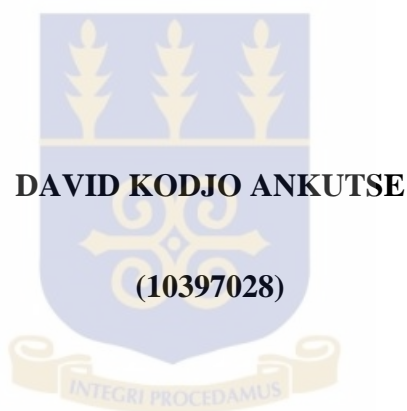


**BIOACTIVITIES OF SIX INDIGENOUS GHANAIAN PLANTS IN MANAGING
SITOPHILUS ZEAMAI AND *PROSTEPHANUS TRUNCATUS* IN STORED
MAIZE IN VOLTA REGION**

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON

BY



**IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF
MPHIL CROP SCIENCE DEGREE
(POSTHARVEST TECHNOLOGY).**

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DECLARATION

This is to satisfy that this thesis is the result of research undertaken by DAVID KODJO ANKUTSE towards the award of the Master of philosophy in Crop Science (Post Harvest Technology) in the Department of Crop Science, University of Ghana.

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ABSTRACT

The increasing rate of pest resistance, high cost and health risk in the use of insecticides have become an issue of Public concern. This research therefore was undertaken to identify and assess botanicals that are used by the farmers of Volta Region to manage *S. zeamais* and *P. truncatus* in stored maize grains. A survey conducted revealed *A. indica*, *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalima*, *N. latifolia* and *M. charantia* as grain protectants against stored insect pests. All the above mentioned botanicals were used for the experiment except *A. indica* since its potential against grain storage pest has long been established. Dried powders at (5 and 10%) and aqueous extracts (0.1 and 0.2 g/mL) of botanicals were prepared and evaluated for their insecticidal activity against *P. truncatus* and *S. zeamais*. The potency of botanicals varied with plant species and dose rate. Maximum toxicity of plant powders and methanol extracts to insects were observed in *V. amygdalima* treatment. At higher concentration of 0.2 g/mL, toxicity of *V. amygdalina* was 83.3 and 86.7% to *P. truncatus* and *S. zeamais* respectively. All plant extracts at 0.2 g/mL showed significant ($P < 0.05$) difference in repellency to Actellic; however, *C. anisata* expressed the highest repellent activity to *P. truncatus* and *S. zeamais* at 80.0 and 66.7% respectively. There was reduction in oviposition and emergence of eggs when grains were treated with extracts of botanicals compared to the control. There was reduction in the number of adult insects when immature stages of insects were treated with methanol extracts of botanicals. These results suggest that the botanicals tested have the potential in the development of post-harvest protection technology against, *P. truncatus* and *S. zeamais* as the major pest of stored grains. It is therefore recommended to be used by farmers to control *P. truncatus* and *S. zeamais* in stored maize grains.

DEDICATION

This work is dedicated to my mother Charoline Ankutse, father Gabriel K. Ankutse of blessed memory, sisters, my lovely wife Vida Ekissi and children for their patience, love, support and prayers that inspired me in all my endeavours.



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LIST OF ABBREVIATIONS

AFR	Applicable Federal Rate
CABI	Centre for Agricultural Bioscience International
FAO	Food and Agriculture Organisation
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
LGB	Larger Grain Borrer
MOFA	Ministry of Food and Agriculture
NGO	Non Governmental Organisation
<i>A. indica</i>	<i>Azadiracta indica</i>
<i>C. anisata</i>	<i>Clausena anisata</i>
<i>M. charantia</i>	<i>Momordica charantia</i>
<i>N. latifolia</i>	<i>Nauclea latifolia</i>
<i>P. amarus</i>	<i>Phyllantus amarus</i>
<i>P. nitida</i>	<i>Picralima nitida</i>
<i>P. truncatus</i>	<i>Prostephanus truncatus</i>
<i>S. zeamais</i>	<i>Sitophilus zeamais</i>
<i>V. amygdalina.</i>	<i>Vernonia amygdalina</i>

CHAPTER ONE

1.0 Introduction

Maize (*Zeamais*) belongs to the family Gramineae and is one of the most important cereal crops grown widely throughout the world in diverse agro ecological environments (Nyarko, 2011). More maize is produced than any other grain and statistics shows that maize makes up 37% of sub-Saharan Africa's total cereal consumption (Quandzie, 2011). In Ghana, it is cultivated in all the 10 regions of the country with the Eastern Region being the largest producer. In terms of production, maize ranks third only after roots and tubers and plantain (MOFA, 2007). The Ministry of Food and Agriculture (MOFA) reported that cultivated maize occupies less land area than either wheat or rice but has a greater average yield per unit area of about 5.5 tonnes per hectare (Obeng-Ofori and Dankwah, 2004).

Maize has three main broad uses namely food for humans, raw materials for industry and as feed for live stocks. According to IITA (2003) in the world about 66% of all maize is used for feeding livestock, 25% for human consumption and 9% for industrial purposes. However, in developing world, like Ghana, about 50% of all maize is consumed by humans as food while 43% is fed to livestock and the remainder for industrial purposes. As food, whole grains are either consumed at the stage of maturity or immature stage (fresh corn) or may be consumed in different processed forms depending on the region or ethnic group. It can also be processed into relatively large number of intermediary products, such as maize grits of different particle size, maize meal, maize flour and flaking grits.

Despite the above importance of maize, storage losses remain very high. According to FAO (2008) study, world-wide loss in store approximates 10% of all stored grain, that is,

13 million tons of grain is lost due to insect pest damage or 100 million tons to failure to store properly. In developing countries, FAO estimates suggest that losses could be as high as 50% of what is produced (Cornelius, 2008). Unlike perishable crops, maize can be stored for a longer period of time although; preservative quality during long term storage is a problem in many parts of the world as quality reduces with time of storage. Losses in storage may be as a result of racking of grains due to over drying, weight loss due to respiration, misapplication of synthetic insecticides. Rodents and insects' infestation, and feeding damage, contamination with mycotoxins caused by moulds and bacteria and dead parts of insects may also result in storage loss (Boxall, 2001).

Maize is exposed to numerous insect pests and the most predominant ones are *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae) and *Sitophilus zeamais* Mosh (Coleopteran Curculionidae). Both the larvae and adults of the two insects feed on the grain causing loss in viability, quality and value, weight and nutrition (Cornelius *et al.*, 2008). This situation results in an increase in food insecurity and poverty level of farmers especially in developing countries like Ghana.

Currently, synthetic insecticides are widely used in most developing countries like Ghana to control insect pests of stored products. However, indiscriminate use of synthetic pesticides has contributed to food poisoning, destruction of natural enemies and non-target species, pest resistance, turning innocuous species into pests and contamination of food, environmental pollution through air and as a residue in food which leads to health risk of man and animal (Ali, 2009).

Thus, most researchers now focus on the use of non-chemical technologies to store grains in order to reduce the use of synthetic insecticides. The use of botanicals has high economic and health benefits for applicators, consumers and the environment (Elhag, 2000; Talukder and Howse, 2000). Application of extracts from botanicals, cause various effects on insects. They act as antifeedants, growth regulators, sterilants, oviposition deterrence, repellent, reduced insect fitness and are non-toxic to warm-blooded animals (Saxena *et al.*, 1989, Schmutterer 1990). According to Obeng-Ofori (2007) the use of botanicals as grain protectants from insect damage is not only gaining eminence but is also generating positive results in the world of late.

It is against this background that both laboratory and field bioassays were conducted to evaluate the efficacy of six indigenous Ghanaian botanical powders and extracts against *S. zeamais* and *P. truncatus* in the Jasikan, Afadjato and South Dayi Districts in the Volta Region.

Objectives

1. To identify different types of botanicals used to stored maize in the selected districts.
2. Establish the efficacies of the six promising- botanical powders against *S. zeamais* and *P. truncatus* in stored maize.
3. Evaluate the toxicity and repellency of methanol extract of the best botanical against *S. zeamais* and *P. truncatus* in stored maize.

4. Determine the best concentration of methanol extract of the most potent botanical against *S. zeamais* and *P. truncatus* in stored maize.

5. To assess effective concentration of promising botanical in the bioassay against *S. zeamais* and *P. truncatus*.

CHAPTER TWO

2.0 Literature Review

2.1 The origin of maize

The present day maize is believed to have been discovered in Cuba by Columbus in 1492 (Lance and Benson, 2002). However, most historians also believe maize was domesticated in the Tehuacan Valley of Mexico some 5600-80,000 years ago (Lance and Benson, 2002). Maize was introduced to Africa in the 16th century; most likely through Portuguese traders and in 1900, it was a relatively minor food crop in Africa (Obeng-Bio, 2010). In the beginning, maize was planted as ornamental plant in Europe, but it soon began to be recognized as a valuable food crop due to its important role in feeding human and animals.

2.2 Cultivation of maize in Ghana

According to IITA (2009) 785 million tons of maize is produced worldwide with the largest producer being United States, producing 42%. Africa produces 6.5% of maize harvested from 29 million hectares and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa.

In Ghana, maize is one of the main staple food crops cultivated in all the ten regions and consume by both man and animals. However, Ghana produces only about 9% of the total acreage of maize in Africa. In the years 2009 through 2011, maize production in Ghana averaged 1.7 million tons harvested from about 990,000 hectares (Alene and Mwalughali, 2012). This quantity of maize is mainly produced by five regions in Ghana with Brong Ahafo being the highest production region, which accounted for 27% of national

production (IFPRI, 2013). Although maize is primarily cultivated by smallholders under traditional production farming practices and rain fed conditions, its production continues to increase over the years mainly due to its high demand for food and feed for animals as well as several maize improvement programs such as Ghana Grains Development Project (GGDP) and Food Crops Development Project (FCDP). Most of the activities by these national research institutes in relation to maize are in varietal improvement and testing. Several trials on agronomic practices, improved land preparation, row planting, fertilizer use and herbicide use, pest and disease control, and water management, among others helps to increase the production and yield of maize in the country.

2.3 Importance of maize

According to Akramov and Malek (2012) maize is the most important staple crop in Ghana and accounts for more than 50 percent of total cereal production in the country. The bulk of maize produced goes into food consumption and it is arguably the most important crop for food security. The development and productivity of the livestock and poultry sectors could also depend on the maize value chain since maize is a major part of poultry and livestock feed.

Maize is prepared or consumed by humans in numerous ways which may vary from one region to another or from one ethnic group to the other. It is commonly prepared in to porridge (*koko* in Ghana, *ogi* in Nigeria and *uji* in East Africa). In some parts of Africa, maize is consumed as thick porridge (*ugali* in East Africa and *sadza* in Zimbabwe) whilst the thin porridge is used to wean babies. Maize grains are also prepared by boiling or

roasting as paste (*kenkey* in Ghana; *tuwo*, *eko*, *abado* and *elukute* in Nigeria). Maize can be roasted and eaten as roast maize in some parts of the world and in Ghana it is popularly referred as *Zoklale* or *Nkyiwie*. Fresh corn, a delicacy of Ghanaians may be boiled in cobs or roasted in fire and consumed as vegetable or green maize. The maize flour may be used in the preparation of thick paste known as *ugali* in East Africa, *owo* in republic of Togo, and *akple*, *banku*, *yakayake* and *atififi* in Ghana (Houssou and Ayernor, 2002).

According to Nagai *et al.* (2010) *Tom Brown* (roasted-maize porridge) is one of the cheapest sources of traditional weaning foods in Ghana of late and it can be fortified with groundnut or soya beans to increase its nutritional level. *Liha* or *Asana*, a locally brewed drink obtained from maize is a common drink enjoyed by Ghanaians and Nigerians. An important and popular staple food from maize *Tuwo* is consumed by people in most African countries especially among the Hawusa's. The Ibos mix cassava flour with maize flour together with onion chips, chilies and palm oil and moulded in to small balls that are dipped in to red palm oil and the balls are called *akple* (Ali Shehu, 2009).

Maize can be industrially processed into starch, high fructose syrup, dextrose, corn oil, ethanol, cosmetic or skin care products, beverages, crayons, soaps, absorbent material for diapers, food additives, biodegradable plastics and food supplements. Corn starch is used in the paper and textile industries as well as a thickener in ingredients like baking powder, candies and puddings. Corn dextrose is utilized in the bakery industries as a yeast nutrient, and provides some sweetness and browning of the crust on baked products. In addition, dextrose has other uses in food canning, packaging frozen foods, ketchup, jams and jellies,

soft drinks, wines and malt liquors. Corn oil is used for making salad, as cooking oil and in the production of margarine. According to Yong (2003) maize is also used to produce bio-ethanol and used as a gasoline additive, which when used as fuel can help reduce air pollution. The maize cobs are used to wrap foods (e.g *kenkey* in Ghana, *lamba* or *tubani* in Nigeria), and may be made into hat, door mats, ropes, cloths, mats and filling mattresses. According to Badu- Apraku *et al.* (2006) the ash of the burnt stem is processed into salt and the cob is made into pipe-bowls. He further attested that in South Africa incinerated cob is included in snuff. The stalks of corn are utilized as compost, fuel, fodder and as roofing materials.

Apart from maize being used as food and raw materials for industries, it can also be used as traditional African medicine to manage some diseases. For instance, water obtained during the preparation of porridge can be used in the treatment of malaria and fever (Abdul rahaman and Kolawole, 2006). Dry cob leaves can be boiled and used for the treatment of anemia. According to them, water filtered through maize stalk charcoal can be used to cure gonorrhoea whilst infusion obtained from the stigma of maize inflorescence can be used in the treatment of urinary tract infections. He also attested that cold-pap or *eko-tutu* is usually mixed with some preparations to cure some spiritual problems or protect oneself against enemies. Ageless (2010) confirmed that corn silk can be used as medicine in the form of tea (infusion) to correct health problems like diuretic, bladder and kidney problems, edema (water retention), obesity, prostate disorders, bed-wetting, reducing stone formation in kidney and clear boils.

2.4 Traditional storage structures and their challenges in Ghana

There are different types of storage structures that have been identified in Ghana. However, they can be grouped into three forms according to the techniques of storage namely: traditional or local grain storage techniques at the farm gate or home which includes local cribs, rhombus and platforms; improved or semi modern grain storage techniques which are ventilated cribs, improved rhombus and brick bins; and modern centralized storage techniques at the commercial level involving silos and warehouses mostly belonging to the central government or companies (Udo *et al.*, 2009).

Crops stored in traditional structures are subjected to different attacks causing enormous losses. All of these losses are related to two main factors namely abiotic (structural architecture, humidity and temperature) or biotic (micro-organisms, rodents, birds and insects). Traditional maize storage structures are generally not hermetically sealed hence allows easy passage of stored product pest and moisture into the structure. These structures are mostly constructed with local plant materials which are easily attacked by rodents. This creates favourable conditions for infestation and proliferation of stored product pests and micro-organisms. According to Nukenine (2010) a major cause of losses in traditional storage structure is the lack of hygiene. During storage of newly harvested grain, the residues of old grain are not always totally removed or fumigated and may serve as a hiding place for proliferation of insects in grains.

