0.333	0.000	0.267 cde
0.5	0.000	0.667	2.000	0.000	0.000	0.533 a-e
1	0.000	2.000	3.333	0.667	0.000	1.200 ab
2.5	0.000	1.333	2.333	0.333	0.667	0.933 abc
5	0.000	1.667	2.000	0.667	0.333	0.933 abc
Mean	0.000 g	0.944 b-f	1.778 a	0.444 c-g	0.167 fg	
Guava						
0.1	0.000	1.333	0.000	2.000	1.000	0.867 abcd
0.25	0.000	0.667	0.667	0.333	1.667	0.667 a-e
0.5	0.000	0.667	1.000	1.000	0.333	0.600 a-e
1	0.000	0.000	1.333	0.667	1.000	0.600 a-e
2.5	0.000	0.000	0.000	0.333	1.667	0.400 b-e
5	0.000	0.000	1.333	2.667	1.667	1.333 a
Mean	0.000 g	0.444 d-g	0.722 b-f	1.167 abcd	1.222 abc	
Neem						
0.1	0.000	0.000	0.000	0.000	0.000	0.000 e
0.25	0.000	0.000	0.000	0.000	0.000	0.000 e
0.5	0.000	1.333	0.333	0.000	0.000	0.333 bcde
1	0.000	1.000	0.667	0.333	0.000	0.400 a-e
2.5	0.000	1.667	0.667	0.667	0.333	0.667 abcd
5	0.000	0.333	0.333	1.333	1.333	0.667 abcd
Mean	0.000 g	0.722 b-f	0.333 d-g	0.389 defg	0.278 efg	
Tephrosia						
0.1	0.000	0.333	1.667	0.667	0.667	0.667 abcd
0.25	0.000	1.000	1.667	1.000	0.667	0.867 ab
0.5	0.000	0.333	1.000	0.667	0.667	0.533 a-e
1	0.000	0.667	0.667	0.333	1.667	0.667 a-d
2.5	0.000	1.000	0.333	0.333	0.667	0.467 a-e
5	0.000	1.333	0.333	1.333	0.667	0.733 abcd
Mean	0.000 g	0.778 b-f	0.944 a-e	0.772 b-f	0.833 b-f	
Water hyacinth						
0.1	0.000	0.667	0.333	0.000	2.000	0.600 a-e
0.25	0.000	0.000	1.000	0.000	2.333	0.667 a-e
0.5	0.000	0.333	0.667	1.000	0.333	0.467 a-e
1	0.000	0.000	0.667	1.000	1.667	0.667 a-e
2.5	0.000	1.000	2.000	0.667	1.333	1.000 ab
5	0.000	0.000	2.000	0.667	1.000	0.733 abcd
Mean	0.000 g	0.333 d-g	1.111 a-d	0.556 c-g	1.444 ab	
Actellic super	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g
Control	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g
C.V	32.1					
Time effect **(Sem=0.1723); Dose effect* (SEm=0.1947)						

Figures followed by the same letter(s) within rows or columns do not differ significantly (P<0.05) ; * Significant at P < 0.05 ; ** Significant at P<0.01; Duncan' Multiple Range Test on square root (x+0.5). SEm - Standard error of the mean

Table 7. Mean number of deformed *Prostephanus truncatus* adults in dried cassava treated with different leaf powders

Treatment	Mean number/100 g dried cassava
Eucalyptus	0.233 ab
Guava	0.289 a
Neem	0.011 c
Tephrosia	0.033 c
Water hyacinth	0.122 bc
Actellic super	0.000 c
Control	0.000 c
Mean	0.098
C.V%	21.7

Figures followed by the same letter within a column are not significant differently at $P<0.01$; Duncan Multiple Range Test on square root (x+0.5).

The results of the regression analysis indicated the existence of a positive linear relationship between insect count and the time (days) at which the counts were made (Table 8). The strongest relationship occurred in Neem applied at 5g/100g. The slopes for regression lines at each dosage were observed to be close suggesting similarity in the rate of decay of the leaf powders.

Table 8. Relationship between total insect count and the sampling interval for the different leaf powder treatments

Dose (g/100)	Treatment	Intercept	Slope	R2	F
0.1	Eucalyptus	2.33 ± 9.04	3.73 ± 2.72	0.059	1.88 ns
	Guava	-1.67 ± 8.50	5.27 ± 2.56	0.182	4.22 ns
	Neem	-3.90 ± 5.37	4.97 ± 1.62	0.375	9.40*
	Tephrosia	3.67 ± 7.33	3.00 ± 2.21	0.057	1.84 ns
	Water hyacinth	0.53 ± 6.04	3.53 ± 1.82	0.165	3.77 ns
0.25	Eucalyptus	-0.90 ± 8.19	4.83 ± 2.47	0.168	3.83 ns
	Guava	-1.70 ± 7.63	5.43 ± 2.30	0.247	5.58 *
	Neem	-1.50 ± 4.75	1.70 ± 1.43	0.028	1.41 ns
	Tephrosia	1.60 ± 4.92	3.00 ± 1.48	0.812	4.09 ns
	Water hyacinth	-1.60 ± 4.93	4.07 ± 1.49	0.316	7.47 *
0.50	Eucalyptus	3.00 ± 4.69	2.13 ± 1.41	2.28	0.084 ns
	Guava	-1.17 ± 7.20	4.63 ± 2.17	0.202	4.55 ns
	Neem	1.13 ± 4.46	2.47 ± 1.34	0.145	3.36 ns
	Tephrosia	2.27 ± 6.08	2.47 ± 1.83	0.055	1.81 ns
	Water hyacinth	1.17 ± 4.27	2.50 ± 1.29	0.165	3.76 ns
1.00	Eucalyptus	3.53 ± 4.05	1.20 ± 1.22	1.00	0.97 ns
	Guava	0.47 ± 5.91	3.60 ± 1.78	0.180	4.08 ns
	Neem	1.03 ± 3.34	1.50 ± 1.01	0.08	2.21 ns
	Tephrosia	3.50 ± 5.73	1.57 ± 1.73	1.08	0.82 ns
	Water hyacinth	-1.03 ± 2.70	2.760 ± 0.82	0.43	11.51 ns
2.50	Eucalyptus	1.27 ± 2.16	0.73 ± 0.65	0.019	1.27 ns
	Guava	1.50 ± 3.21	0.73 ± 0.96	1.03	0.58 ns
	Neem	0.50 ± 1.73	0.63 ± 0.52	0.03	1.48 ns
	Tephrosia	-1.70 ± 1.92	1.57 ± 0.58	0.312	7.34 *
	Water hyacinth	0.40 ± 1.52	1.07 ± 0.46	0.24	5.45 *
5.00	Eucalyptus	0.03 ± 1.33	0.83 ± 0.40	0.191	4.31 ns
	Guava	0.57 ± 1.54	1.17 ± 0.46	0.275	6.31 *
	Neem	-0.83 ± 0.66	0.90 ± 1.99	0.582	20.47 **
	Tephrosia	0.60 ± 1.11	0.53 ± 0.34	0.98	2.53 ns
	Water hyacinth	0.80 ± 1.57	0.40 ± 0.47	1.02	0.72 ns

** - Significant at P < 0.01

 * - Significant at P < 0.05

There were significant differences (P<0.01) amongst the treatments for the weight loss in dried cassava chips caused by the boring and tunnelling activity of the larger grain borer, *P. truncatus*. After 70 days of storage, the lowest (0.23%) and highest (39.02%) weight losses were in Actellic treated cassava and control, respectively (Table 9). On the hand , the leaf powder treated cassava had significantly (P<0.01) lower weight loss than the untreated cassava (control). The mean percent weight loss ranged from 1.09 % in Neem at 5g/100g at 14 DAT to 35.05% in Guava applied at 1g/100g dried cassava, 70 DAT.

There was a significant increase in weight loss from 14 to 70 DAT among leaf powders treatments. The biggest increase occurred in Guava, followed by Eucalyptus. The least was in Neem. At 14 and 28 DAT, the highest mean weight loss was in Guava treated cassava and the lowest in Neem. At 42 DAT, the highest (12.56%) occurred in Eucalyptus, representing an increase of 8% over the weight loss recorded at 14 DAT. The smallest increase over the same period was in Neem (4.35%). At 56 DAT, the lowest weight loss was in Neem (9.35%) followed by Water hyacinth (13.52%). At 70 DAT, the highest weight loss was in the control, 39.02%. Among the leaf powder treatments, the highest (20.09%) and lowest (13.20%) were in Guava and Neem, respectively. The weight loss in the control was 2.9 times more than in Neem.

Table 9. Mean percent weight loss of dried cassava chips treated with different doses of leaf powders, caused by *Prostephanus truncatus'* boring and tunnelling during 70 days of storage

Dose (g/100g)	Days after treatment					Mean
	14	28	42	56	70	
Eucalyptus						
0.1	6.27	7.67	19.55	25.26	31.05	17.96 ab
0.25	4.31	8.23	21.54	26.14	26.78	17.33 ab
0.5	4.19	5.73	8.54	12.54	16.90	9.58 gh
1	5.33	6.04	9.32	11.71	11.92	9.97 efgh
2.5	4.42	6.10	8.79	10.59	12.29	8.44 gh
5	3.04	4.75	7.98	9.36	10.20	7.06 hij
Mean	4.59 mno	6.42 l	12.56 ghi	15.94 def	18.19 cd	
Guava						
0.1	8.14	8.78	11.68	23.63	35.41	15.51 abc
0.25	7.74	10.19	12.52	13.63	21.47	15.11 abc
0.5	8.86	9.59	15.51	14.87	19.99	13.77 bc
1	3.00	5.14	9.20	15.61	18.26	10.24 defg
2.5	4.25	6.79	9.95	13.08	16.22	10.06 defg
5	4.40	6.75	9.77	10.77	9.19	8.18 ghij
Mean	6.07 mno	7.88 kl	11.44 hij	15.25 def	20.09 c	
Neem						
0.1	3.05	5.65	8.03	12.91	18.36	9.06 gh
0.25	2.67	5.13	8.11	11.74	18.92	9.32 fgh
0.5	2.30	3.29	5.19	7.65	12.25	6.14 ijk
1	1.85	2.89	5.32	7.71	11.77	5.91 jk
2.5	2.48	5.75	8.05	9.40	9.90	7.12 ghij
5	1.09	2.30	4.83	6.67	7.99	4.58 k
Mean	2.24 p	4.17 no	6.59 l	9.35 jk	13.20 fgh	
Tephrosia						
0.1	3.08	6.85	13.60	17.32	20.17	12.20 cdef
0.25	5.40	9.64	15.51	19.09	20.86	14.10 bc
0.5	5.58	7.78	12.36	16.34	18.70	12.15 cd
1	3.80	5.48	9.70	12.04	14.39	9.08 efgh
2.5	2.34	3.80	8.23	13.42	15.63	8.08 ghi
5	1.94	2.26	5.87	11.74	13.39	7.04 hijk
Mean	3.69 op	5.67 lmn	10.98 hij	14.99 def	17.19 cd	
Water hyacinth						
0.1	4.99	7.30	12.92	17.46	24.62	13.46 c
0.25	4.19	8.13	15.56	17.90	19.72	13.10 c
0.5	5.34	8.41	11.86	15.46	16.89	11.59 cde
1	3.38	5.25	8.46	12.54	15.12	8.95 gh
2.5	1.44	3.60	7.50	8.98	12.26	6.76 hijk
5	1.33	4.46	8.06	8.80	10.16	6.56 hijk
Mean	3.45 op	6.19 lm	10.73 hij	13.52 efgh	16.46 cde	
Actellic super	0.23 q	0.23 q	0.23 q	0.23 q	0.23 q	0.23 l
Control	2.98 op	9.84 ij	14.90 def	24.18 b	39.02 a	18.20 a
C.V	38.4					
Time effect ** (SEm = 1.327); Dose effect ** (SEm = 1.327)						

Figures followed by the same letter(s) within rows or columns do not differ significantly ($P<0.05$); ** significant at $P<0.01$. Duncan' Multiple Range Test on square root (x + 0.5). SEm = Standard error of mean

Dried cassava chips treated with higher dosages of leaf powders, 1.0g, 2.5g and 5.0g, had significantly ($P<0.01$) lower weight loss compared to those where lower doses, 0.1g 0.25g and 0.5g were applied (Table 9). The mean values revealed that dried cassava chips treated with 5.0g Neem leaf powder had lowest weight loss. However, this was not significantly different ($P<0.05$) from Neem at 2.5g, Water hyacinth and Tephrosia at *2.50g and 5.00g/100g. The highest weight loss was in Eucalyptus applied at 0.10g/100g.* This was not significant differently ($P<0.05$) from Guava at the same dose and the control.

The destructive stages of the test insects (Hodges, 1986; GASGA, 1993) were significantly correlated to weight loss in treated dried cassava chips, though the damage by larvae in the Neem treatment was insignificant (Table 10). The larval population in the untreated cassava, unlike in the leaf powder treatments, was very highly correlated to the weight loss.

Table 10. Correlation of destructive life stage of *Prostephanus truncatus* to the weight loss of dried cassava chips treated with leaf powders

Treatment	Correlation coefficient	
	Larvae	Adult
Eucalyptus	0.275 **	0.403 **
Guava	0.210 *	0.553 **
Neem	0.183 ns	0.584 **
Tephrosia	0.214 *	0.503 **
Water hyacinth	0.217 **	0.640 *
Control untreated	0.375 **	0.271 **

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

4.1.2. Repellency study

Prostephanus truncatus adults demonstrated negative orientation response to the cassava powder treated with leaf powder. Except in Neem, there were no significant differences ($P<0.05$) in repellency over time in all the leaf powder treatments (Table 11.). However the repellency increased significantly ($P<0.01$) with dosage. Repellency was greatest at higher doses (2.5 and 5g/100g) but were not significant different ($P<0.05$). The least effect exerted at 0.1g/ 100g in all leaf powder treatments.

Tephrosia leaf powder exhibited strong repellent effect. The leaf powder of Neem was next best. The decreasing order of efficacy of the five leaf powders was as follows: Tephrosia>Neem >Water hyacinth>Guava>Eucalyptus.

Table 11. Mean percent repellency of leaf powders to *Prostephanus truncatus* adults using cassava as the food substrate

Dose (g/100g)	Days after treatment					Mean
	1	2	3	4	5	
Tephrosia						
0.1	26.7	16.7	30.0	13.3	13.3	20 c
0.25	40.0	56.7	50.0	53.3	50.0	50 b
0.5	40.0	46.7	50.0	50.0	46.7	46.7 b
1	50.0	40.0	53.3	50.0	63.3	46.7 b
2.5	66.7	70.0	73.3	63.3	60.0	66.7 a
5	66.7	73.7	70.0	76.7	76.7	72.7 a
Mean	48.3	50.6	54.4	51.1	47.8	
C.V	30.0					
Time effect ns ; Dose effect** (SEm = 5.52)						
Water Hyacinth						
0.1	26.7	40.0	33.3	13.3	6.7	24.0 b
0.25	40.0	50.0	33.3	36.7	30.0	38.0 ab
0.5	43.3	70.0	60.0	26.7	23.3	44.7 ab
1	56.7	66.7	66.7	43.3	33.3	53.3 a
2.5	60.0	36.7	56.7	63.3	50.0	53.3 a
5	76.7	60.0	33.3	73.3	53.3	59.3 a
Mean	50.6	53.9	47.2	42.8	32.8	
C.V	50.9					
Time effect ns ; Dose effect**(SEm =8.44)						
Eucalyptus						
0.1	13.3	40.0	16.7	16.7	20.0	21.3 b
0.25	23.3	46.7	36.7	40.0	23.3	34.0 ab
0.5	16.7	46.7	36.7	66.7	36.7	40.7 ab
1	46.7	10.0	53.3	60.0	56.7	45.3 ab
2.5	50.0	46.7	40.0	66.7	46.7	50.0 a
5	63.3	53.3	56.7	56.7	53.3	56.7 a
Mean	35.6	40.6	40.0	51.1	39.4	
C.V	60.6					
Time effect ns ; Dose effect**(SEm =9.14)						
Neem						
0.1	13.3	23.3	16.7	40.0	16.7	22.0 c
0.25	26.7	16.7	10.0	46.7	40.0	28.0 c
0.5	53.3	76.7	60.0	53.3	60.0	60.7 ab
1	40.0	46.7	46.7	60.0	56.7	50.0 b
2.5	63.3	60.0	56.7	70.0	66.7	63.3 ab
5	66.7	73.3	70.0	70.0	76.7	71.3 a
Mean	43.9 ab	49.4 ab	43.3 b	56.7 a	52.8 ab	
C.V	36.2					
Time effect* (Sem = 4.00); Dose effect**(Sem =6.51)						
Guava						
0.1	16.7	20.0	16.7	26.7	23.3	20.7 c
0.25	26.7	40.0	40.0	53.3	23.3	36.7 b
0.5	36.7	43.3	50.0	40.0	36.7	41.3 ab
1	50.0	50.0	40.0	43.3	63.3	49.3 ab
2.5	53.3	56.7	43.3	43.3	40.0	47.3 ab
5	63.3	53.3	50.0	60.0	60.0	57.3 a
Mean	41.1	43.9	40.0	44.4	41.1	
C.V	36.6					
Time effect ns; Dose effect**(SEm = 5.62)						

Figures followed by the same letter(s) within row or column do not differ significantly at P<0.05, ns - not significant; * - significant (P>0.05); ** - highly significant (P>0.01); Duncan' Multiple Range Test. SEm - Standard error of mean.

4.1.3. Anti-feeding study

The leaf powder treatments produced significantly ($P<0.05$) higher anti-feeding effect on the adult *P. truncatus* than the control (Table 12). Among leaf powder treatments, the mean differences were statistically insignificant ($P<0.05$) however, the highest feeding deterrence was in the Neem , where the test insects made fewer holes in the filter paper at all the doses. This was followed by Tephrosia. The least effect was in Guava. An increase in antifeeding activity was observed with increasing dose though, not significant different ($P<0.05$).