Living organisms like insects, rodents, birds (on-farm storage) and micro-organisms are serious constraints to the traditional storage systems of Africa (Nukenine, 2010).

organisms passes through channel to cause great loss to stored products through contamination and unit loss leading to food insecurity and reduction of farmers income.

2.5 Grain losses during storage

Grain storage is one of the most important aspects in sustaining food security in developing countries as well as Ghana. This is very important since most cereals, including maize, are produced on a seasonal basis, harvested once or twice a year, which itself may be subject to failure, and inadequate processing factories to convert the grains to finished products. Storage also helps to reduce fluctuations in market prices due to the increase in supply of grains as a result of bumper harvest or shortage of grains during lean season. However, grain storage are implicated with numerous problems like insect pest infestation, poor storage structures, microfora attacks and high moisture content just to mention a few.

Among the various causes of losses, insect pest is the most common and may result in major economic losses to farmers throughout the world (Obeng-Ofori, 2007). According to Cornelius *et al.* (2008) a worldwide loss in food storage is projected 5-15% but in most developing countries it could be as high as 50% or even 100%. It is attested that if the conventional figure of 10% loss due to insects damage was applied to most important cereals and legumes cultivated in the world, the total food loss was enough to feed about 740 million people in Africa for 16 months (Ayertey, 2002). In many African countries post-harvest losses of grains are estimated 25% whilst 30% in Ghana (AFR, 2006; Dawson, 2004). Mould (1973) modified by Issa (2011) reported that there are about 20 different insect pests that attack stored maize in Ghana. Among these insect pests are *S.*

zeamais and *P. truncatus*, which according to Vowotor *et al.* (2005) the most destructive insect pests of maize in West Africa are *S. zeamais* and *P. truncatus*, they have very high rate of multiplication and within one season, they may destroy the grain create hot spots and also leave behind undesirable odours and flavours . In Ghana, both *S. zeamais* and *P. truncatus* cause significant loss of about 10-15% and 10-20% or more respectively to stored maize grains (Jess and Jones, 2013).

2.6 Maize Weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae)

2.6.1 Origin and Distribution of *Sitophilus zeamais*

According to Anne *et al.* (2011) the origin of the maize weevil (*S. zeamais*) is not known as at now but it is found in all warm and tropical parts of the world. It is an insect pest of numerous stored products such as maize, dried cassava, yam, sorghum and wheat. Both adults and larvae feed on internal parts of maize grains and infestation of crops can start in the field (when the cob is still on the plant) but most damage occurs in storage.

2.6.2 Description of *Sitophilus zeamais*

The maize weevil, *S. zeamais*, is a primary field to store pest and one of the most destructive insect pests of grains in the world. It contains three most important species namely *S. zeamais*, *S. oryzae* and *S. granarius* (Cornelius *et al.*, 2008). The adult *S. zeamais* has long forward rostrum, snout-like extension of the head that carries the mouth parts readily position for perforating plant tissue. It is about 3 – 3.5 mm long, dark brown – black in colour and shiny and pitted with numerous punctures (Plate 2.1). The punctures on the thorax are in an irregular pattern while those on the elytra (wing cases) are in lines. The

elbowed antennae of the weevil have eight segments and are often carried in an extended position when the insect is walking. The larvae of maize weevils are white, fleshy and legless.



Plate 2.1 Adult *S. zeamais*

2.6.3 Biology and Ecology of *Sitophilus zeamais*

S. zeamais is one of the most serious cosmopolitan pests of stored maize that starts to infest the maturing maize crop in the field when the grain moisture content is still 50-55% (Adedire, 2001). The adults under suitable environmental conditions can live for several

months and are able to lay about 150 eggs in their life time. The female lay eggs individually in small cavities in maize grains and each cavity is sealed with waxy secretion (egg plug) produced by the female. The eggs incubate about six days under suitable temperature of 25°C into larva. The larva feeds inside the grain chambers creating a tunnel as it develops into all the four larval instars. As larval stages feed on the internal parts of the grain, it is difficult to detect infestations early. Pupation takes place after 25 days at 25°C and 70% relative humidity in the maize grain. The pupated (newly developed adult) weevil chews and tunnel out from the maize grain. Development time ranges from about 35 days under optimal conditions to over 110 days in unfavourable conditions (Cornelius *et al.*, 2008).

2.6.4 Economic importance of *Sitophilus zeamais*

The maize weevil, *S. zeamais* is a primary field to store pest that starts to infest the ripening maize crop in the field before harvesting. Both adult weevils and larvae feed on undamaged grains and reduce them to powder. The pest creates holes in whole previously undamaged grains causing the grain to loss its viability and market value. In severe infestations, it is only the grain hull that is left along with powdery white frass (insect waste). The large emergence holes with irregular edges are characteristic of grains causing them to float in water often indicating larval damage. According to Markham *et al.* (1994) and CABI (2005) *S. zeamais* have been recognized as an increasingly important constraint to maize production in Africa and its heavy infestation may cause weight losses as much as 30-40% of the produce. Although being primary pest of stored maize, dried cassava roots, yam, common sorghum and wheat in the East African Region it can also be regarded as

secondary pest of several other crops such as rice, sorghum, yam products, and cassava flour in storage (Nwanna 1993)

2.7 The Larger Grain Borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae)

2.7.1 Origin and Distribution of *Prostephanus truncatus*

The Larger Grain Borer (*P. truncatus*) (Horn) belongs to the family Bostrichidae. It is a pest of particular importance in the world and its origin, Southern parts of the United States (like Texas) through Mexico and Central America into Northern South America (Hodges, 1986). It attacks maize and dried cassava mainly under conditions of subsistence agriculture but also has large populations living in natural habitats such as woodland and forest. It was introduced into sub-Saharan Africa through Tanzania in east Africa in 1970's and has since spread to Kenya, Burundi, Togo, Benin, Ghana, Malawi and Nigeria. This pest has spread long distances through its movement in infested grain as aid to countries during disaster or as a result of trade.

2.7.2 Description of *Prostephanus truncatus*

The larger grain borer is a serious pest that attack mainly dried cassava and maize cobs through the apex. The adult beetle is cylindrical in shape and is about 3 - 4.5 mm long. It is dark brown in colour with a body that looks like a flattened tube, the end of which appears to have been cut straight. The head is curved under the thorax to prevent the back of the head being seen from the above. On the antennae are 10 segments made up of seven

segment 'stem' and a 3-segment 'club'. According to Anne *et al.* (2011) the eggs of LGB are white to yellow, with no surface features and have a broad ovoid (ellipsoidal) shape whilst the larva is white, fleshy and has a sparse covering of hairs. It has a parallel-sided C-shaped (scarabaeiform) body. The legs are short and the head is small. Plate 2.2 shows the Larger Grain Borrer (*P. truncatus*).



Plate 2.2 *Prostephanus truncatus*

2.7.3 Biology and ecology of *Prostephanus truncatus*

The LGB is a long-lived species with unlimited oviposition period and relatively rapid larva developmental stage. It has a possible life span of several months, during which adults continue to feed and lay eggs. The female may generally lay 2-40 eggs, however when long lived can lay up to 600 eggs (Anne *et al.*, 2011). Eggs are laid singly and in groups in a neat round hole made in grains by the adult female. Eggs that are laid on grains in maize cob are more successful to hatch than on shelled grains. Larvae will molt two to four times before pupation which will usually take place inside grain after which the Adult comes out of the grain. The adult can tolerate dry conditions and can breed on maize with 9% moisture content which other pests like *Sitophilus* cannot survive (Hodges 1986 modified by Cornelius *et al.*, 2008). The minimum time to complete the lifecycle under ideal conditions is 25 days, although such conditions are rarely found in the field.

2.7.4 Economic Importance of *Prostephanus truncatus*

Prostephanus truncatus, the larger grain borer, is a pest of particular significance since its destruction to grains can cause up to 40% in stored maize cob for six months. The damage is caused by both adult and larva which produce neat round holes where they eat into the maize grains. They tunnel from grain to grain producing large quantities of maize frass. Its host is mainly maize and cassava but can also be found in minor hosts such as yam, sorghum, triticale and wheat. They bore into several foodstuffs and other materials such as wood causing considerable weight loss. The insect is exploratory hence boring holes into solid substances like wood used to construct farm structures, groundnut, beans, Perspex

and polythene not for breeding or nutritional value. These result in increased cost of farming and loss of valuable items (Cornelius *et al.*, 2008).

2.8 Control of insect pests of stored products

Pest control is as old as agriculture, as there has always been a need to keep crops free from pests. Insect pests cause significant losses to plants and crops throughout the world. As a result, producers have adapted preventive and curative means against pest of stored products (Zehrer, 1980). Pest infestation starts from the field before crops are harvested and kept in warehouses. Preventive measures employed by farmers include use of pest resistant cultivars, timely harvesting, crop rotation, use of proper cultural practices in growing crops, good store hygiene, appropriate choice of site for cultivation and storage and manipulation of storage environment. Other control methods like traditional biological, chemical, and phytochemicals can also be used to destroy, repel and inhibit reproduction of insect pest.

2.9 Control of *Sitophilus zeamais* and *Prostephanus truncatus*

2.9.1 Traditional and cultural methods of storage

The conventional approach might have probably been the first to be employed in food storage, since it is comparatively easy to prevent pest attack from stored grains. It involves the use of techniques such as the selective breeding of pest-resistant cultivars, timely harvesting of crops, cleaning stores between harvests, removing and burning infested residues, immersing grain sacks in boiling water, removing wood from stores or fumigating the store to eliminate residual infestations, the selection of only uninfected

material for storage, sun drying of produce, smoking of cobs in barns as well as the use of sand and wood ash to store grains. According to Poswal and Akpa (1991) ash and sand were among the local materials used by most African countries to protect their grains from insect pest (*S. zeamais* and *P. truncatus*) attack during storage. The protectants do not have any insecticidal value but fill the spaces between grains restricting the movement of adult insects from oviposition. They also act as desiccant dehydrating insects leading to their death. The powders of these protectants in addition may block the respiratory tract of insects leading to eventual suffocation. Golop (1997) reported that some types of sand that contain high amount of quartz cause damage to sensitive cuticle of newly hatched larva by removing waxy layer of the cuticle of the exoskeleton resulting in 80% of mortality in *Callosobruchus maculatus*.

Maize cobs that suspended on bamboo fork sticks in kitchen and smoked completely prevents storage insect pest from damaging the seed (Poswal and Akpa, 1991). Continuous drying of maize grains under the sun may reduce grain moisture content leading to the reduction of the activity of insect pest (*S. zeamais* and *P. truncatus*) in the grain. Mina and Lale (2004) also confirmed that drying of cowpea in direct sunlight for 4 hours in Northern Nigeria appears to be effective such that no adult progeny of *Callosobruchus maculatus* was found in the grain. Harvesting of maize should be done as soon as possible after it has reached maturity and of moisture content of about 12% or less as it will reduce the chances of attack by storage pests. The use of resistant varieties may also reduce the severity of an infestation. Varieties with a good husk cover are less likely to be attacked by *S. zeamais* and *P. truncatus*. Granaries should be well cleaned to destroy hiding places of insects

before new grains are filled into the stores. Bins and airtight stores should be closed to prevent *S. zeamais* and *P. truncatus* from getting oxygen.

2.9.2 Chemical control

It involves the use of chemicals to kill pests or to inhibit their feeding, mating, or other essential behaviours. It is quickest, easiest and effective method of controlling insect pests such as *S. zeamais* and *P. truncatus* in warehouses where their populations build up is very high. Major ways of chemical control of storage pests are fumigation and application of contact insecticides. In fumigation, toxic gasses (fumigants) are used in an enclosed area to penetrate the mass commodity in order to kill the hidden insects either in the grain or in the warehouse. Fumigants are only effective if they are used in an airtight warehouses, bins or silos where the gas can be concentrated to kill the insects. Of late, phosphine is one of the common fumigant used, although minor fumigants like chloropicrin, tetrachloride and hydrogen cyanide could also be used (Cornelius *et al.*, 2008). Phosphine is a small molecule, non-polar and can easily diffuse in stalks to kill insects even at places far away from point of application. These properties allow its use both in small and large scale storage.

Among insecticides being used now are organophosphates, carbamates and synergized pyrethroids. Organochlorines like lindane were formerly used as grain protectants but now banned due to chronic poisoning, high persistence and toxicity to consumers. Organophosphorus like *pirimiphos-methyl* (Actellic) which is broad spectrum (kills both insects and mites), high knockdown effect and prevent re-infestation of pest (like *S.*

zeamais and *P. truncatus*) in long storage. Other organophosphorus compounds include *Etrimfos* (Satisfar), *Methacrifos* (Damfin) and *Chlorpyrifos-methyl* has low toxicity and high knockdown effect, high persistent and effective against eggs and larvae of insects in storage.

Synthetic pyrethrins/ pyrethroids include bioresmethrin (Resbuthrin) have low toxicity and acts by disrupting transmission of nerve impulses. Its action on insects is by contact, inhalation and ingestion of chemicals.

2.9.3 Biological control.

The population of insect pests (such as *Prostephanus truncatus* and *Sitophilus zeamais*) can easily increase in a storage environment where there is enough food, suitable environmental condition and no predators or pathogens or parasites. The management of insect pests by the use of natural enemy is gaining grounds of late because of its safety to consumers compared to chemical control. According to Brower *et al.* (1995) the use of natural enemies to control insect pest can be classified into different ways; based on their life history, population dynamics and ecology. Predators prey on other individual insects for survival. For instance, a predatory beetle (*Teretrius nigrescens*) which only eats LGB (i.e. is specific) has specifically been introduced to Africa for the control of larger grain borer.

Parasitoids (such as *Anisopteromalus calandrae*, *Cephalonomia tarsalis*, *Lariophagus distinguendus* and *Theocolax elegans*) could be effective if introduced early in the storage of maize grain to manage maize weevil. The fungus *Beauveria bassiana* can be used as a

biological insecticide to control maize weevil in stored maize. The bacterium *Bacillus thuringiensis* can also be used in the control of adult weevil (Anne *et al.*, 2011).

2.9.4 Physical control

They are methods that physically keep insect pests from reaching their hosts. Or the removal of insects (such as *Prostephanus truncatus* and *Sitophilus zeamais*) from the grain by sieving to reduce populations but this is very labour-intensive. The use of inert dusts such as ash and clay to the grain can also reduce insect numbers by causing the insects to die from desiccation. Barriers such as window screens are used for keeping health and nuisance pests out and into the warehouse. There are other types of traps that can be used to prevent rodents and insects pest from grain damage (Dayan *et al.*, 2009).

2.9.5 Use of Phytochemicals.

The problem of pest resistance to synthetic insecticides, increase in pesticide residue in stored produce and contamination of the biosphere associated with large-scale use of broad spectrum synthetic pesticides, have led to the need for effective biodegradable pesticides with greater selectivity. According to Dayan *et al.* (2009) the curiosity of developing newer insecticides has emerged in the whole world. However, the newer insecticide must be pest specific, nonphytotoxic, nontoxic to mammals, ecofriendly, less prone to pesticide resistance, relatively less expensive, and locally available. One of the ways to meet such standard is to go back to the use of locally available plant materials which were in century used as grain protectants in both developing and underdeveloped countries (Sahayaraj, 2008 and Obeng-Ofori, 2007).