Table 12. Antifeeding effect of different doses of leaf powders on the feeding behaviour of *Prostephanus truncatus* adults

Dose (g/100g)	Mean no. holes/filter						
	Eucalyptus	**Guava**	**Neem**	**Tephrosia**	**Water hyacinth**	**Control**	**Mean**
0.10	22.33	22.00	14.00	22.67	19.33	33.33	22.83
0.25	20.67	23.67	16.67	22.33	14.00	31.33	21.44
0.50	19.00	17.67	11.00	11.67	14.67	37.67	18.61
1.00	17.33	15.00	9.67	11.67	13.67	22.67	15.00
2.50	10.67	14.33	8.33	11.67	12.00	42.00	16.50
5.00	10.33	13.00	8.00	10.33	12.00	54.33	18.00
Mean	16.72 B	17.61 B	11.28 B	15.06 B	14.28 B	36.89 A	
CV	53.3						
Leaf Powder effect* (SEm = 2.129); Dose effect ns							

Mean followed by the same letter (s) within the row do not differ significantly (P<0.05); ns – not significant, * - significant (P<0.01). Duncan Multiple Range Test
SEm – Standard error of means.

4.1.4. Food Preference study

Significantly ($P<0.01$) higher numbers of *P. truncatus* adults preferred untreated cassava (control) to the leaf powder treatments (Table 13). Among the leaf powder treated cassava, Neem had the lowest number of *P. truncatus* that exhibited preference, followed by Tephrosia though their differences were not significant ($P<0.05$) where as Guava had the high preference. The mean values for dose versus food preference revealed though there was a slight reduction in preference with increasing dose, the differences were not significant.

Table 13. Mean number of the adults of the larger grain borer, *Prostephanus truncatus'* exhibiting preference for cassava treated with leaf powders.

Treatment	Mean no. adults
Eucalyptus	1.489 bc
Guava	1.650 b
Neem	0.694 e
Tephrosia	0.956 de
Water Hyacinth	1.217 cd
Control	2.722 a
Mean	1.455
C.V	25.6

Figures followed by the same letter(s) within the column do not differ significantly (P<0.05); Duncan's Multiple Range Test.

4.2. Petroleum ether leaf extract studies

4.2.1. Vapour -method

The median lethal concentration, LC_{50} ranged from 0.384 % for Neem to 4.027% for Guava vapours (Table 14). Neem vapours were the most toxic against *Prostephanus truncatus* adults followed by Tephrosia. Vapours from Neem were 8 times more toxic to the test insects than those of Guava. The confidence limits and slopes of dosage-mortality curves obtained indicated no difference in the toxicity of Neem, Tephrosia and Water hyacinth. Toxicity of the vapours that were emitted from the impregnated filter papers on the test insects were of the following sequence: Neem > Tephrosia > Water hyacinth > Eucalyptus > Guava.

Table 14. Toxicity effect of vapours of petroleum ether leaf extracts on *Prostephanus truncatus* adults

Extracts	LC_{50}	95% C.L	Slope + SE	Chi-square	Df	Heterogeneity
Eucalyptus	1.3256	0.678 – 2.72	0.931 ± 0.346	1.651	10	.17
Guava	4.0279	1.228 – 6.821	0.783 ± 0.371	1.940	10	.19
Neem	0.3841	0.227 – 0.692	1.138 ± 0.327	3.324	10	.33
Tephrosia	0.5120	0.331 – 1.058	1.288 ± 0.339	6.116	10	.61
Water Hyacinth	0.5149	0.281 – 0.870	0.824 ± 0.321	2.791	10	.28

LC_{50} = concentration (%) calculated to give 50% mortality
S.E = Standard error
C.L = Confidence limit.
Df = Degrees of freedom

4.2.2. Residual surface film exposure

Eucalyptus was found to be the most toxic to *P. truncatus*, followed by Neem, where as Guava was the least (Table 15). Eucalyptus residual surface film had the lowest LC_{50} values (5.05, 7.72 and 4.88%) through out the 72-hour exposure period (Table 15). These were on average 20.5 times more toxic than those of Guava. The lower LC_{50} values at 48 and 72 hours for all petroleum ether leaf extracts indicated an increased insect mortality with an increase in exposure time.

Table 15. Toxicity effect of the residual surface film of the petroleum ether leaf extracts on *Prostephanus truncatus* adults during the 72-hour exposure period.

Extract	LC_{50}		
	Exposure period (hours)		
	24	**48**	**72**
Eucalyptus	7.726	5.0599	4.889
	(1.462 ± 0.551)	(1.151 ± 0.577)	(0.872 ± 0.476)
Guava	141.876	103.339	98.962
	(1.404 ± 0.859)	(0.268 ± 0.719)	(0.677 ± 0.694)
Neem	14.018	9.667	7.5324
	(0.618 ± 0.509)	(1.183 ± 0.477)	(0.896 ± 0.468)
Tephrosia	37.713	14.971	7.258
	(0.446 ± 0.609)	(0.815 ± 0.514)	(1.157 ± 0.471)
Water hyacinth	88.056	10.506	7.365
	(0.000 ± 0.597)	(1.138 ± 0.465)	(0.823 ± 0.412)

LC_{50} = concentration (%) calculated to give 50% mortality
Slope ± Standard Error are in parenthesis

4.2.3. Topical application method

Neem had the lowest LC_{50} value (0.135 and 0.079%) at 24 and 48 hours after treatment, while the highest (0.573 and 0.260%) were found in Guava (Table 16). At 72 and 96 hours, Tephrosia had the lowest LC_{50} values (0.042 and 0.033%) followed by Water hyacinth (0.048 and 0.036%). At 120 hours after treatment, Tephrosia and Water hyacinth extracts were found to be highly toxic, had the lowest LC_{50} value of 0.027%. Guava was the least toxic, with a relative high LC_{50} value of 0.092%. Increased *P. truncatus* mortality was observed in all five extracts, during the observation period. The closeness of the dose-mortality curves as shown by the slopes indicates that except for Guava, there were no marked differences in contact toxicity amongst the extracts.

Table 16. Response of *Prostephanus truncatus* adults to the petroleum ether leaf extracts after topical application.

Extract	LC_{50}				
	Observational period (hours)				
	24	**48**	**72**	**96**	**120**
Eucalyptus	0.379	0.158	0.083	0.048	0.034
	(0.000 ± 3987126)	(2.221 ± 0.911)	(0.719 ± 0.348)	(0.323 ± 0.320)	(0.300 ± 0.319)
Guava	0.573	0.260	0.171	0.108	0.092
	(0.875 ± 0.228)	(0.775 ± 0.225)	(0.806 ± 0.226)	(0.788 ± 0.230)	(0.739 ± 0.231)
Neem	0.135	0.079	0.057	0.042	0.040
	(0.666 + 0.225)	().767 ± 0.231)	().585 ± 0.232)	(0.575 ± 0.235)	(0.594 ± 0.236)
Tephrosia	0.189	0.110	0.042	0.033	0.027
	(0.737 + 0.224))	(0.020 ± 0.226))	(0.597 ± 0.234)	(0.506 ± 0.237)	(0.492 ± 0.239)
Water hyacinth	0.197	0.105	0.048	0.036	0.027
	(0.567 ± 0.222)	(0.664 ± 0.226)	(0.629 ± 0.233)	(0.623 ± 0.236)	(0.560 ± 0.240)

LC_{50} = concentration (%) calculated to give 50% mortality. Slope + Standard Error are in the parenthesis

4.2.4 Larval dipping method

There was marked behavioural and morphological change in the *P. truncatus* larvae after treatment application; webbing practically stopped. When compared with the control larvae, some petroleum ether leaf extract treated larvae had shrunk in size. By the eighth day, Tephrosia, Neem and Water hyacinth produced 100% larval mortality. Between 30 - 70% of the larvae treated with Guava and Eucalyptus had not died by the eighth day. Even after the twelfth day, these were observed to be slower in their movement. There was however, a colour change in the leaf extract treated larvae from whitish cream to dark brown. Less that 20% of the larvae in the Guava and Eucalyptus treatments that remained alive managed to pupate but all the emerging adults later died 2-3 days later. These adults were small and too weak to move when compared to a normal adult. Those larvae that did not pupate died in the larval stage. Pupation was however normal with the acetone treated larvae.

It was found that Tephrosia was most toxic to *P. truncatus* larvae followed by Neem where as Guava extracts was least toxic (Table 17). The decreasing LC_{50} values obtained for all extracts from first to the eighth day after treatment indicated an increase in mortality in the *P. truncatus* larvae. This also suggests that all the extract exhibited persistence in their action. On the first day after treatment, no larval mortality was observed in Eucalyptus. Between 2 and 4 days after treatment, Eucalyptus produced the least larvicide hence the high LC_{50} values. From day onwards, Guava had high LC_{50} values suggesting that these two extracts were ineffective in causing larval mortality. The order of decreasing mortality was as follows: Tephrosia >Neem > Water hyacinth > Eucalyptus >Guava.

Table 17. Contact toxicity effect of petroleum ether leaf extract on *Prostephanus. truncatus* larvae after being dipped in the extracts for 5 seconds.

Extract	LC_{50}							
	Days after treatment							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Eucalyptus	0.000	51.954	2.643	1.187	1.101	0.155	0.143	0.0851
	(0)	(2.221 ± 0.911)	(0.719 ± 0.348)	(0.323 ± 0.320)	(0.300 ± 0.319)	(0.481 ± 0.316)	(1.026 ± 0.326)	(1.174 ± 0.338)
Guava	12708.962	3.462	1.813	1.543	1.475	1.154	1.064	0.939
	(0)	(1.808 ± 0.794)	(2.127 ± 0.626)	(2.126 ± 0.574)	(2.259 ± 0.584)	(1.735 ± 0.459)	(1.747 ± 0.449)	(1.706 ± 0.183)
Neem	32.398	3.573	0.195	0.0676	0.0636	0.0215	0.0033	0.000
	(23.003 ± 16879892.031)	(1.059 ± 0.447)	(1.224 ± 0.332)	(0.874 ± 0.353)	(1.963 ± 1.021)	(1.110 ± 0.465)	(16.828 ± 4947331.092)	
Tephrosia	16.103	9.937	0.0708	0.037	0.033	0.000	0.000	0.000
	(3.193 ± 1.459)	(2.038 ± 0.807)	(0.855 ± 0.343)	(1.012 ± 0.401)	(0.726 ± 0.380)			
Water hyacinth	10.281	3.298	0.261	0.098	0.050	0.011	0.009	0.009
	(1.917 ± 1.012)	(1.592 ± 0.542)	(1.487 ± 0.339)	(1.009 ± 0.349)	(1.013 ± 0.390)	(1.587 ± 0.785)	(1.298 ± 0.777)	(1.298 ± 0.777)

LC_{50} = concentration (%) calculated to give 50% mortality. Slope and Standard Error are in the parenthesis.

5.0. DISCUSSION

The studies demonstrated that leaf powders effectively suppressed *P. truncatus* populations in dried cassava chips. The reproduction potential was reduced but not completely inhibited. The effect was observed to be plant-specific and dose-related. Several workers (Obeng-ofori and Reichmuth, 1997; Niber, 1995; Chimbe and Galley, 1996) have reported the ability of different leaf extracts to inhibit the reproductive capacity of *P. truncatus*. The reduction in the numbers of *P. truncatus* progenies (larvae, pupae and emerging adults) in the leaf powder treated cassava could have been due to anti-oviposition, delayed egg-hatching and insect growth disrupting effects of the leaf powders (Singh, 1993). The zero larval counts in the leaf powder treatments at 14 DAT could have been as a result of these effects.

The use of these powders as a cassava treatment was observed to be detrimental to the development of later stages of the *P. truncatus*. The egg takes on average 3 - 4 days to hatch (Hashem, 1989), the zero larval counts at 14 DAT were a clear manifestation of the anti-hatching effect and the lengthening of the hatching period (Schmutterer, 1990). Under non-interference conditions, larvae could have been produced in treated cassava. Increased insect population in the leaf powder treatments from 28 DAT onwards suggests possible reduction in the anti-hatching effect of the treatments due to the biodegradation of the powder as the storage period lengthened. However, the reduction in larval numbers between 56 and 70 DAT could have been attributed to physiological effects the leaf powders may have had on *P. truncatus* offsprings, such as the exposed females becoming sterile (Schmutterer, 1993).

The closeness of regression coefficients (Steel and Torries, 1980) calculated for different leaf powder treatments when regressed against the time at which the *P. truncatus* counts were made, indicates that the rate of breakdown of these leaf powders was similar. The relationship was strongest in Neem when applied at 5.0g/100g dried cassava. Significantly low numbers of *P. truncatus* were recorded in Neem treated cassava at each sampling time indicating that Neem was more persistent in its effect than other leaf powders. The high *P. truncatus* populations in Guava and Eucalyptus treatments were a result of the rapid loss in toxicity. This could have been caused by the strong breakdown of the leaf powders of these two plants belonging to the same genera (Sharaby, 1988).

It was observed that the higher the dose of leaf powders, the lower the numbers of offspring in the subsequent generations. These findings agree with those of Sharaby (1988) on *Sitophilus* species. Neem leaf powders showed high reproduction and growth inhibition in *P. truncatus* adults, followed by Tephrosia and Water hyacinth. Though there were variation in adult mortality due to leaf powder treatment, there was an increase in mortality as higher doses were applied. Mortality may have due to starvation or reduced feeding due to the presence of the leaf powders (Delobel and Malonga, 1987). The time taken for mortality to occur in leaf powder treatments is longer when compared to synthetic insecticides like Actellic super with high contact toxicity (Schmutterer, 1993). Hence the low mortality rate in the leaf powder treatments. However, Baker *et al.*, (1991) have demonstrated that non-lethal inhibition of populations may result in prolonged significant reductions in storage insect pests.

Prostephanus truncatus has been reported to cause weight losses as high as 73.6% after 17 weeks of storage (Hodges *et al.*, 1985). The application of the leaf powders kept weight loss to less than 20% compared to 39% in the control after 70 days of storage. Neem treatment produced the lowest weight loss followed by the Water hyacinth. The weight loss in cassava was highly correlated with the numbers of the larvae and adults produced (Howard, 1984; Wright, 1984) and not the larval or adult stage alone as observed in Neem treated cassava. This furthermore indicates that the contribution of the damage and consequently weight loss caused by *P. truncatus* larvae in this treatment was not significant as in other treatments. The weight loss observed in *Actellic*-super treated cassava could have been due to the initial damage by *P. truncatus* before being killed by the insecticide. The observed effectiveness of the *Actellic super* in protecting cassava suggests that even though no specific chemical method of protecting the cassava has been recommended, farmers could be advised to use the dosage of *Actellic super* recommended for maize (Hodges, 1994; Mwaya, 1997).

The repellency effect of the leaf powders was sustained throughout the period of observation. The repellent effect of these powders largely dependent on olfactory and gustatory sensation of the test insects (Schmutterer, 1990). The repellent odour made *P. truncatus* adults restless. The insects were observed to be turning away and settling on the untreated cassava. The choice for the untreated cassava was because of the repellent chemicals inherent in the leaf powders (Jilani *et al.*,1988). Insect repellents are secondary metabolites which have been identified to be alcohols, alkaloids, phenolics, flavonoids and terpenes (Dales, 1996). Tephrosia leaf powder exhibited a strong repellent effect on *P. truncatus* adults. In the preference test, the insects were seen to be crawling more towards untreated cassava than leaf powder treated cassava. The presence of these secondary metabolites in the leaf powders made treated cassava to be the least preferred food media.

Fewer punctures (holes) were made in the treated than untreated filter paper used to wrap the cassava. The possible presence of insect anti-feeding allelochemicals (Saxena *et al*, 1989) in the leaf powders may have deterred the insects from penetrating the filter papers. Neem followed by Water hyacinth leaf powders were more effective feeding deterrents than Tephrosia, Eucalyptus and Guava. The outstanding effectiveness of Neem leaf powders in particular, have also been reported by other scientists (Niber, 1994; 1995; Saxena, 1989; 1993; Saxena *et al*; 1989; Schmutterer, 1990).

Petroleum ether leaf extracts produced high mortality and growth regulatory effects on almost all the treated insects compared to the leaf powders due to the high concentration of the active compounds in the former. Significantly high effects were produced by Tephrosia, Neem and Water hyacinth extracts. *Prostephanus truncatus* mortality was dose-dependent, increasing with an increase in dose. Mortality was highest when *P. truncatus* adults were exposed to Neem vapours followed by Tephrosia.

Adult mortality due to exposure to the residual surface film of the extracts was lower than that caused by vapour and topical treatments, hence the high LC_{50} values observed. This is because of the low residual activity of the extracts. Many researchers have investigated the potential role of various absorbent coatings to increase the persistence of contact insecticides (Gudrups *et al.*, 1994). However, no appropriate coatings have been developed for botanicals. The decreasing LC_{50} values indicated increasing mortality with time. The low values at 72 hrs compared to those at 24 hrs in all the extracts except that of Guava suggests that susceptibility of test insects increased with an increase in exposure period.

In topical treatment, the active fractions in the petroleum ether leaf extracts may have caused mortality by direct interference with insect physiological balance (Pierce and Schmidt, 1993). The restlessness in the treated insects before death suggests hormonal involvement in the action of these compounds (Rani and Jamil, 1989). Malformed elytra and crumpled hind wings were observed in adults that emerged from larvae that had been dipped in the extracts. Similar observations have been reported for other plant extracts (Chimbe and Galley, 1996; Obeng-Ofori and Reichmuth, 1997; Su, 1991).

In the larval dipping method, Jamil *et al.*, (1984) and Rani and Jamil, (1989) have suggested that larval mortality is caused by interference of the extracts with the cuticular deposition, and insect growth and metamorphosis. The extracts induced moult inhibition. They acted as insect regulators disrupting the moult cycle. Ecdysis in treated larvae was stopped. Initiation of the new cuticle was disrupted. At higher concentration of the petroleum ether extracts, increased pigmentation, which was distributed almost entirely over the body occurred in all the treatments except Guava and the control. In the Tephrosia, Neem and Water hyacinth treatments, over 90% of larvae dipped in the petroleum ether extracts died by the 8th day while in the Guava and Eucalyptus, larvae were found moving even 12 days after the treatments, indicating these two were relatively ineffective.

The LC_{50} values of the petroleum ether extracts shows that Tephrosia, Neem and Water hyacinth displayed the highest potency against test insects while Guava was the least toxic. The toxicity effect may be attributed to the secondary metabolites (Dales, 1996) These tend to affect insects in several ways such as disrupting major metabolic pathways and causing rapid death, acting as deterrents, phagostimulants or antifeedants, or modifying oviposition (Jilani, 1992). These secondary compounds may also retard or accelerate development, or interfere with the life cycle of the insects. The differences in the toxicity of Eucalyptus and Guava to *P. truncatus*, although belonging to the same family, *Myrtaecae*, may be attributed to a species-specific factor (Kamal *et al.*, 1988).