In eastern Africa, leaves of the wild shrub *Ocimum suave* and the cloves of *Eugenia aromatic* are traditionally used as stored grain protectants (Powel, 1989). Cobbinah and Appiah –Kwarteng (1989) reported that 26 different botanicals were identified as grain protectants when a survey was conducted in 12 districts in Ashanti region of Ghana. Niber, (1994) noted that 10 botanical species have both medicinal and insecticidal properties by local herbalist in Ghana against the larger grain borer and weevils. Although there are other botanicals used as grain protectants from one locality to another, the Ministry of Food and Agriculture (Ghana) has confirmed 16 different botanical species used by Ghanaian farmers to manage stored insect pest (Table 2.1).

Table 2.1 Botanicals used by farmers to protect food stuffs against pest infestation in Ghana

Name Botanical	
African violet	<i>Lippia multiflora</i> .
<i>Azadiracta indica</i>	Mitragyma Africana
<i>Capsicum annum</i>	<i>Mitragyma inermis</i>
<i>Cassia sophera</i>	<i>Ocimum Americana</i>
<i>Chamaecrista nigricens</i>	<i>Pleiocapa mutica</i>
<i>Citrus sinensis, Combretum sp</i>	<i>Pterocapus erinaceus</i>
<i>Cymbopogon schoenanthus</i>	<i>Securidaca longipeduncalata</i>
<i>Chromolaena odorata</i>	<i>Synedrella nodiflora</i>
<i>Khaya senegalensis</i>	<i>Vitellaria paradoxa</i>

Belmain and Stephenson (2001)

The insecticidal properties of botanical plants can be found in all parts of the plants (seed, leaf, stem, bark and root). Wink (1988) noted that plant extracts contain about 3,000 broad spectra phytochemicals (secondary metabolites) such as alkaloids, flavonoids, tannins, saponins, phenols, glycosides, terpenoids, phlobatannins, polyphenols and steroids. These secondary metabolites affect insects in different ways. Based on the physiological activities of plants extract on insects, Jacobson (1982) conventionally classified the plant components into 6 groups, namely, repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemosterilants, and attractants. This research has focus on six plants used by farmers in three districts of the Volta Region that might be compatible with other

already used botanicals in Ghana. These identified botanicals from the survey includes *Azadiracta indica*, *Clausena anisata*, *Phyllanthus amarus*, *Picralima nitida*, *Vernonia amygdalina*, *Nauclea latifolia* and *Mormordica charantia* and are different from the sixteen published plants.

2.10 *Vernonia amygdalina* (Bitter Leaf)

2.10.1 Distribution and ecology and description.

Vernonia amygdalina belongs to the family Asteraceae (Compositae). It is commonly known in Ghana by various vernacular names as indicated in Table 2.2.

Table 2.2 Vernacular names of *Vernonia amygdalina* in Ghana

Tribe	Local Name
Twi	Awɔnwene
Fante	Bɔwen
Ga	Akpa
Ewe	Gbɔti
Gonja	Sanka

Vernonia amygdalina commonly known in Ewe as Gbɔti (meaning it is poisonous to goats) occurs wild in most countries of tropical Africa, from Guinea east to Somalia and South to North-Eastern South Africa, and in Yemen. It is commonly grown as a vegetable in Benin,

Nigeria, Cameroon, Gabon and DR Congo, and to a lesser extent in their neighbouring countries such as Ghana (Ucheck, 2004). *Vernonia amygdalina*, commonly known as bitter leave, is a Shrub or small tree up to 10 m tall, with several branches and trunk up to 40 cm in diameter. The bark of the tree is grey to smooth brown, becoming fissured with young branches which are densely pubescent. The leaves are alternate, simple; stipules absent with petiole of about 0.2–4 cm long. The leaf blade is ovate-elliptical to lanceolate, rounded at base, shortly acuminate at apex with minutely toothed to coarsely serrate at the margin. The inflorescence of the head is arranged in terminal, compound and umbel-like cymes with the head stalk up to 1 cm long. It produces bisexual flowers of inner creamy or brownish bristles of 4–7 mm long with tubular corolla (Ucheck, 2004).

The ecology of *Vernonia amygdalina* is along rivers and lakes, forest margins, woodland and grassland up to 2000 m altitude. It often occurs naturally in localities such as abandoned farmland, and can be found growing spontaneously in secondary forest. It requires full sunlight in cultivation but flowering is induced by short days. It prefers a humid environment although it is fairly drought tolerant. It can be found on all soil types, but performs best in soils rich in humus. It is grown from stem cuttings and used as hedge plants in many parts of Ghana. (Plate 2.3).



Plate 2.3 *Vernonia amygdalina* (Biter Leaf)

2.9.2 Uses of *Vernonia amygdalina* (Biter Leaf)

Vernonia amygdalina is a widely used local plant in Africa for both therapeutic and nutritional purposes. Wargovich *et al.* (2001) reported that *V. amygdalina* is used as herbal medicine by ancient people of Africa, Asia, Europe and America. Huffman and Seifu, (1989) attested that *V. amygdalina* has been used by wild chimpanzee for the treatment of parasite related diseases in Tanzania. Philipson *et al.* (1993) also reported the antiplasmodial effects of sesquiterpene and steroidal constituents of *V. amygdalina* against *plasmodium falciparium in vitro*. The bitter bark of the roots and stem can be used to cure diarrhoea, gonorrhoea and fever. Macerated leaf in honey or sugar can be used as diuretic, purgative and vomitive. Uhegbu and Ogbuehi (2004) reported that aqueous extract of leaves of *V. amygdalina* is very effective against diabetic and other metabolic diseases associated with the liver . The bitter leaf contains peptides that can be used to prevent breast cancer by regulating the growth of tumour (Izevbigie 2003).

In Nigeria, the leaf is prepared as a special food with butter and condiments while the stems are chewed as toothpaste in Uganda. The bitter leaves are sold in the market for the preparation of palaver sauce. The leaves are rubbed inside the honey jars to give bitter flavour to the honey. Animals like cattle browse on the leaves of *V. amygdalina*.

2.10. *Picralima nitida* (Akuamma plant)

2.10.1 Distribution, ecology and description.

Picralima nitida, belongs to the family Apocynaceae and it is commonly known as Akuamma plant, or Igbo: Osi-Igwe in Nigeria. It has the following vernacular names in Ghana as indicated in Table 2.3.

Table 2.3 Vernacular names of *Picralima nitida* in Ghana.

Tribe	Local name
Twi	Ekuama/ kanwene
Fante	Onwemba
Ada	Kpetekpetetso
Ewe	Ewe quinine

Picralima nitida tree is mostly found in rainforest, mature secondary forest and semi-deciduous forest along river banks, up to 900 m altitude throughout Africa (Yakeu *et al.*, 2012). In Ghana, it is widely distributed in areas such as Jasikan, Aburi, Kumasi, Obuasi and Tarkwa although; it is believed to have originated from Ivory Coast, Democratic Republic of Congo and Uganda.

Akuamma tree is about 80 ft tall with dense crown and dark brown or blackish branchlets. Its leaves are opposite, simple and entire with absent stipules (Plate 2.4). It has 1–2 cm long petiole and leaf blades are elliptical to oblong with cuneate base. The leaf apex is abruptly acuminate, thickly papery to thinly leathery, innately veined with 14–23 pairs of lateral veins. It has a terminal or axillary compound inflorescence with 10–35 flowers. The floral peduncle is about 2–35 mm long with 3 primary branches and very small bracts. Flowers are bisexual, regular and open corolla during the day. Fruits consist of 2 free obovoid to ellipsoid follicles 11–20 cm long, smooth, apex rounded and are yellow to orange in colour. It has 2 valved with many-seeds. The seeds obliquely ovate, obovate to oblong, flattened, 2.5–4.5 cm long, smooth, brown to orange, embedded in soft white to orange pulp (Nyunaï and Njifutié, 2006). The wood is slightly yellow, hard and elastic which may be used to construct several structures.



Plate 2.4 *Picralima nitida* (Akuamma plant)

2.10.2 Uses of *Picralima nitida*

There are numerous traditional herbalists who have claimed to use the leaves, roots, seeds or stem bark of Akuamma plant for the treatment of various diseases such as fever, hypertension, jaundice, gastrointestinal disorders, gonorrhoea and malaria (Iwu, 1993 and Etukudo, 2003). Other people have also established the use of these various parts of the plant to manage insect pest of stored products.

As a medicinal plant, the seed, stem and roots have been reported to be effective as a cough suppressant antiseptic, as well as an aphrodisiac and hypoglycemic agent in the treatment of diabetes (Ayensu, 1978; Oliver, 1960). The dried bitter seeds are crushed and eaten with lemon juice to treat hernia, vomiting or diarrhoea and also applied to abscesses. A mixture of ground seed and Shea butter is rubbed on the abdomen to treat leucorrhoea in women. Diabetes mellitus is a major endocrine disease that is treated with the extracts of the plant (Inya-Agha *et al.*, 2006). The berries are used in traditional medicines for fighting muscular pain and typhoid (Adjanohoun *et al.*, 1996; Yakeu *et al.*, 2012). In Ghana a decoction of the seeds is employed as an enema and analgesic. It is also chewed as a tonic and stimulant. The dry leaves are boiled into water and taken to treat guinea worm. Leaf sap is dripped into the ear to treat otitis in some villages in Ghana. The crushed seeds, roots or fruit pulp are also ingredients for arrow poison for hunting. In Ghana and Dr Congo, immature fruits are pounded and thrown in the water as a fish poison. According to Ubulom *et al.*, (2012) *P. nitida* contains photochemical substances such as alkaloids, cardiac glycosides, saponins and terpenes. The leaf of *P. nitida* also possesses larvicidal and antifungal potential that enables the plant to be used to manage several diseases.

The wood, which is slightly yellow, hard and elastic, is used to make a variety of small utensils such as paddles, shuttles for weaving, dolls, combs, walking sticks, pestles and mortars, incense holders, bows and arrows, spade handles or spoons. Spoons or dippers are also made of the hard shell of the fruit. The various parts of the plant are sold in the local markets as medicine and utensils for money. (Nyunaï and Njifutié, 2006).

2.11. *Phyllanthus amarus* (Hurricane weed)

2.11.1 Distribution, ecology and description

Phyllanthus amarus, it is a vital herbaceous medicinal plant, belongs to the genus *Phyllanthus* in the Euphorbiaceae family (Plate 2.5). It is commonly known in Ewe as *Kpevideme* due to the seed it carries at the back of the leaves. It is believed to have originated from tropical America and has spread as a weed throughout the tropical and subtropical countries in the world (Nyunaï and Njifutié, 2006). *P. amarus* thrives well in open localities, waste ground, grassy scrub vegetation and dry deciduous forest, usually on humid, sandy soils, from sea-level up to 1000 m altitude. It is reported as a worrying weed in pulses, soya bean, groundnut, cereals, sugar cane, cassava, taro, sesame, sunflower and cotton (Oudhia, 2008).

The plant is described as a monoecious, annual, erect, glabrous herb up to 60 cm tall which is greenish to reddish in colour. The branchlets are flattened, often slightly winged and sparsely hairy. It has alternate leaves which are crowded along lateral branchlets. *Phyllanthus amarus* has 1–2 flowers in the axils of leaves which are unisexual, pale green

and often flushed red. The fruit has an obtusely 3-lobed capsule 2–2.5 mm in diameter which is smooth, hanging with 6-seeded (Xavier *et al.*, 2012 and Oudhia, 2008). The Seeds are 1 mm long with transverse ridges (Plate 2.5).



Plate 2.5 *Phyllanthus amarus* (Hurricane weed)

2.11.2 Uses of *Phyllanthus amarus*

It is a tropical plant widely in use as folk medicine for the promotion of liver regeneration and against hepatitis B virus (HBV) and Wood chunk Hepatitis Virus (WHV) (Syamasunde *et al.*, 1989). It is used in the traditional medicines for the treatment of jaundice, asthma, hepatitis, tuberculosis, ulcer, urinary diseases, dyspepsia, colic, diarrhea, dysentery and for external application in case of swelling and inflammation. Gaidhani *et al.* (2009) reported that the plant extracts were found active against prostrate cancer cell. The leaf paste can be used as suppository in the vagina to treat absence of menstruation and polyps. In Côte d'Ivoire the decoction plant is taken to facilitate childbirth, to treat oedema and pain caused by fever or a sore throat. In Mali the leaf decoction is drunk to treat jaundice whilst in Benin is drunk to treat palpitations. In Uganda, ground aerial parts

are applied to snakebites whilst the ground material in water is also drunk to treat poisoning by snakebites. A decoction of the aerial parts is drunk to treat candidosis, diabetes and tachycardia. The herbaceous plant can also be used to manage insect pest of stored products. For instance Vanmathi *et al.* (2010) Observed that *Phyllanthus amarus* extracts showed more than 50% repellent and/or oviposition deterrent principles to *C. maculatus* at lower concentration.

2.12 *Clausena anisata* (Willd.) Hook Horsewood or maggot killer

2.12.1 Distribution and ecology and description

Clausena anisata (Willd.) Hook. f. is a deciduous shrub or small tree, belonging to the Rutaceae or Citrus family. It is widely spread in the tropical ecozone or Sub-Saharan Africa but absent from the drier regions. It is also found in South-East Asia, growing in India and Sri Lanka and extending as far as Queensland in north-eastern Australia and some Pacific islands (Nyunaï and Njifutié, 2006). It is cultivated and sold in Malaysia and Indonesia for its medicinal purposes. It is grown in almost all parts in the country (Ghana). Table2.4 shows the vernacular names of *C. anisata* in Ghana.

Table 2.4 Vernacular names of *Clausena anisata* in Ghana.

Tribe	Local name
Twɩ	Uawonsi
Brong	Eduasin
Ga	Samanyobli
Ewe	Ayira

Tchinda, (2011) reported that *C. anisata* is a deciduous shrub of 4–10 m tall with smooth bark and grey-green mottled young twigs. Its leaves are alternate, up to 30 cm long with stipules absent. According to Vanmathi *et al.* (2010) the leaflets are 11–37 in number and are alternate or almost opposite, ovate to narrowly elliptical, 1–7(–11) × 0.7–3(–4.3) cm, asymmetrical base. The leaves are densely covered with glandular dots and are strongly aromatic when crushed (Plate 2.6). The plant has short hairy inflorescence with lax axillary panicle of about 10–35 cm long. Flowers are bisexual, regular with 4 sepals and petals with yellowish white colour. Fruit are ovoid with fleshy berry, red or purple-black containing 1–3 seeds (Vanmathi *et al.*, 2010).



Plate 2.6 *Clausena anisata* (Hook) Horsewood or maggot killer

2.12.2 Uses of *Clausena anisata*

Clausena anisata is commonly used in treating wide range of ailments and conditions in Africa and Asia. A decoction of the leaves or roots is used to treat gastro-intestinal disorders, fever, pneumonia, headache, sore throat, sinusitis and worms. The crushed leaves are used as antiseptic and analgesic against wounds, aching teeth and other mouth infections, also otitis, itch, sores, abscesses, burns, haemorrhoids, rheumatism and other body pains (Lorraine, 2009). The Crushed leaves are also used to treat wounds in domestic animals, as a snake-bite antidote as well as treatment of whooping cough, malaria, syphilis, kidney troubles and diabetes. The root decoction is taken as a tonic by pregnant women, to enhance child birth and cleanse the uterus as well as prevention of convulsion in children (Tchinda, 2011). In East Africa, the roots are chewed to treat indigestion whilst in Kenya, a root decoction is drunk to treat irregular menses, threatening abortion, skin diseases and epilepsy. In Seychelles, a leaf decoction is drunk to treat hypotension and a sore throat.

Leaves are poultice on boils and spots. A mixture of crushed leaves, salt, peppers and tamarind seeds, is taken to treat lack of appetite, bloating and indigestion. Dried leaves are widely used to repel arthropod in mattresses and pillows against fleas, lice and bedbugs. The fruits are sweet and readily eaten by people and other animals. The bark of the stem contains fibre which is pounded and used as rope (Lorraine, 2009).

2.13 *Mormodica charantia* (Bitter melon)

2.13.1 Distribution, ecology and description of *Mormodica charantia*.

It is an annual and perennial climbing vine or herbaceous small shrubs belonging to the family Cucurbitaceae and a native to tropical and subtropical Africa and Asia (Englberger, 2009). It has several common names as balsam apple, balsam pear, bitter balsam apple, bitter cucumber, bitter melon, bitter gourd and paria. In Ghana it is mostly called by the local names as indicated in Table 2.5 below.

Table 2.5 Vernacular names of *Mormodica charantia* in Ghana.

Tribe	Local Names
Twɩ	Ahensaw
Fante	Saw
Ga	Ansao
Ewe	Akutsa/ Kakle

It is now widely distributed throughout tropical and subtropical regions on all continents. It grows on various types of soil and even in vegetable, orchard and plantation farms where its vines climb over them, competing for light, nutrients and water.

The plant is described as herbaceous, tendril-bearing vine grows to 2- 5 m tall. It produces simple, alternate leaves 4–12 cm across with three to seven deeply separated lobes. It develops a central taproot, from the apex of which the stems spread to climb over any available support. The branches are slender with green stems which are slightly ridged and carry unbranched tendrils in the leaf axils. The leaves are located singly along the stems on 3-5 cm long stalks and each leaf is 4-10 cm long. The leaves are rounded in outline and deeply 5-9 lobed. The foliage is a nuisance in pastures as it has an unpleasant odour when bruised and is unpalatable to stock and may even be harmful to stock (Hiaso, 1996). Each plant bears separate yellow male and female flowers which are similar except that the female has a warty smell (Plate 2.7). The fruits are egg-shaped, 2-10 cm and covered with longitudinal ridges and warts. In the fruit are seeds which are flattened, 5-9 mm long with pitted surfaces (Englberger, 2009).



Plate 2.7 *Mormodica charantia* (Bitter melon)

2.13.2 Uses of *Mormodica charantia*

The plant is used as food, vegetable and medicine. As food, the leaves are parboiled and used as vegetable in the preparation of stew that are served on diets. In Peru, unripe fruits are boiled or fried and are eaten as salads. The plant has numerous medicinal uses such as purgative, pain reliever, and for treatment of haemorrhoids, internal parasites and rashes. The seed extract has the capacity to cure certain cancerous tumours and may have anti-leukaemic activity. An infusion of the leaves is taken before breakfast to decrease blood sugar levels or diabetes mellitus and is locally known as papailla (Holm *et al.*, 1997). In Brazil and Ghana the plant is used in baths to cure eczemas and herpes. The decoction of the leaves is used to treat rheumatism, stomachache, menstrual pains, colds, fevers, arthritis to remedy kidney stones. The root decoction is used in Yucatán to treat aphrodisiac problems.

2.14 *Nauclea latifolia* (African peach)

2.14.1 Distribution, ecology and description of *Nauclear latifolia*

Nauclea latifolia (Pin Cushion Tree or African peach) is a shrub or small spreading tree belonging to the family Rubiaceae and to the class Magnoliopsida (Dicotyledons). It is a widely dispersed savanna plant native to Africa and Asia which is found in the forest and tropical forest (Arbonnier 2000). It is found in almost all parts of West Africa. In Ghana, is locally known by the vernacular names as indicated in Table 6.

Table 2. 6 Vernacular names of *Nauclea latifolia* in Ghana.

Tribe	Local name
Twi	Kankanu
Brong	Hwene Hwenti
Ga	Oyefa-Owenfa
Ewe	Nyimɔ
Ada	Dikabi-Atso

Nauclea latifolia is a struggling shrub or small spreading tree in the savanna wood land above 20 ft tall or a large tree in the forest zone above 100 ft tall. The leaves are 7 x 4-5 inches which are glabrous, obovate, short and abruptly acuminate with dark upper surface leaves (Arbonnier 2000). According to him, the petiole is red, stipules short, ovate and more persistent (Plate 2.87). The plant has white floral heads up to 2 inches in diameter which are sweet scented. The fruits are red, fleshy with up to 3 inches in diameter. They are edible with many seeds embedded in the fruit.

**Plate 2.8 *Nauclea latifolia* (African Peach)**

2.14.2 Uses of *Nauclea latifolia* (African Peach)

In several African communities, the plant is used for treatment of various ailments and conditions. Phytochemical investigation of the plant revealed the presence of naturally occurring secondary metabolites such as monoterpene, triterpene, alkaloids, saponins, flavonoids, steroids, glycosides and traces of inorganic compounds. The root decoction is used in the treatment of malaria, gastro intestinal tract disorders, sleeping sickness, gonorrhoea, hypertension, diabetics, dental caries, septic mouth, dysentery, diarrhea, and diseases of the central nervous system such as epilepsy (Amos *et al.*, 2005; Ngo Bum *et al.*, 2009; Abbah *et al.*, 2001). Akpanabiantu *et al.* (2005) reported that the decoction of *N. latifolia* root has antihypertensive and laxative activities when taken. In Ghana, the leave and the root decoction are used to cure stomach problems and for the treatment of wounds. The ground fruits are used to treat piles and dysentery.

CHAPTER THREE

3.0 Materials and methods

3.1 The study area

A survey was conducted in three Districts in the Volta Region of Ghana (Jasikan, Afadjato and South Dayi) to identify the types of botanicals used by farmers to store maize grains against insect pests. The Jasikan District forms part of the twenty five (25) Municipalities and Districts in the Volta Region of Ghana. Its Administrative capital is Jasikan. The District Shares boundaries with the Republic of Togo to the east, to the west with the Volta River, to the north with Biakoye District and to the south with Afadjato District and Kpandu Municipal respectively. It covers an area of 1355 km² with 33 villages and made up of 33 sub-towns. The main occupation of the people is farming; with majority of them being women producing on small scale (ghanadistricts.com, 2013).

The Afadjato District was carved out from Hohoe Municipal in the year 2012. The Administrative capital of the District is Ve-Golokwati. The District shares boundaries with Hohoe Municipal to the North, Kpando Municipal to the west, to the east with the Republic of Togo and to the south with Ho West District and South Dayi District respectively. It covers about 238,533 km² and majority of the people are peasant farmers who cultivate mainly maize on subsistence bases (ghanadistricts.com, 2013).

South Dayi District lies within latitudes 3.020'N and 3.5005'N, and lies approximately on longitude 0017'E. It shares boundaries with Kpando and Afadjato South to the North, Ho

West to the east and Asougyaman District in the South while the Volta Lake forms the Western boundary. The District covers a total area of 1,000 square kilometers with about 20 percent of the area submerged by the Volta Lake. The average annual rainfall varies from 900 mm to 1300 mm. A mix of guinea woodland and deciduous forests dominate the vegetation of the District, Based on the 2010 Population and Housing Census, the human population of South Dayi District as at September, 2010 was 46,661. Approximately 62% of the economically active population is actively engaged in farming and fishing activities (ghanadistricts.com, 2013).

The laboratory and the final field trials were conducted at the University of Ghana, Entomology Laboratory in the Crop Science Department and the University of Ghana Farm respectively. At the University farm of Ghana- Legon, a ventilated crib of 3 x 1.5 x 1.5 m was constructed with a wooden structure (Plate 3.1). Grains treated with four botanicals at two levels of concentration were stored in the crib to determine the efficacy of the botanical extracts against *Sitophilus zeamais* and *Prostephanus truncatus* in bioassay.



Plate 3.1 Constructed Ventilated Crib at University of Ghana Farm

3.2 Field Survey

Field survey was conducted in three Districts of the Volta Region namely Jasikan, Afadjato, and South Dayi. In each of the Districts, three villages were selected at random to represent a total of nine villages in which ten maize farmers in each village were selected with the assistance of extension officers. Open and close-ended type of questions was administered to ninety (90) farmers from the three Districts. The questionnaires consisted of the demography of farmers, method of storage, types and effectiveness of botanicals and customer acceptability of grain treated with botanical. Data was analyzed using method of storage SPSS.

3.3 Culturing of insects

3.3.1 *Sitophilus zeamais*

Stock of *S. zeamais* was collected from infested maize grains from a maize farmer at Kpeve in the Volta Region. In the Crop Science Laboratory, one hundred adult insects of mixed sexes were infested in to 500 g of sterilized grains in a glass jar covered with muslin cloth (Plate 3.2). The culture was kept on the shelf of the laboratory for one week to allow for oviposition. The adult insects were sieved out and emerging generations were used to set up the experimental cultures. The culturing of *S. zeamais* was replicated four times to get enough insects for the experiments.

3.3.2 *Prostephanus truncatus*

Samples of *P. truncatus* were obtained from infested maize grain stock at Baika in the Jasikan District of the Volta Region and from the old stock in the Crop Science Laboratory. Whole maize grains were sterilized in an oven at 60°C for 3 hours and allowed to cool for 12 hours before being used for the culture. With the aid of an aspirator, 100 mixed sexes of insects were introduced into 500 g of sterilized maize grains in a glass jar at a controlled room of $28 \pm 2^\circ\text{C}$, 65% relative humidity (Osafo, 1998; Weaver *et al.*, 1998; Udo *et al.*, 2009). (Plate3.2). After one week of oviposition, the adult insects were sieved out and the culture allowed to stand for emerging progeny which were used to set up the experimental cultures (Udo *et al.*, 2009).



Sitophilus zeamais (a)



Prostephanus truncatus (b)

Plate 3.2 Insect Culture

3.4 Selection of plants.

The selection of botanicals used in the storage of grains in this research was based on the following factors by the farmers during the field survey. These factors include effectiveness of the botanical against stored insects, availability, how often the botanical is used in the area and if the botanical has not been used or sufficiently worked on in the country to store grains.

Basically, seven plants (*A. indica*, *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina*, *N. latifolia* and *M. charantia*) were identified, however, *Azadiracta indica* was not chosen since it has been extensively worked on in the country. A reference synthetic pesticide-actellic was selected based on the fact that it is one of the most commonly used synthetic chemical to store grains in Ghana. Table (3.1) shows the names of the plants, local names

in the area stage of collection and parts that are used for the preparation of the plant powders and extracts.

Table 3.1 Plants used for the experiment.

Treatment	Stage of collection	Local Name	Common Name	Parts Use
<i>Clausena anisata</i>	Before flowering	<i>Ayira</i>	Horsewood	Leaves
<i>Phyllanthus amarus</i>	During flowering	<i>Kpavideme</i>	Phyllanthus	Leaves
<i>Picralima nitida</i>	Matured seed	<i>Quinine</i>	Akuamma plant	Seed
<i>Vernonia amygdalina</i>	Before flowering	<i>Gbɔti</i>	Bitter Leaf	Leaves
<i>Nauclear latifolia</i>	Maturity	<i>Nyimɔke</i>	African peach	Root
<i>Momordica</i>	During flowering	<i>Kakle</i>	Bitter gourd	Leaves

3.5 Preparation of plant powders

The six plant parts were all obtained from Baika in the Jasikan District of the Volta Region. They were brought into the Crop Science Laboratory of the University of Ghana – Legon where they were prepared for the confirmation of their identity at the Herbarium in the Botany Department of the University. The plant specimens were then washed with tap water to remove sand and other unwanted particles and air dried under room temperature for 15 days. The selected botanicals were pounded using mortar and pestle after which they were ground to give a fine powder. The powders were sieved with Impact Test Sieve of a mesh size 70 μ to give a uniform size powders. The ground powders were kept in six different air tight containers a day before being used for the treatment of the grains.

3.6 Preparation of methanol extract of plants

About 100 g each of the plant powders were weighed into six different conical flasks containing 430 mL each of 100% methanol. The flasks were covered with Parafilm and placed in a shaker for 48 hours. The solution was filtered with a net of 2.5 μ and concentrated using rotary evaporator at 60°C after which the residues were dissolved in acetone to give a concentration of 0.1 g/mL and 0.2 g/mL for the various bioassays.

3.7 Screening of the six plant powders

3.7 Effect of plant powders on adult insects

Whole grains (4 kg) were kept on a metal tray and sterilized in an oven at 60°C for 3 hours. The sterilized grains were equilibrated under a controlled environment at 28 \pm 2 °C at 65% relative humidity for 24 hours. Sterilized whole maize grains (100 g) were put in to glass jars and six botanicals powders of two sets (5% and 10%) were admixed to the grains. Actellic 25 EC was applied at 2 ml/L of acetone while the control treatment was without any botanical powder. The set ups were left to stand for one hour before the introduction of 20 adult *S. zeamais* and *P. truncatus* (5-10 days old) in to the treated and untreated maize grains. The treatments were replicated four times under complete randomized designed. Daily mortality of insects was recorded for seven days. Insects were considered dead if they did not respond to probing of by a blunt probe.

3.8 Effect of methanol extracts on adult insect in treated grains.

Sterilized maize grains (50 g) were put in kilner glass jars and four different botanicals (*C. anisata*, *P. amarus*, *P. nitida* and *V. amygdalina*) with two concentrations (0.1 g/mL and

0.2 g/mL) were applied to each jar. Actellic, of (2 ml/L) and a control which was also treated with only acetone were applied to grains. The treated grains were air dried for one hour to evaporate the solvent. Twenty adult *S. zeamais* and *P. truncatus* (5-10 days old) were introduced into the treated and untreated maize grains after which the jars were covered with muslin cloth held with rubber bands. The treatments were replicated four times and left under controlled room at $28 \pm 2^\circ$ C and 65% relative humidity for one week. Mortality of insects was taken as insects were considered dead if they did not respond to three probing with blunt probe.

3.9 Contact toxicity by topical application

In this test, the method adopted by Obeng-Ofori and Reichmuth (1997) was used. Ten adult *S. zeamais* and *P. truncatus* (5-10 days old) each were placed in a separate petri dish lined with moist filter paper to immobilised insects for three minutes. One micro litre each of four botanicals extracts, actellic and a control (water) were applied to the dorsal surface of the thorax of insects using micro – pipette. The experiment was replicated four times. The mortality of insects was taken for five days

3.10 Effect of methanol extracts on oviposition

Maize grains (50 g) were weighed into glass jars and treated with four different botanicals each. Another jar was treated with Actellic at (2 ml/L) whilst the control has no treatment. The treated grains were left for one hour after which the grains were infested with mixed sexes of 20 adult *S. zeamais* and *P. truncatus* (5-10 days old). The jars were covered with muslin cloth held with rubber band and placed under control environment at $28 \pm 2^\circ$ C and

65% relative humidity for seven days to allow for oviposition. The experiment was arranged in completely randomized design with three replicates. The adult insects were sieved on the eighth day and the number of eggs laid was determined using the egg plug staining techniques (acid fuchsin method) FAO (2008).