6.0. CONCLUSION AND RECOMMENDATIONS

Plant-derived materials are known sources of secondary metabolites with insecticidal properties. Assessment of the plant extracts could contribute greatly to their use as protectants for stored farm products. Based on the evidence presented in this research, the results have shown that it is possible to reduce the reproductive capacity of, and damage by the *P. truncatus* on dried cassava by treating the latter with leaf powders. The findings, though preliminary, indicate that the most promising plants for consideration as dried cassava protectants against *P. truncatus*, belong to the genera *Azadirachta* (Neem), *Pontederaecae* (Water hyacinth) and *Leguminosae* (Tephrosia). Although, the insecticidal activity of these leaf extracts against *P. truncatus* gave a ray of hope, their mammalian toxicity requires thorough evaluations.

Cassava is considered to be a crop of low value, hence little attention is paid to its safe storage. Management of storage pests of this farm product using plant extracts presents three major problems compared to pulses and cereal grains. First, consumer preference is to some extent determined by colour. Application of botanicals as powders may taint the dried cassava thereby affecting its acceptability. Secondly, the plant crude extracts are cumbersome to prepare, a lot may be required to sufficiently exert the same level of control as synthetic insecticides. Thirdly, accelerated biodegradability of the plant extracts affects their persistence. To avert this, i.e., the extracts have to be used soon after preparation. However, more studies are required to evaluate the utility of these environmental friendly, low cost, naturally occurring control agents for storage insect pests. The technologies once developed would help alleviate poverty and ensure household food security.

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APPENDICES

Appendix 1. Mean number of *Prostephanus truncatus* in dried cassava chips treated with different doses of leaf powders during 70 days of storage

Treatment	Mean number/ 100 g dried cassava		
	Larvae	Pupae	Adults
Eucalyptus	3.59 bc	0.422 bc	4.270 bc
Guava	4.42 b	0.567 b	4.920 b
Neem	2.43 c	0.067 cd	3.499 c
Tephrosia	3.20 bc	0.222 bcd	4.30 bc
Water Hyacinth	2.91 bc	0.289 bcd	4.019 bc
Actellic super	0.00 d	0.000 d	0.00 d
Control	11.44 a	2.778 a	11.66 a
Mean	4.00	0.621	4.66
C.V	40.7	34.1	37.7

Figures followed by the same letter in the same column are not significant different at P<0.01; Duncan Multiple Range Test on square root (x+0.5)

Appendix 2. Mean number of *Prostephanus truncatus* larvae in dried cassava treated with different doses of leaf powders during 70 days of storage

Dose (g/100g)	Days after treatment					
	14	28	42	56	70	Mean
Eucalyptus						
0.10	0.00	2.67	23.00	11.00	0.00	7.33 a
0.25	0.00	2.00	21.00	6.67	0.00	5.93 a
0.50	0.00	2.67	11.33	6.67	0.00	4.13 ab
1.00	0.00	0.67	11.33	3.00	0.00	3.00 b-f
2.50	0.00	0.00	1.00	0.67	1.00	0.53 d-h
5.00	0.00	0.00	0.00	2.00	1.00	0.60 d-h
Mean	0.00 g	0.33 g	11.28 bc	5.00 ef	0.33 g	
Guava						
0.10	0.00	1.33	15.67	11.67	1.33	6.00 a
0.25	0.00	1.67	14.67	13.33	0.67	6.07 a
0.50	0.00	0.00	17.67	12.00	0.00	5.93 ab
1.00	0.00	1.33	13.67	13.33	1.33	5.93 a
2.50	0.00	5.67	1.67	0.67	0.67	1.73 b-h
5.00	0.00	0.33	2.00	0.00	2.00	0.87 c-h
Mean	0.00 g	1.72 g	10.89 bc	8.50 cde	1.00 g	
Neem						
0.10	0.00	0.33	15.67	10.00	1.33	5.47 ab
0.25	0.00	0.00	12.67	3.33	1.33	3.47 a-f
0.50	0.00	1.33	8.00	3.33	0.67	2.67 a-g
1.00	0.00	0.33	6.33	5.33	0.67	2.53 a-g
2.50	0.00	0.00	0.33	0.00	1.33	0.33 f-h
5.00	0.00	0.33	0.00	0.33	0.00	0.13 gh
Mean	0.00 g	0.39 g	7.17 def	3.72 f	0.89 g	
Tephrosia						
0.10	0.00	1.33	25.00	6.00	0.00	6.47 a
0.25	0.00	0.00	12.33	7.00	0.00	3.87 a-e
0.50	0.00	1.67	12.33	4.67	0.33	3.80 a-d
1.00	0.00	0.33	15.67	3.33	0.00	3.87 a-e
2.50	0.00	0.00	0.00	0.67	3.33	0.80 c-h
5.00	0.00	0.00	0.33	1.00	0.67	0.40 e-h
Mean	0.00 g	0.56 g	10.94 bcd	3.78 ef	0.72 g	
Water hyacinth						
0.10	0.00	1.33	15.67	7.33	0.00	4.87 ab
0.25	0.00	0.33	17.67	3.67	0.00	4.33 abc
0.50	0.00	2.33	9.67	8.33	0.00	4.07 abc
1.00	0.00	1.67	6.67	7.33	0.00	3.13 a-d
2.50	0.00	0.33	1.33	0.00	2.33	0.80 c-h
5.00	0.00	0.33	0.00	0.33	0.67	0.27 f-h
Mean	0.00 g	1.06 g	8.50 cde	4.50 ef	0.50 g	
Actellic super	0.00 g	0.00 g	0.00 g	0.00 g	0.00 g	
Control	4.39 ef	11.83 ab	14.39 a	12.06 a	14.56 a	
C.V	40.7					
Time effect ** (SEm = 0.939) ; Rate effect** (SEm=1.010)						

Means followed by the same letter(s) in row or column do not differ significantly.* significant at P< 0.05; ** significant at P< 0.01; ns - not significant different. Duncan' Multiple Range Test on square root (X+0.5).SEm - Standard error of the mean

Appendix 3. Mean number of deformed *Prostephanus truncatus* larvae in dried cassava treated with different doses of leaf powders during 70 days of storage

Dose (g/100g)	Days after treatment					
	14	28	42	56	70	Mean
Eucalyptus						
0.1	0.000	0.000	1.000	1.333	0.000	0.467
0.25	0.000	0.000	1.000	0.333	0.000	0.267
0.5	0.000	0.000	1.333	1.000	0.000	0.467
1	0.000	0.000	0.333	0.333	0.000	0.133
2.5	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 d	0.000 d	0.611 ab	0.500 abcd	0.000 d	
Guava						
0.1	0.000	0.000	0.667	0.667	0.000	0.267
0.25	0.000	0.000	0.667	2.000	0.000	0.600
0.5	0.000	0.000	1.000	1.333	0.000	0.467
1	0.000	0.000	0.667	1.333	0.000	0.400
2.5	0.000	0.000	0.000	0.667	0.000	0.133
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 e	0.056 cd	0.500 abc	1.000 a	0.000 d	
Neem						
0.1	0.000	0.000	1.333	2.333	0.667	0.867
0.25	0.000	0.000	1.000	0.667	0.000	0.333
0.5	0.000	0.000	1.000	1.000	0.000	0.400
1	0.000	0.000	0.000	1.333	0.333	0.333
2.5	0.000	0.000	0.333	0.000	0.333	0.133
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 d	0.000 d	0.611 abcd	0.889 a	0.222 bcd	
Tephrosia						
0.1	0.000	0.000	2.333	0.667	0.000	0.600
0.25	0.000	0.000	0.667	0.000	0.000	0.133
0.5	0.000	0.000	1.000	0.000	0.333	0.267
1	0.000	0.000	1.333	0.333	0.000	0.333
2.5	0.000	0.000	0.000	0.333	0.000	0.067
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 d	0.000 d	0.889 a	0.222 bcd	0.056 cd	
Water hyacinth						
0.1	0.000	0.333	0.667	1.000	0.000	0.400
0.25	0.000	0.000	1.000	0.000	0.000	0.200
0.5	0.000	0.000	1.667	1.667	0.000	0.667
1	0.000	0.333	0.000	1.000	0.000	0.267
2.5	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	1.000	0.000	0.000	0.000
Mean	0.000 d	0.111 cd	0.556 abcd	0.611 abc	0.000 d	
Actellic	0.000 d	0.000 d	0.000 d	0.000 d	0.000 d	
Control	0.000 d	0.000 d	0.000 d	0.000 d	0.000 d	
C.V	29.6					
Time effect** (Sem=0.1429) ; Dose effect ns						

Means followed by the same letter(s) within row or column do not differ significantly. * significant at P<0.05; ** significant at P<0.01, ns - not significant different. Duncan' Multiple Range Test. SEm - Standard error of the mean

Appendix 4. Mean number of dead *Prostephanus truncatus* larvae in dried cassava treated with different doses of leaf powders during 70 days of storage