3.11 Effect of methanol extracts of plants on eggs and immature stages.

3.11.1 Effect on eggs.

Sterilized maize grains (100 g) of 12% moisture content were weighed into six glass jars. The grains were infested with 20 adult *S. zeamais* and *P. truncatus* (5-10 days old) of mixed sexes into the two sets of jars respectively to allow for egg laying. The adult insects were removed after seven days of oviposition and the percentage oviposition was determined before grains were treated with methanol extract of *C. anisata*, *P. amarus*, *P. nitida* and *V. amygdalina* at 0.1 g/ml and 0.2 g/ml. The control and the reference were treated with water and actellic and each treatment was replicated three times. The emerging adults were counted and recorded.

3.11.2 Toxicity of methanol extracts to larva.

Twelve glass jars containing 100 g of sterilized maize each were infested with 20 adult *S. zeamais* and *P. truncatus* (5-10 days old) of mixed sexes and allowed for oviposition for seven days. The adult insects were sieved out on the seventh day and the grains were allowed to stay for extra seven days for the eggs to hatch into larva. The grains were then treated with two levels of concentrations (0.1 g/ml and 0.2 g/ml) of the botanicals and

actellic whilst the control treated with acetone. The experiment was replicated four times under completely randomized design. The emerging adults were counted and recorded.

3.11.3 Effect of methanol extracts on the pupa.

In this experiment, 100 g of sterilized maize grains each was put in twelve glass jar twenty adult *S. zeamais* (5-10 days old) of mixed sexes were introduced into six of the jars whilst the other six jars were also infested with twenty adult *P. truncatus*. The adult insects were sieved on the seven day after oviposition. On the 22nd day, the grains were treated with four different botanicals extracts and actellic at two concentrations (0.1 g/mL and 0.2 g/mL) whilst the control was treated with water. Each treatment was replicated three times in a completely randomized design and the adults that emerged were counted and recorded.

3.12 Repellency Assay

The repellency of methanol extract of botanicals on *Sitophilus zeamais* and *Prostephanus truncatus* was assessed using the method adopted by Obeng-Ofori and Reichmuth (1997) and carried out in the laboratory at 28 ± 2 and 68-73% relative humidity. Full disc filter papers were divided into two halves in which one half of the filter papers were treated with the test solutions (0.1 g/mL and 0.2 g/mL) whilst the other halves were treated with water using micro pipette. The treated filter papers were air dried in the laboratory for three hours. The treated and untreated filter papers of the same dimension were attached to each other to form a full disc using sellotape. Each of the filter paper was placed in a petri dish and 10 adult (5-10 days old) *S. zeamais* and *P. truncatus* of mixed sexes were put at the

center of each of the filter paper and covered. The experiment was replicated three times. After 30 minutes of the introduction of the insects, the number of insects present on treated (Nt) and control (Nc) were counted and recorded. (Plate 3.3). The percentage repellency (PR) values were computed using $PR = [(Nc - Nt) / (Nc + Nt)] \times 100$.

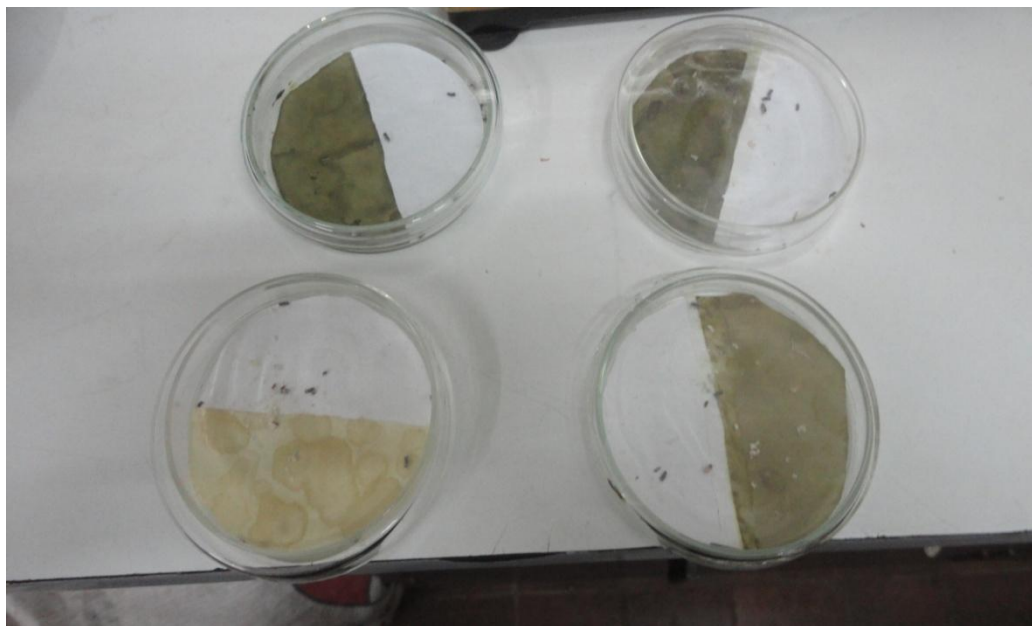


Plate 3.3 Part of repellency set up.

3.13 Damage assessment

Grain damage was assessed using the method adopted by Cornelius *et al.* (2008). Sterilized whole maize grains (2 kg) each was treated with methanol extracts of four botanicals. The control was treated with methanol only. The treated grains were air dried for three hours after which the grains were introduced into 30 x 40 cm sacks. One hundred adult (5-10 days old) *S. zeamais* and *P. truncatus* of mixed sexes were released into the two different bags respectively. Each treatment was replicated three times. The

bags were then kept in a crib at the University of Ghana farm for 10 weeks after which loss was assessed using count and weigh method. Samples of 1000 grains were taken from each of the treatments and 500 grains each were counted from the 1000 grains. The 500 grains were separated into damaged and undamaged grains. Each of them was counted and weighed. Percentage weight loss was computed using the method adopted by FAO (1985) as modified by Cornelius *et al.* (2008) as:

$$\text{Percent Weight Loss} = (UNd)-(DNu)/ U(Nd + Nu) \times 100$$

Where Nu is the number of undamaged grains

Nd is the number of damaged grains

U is the weight of undamaged grains

D is weight of damaged grains

The grains were also sieved separately and the frass of each treatment was also weighed and their means Compared.

CHAPTER FOUR

4.0 Results

4.1 Survey

A summary of survey results from the three Districts of the Volta region.

Profile respondent: This includes the Sex, Age Group, Marital Status, Educational Level, Dependents and Farming experienced. The study showed that both men and women were involved in the use of botanicals to manage stored product pests, although the demography expressed a higher proportion of 72% of the respondent as female. The age and educational levels of the farmers in the three districts did not show major variations. All the respondents were adults' however, 60% of them were between the ages of 40-60 years old. Ninety four percent of the farmers had some levels of education and 85% of them were married with dependents (Table 4.1). At least 70% of the respondents had 10-20 years experience of farming and the use of botanicals to store their produce.

Type of crops grown and storage method by farmers in Volta Region

Although several types of crops were grown, 90% of all the respondents cultivated maize in subsistence farming mostly in the minor season for storage. Hundred percent of farmers harvested their grains manually and stored them for future use. Fifty percent of the farmers stored their cobs in crib whilst the other halves stored grains in 15 L oil gallon (hermetic) with botanicals, barns and in sacks (Plate 4.1).

Table 4.1 A summary of survey results from the three Districts of the Volta region

Sex	Frequency	Percentage
Male	25	28
Female	65	72
Age of farmers (range)	Frequency	Percentages
Under 21	0	0
21-40	22	25
41-60	54	60
Above 60	14	15
Educational level	Frequency	Percentages
None	5	6
Basic	49	54
Secondary	27	30
Tertiary	9	10
Method of storage	Frequency	Percentages
Crib	45	50
Barn	15	17
Hermetic	30	33
Total	60	100



Integrated storage method (a)



Crib (b)



Barn (c)



Integrated Storage Method (d)

Plate 4.1 Methods of maize storage with botanicals in Jasikan, Afadjato and South Dayi Districts

The use of botanicals, effectiveness and marketing of grains treated with botanicals

According to the study 90% of the respondents used only botanicals whilst 10% used both botanicals and synthetic chemical (actellic). In all, seven botanicals were used by the farmers to protect their grains against infestation by insect pests (Table 4.2).

Table 4.2 Botanicals used by farmers in Volta Region to store maize grains.

Botanicals	Local Name	Common Name
<i>Azadiracta indica</i>	<i>Liliti</i>	Neem
<i>Clausena anisata</i>	<i>Ayira</i>	Horsewood
<i>Phyllanthus amarus</i>	<i>Kpavideme</i>	Phyllanthus
<i>Picralima nitida</i>	<i>Quinine</i>	Akuamma plant
<i>Vernonia amygdalina</i>	<i>Gbɔti</i>	Bitter Leaf
<i>Nauclear latifolia</i>	<i>Nyimɔke</i>	African peach
<i>Momordica</i>	<i>Kakle</i>	Bitter gourd

Out of the above botanicals, 73.5% of the respondent acknowledged that *A. indica*, *C. anisata*, *P. nitida*, *V. amygdalina* were more effective in managing stored insect pest. All the respondents agreed that they did not encounter any problem in the sales of grains stored with botanicals.

4.2 Effect of plant powder on *Prostephanus truncatus* and *Sitophilus zeamais* in treated maize

The response of all the six plant powders at 5% and 10% against adult *P. truncatus* and *S. zeamais* after seven days are illustrated in Fig 4.1-4.4. In all the six plant powders at 5% and 10%, the survival of *S. zeamais* after seven days of treatment ranged from 54-86% and 41-64% respectively, while 55-86% and 42-71% survival respectively was recorded in *P. truncatus*. All the values were significantly ($P < 0.05$) lower than was induced by Actellic.

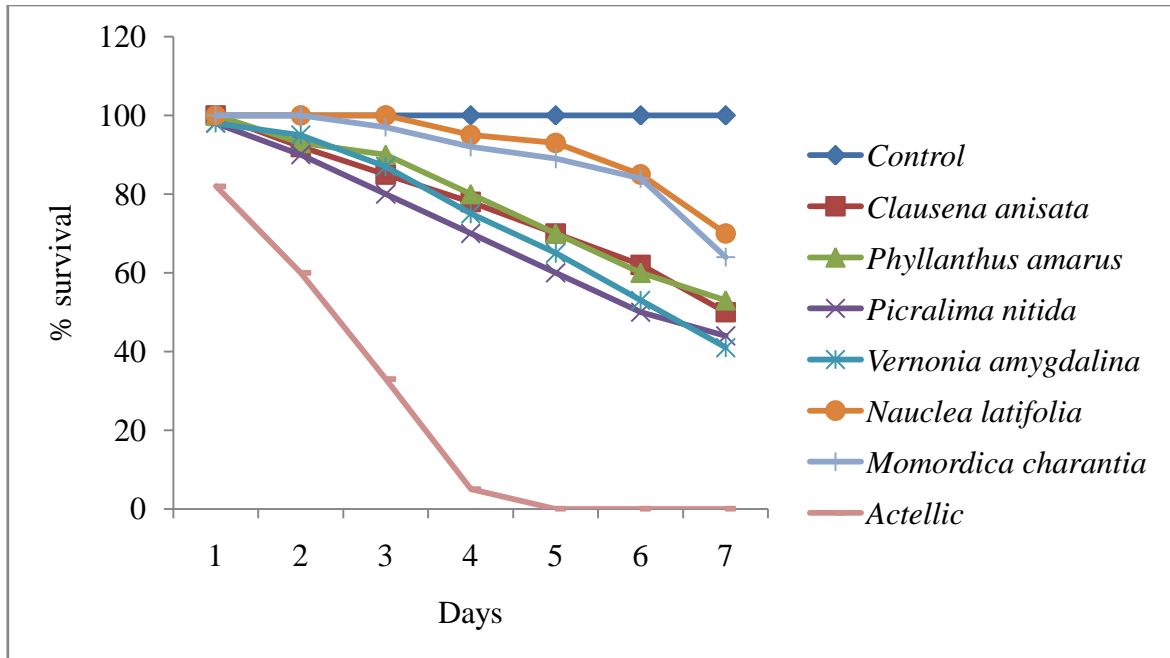


Figure 4.1 Effect of six botanical powders at 10% on the survival of adult *Sitophilus zeamais*.

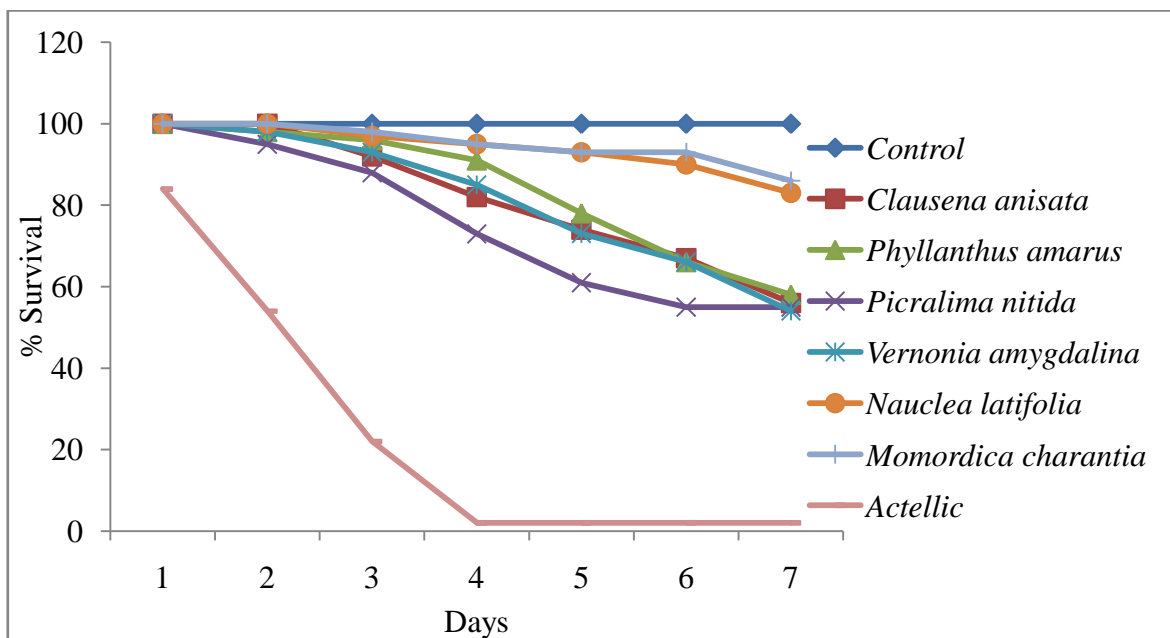


Figure 4.2 Effect of six plant powders at 5% on the survival of adult *Sitophilus zeamais*

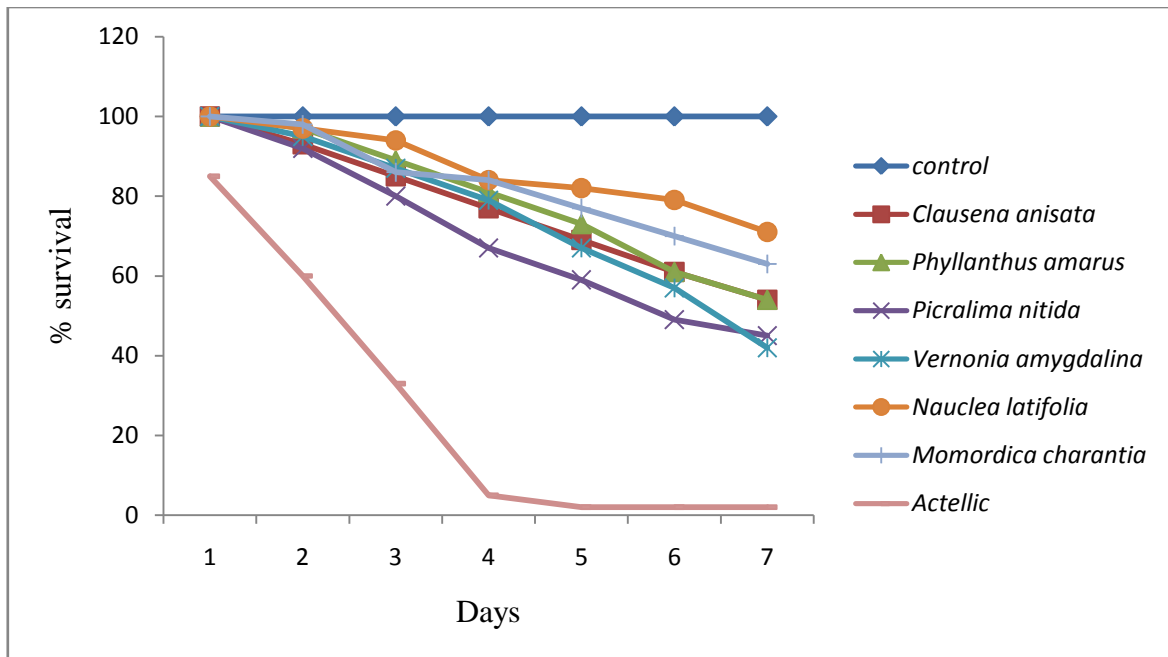


Figure 4.3 Effect of six plant powders at 10% on the survival of adult *Prostephanus truncatus*.

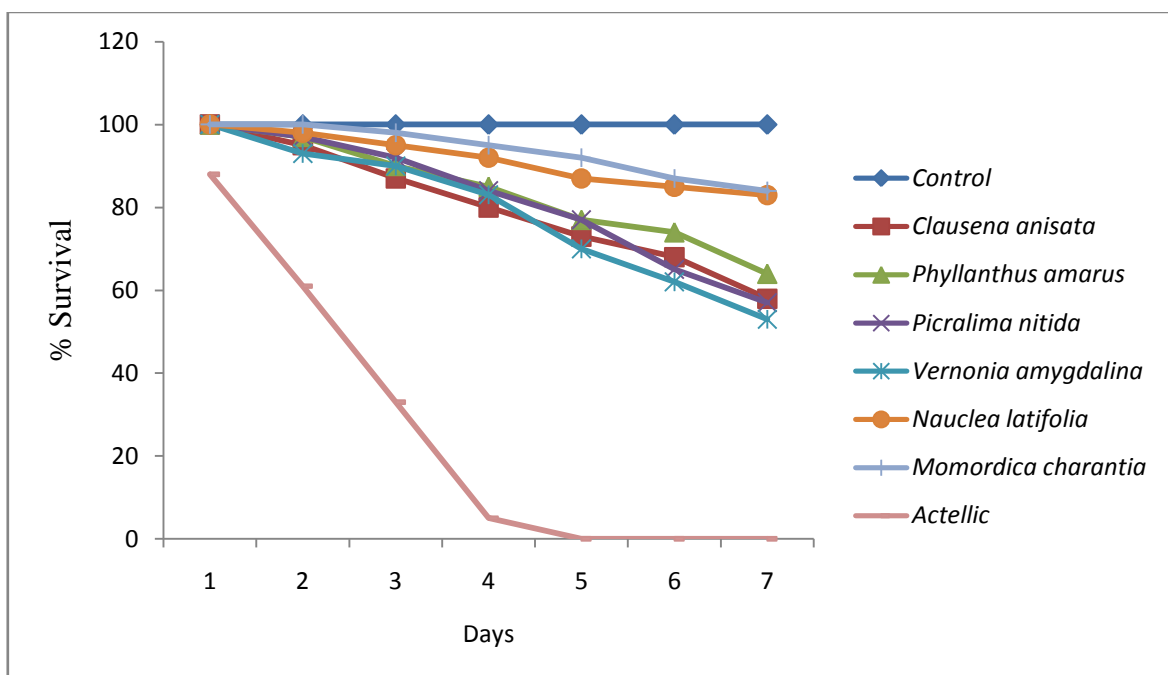


Figure 4.4 Effect of six plant powders at 5% on the survival of adult *Prostephanus truncatus*

4.3 Contact toxicity by topical application

Adult mortality of *P. truncatus* and *S. zeamais* treated with methanol extract of *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalima* at a concentration of 0.1 g/mL and 0.2 g/mL by contact toxicity are presented in Table 4.3. The results showed that the toxicity of methanol extract of the various plants were significantly ($P < 0.05$) influenced by type of plant and concentration of extract applied. The mortality of *P. truncatus* and *S. zeamais* ranged between 36.7-60% and 50-70% respectively in the lower (0.1g/mL) concentration whilst in the higher (0.2/mL) concentration, it varied between 50-83% and 56.7-86.7 in *P. truncatus* and *S. zeamais* respectively. The mortality of insects in the higher concentration was higher than that of the lower concentration.

Table 4.3 Contact toxicity of methanol extract of four botanicals by topical application to *Sitophilus zeamais* and *Prostephanus truncatus* after 96 hrs.

Treatment	Percentage mean mortality (\pm SE) after 96 hrs	
	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	53.3 \pm 0.67	63.3 \pm 0.67
<i>Phyllanthus amarus</i>	36.7 \pm 0.33	50.0 \pm 0.57
<i>Picralima nitida</i>	50.0 \pm 1.00	56.7 \pm 1.20
<i>Veronia amygdalina</i>	60.0 \pm 0.58	70.0 \pm 0.16
Actellic (standard)	100 \pm 0.00	100 \pm 0.00
Control	00.0 \pm 0.00	00.0 \pm 0.00
LSD(P<0.05)	19.66	19.66
0.2 g/mL		
<i>Clausena anisata</i>	70.0 \pm 1.16	80.0 \pm 1.16
<i>Phyllanthus amarus</i>	50.0 \pm 0.16	56.7 \pm 1.20
<i>Picralima nitida</i>	73.3 \pm 1.90	73.3 \pm 1.80
<i>Vernonia amygdalina</i>	83.3 \pm 0.89	86.7 \pm 0.33
Actellic (standard)	96.7 \pm 0.33	100 \pm 0.00
Control	00.0 \pm 0.00	00.0 \pm 0.00
LSD(P<0.05)	20.64	20.6

4.4 Toxicity of extracts to *Sitophilus zeamais* and *Prostephanus truncatus* in treated grain.

The toxicity of methanol extract of *C. anisata*, *P. amarus*, *P. nitida*, and *V. amygdalina* at concentration of 0.1 g/mL and 0.2 g/mL on adult insects in treated grains are illustrated in Figs 4.5, 4.6, 4.7, and 4.8. In both treatments, survival of both insects increased with increasing in concentration. The lowest survival rates of *P. truncatus* and *S. zeamais* at 0.1 g/ml were 35% and 38% whilst at 0.2 g/ml it further decreased to 28% and 23% respectively. The reference product recorded zero survival in almost all the treatment.

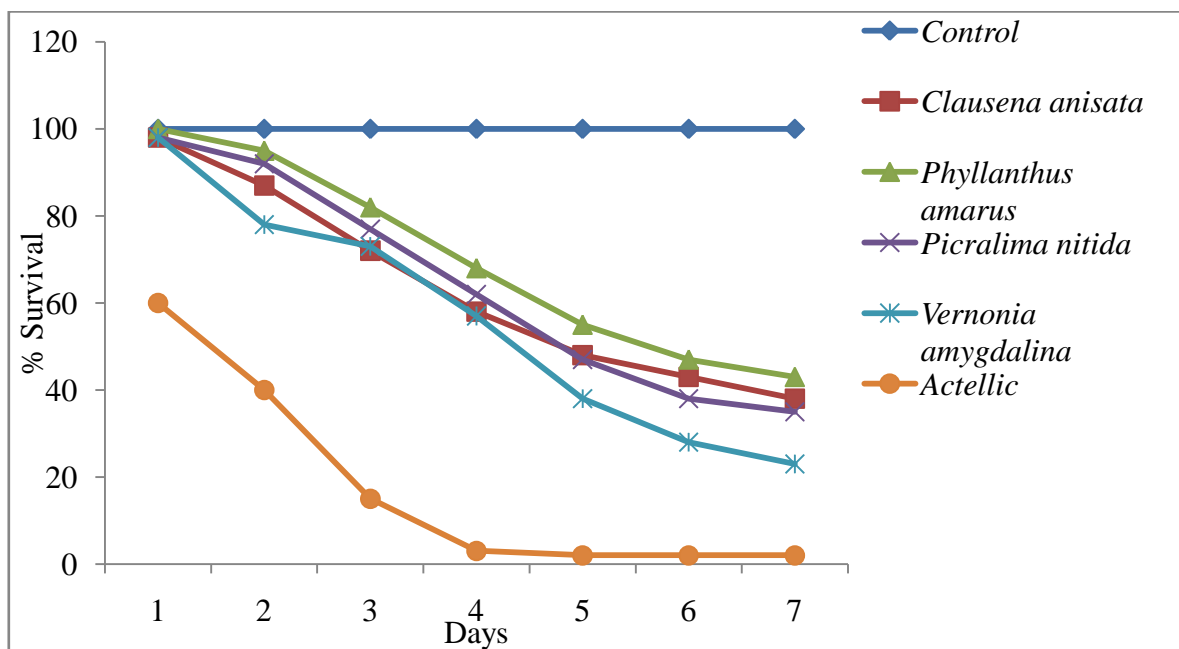


Figure 4.5 Effect of methanol extract of four botanicals at 0.2 g/mL on the survival of adult *Sitophilus zeamais* in treated grain.

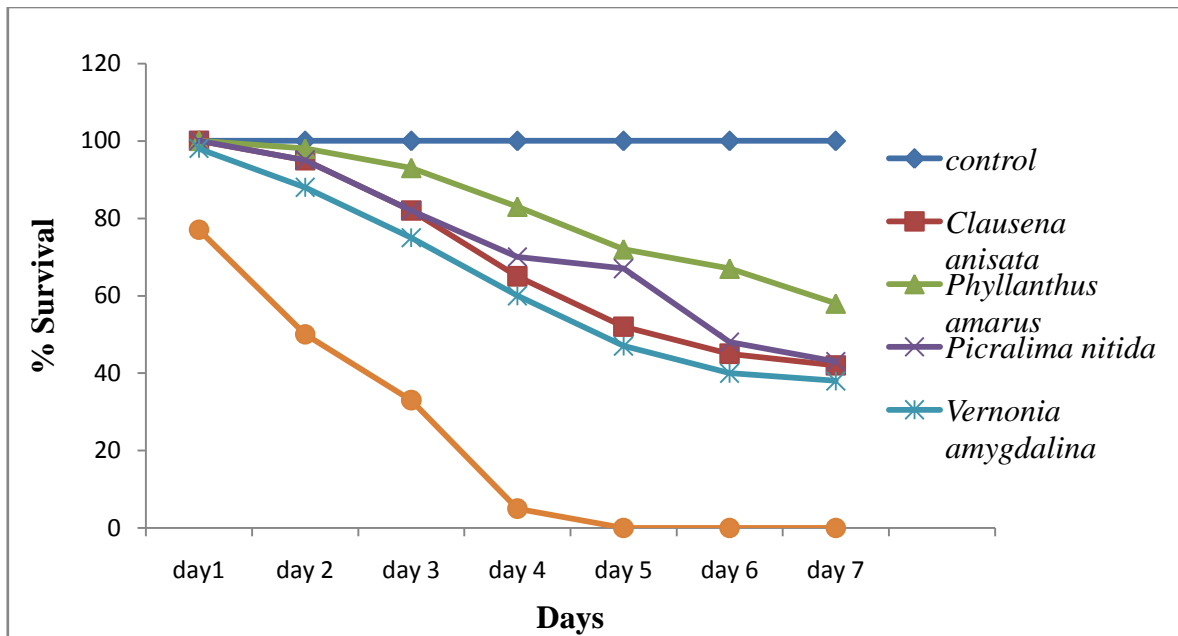


Figure 4.6 Effect of methanol extract of four botanicals at 0.1 g/mL on the survival of adult *Sitophilus zeamais* in treated grain.

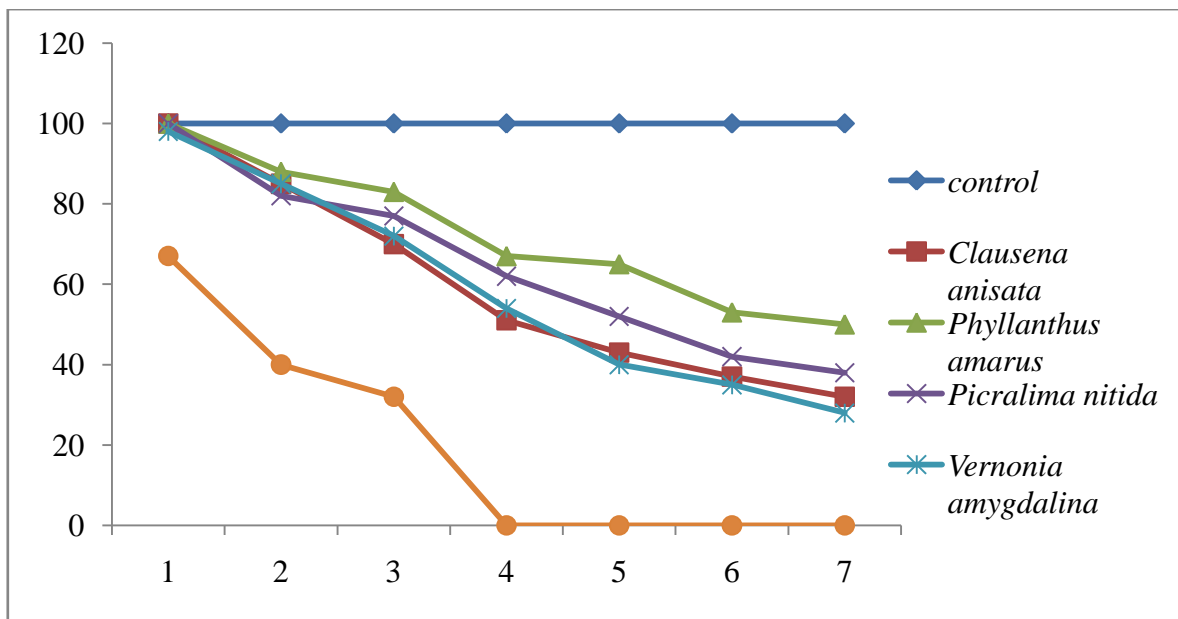


Figure 4.7 Effect of methanol extract of four botanicals at 0.2 g/ml on the survival of adult *P. truncatus* in treated grain.