Dose (g/100g)	Days after treatment					
	14	**28**	**42**	**56**	**70**	**Mean**
Eucalyptus						
0.1	0.000	0.000	1.667	2.333	0.000	0.800
0.25	0.000	0.000	1.000	1.333	0.000	0.467
0.5	0.000	0.000	1.667	1.000	0.000	0.533
1	0.000	0.000	0.667	0.333	0.000	0.200
2.5	0.000	0.000	0.000	0.333	0.000	0.067
5	0.000	0.000	0.000	0.333	0.000	0.067
Mean	0.000 e	0.000 e	0.833 abc	0.944 abc	0.000 e	
Guava						
0.1	0.000	0.000	0.667	0.667	0.000	0.267
0.25	0.000	0.333	0.667	2.333	0.000	0.667
0.5	0.000	0.000	1.000	1.667	0.000	0.533
1	0.000	0.000	1.000	0.667	0.000	0.533
2.5	0.000	0.000	0.333	0.000	0.000	0.200
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 e	0.056 de	0.611 abcd	1.167 a	0.000 e	
Neem						
0.1	0.000	0.000	1.333	2.333	1.333	1.000
0.25	0.000	0.000	1.000	0.667	0.000	0.333
0.5	0.000	0.000	1.000	1.000	0.333	0.467
1	0.000	0.000	0.000	1.333	0.667	0.400
2.5	0.000	0.000	0.333	0.000	0.333	0.133
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 e	0.000 e	0.611 a-e	0.889 abc	0.444 bcde	
Tephrosia						
0.1	0.000	0.000	2.333	1.333	0.000	0.733
0.25	0.000	0.000	0.667	0.000	0.000	0.133
0.5	0.000	0.000	1.000	0.000	0.333	0.267
1	0.000	0.000	1.333	0.667	0.000	0.400
2.5h	0.000	0.000	0.000	0.333	0.000	0.067
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 e	0.000 e	0.889 abc	0.389 cde	0.056 de	
Water hyacinth						
0.1	0.000	0.333	0.667	0.667	0.000	0.600
0.25	0.000	0.000	1.000	0.667	0.000	0.200
0.5	0.000	0.000	1.667	0.000	0.000	0.867
1	0.000	0.333	0.000	0.000	0.000	0.467
2.5	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.067
Mean	0.000 a	0.111 de	0.556 a-e	1.167 ab	0.000 e	
Actellic super	0.000 e	0.000 e	0.000 e	0.000 e	0.000 e	
Control	0.000 e	0.000 e	0.000 e	0.000 e	0.000 e	
C.V	33.7					
Time effect** (SEm=0.1734) ; Dose effect ns						

Means followed by the same letter(s) within rows or columns do not differ significantly.* significant at P<0.05; ** significant at P<0.01, ns - not significant different. Duncan' Multiple Range Test on square root (x + 0.5). SEm - Standard error of the mean

Appendix 5. Mean number of *Prostephanus truncatus* pupae in dried cassava treated with different doses of leaf powder during 70 days of storage

Dose (g/100g)	Days after treatment					
	14	28	42	56	70	Mean
Eucalyptus						
0.1	0.00	0.00	2.000	1.000	0.000	0.600 efg
0.25	0.00	0.00	3.667	3.667	0.000	1.467 cde
0.5	0.00	0.00	1.000	1.333	0.000	0.467 efg
1	0.00	0.00	0.000	0.000	0.000	0.000 g
2.5	0.00	0.00	0.000	0.000	0.000	0.000 g
5	0.00	0.00	0.000	0.000	0.000	0.000 g
Mean	0.00 h	0.00 h	1.111 de	1.000 efg	0.000 h	
Guava						
0.1	0.000	0.000	4.333	3.333	0.000	1.533 cdef
0.25	0.000	0.000	0.667	4.000	0.000	0.933 defg
0.5	0.000	0.000	0.333	1.333	0.000	0.333 efg
1	0.000	0.000	0.667	2.333	0.000	0.600 efg
2.5	0.000	0.000	0.000	0.000	0.000	0.000 g
5	0.000	0.000	0.000	0.000	0.000	0.000 g
Mean	0.000 h	0.000 h	1.000 efg	1.833 cd	0.000 h	
Neem						
0.1	0.000	0.333	0.667	0.000	0.000	0.133 g
0.25	0.000	0.000	0.000	0.333	0.000	0.133 g
0.5	0.000	0.000	0.667	0.000	0.000	0.133 g
1	0.000	0.000	0.000	0.000	0.000	0.000 g
2.5	0.000	0.000	0.000	0.000	0.000	0.000 g
5	0.000	0.000	0.000	0.000	0.000	0.000 g
Mean	0.000 h	0.056 gh	0.222 fgh	0.056 gh	0.000 h	
Tephrosia						
0.1	0.000	0.000	0.333	1.000	0.000	0.267 efg
0.25	0.000	0.000	1.000	0.333	0.000	0.267 fg
0.5	0.000	0.000	0.333	2.333	0.000	0.533 efg
1	0.000	0.000	0.333	0.667	0.000	0.200 g
2.5	0.000	0.000	0.000	0.333	0.000	0.067 g
5	0.000	0.000	0.000	0.000	0.000	0.000 g
Mean	0.000 h	0.000 h	0.333 efgh	0.778 efg	0.000 h	
Water hyacinth						
0.1	0.000	0.000	0.667	1.667	0.000	0.467 efg
0.25	0.000	0.333	1.667	1.667	0.000	0.733 defg
0.5	0.000	0.000	0.333	0.667	0.000	0.200 g
1	0.000	0.333	0.000	1.333	0.000	0.333 efg
2.5	0.000	0.000	0.000	0.000	0.000	0.000 g
5	0.000	0.000	0.000	0.000	0.000	0.000 g
Mean	0.000 h	0.111 gh	0.444 efgh	0.889 ef	0.000 h	
Actellic super	0.000 h	0.000 h	0.000 h	0.000 h	0.000 h	
Control	0.000 h	2.444 bc	2.833 b	3.500 b	5.111 a	
C.V	34.1					
Time effect ** (SEm = 0.253) ; Rate effect** (SEm=0.287)						

Means followed by the same letter(s) withins row or columns do not differ significantly. * significant at P< 0.05; ** significant at P< 0.01, ns - not significant different. Duncan' Multiple Range Test on square root (x + 0.5).SEm - Standard error of the mean

Appendix 6. Mean number of *Prostephanus truncatus* adults in dried cassava treated with different doses of leaf powders during 70 days of storage

Dose (g/100g)	Days after treatment					
	14	28	42	56	70	Mean
Eucalyptus						
0.1	0.00	2.67	5.67	8.67	11.00	5.60
0.25	0.00	1.33	4.67	8.67	16.33	6.20
0.5	0.00	4.33	7.67	3.67	8.33	4.80
1	0.00	4.67	7.67	2.33	6.00	4.13
2.5	0.00	4.69	4.67	1.33	4.00	2.93
5	0.00	2.33	3.67	0.67	3.00	1.93
Mean	0.00 g	3.33 ef	5.67 cde	4.22 ef	8.11 bcd	
Guava						
0.1	0.00	2.67	6.33	9.00	15.00	6.60
0.25	0.00	3.67	4.67	18.33	11.33	7.60
0.5	0.00	3.67	6.33	8.00	14.33	6.47
1	0.00	4.67	6.00	2.33	10.67	4.73
2.5	0.00	2.33	0.67	1.33	6.00	2.07
5	0.00	1.00	2.33	5.00	2.00	2.07
Mean	0.00 g	3.00 ef	4.39 def	7.33 cde	9.89 bc	
Neem						
0.1	0.00	2.67	1.33	6.00	17.00	5.40
0.25	0.00	3.33	2.67	3.67	5.33	3.00
0.5	0.00	7.67	4.33	4.33	12.33	5.73
1	0.00	4.00	3.67	2.00	5.33	3.00
2.5	0.00	4.33	1.33	1.33	3.33	2.07
5	0.00	1.00	1.67	2.00	4.00	1.73
Mean	0.00 g	3.83 ef	2.50 f	3.22 ef	7.89 bcd	
Tephrosia						
0.1	0.00	5.67	7.33	3.33	13.33	5.93
0.25	0.00	6.67	8.00	6.00	11.67	6.47
0.5	0.00	4.67	9.33	2.00	10.67	5.33
1	0.00	3.33	7.67	4.00	5.67	4.13
2.5	0.00	3.00	1.00	2.33	4.33	2.13
5	0.00	3.33	1.67	1.67	2.33	1.80
Mean	0.00 g	4.44 def	5.83 cde	3.22 ef	8.00 bcd	
Water hyacinth						
0.1	0.00	2.33	6.00	11.33	9.33	5.80
0.25	0.00	1.00	4.33	7.67	14.67	5.53
0.5	0.00	3.67	5.00	4.67	8.67	4.40
1	0.00	1.33	4.33	4.33	9.00	3.80
2.5	0.00	3.00	4.67	3.33	3.00	2.80
5	0.00	2.00	3.67	1.33	1.67	1.73
Mean	0.00 g	2.22 f	4.67 def	5.44 def	7.72 bcd	
Actellic super	0.00 g	0.00 g	0.00 g	0.00 g	0.00 g	
Control	0.00 g	10.33 b	15.73 a	14.72 a	17.44 a	
C.V	37.7					
Time effect** (SEm=0.997) ; Rate effect ns						