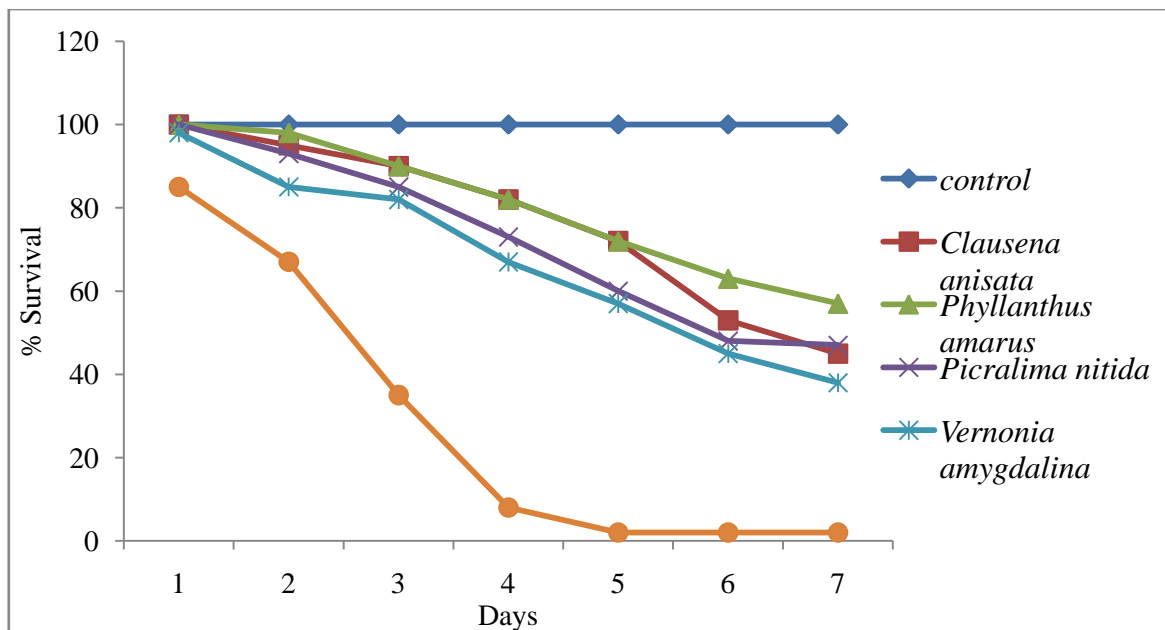


Figure 4.8 Effect of methanol extract of four botanicals at 0.1 g/mL on the mortality of adult *Prostephanus truncatus* in treated grain

4.5 Effect of methanol extract of botanicals on oviposition of *Prostephanus truncatus* and *Sitophilus zeamais*

The number of eggs laid by *P. truncatus* and *S. zeamais* on grains (50 g) treated with *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina* at concentration of 0.1 g/ml and 0.2 g/ml and Actellic (2 ml/ L) is presented in Fig. 4.9 and 4.10. It was observed that the higher concentration had the least number of eggs (3.0 and 4.0) laid by *P. truncatus* and *S. zeamais* respectively as compared to lower concentration (4.5 and 5.3). There was a significant ($P < 0.5$) difference between the eggs laid on the treated grains and the control. The reference product (Actellic) was able to reduce the number of eggs laid on grains than other treatment.

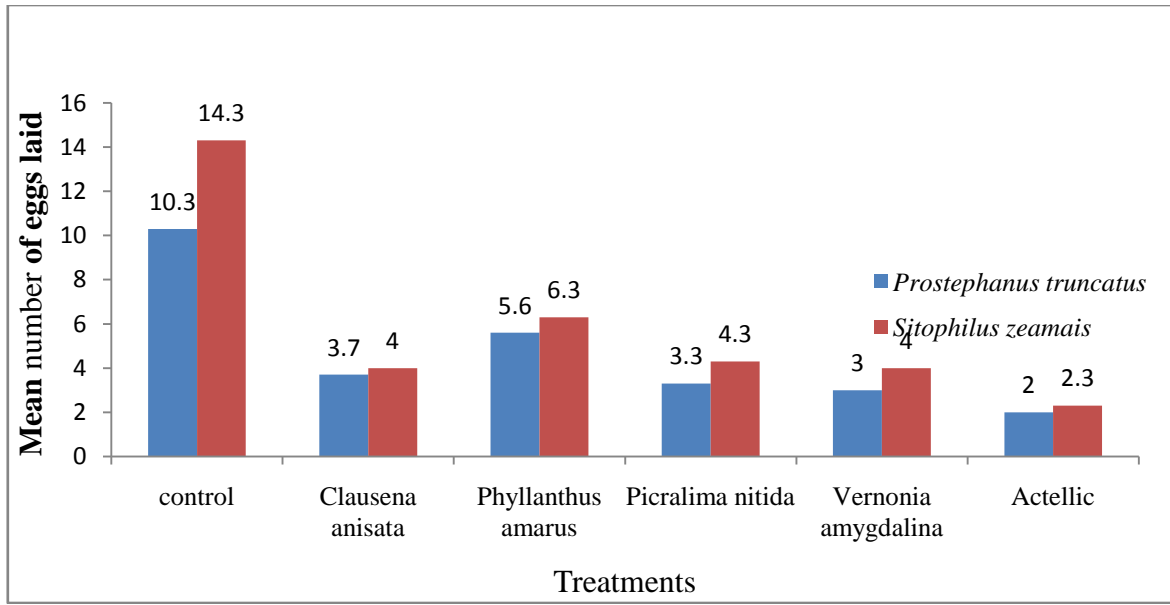
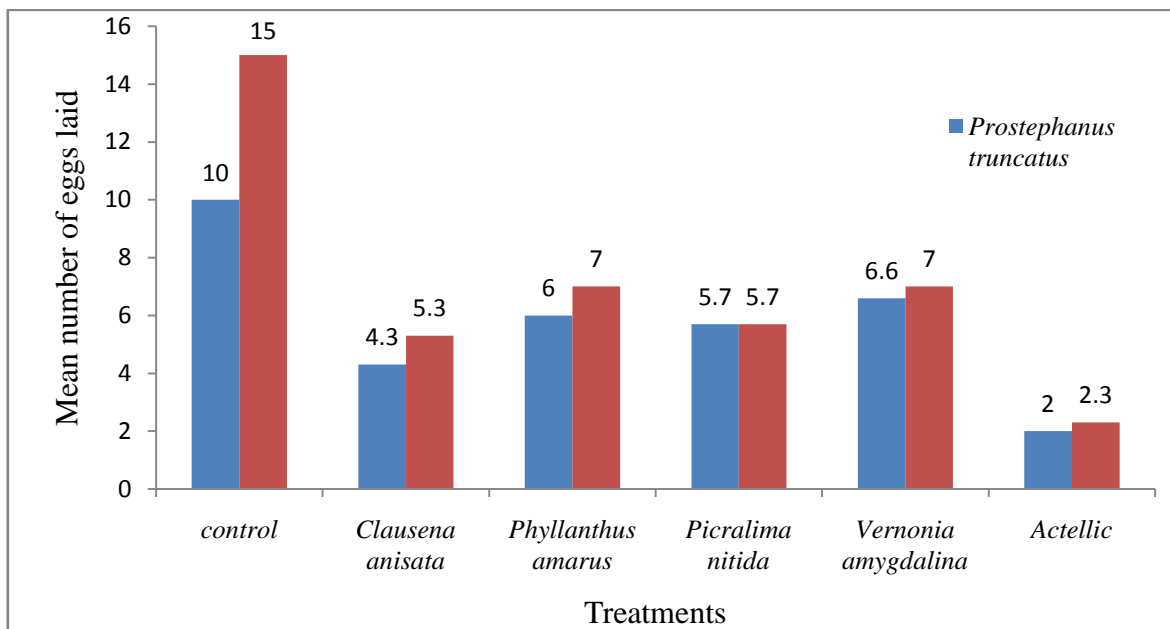


Figure 4.9 Effect of methanol extract of four botanicals at 0.2 g/ml on oviposition *Prostephanus truncatus* and *Sitophilus zeamais*.



4.10 Effect of methanol extract of four botanicals at 0.1 g/mL on oviposition of *Postephanus truncatus* and *Sitophilus zeamais*.

4.6 Effect of methanol extract of four botanicals on eggs and immature stages.

4.6.1 Effect of methanol extracts of four botanicals on eggs of *Prostephanus truncatus* and *Sitophilus zeamais*.

Methanol extracts of *C. anisata*, *P. amarus*, *P. nitida* and *V. amygdalina* (0.1 g/mL and 0.2 g/mL) reduce the emergence of *P. truncatus* and *S. zeamais* in treated grain (Table 4.4). There was significant ($P < 0.05$) difference between the extract treated grains and the control. There was no emergence of insects from grains treated with Actellic, *C. anisata* and *V. amygdalina* at a higher(0.2 g/L) concentration.

Table 4.4 Effect of methanol extract of four botanicals on eggs of *Prostephanus truncatus* and *Sitophilus zeamais*

Treatment	Mean number of adult emerged(\pm SE)	
	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	2.0 \pm 0.33	2.0 \pm 0.00
<i>Phyllanthus amarus</i>	3.0 \pm 0.33	2.0 \pm 0.33
<i>Picralima nitida</i>	2.0 \pm 0.00	1.0 \pm 0.33
<i>Veronia amygdalina</i>	1.0 \pm 0.33	0.0 \pm 0.00
Actellic	0.0 \pm 0.00	0.0 \pm 0.00
Control	8.0 \pm 1.15	5.0 \pm 0.33
LSD(P<0.05)	1.22	1.22
0.2 g/mL		
<i>Clausena anisata</i>	0.0 \pm 0.00	0.0 \pm 0.00
<i>Phyllanthus amarus</i>	1.0 \pm 1.16	1.0 \pm 0.33
<i>Picralima nitida</i>	1.0 \pm 0.58	1.0 \pm 0.33
<i>Veronia amygdalina</i>	0.0 \pm 0.00	0.0 \pm 0.00
Actellic	0.0 \pm 0.00	0.0 \pm 0.00
Control	7.0 \pm 1.15	8.0 \pm 0.33
LSD(P<0.05)	1.12	1.12

4.6.2 Effect of methanol extract of four botanicals on the larvae of *Prostephanus truncatus* and *Sitophilus zeamais*.

Table 4.5 showed the effect of leaf extract of *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina* and Actellic on grains containing larvae of *P. truncatus* and *S. zeamais*. At both concentration there were significance ($P < 0.05$) difference between emergence of insects in grains treated with extract and the control. The highest concentration (0.2 g/ml) recorded the least insect emergence and even in some cases no insect emerged.

Table 4.5 Effect of methanol extract of four botanicals on the larvae of *Prostephanus truncatus* and *Sitophilus zeamais*.

Treatment	Mean number of adult that emerged (\pm SE)	
	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	2.00 \pm 0.89	1.00 \pm 0.33
<i>Phyllanthus amarus</i>	2.00 \pm 1.20	2.00 \pm 0.88
<i>Picralima nitida</i>	1.00 \pm 0.88	2.00 \pm 0.58
<i>Veronia amygdalina</i>	1.00 \pm 0.33	0.00 \pm 0.33
Actellic	0.00 \pm 0.00	0.00 \pm 0.00
Control	6.00 \pm 0.89	4.00 \pm 0.33
LSD(P<0.05)	1.12	1.12
0.2 g/mL		
<i>Clausena anisata</i>	0.00 \pm 0.00	0.00 \pm 0.00
<i>Phyllanthus amarus</i>	1.00 \pm 0.66	1.00 \pm 0.33
<i>Picralima nitida</i>	1.00 \pm 1.33	1.00 \pm 0.00
<i>Veronia amygdalina</i>	0.00 \pm 0.00	0.00 \pm 0.00
Actellic	0.00 \pm 0.00	0.00 \pm 0.00
Control	6.00 \pm 1.20	4.00 \pm 0.88
LSD(P<0.05)	1.61	1.61

4.6.3 Effect of methanol extract of four botanicals on the pupae of *Prostephanus truncatus* and *Sitophilus zeamais*.

The extracts of *C. anisata*, *P. amarus*, *P. nitida* and *V. amygdalina* were significantly ($P < 0.05$) toxic to pupae of *P. truncatus* and *S. zeamais* when grains were treated with botanicals compared to the control (Table 4.6). There were no significance difference among botanicals and Actellic ($P < 0.05$) at both concentrations. The highest concentration (0.2 g/mL) of botanical extracts had the least survival on both insects and even in *V. amygdalina* and *C. anisata* no survival of the pupae after 35 days of storage.

Table 4.6 Effect of methanol extracts of botanicals on pupae of *Prostephanus truncatus* and *Sitophilus zeamais*.

Percentage mean mortality (\pm SE) after 96 hrs		
Treatment	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	1.00 \pm 0.00	1.00 \pm 0.33
<i>Phyllanthus amarus</i>	2.00 \pm 0.00	1.00 \pm 0.67
<i>Picralima nitida</i>	1.00 \pm 0.58	1.00 \pm 0.66
<i>Vernonia amygdalina</i>	0.00 \pm 0.00	0.00 \pm 0.00
Actellic	0.00 \pm 0.00	0.00 \pm 0.00
Control	7.00 \pm 0.88	6.00 \pm 0.33
LSD(P<0.05)	1.46	1.46
0.2 g/mL		
<i>Clausena anisata</i>	0.00 \pm 0.33	0.00 \pm 0.00
<i>Phyllanthus amarus</i>	2.00 \pm 0.33	2.00 \pm 0.33
<i>Picralima nitida</i>	1.00 \pm 0.66	1.00 \pm 0.33
<i>Veronia amydalina</i>	0.00 \pm 0.00	0.00 \pm 0.00
Actellic	0.00 \pm 0.00	0.00 \pm 0.00
Control	6.00 \pm 0.88	6.00 \pm 0.60
LSD(P<0.05)	1.22	1.22

4.7 Repellency

Table 4.7 shows the repellent action of *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina* at a concentration of 0.1 g/mL and 0.2 g/mL against *P. truncatus* and *S. zeamais* in stored maize grains. All the botanical extracts were more repellent to *P. truncatus* and *S. zeamais* compared to actellic. Generally, the botanicals were more repellent to *P. truncatus* than *S. zeamais*. Also, the repellent action of all the treatments at higher concentration (0.2 g/mL) was more than at the lower concentration (0.1 g/mL) to both insects.

Table 4.7 Percentage Mean Repellency of methanol extract of four botanicals on *Prostephanus truncatus* and *Sitophilu zeamais*.