Means followed by the same letter(s) within rows or columns do not differ significantly. * significant at P<0.05; ** significant at P<0.01, ns - not significant different. Duncan' Multiple Range Test on square root (x + 0.5). SEm - Standard error of the mean

Appendix 7.Mean number of deformed *Prostephanus truncatus* adults in dried cassava treated with different doses of leaf powders during 70 days of storage

Dose (g/100g)	**Days after treatment**					
	14	**28**	**42**	**56**	**70**	**Mean**
Eucalyptus						
0.1	0.000	0.000	0.000	0.333	0.000	0.067
0.25	0.000	0.000	0.333	0.000	0.000	0.067
0.5	0.000	0.000	0.667	0.000	0.000	0.133
1	0.000	0.000	1.333	0.000	0.000	0.267
2.5	0.000	1.000	1.333	0.333	0.000	0.533
5	0.000	1.000	0.667	0.000	0.000	0.333
Mean	0.000 d	0.333 bcd	0.722 a	0.111 cd	0.000 d	
Guava						
0.1	0.000	1.333	0.000	1.000	0.333	0.533
0.25	0.000	0.667	0.000	0.000	0.000	0.133
0.5	0.000	0.667	0.000	0.667	0.000	0.267
1	0.000	0.000	0.333	0.000	0.333	0.133
2.5	0.000	0.000	0.000	0.000	0.667	0.133
5	0.000	0.000	0.000	1.667	1.000	0.533
Mean	0.000 d	0.444 abc	0.056 cd	0.556 ab	0.389 abc	
Neem						
0.1	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.000	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000
2.5	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.333	0.000	0.000	0.000	0.067
Mean	0.000 d	0.056 cd	0.000 d	0.000 d	0.000 d	
Tephrosia						
0.1	0.000	0.333	0.000	0.333	0.000	0.133
0.25	0.000	0.333	0.000	0.000	0.000	0.067
0.5	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000
2.5	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 d	0.111 cd	0.000 d	0.056 cd	0.000 d	
Water hyacinth						
0.1	0.000	0.333	0.000	0.000	0.333	0.133
0.25	0.000	0.000	0.000	0.000	0.667	0.133
0.5	0.000	0.333	0.000	0.667	0.000	0.200
1	0.000	0.000	0.000	0.333	0.333	0.133
2.5	0.000	0.000	0.000	0.000	0.667	0.133
5	0.000	0.000	0.000	0.000	0.000	0.000
Mean	0.000 d	0.111 cd	0.000 d	0.167 cd	0.333 bcd	
Actellic super	0.000 d	0.000 d	0.000 d	0.000 d	0.000 d	
Control	0.000 d	0.000 d	0.000 d	0.000 d	0.000 d	
C.V	21.7					
Time effect**(SEm=0.0909) ; Rate effect ns						

Means followed by the same letter(s) in row or column do not differ significantly * significant at P<0.05; ** significant at P<0.01; ns - not signicant different. Duncan' Multiple Range Test. SEm - Standard error of the mean

Appendix 8. Mean number of *Prostephanus truncatus* adults that exhibited preference for dried cassava chips treated with different doses of leaf powders

Dose(g/100g)	Hours after treatment					
	24	**48**	**72**	**98**	**120**	**Mean**
Eucalyptus						
0.1	2.167	1.667	1.667	1.833	1.333	1.733
0.25	0.333	1.667	2.167	1.667	1.500	1.467
0.5	2.000	2.167	1.333	1.833	1.000	1.667
1	1.167	1.167	2.000	1.833	2.167	1.700
2.5	0.333	1.167	1.500	1.667	1.333	1.200
5	1.833	1.167	0.833	0.667	1.167	1.167
Mean	1.306	1.500	1.611	1.583	1.444	
Guava						
0.1	0.833	2.500	2.333	1.667	2.667	2.000
0.25	1.833	1.667	2.000	1.333	1.667	1.700
0.5	1.833	1.667	2.167	1.333	1.000	1.600
1	2.500	2.500	1.167	1.500	1.500	1.833
2.5	1.833	0.667	1.000	1.500	1.667	1.333
5	1.833	0.833	1.167	1.500	1.833	1.433
Mean	1.778	1.639	1.639	1.472	1.722	
Neem						
0.1	1.833	1.333	0.833	0.000	1.000	1.000
0.25	0.333	0.833	1.000	0.833	0.833	0.767
0.5	0.833	0.500	1.000	0.667	0.167	0.633
1	0.333	1.167	0.667	0.333	0.667	0.633
2.5	0.333	1.000	1.000	0.833	0.000	0.633
5	0.333	0.500	0.500	0.500	0.667	0.500
Mean	0.667	0.889	0.833	0.528	0.556	
Tephrosia						
0.1	0.667	1.000	0.667	1.333	0.833	0.900
0.25	0.333	0.500	1.167	0.500	1.000	0.700
0.5	1.500	0.667	1.167	1.000	1.167	1.100
1	1.333	1.000	1.667	1.000	1.667	1.133
2.5	1.000	1.833	0.500	1.167	1.000	1.100
5	0.667	1.000	0.833	0.667	0.833	0.800
Mean	0.917	1.000	1.000	0.944	0.917	
Water hyacinth						
0.1	0.833	1.000	1.333	0.833	2.000	1.056
0.25	0.667	1.333	1.667	1.000	1.333	1.000
0.5	1.833	1.167	1.667	1.833	1.000	1.417
1	0.667	0.500	1.333	1.667	0.833	1.444
2.5	1.333	1.333	1.333	2.000	1.333	1.167
5	1.000	0.667	1.167	1.333	0.500	
Mean						
Control	2.278	2.667	2.861	3.028	2.778	2.722
C.V	65.8					
Time effect ns ; Dose effect ns						

Means followed by the same letter(s) in row or column do not differ significantly. * significant at P<0.05,ns - not significant different Duncan Multiple Range Test.

Appendix 9: Analysis of variance for percent reduction in the number of *Prostephanus truncatus* larvae in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom*	*Sum of Square*	*Mean square*	*F-value.*
Time	4	985.446	246.361	61.93 **
Error (a)	8	31.823	3.978	2.20
Dose	5	333.010	66.602	36.82 **
Time x Dose	20	606.940	30.347	16.78 **
Error (b)	50	90.434	1.809	0.57
Plant	6	5099.790	849.965	266.69**
Time x Plant	24	456.309	19.013	5.97**
Dose x Plant	30	183.974	6.132	1.92**
Time x Dose x Plant	120	462.820	3.857	1.21
Error (c)	360	1147.348	3.187	
Total	629	9411.387		
C.V %	23.8			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

Appendix 10: Analysis of variance for total number of *Prostephanus truncatus* larvae in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of. Freedom*	*Sums of square*	*Mean square*	*F-value*
Time	4	233.9184	58.4796	200.82 **
Error (c)	8	2.3297	0.2912	1.14
Rate	5	57.6317	11.5263	44.94 **
Time x Dose	20	100.8017	5.0401	19.65 **
Error (b)	50	12.8237	0.2565	0.57
Plant	6	343.3370	57.2228	126.25**
Time x Plant	24	80.9669	3.3736	7.44**
Dose x Plant	30	27.9434	0.9314	2.06**
Time x Dose x Plant	120	84.5370	0.7045	1.55**
Error (c)	360	163.1676	0.4532	
Total	629	1107.6569		
C.V %	40.7			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

Appendix 11: Analysis of variance for the number of deformed *Prostephanus truncatus* larvae in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom*	*Sum of squares*	*Mean square*	*F-value*
Time	4	5.08510	1.27128	17.73 **
Error (a)	8	0.57371	0.07171	1.82
Dose	5	2.04714	0.40943	10.37 **
Time x Dose	20	2.85665	0.14283	3.62 **
Error(b)	50	1.97337	0.03947	0.72
Plant	6	1.90095	0.31683	5.79 **
Time x Plant	24	3.35069	0.13961	2.55 **
Dose x Plant	30	1.61583	0.05386	0.98
Time x Dose x Plant	120	4.55282	0.03794	0.69
Error (c)	360	19.69312	0.05470	
Total	629	44.00309		
C.V %	29.6			

Square root (x + 0.5) transformed data

* *Significantly different at 0.01 probability

Appendix 12: Analysis of variance for the number of dead *Prostephanus truncatus* larvae in dried cassava treated with different doses of leaf powders

Source of variation	*Degree of freedom*	*Sums of squares*	*Mean square*	*F-value*
Time	4	7.43269	1.85817	17.38 **
Error(a)	8	0.85525	0.10691	2.12
Rate	5	2.56821	0.51372	10.17 **
Time X Dose	20	3.19852	0.15993	3.16 **
Error (b)	50	2.52678	0.05054	0.68
Plant	6	2.74387	0.45731	6.16 **
Day x Plant	24	4.70537	0.19606	2.64 **
Rate x Plant	30	2.26067	0.07536	1.01
Time x Dose x Plant	120	6.15605	0.05130	0.69
Error (c)	360	26.72750	0.07424	
Total	629	59.74758		
C.V %	33.7			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

Appendix 13: Analysis of variance for percent reduction in the number of *Prostephanus truncatus* pupae in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	4.553	1138.405	26.92 **
Error (a)	8	338.349	42.294	2.09
Dose	5	230.751	46.150	2.28
Time X Dose	20	790.976	39.549	1.95 *
Error (b)	50	1012.936	20.259	6.22
Plant	6	3123.453	520.576	159.87 **
Time x Plant	24	936.578	39.024	11.98 **
Dose x Plant	30	161.505	5.383	1.65 *
Time x Dose x Plant	120	503.491	4.196	1.29
Error (c)	360	1172.231	3.256	
Total	629	12942.863		
C.V%	30.2			

Square root (x + 0.5) transformed data
** Significantly different at 0.01 probability
* Significantly different at 0.05 probability

Appendix 14: Analysis of variance for the total number of *Prostephanus truncatus* pupae produced in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	12.7650	3.1912	52.54 **
Error (a)	8	0.4859	0.0607	0.70
Dose	5	3.4439	0.6888	7.97 **
Time X Dose	20	6.9366	0.3468	4.01 **
Error (b)	50	4.3215	0.0864	0.86
Plant	6	54.6827	9.1138	91.03**
Time x Plant	24	23.9362	0.9973	9.96**
Dose x Plant	30	7.8450	0.2615	2.61**
Time x Dose x Plant	120	14.6199	0.1218	1.22
Error (c)	360	36.0433	0.1001	
Total	629	165.1216		
C.V %	34.1			

Square root (x + 0.5) transformed data
** Significantly different at 0.01 probability

Appendix 15: Analysis of variance for percent reduction in the total number of *Prostephanus truncatus* adults produced in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	3753.267	938.317	53.75 **
Error (a)	8	139.656	17.457	1.77
Dose	5	148.042	29.608	3.00 *
Time x Dose	20	194.231	9.712	0.98
Error (b)	50	493.355	9.867	2.63
Plant	6	2843.454	473.909	126.25 **
Time x Plant	24	828.908	34.538	9.20 **
Dose x Plant	30	145.494	4.850	1.29
Time x Dose x Plant	120	409.684	3.414	0.91
Error (c)	360	1351.294	3.754	
Total	629	10466.904		
C.V%	34.8			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

* Significantly different at 0.01 probability

Appendix 16: Analysis of variance for the total number of *Prostephanus truncatus*, adults produced in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom*	*. Sum of squares.*	*Mean square*	*F-value*
Time	4	263.6848	65.9212	150.79 **
Error (a)	8	3.4973	0.4372	0.92
Dose	5	36.2017	7.2403	15.27 **
Time X Dose	20	36.1737	1.8087	3.81 **
Error (b)	50	23.7149	0.4743	0.93
Plant.	6	275.2840	45.8807	89.66 **
Time x Plant	24	90.4520	3.7688	7.36 **
Dose x Plant	30	19.5738	0.6525	1.27
Time x Dose x Plant	120	44.4746	0.3706	0.72
Error(c)	360	184.2273	0.5117	
Total	629	977.4774		
C.V %	37.7			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

Appendix 17: Analysis of variance for the number of deformed *Prostephanus truncatus* adults produced in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	0.34766	0.08691	2.77
Error (a)	8	0.25058	0.03132	1.13
Dose	5	0.07721	0.01544	0.56
Time x Dose	20	0.58825	0.02941	1.06
Error (b)	50	1.38963	0.02779	1.05
Plant	6	1.51137	0.25189	9.48 **
Time x Plant	24	2.18233	0.09093	3.42 **
Dose x Plant	30	1.00858	0.03362	1.26
Time x Dose x Plant	120	3.47476	0.02896	1.09
Error (c)	360	9.56790	0.02658	
Total	629	20.69566		
C.V%	21.7			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

* Significantly different at 0.05 probability

Appendix 18: Analysis of variance for the number of dead *Prostephanus. truncatus* adults produced in dried cassava chips treated with different doses of leaf powders

Source of variation	*Degree of freedom.*	*Sum of square.*	*Mean square.*	*F-value.*
Time	4	6.54537	1.63634	20.00 **
Error (a)	8	0.65455	0.01882	0.79
Dose	5	1.21101	0.24220	2.35
Time x Dose	20	2.01354	0.10068	0.98
Error (b)	50	5.15467	0.10309	1.24
Plant	6	10.59341	1.76557	21.16 **
Time x Plant	24	9.65897	0.40246	4.82 **
Dose x Plant	30	3.71020	0.12367	1.48
Time x Dose x Plant	120	1.72366	0.09770	1.17
Error (c)	360	30.03396	0.08343	
Total	629	81.34581		
C.V %	32.1			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

Appendix 19: Analysis of variance for per cent weight loss in dried cassava caused by *Prostephanus truncatus'* boring and tunnelling activity

Source of Variation	*Degree of freedom*	*Sum of Squares*	*Mean Square*	*F-value.*
Time	4	358.5633	89.6408	137.51 **
Error(a)	8	5.2150	0.6519	4.47
Dose	5	42.0636	8.4127	57.72 **
Time x Dose	20	6.2317	0.3116	2.14
Error(b)	50	7.2869	0.1457	0.52
Plant	6	547.9003	91.3167	326.45 **
Time x Plant	24	109.8328	4.5764	16.36 **
Dose x Plant	30	41.3885	1.3796	4.93 **
Time x Dose x Plant	120	25.3784	0.2115	0.76
Error(c)	360	100.7026	0.2797	
Total	629	1245.5667		
C.V%	18.1			

Square root (x + 0.5) transformed data

** Significantly different at 0.01 probability

* Significantly different at 0.05 probability

Appendix 20: Analysis of variance for percent repellency of Tephrosia leaf powders on *Prostephanus truncatus* adults

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	504.4	126.1	0.09
Error (a)	8	10868.9	1358.6	5.95
Dose	5	25688.9	5137.8	22.49 **
Time x Dose	20	1922.2	96.1	0.42
Error (b)	50	11422.2	228.4	
Total	89	53182.2		
C.V %	30.0			

** Significantly different at 0.01 probability level

* Significantly different at 0.05 probability level

Appendix 21: Analysis of variance for per cent repellency of Water hyacinth leaf powders on *Prostephanus truncatus* adults

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	4826.7	1206.7	0.89
Error (a)	8	10860.0	1357.5	2.54
Dose	5	12498.9	2499.8	4.68 **
Time x Dose	20	10706.7	535.3	1.00
Error (b)	50	26711.1	534.2	
Total	89	73632.2		
C.V %	50.2			

** Significantly different at 0.01 probability level
* Significantly different at 0.05 probability level

Appendix 22: Analysis of variance for per cent repellency of Eucalyptus leaf powders on *Prostephanus truncatus* adults

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	2428.9	607.2	0.42
Error (a)	8	11471.1	1433.9	2.29
Dose	5	11706.7	2341.3	3.73**
Time x Dose	20	10571.1	528.6	0.84
Error (b)	50	31355.6	627.1	
Total	89	69240.0		
C.V %				

** Significantly different at 0.01 probability level
* Significantly different at 0.05 probability level

Appendix 23: Analysis of variance for per cent repellency of Neem leaf powders on *Prostephanus truncatus* adults

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	2362.2	590.6	4.10*
Error (a)	8	1151.1	143.9	0.45
Dose	5	30165.6	6033.1	18.97 **
Time x Dose	20	4251.1	212.6	0.67
Error (b)	50	15900.0	318.0	
Total	89	54845.6		
C.V %	36.2			

** Significantly different at 0.01 probability level
* Significantly different at 0.05 probability level

Appendix 24: Analysis of variance for per cent repellency of Guava leaf powders on *Prostephanus truncatus* adults

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	271.1	67.8	0.31
Error (a)	8	1728.9	216.1	0.91
Dose	5	12018.9	2403.8	10.14**
Time x Dose	20	4008.9	200.4	0.85
Error (b)	50	11855.6	237.1	
Total	89	30098.9		
C.V %	36.6			

** Significantly different at 0.01 probability level
* Significantly different at 0.05 probability level

Appendix 25: Analysis of variance for the number of holes created by *Prostephanus truncatus* adults in the filter paper.

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Dose	5	858.64	171.73	2.67
Error (a)	10	644.06	64.41	0.65
Plant	5	7629.08	1525.82	15.47 **
Dose x Plant	25	936.53	37.46	0.38
Error (b)	60	5917.89	98.63	
Total	107	16558.92		
C.V %	53.3			

** Significantly different at 0.01 probability
 * Significantly different at 0.05 probability

Appendix 26: Analysis of variance for the number of *Prostephanus truncatus* showing preference for cassava admixed with leaf powders

Source of variation	*Degree of freedom.*	*Sum of square*	*Mean square*	*F-value*
Time	4	3.0806	0.7701	1.66
Error (a)	8	3.7167	0.4646	1.23
Dose	5	6.1301	1.2260	3.24
Time x Dose	20	12.5528	0.6276	1.66
Error (b)	50	18.8935	0.3779	0.41
Plant	5	227.6745	45.5349	49.70 **
Time x Plant	20	9.6750	0.4837	0.53
Dose x Plant	25	15.9338	0.6374	0.70
Time x Dose x Plant	100	62.7533	0.6276	0.69
Error(c)	300	274.8333	0.9161	
Total	539	636.1384		
C.V %	65.8			

** Significantly different at 0.01 probability
 * Significantly different at 0.05 probability