<u>(%) Mean Repellency (PR) ± SE</u>		
Treatment	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1g/mL		
<i>Clausena anisata</i>	60.0 ± 1.56	53.3 ± 1.33
<i>Phyllanthus amarus</i>	33.3 ± 0.65	26.7 ± 0.65
<i>Picralima nitida</i>	46.7 ± 1.76	40.0 ± 1.55
<i>Veronia amydalina</i>	53.3 ± 1.33	46.7 ± 1.76
Actellic	33.3 ± 1.33	6.7 ± 0.67
LSD(P<0.05)	20.63	20.63
0.2 g/ml		
<i>Clausena anisata</i>	80.0 ± 1.56	66.7 ± 2.40
<i>Phyllanthus amarus</i>	53.3 ± 0.67	46.7 ± 1.76
<i>Picralima nitida</i>	60.0 ± 1.56	46.7 ± 0.67
<i>Veronia amydalina</i>	73.3 ± 0.56	66.7 ± 1.76
Actellic	33.3 ± 1.33	26.7 ± 0.67
LSD(P<0.05)	20.63	20.63

4.8 Loss assessment

There were significant ($P < 0.05$) difference in weight of powder produced by *S. zeamais* and *P. truncatus* when grains were treated with methanol extract of botanicals after 10 weeks of infestation. The least mean weight of powder was recorded in *V. amygdalina* with a mean value of 10.5 and 7.2 g in *P. truncatus* and *S. zeamais* respectively at 0.2 g/mL concentration of botanical extract when applied to the grains. The highest loss in weight was 24.2 g in *P. amarus* at a concentration of 0.1 g/ml (Table 4.8). The higher concentration produced minimal powder compared to the lower concentration.

Table 4.8 Effect of methanol extract of four botanicals on grain loss (powder) caused by *Prostephanus truncatus* and *Sitophilus zeamais* after 10 weeks of treatment.

Mean weight of powder (\pm SE) (g) after 10 weeks		
Treatment	<i>Prostephanus truncatus</i>	<i>Sitophilus zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	18.6 \pm 2.37	18.0 \pm 1.60
<i>Phyllanthus amarus</i>	24.2 \pm 2.23	22.8 \pm 1.42
<i>Picralima nitida</i>	14.5 \pm 1.66	12.4 \pm 1.84
<i>Veronia amygdalina</i>	11.5 \pm 1.53	8.0 \pm 0.52
Actellic (0.2 ml/L)	1.4 \pm 0.06	1.4 \pm 0.07
Control	30.0 \pm 0.58	31.0 \pm 0.86
LSD(P<0.05)	4.22	4.22
0.2 ml/g		
<i>Clausena anisata</i>	13.5 \pm 1.52	11.9 \pm 0.54
<i>Phyllanthus amarus</i>	22.0 \pm 0.99	23.0 \pm 1.94
<i>Picralima nitida</i>	13.4 \pm 0.58	11.4 \pm 1.16
<i>Veronia amydalima</i>	10.5 \pm 0.33	7.2 \pm 0.69
Actellic (0.2 ml/L)	1.4 \pm 0.12	1.4 \pm 0.07
Control	30.0 \pm 0.58	31.0 \pm 0.86
LSD(P<0.05)	2.75	2.75

4.9 Damage assessment

Generally, all grains treated with botanicals gave higher protection against insect damage compared to untreated grains. However, there were no significant ($P < 0.05$) difference between all the four botanicals and Actellic (Table 4.9). All tested botanicals were more effective at higher (0.2 g/mL) dosage than at lower (0.1 g/mL) dosage in terms of reducing weight loss. Comparatively *P. Truncatus* caused more weight loss in grains treated with botanical extracts than *S. zeamais*.

Table 4.9 Effect of methanol extract of botanicals on damage caused by *Prostephanus truncatus* and *Sitophilus zeamais* after 10 weeks of treatment.

Mean % Weight Loss (\pm SE) after 10 weeks		
Treatment	<i>P. truncatus</i>	<i>S. zeamais</i>
0.1 g/mL		
<i>Clausena anisata</i>	1.41 \pm 2.28	2.1 \pm 0.14
<i>Phyllanthus amarus</i>	5.28 \pm 1.32	4.18 \pm 0.59
<i>Picralima nitida</i>	2.60 \pm 2.25	3.34 \pm 0.83
<i>Veronia amygdalina</i>	1.14 \pm 0.69	0.59 \pm 0.12
Actellic	0.69 \pm 0.27	0.52 \pm 0.09
Control	13.33 \pm 2.99	11.02 \pm 4.19
LSD(P<0.05)	6.46	6.46
0.2 g/mL		
<i>Clausena anisata</i>	0.69 \pm 0.45	0.49 \pm 0.23
<i>Phyllanthus amarus</i>	3.66 \pm 1.45	3.47 \pm 1.19
<i>Picralima nitida</i>	1.89 \pm 0.45	1.88 \pm 0.60
<i>Veronia amygdalina</i>	0.66 \pm 0.96	0.39 \pm 0.18
Actellic	0.32 \pm 0.23	0.41 \pm 0.27
Control	11.56 \pm 2.07	9.91 \pm 1.68
LSD(P<0.05)	3.64	3.64

CHAPTER FIVE

5.0 Discussion

5.1 Survey

The result from the survey showed that both men and women were engaged in farming and mostly use botanicals to store maize grains against stored insect pest. However, majority of the respondents were women and this confirmed earlier work by Cornelius *et al.* (2008) that about 70-80% of the household food in Africa is produced by women. Matobola (2014) also reported that more women were involved in rural agricultural economic sub-sector areas but mostly did not have access to assets, a factor that infringes on their ability to purchase inputs. Thus such house-holds have no chance but to rely on local materials to produce and store crops on a large scale.

The seven botanicals used were arranged according to their decreasing order of effectiveness in the control of insect as revealed in the survey as *A. indica*, *V. amygdalina*, *P. nitida*, *C. anisata*, *P. amarus*, *N. latifolia* and *M. charantia*. *A. indica* was not selected for the research since its potential against grain storage pest has long been established.

5.2 Effect of plant powders on *Prostephanus truncatus* and *Sitophilus zeamais*.

The ground powders of *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina*, *N. latifolia* and *M. charantia* showed different levels of effectiveness against *P. truncatus* and *S. zeamais* in treated grains after seven days. Survival of insects reduced with increasing in quantity of powder from 5%- 10%.

The survival of *P. truncatus* and *S. zeamais* in grains treated with *V. amygdalina* powder at 10% showed that the botanical is a promising control agent against the two insects since it contained alkaloids such as caffeine, cocaine, morphine, and nicotine Irvine (1961). These compounds are toxic to both insects and might have been responsible for the low survivorship of insects in the treated grains. This, therefore, confirm earlier work by Irvine (1961) that the bitter principle, *vernonine* in *V. amygdalina* is poisonous to mites. Similarly, Asawalam and Hassanali, (2006) and Bouda *et al.* (2001) earlier reported that the toxicity of *V. amygdalina* essential oil against *S. zeamais* was attributed to the major component terpenoids that act as insect neurotoxins.

The results of this work have confirmed the protectant potential of *P. nitida* powder against the two insect species that attack stored maize grains, (Ojo and Ogunleye, 2013). The lethality pattern of the aqueous leaf and seed extract of *P. nitida* on *Anopheline* larva and some species of fungi was high and might have been as a result of the presence of bioactive compounds: alkaloids, cardiac glycosides, saponins, tannins, flavonoids, terpenes and steroids in the tested plant (Dibua *et. al.*, 2000). The presence of these compounds might have caused the reduction in survival of *P. truncatus* and *S. zeamais* in treated grains and hence may explain the efficacy of *P. nitida* in this study.

The present investigation revealed that *P. amarus* powder has the efficacy to reduce the survival of *S. zeamais* and *P. truncatus* to 56% when applied at 5% concentration. The survival of insects further reduced to 52% as the dosage of the powder increased to 10%. Shifa *et al.* (2010) earlier observed that higher concentrations of plant extracts were found

to be more effective than lower concentrations in reducing oviposition and increasing the mortality of the target insect pests.

The effectiveness of *C. anisata* leaf powder against the two insects expressed a possible contact action. This might be due to the presence of a highly toxic chemical component “estragole” identified in the leaf oil (Sentilkumar and Venkatesalu, 2009). The leaf powder *C. anisata* might have also contained other chemical compounds preventing insects from feeding on grains that have been treated with the powder.

The use of *N. latifolia* and *M. charantia* powder as grain protectants against *S. zeamais* and *P. truncatus* caused higher survivorship than other four botanicals discussed above. Although, *N. latifolia* and *M. charantia* contain alkaloids, terpenoid, morphine and phenol, they may be in smaller concentration in the plants parts that have been used for the experiment compared to other four botanicals (Akinkurolere, 2012). This might have led to the high survivorship of *P. truncatus* and *S. zeamais* in the treated grains. This observation does not support the findings of Akinkurolere (2012) that *M. charantia* is highly toxic to *S. zeamais* and *C. maculatus*. The change in the effectiveness of these botanicals might have also been due to the change in climatic and soil factors as well as the parts used and time of harvesting (Ndomo *et al.*, 2009 and Jorge *et al.*, 2009).

5.3 Toxicity of extracts applied topically to insects

In this study, all the botanical extracts were toxic to insects at different levels compared to the control after 96 hrs of treatment by topical application. In all the treatments, the higher concentration (0.2 g/mL) was more effective to both insects than the lower concentration

(0.1 g/mL). *Vernonia amygdalina* was highly toxic to both insects due to the presence of chemical compounds like alkaloids, flavonoids, lignans and vernonine in it (Irvine, 1961). At 0.2 g/mL *V. amygdalina* caused the highest lethality of 83.3% to *P. truncatus* and 86.7% to *S. zeamais*. This confirms similar work conducted by Asawalam and Hassanali (2006) that essential oil of *V. amygdalina* contained various terpenoids and induced 82% mortality with essential oil at 750 mg/250 g application rate after 7 days of treatment to *S. zeamais*. *Prostephanus truncatus* was more resistant to methanol extract than *S. zeamais* and this might be attributed to its more robust nature, high feeding ability and highly sclerotized cuticle which might have reduced the physical absorption of the active component of the extract on the cuticle.

5.4 Toxicity of extracts to *Sitophilus zeamais* and *Prostephanus truncatus* in treated grain.

The methanol extracts at both concentration applied to adult insects in treated grain after seven days caused significant ($P < 0.05$) reduction in survival to both insects compared to the control. The toxicity of the extract applied to adult insects in treated grain was influenced by the type of plant, concentration applied and contact duration (days). The most effective botanical was *V. amygdalina* whilst the least effective was *P. amarus*. Although *P. amarus* also contains similar chemical constituents such as lignans, flavonoids and phyllanthin, they might have not been potent enough to kill insect pests as compared to *V. amygdalina*. However, they can be used to prevent fungi attack in stored grains (Oudhia, 2008). The higher concentration of the botanical induced lower insect survivorship. The duration of contact (days) significantly influenced the percentage

survivorship of adult *P. truncatus* and *S. zeamais* due to the continuous accumulation of the chemical component of the botanical in the insects. Whilst the standard (Actellic) caused the highest mortality (100%) or no survivorship after 5 days of contact, *V. amygdalina* at 0.2 g/mL recorded mortality of (62%) or (Survivorship of 38%) in *P. truncatus* after 5 days off treatment. Therefore, the extracts were slower in killing insects than the synthetic chemical (acthellic). This confirms earlier report by Obeng- Ofori and Dankwa (2004) that actellic has rapid knock down action which instantly killed adult insects on contact.

5.5 Effect of methanol extract of botanicals on oviposition of *Prostephanus truncatus* and *Sitophilus zeamais*

All extracts of the various botanicals were effective in reducing the number of eggs laid by both insects after seven days of treatment compared to the control. *Clausena anisata* was the most effective among all the botanicals at a higher concentration of 0.2 g/mL to both insects. This means that *C. anisata* might possess repellent and/or oviposition deterrent action which might have resulted in the changes induced in physiology and behaviour in the adult insects as reflected by their egg laying capacity. This confirms the work done by Schmuttere (1990) and Ndomo *et al.* (2009) that botanical extracts and their essential oils have anti-oviposition and fecundity reducing properties on a range of insects. In all the treatments, *S. zeamais* was able to lay more eggs than *P. truncatus*. This might have been as a result of high fecundity level of *S. zeamais* than *P. truncatus*.

5.6 Effect of methanol extract of botanicals on eggs and immature stages of *Prostephanus truncatus* and *Sitophilus zeamais*

The methanol extract of all botanicals were potent to the eggs, larvae and pupae of *P. truncatus* and *S. zeamais* at both concentrations compared to the control. This agrees with earlier observation by Jayakumar *et al.* (2005) that plant extracts have obvious effects on postembryonic survival of the insect and resulting in the reduction in adult emergence of insect when treated with different plants. Toxicity of extracts to eggs, larvae and pupae resulted in a significant reduction in the number of adults emerging from the treated seeds. The potency might be due to bitter antinutritive secondary metabolites of the extract on the seed coat acting as a barrier to prevent the eggs from hatching into adults (Tchinda, 2011). Methanol extract of *V. amydalina* and *C. anisata* at 0.2 g/mL concentration totally inhibited the development of eggs, larvae and pupae of both insects into adults after 35 days of treatment. This is equally comparable to the standard (Actellic) which also totally inhibited adult.

The eggs of *P. truncatus* and *S. sitophilus* in treated grains were more susceptible to the extracts of *V. amydalina* as compared to the immature stages developing inside cowpea seed. This might have resulted from the relative inactivity, reduced metabolism and better exoskeleton development which reduced the activity of the extract to pupae as compared to larvae in both insects. This validate Law-Ogbomo and Enobakhare (2007) that one to 5 g of dry leaf powder *V. amygdalina* inhibited the growth of *S. zeamais* and *S. oryzae* on stored maize grains and rice. The complete inhibition of the development of the eggs and

immature stages within the treated grain increase the protectants potential of *V. amygdalima* and *C. anisata* against insect damage in stored grains.

5.7 Repellency

All the four botanical extracts have demonstrated greater repellency against *P. truncatus* and *S. zeamais* than the synthetic commercial pesticide (Acthellic). However, *C. anisata* was observed to be highly repellent to the two tested insects, with overall mean repellency of 80.0 and 66.7% respective to *P. truncatus* and *S. zeamais* at 0.2 g/mL. This was similar to the findings of Tchinda (2011) that throughout tropical Africa the dried leaves of *C. anisata* were used as insect repellents and in Kenya the leaves were used as mattress filler, because they were aromatic and repel insects. The major chemical components of *C. anisata* are carbazole alkaloids, peptide derivatives and phytosterol which could be attributed to the high repellent action of the plant to the insects (Songue *et al.*, 2012).

5.8 Damaged assessment

In all the botanicals tested, mean weight loss in the treated grains was lower with higher (0.2 g/mL) concentration than in the lower (0.1 g/mL) concentration. The number of damaged seeds observed in maize treated with extracts of botanicals was by far lower than the control. This was agreed by Law-Ogbomo and Enobakhare (2007) that percentage punctured grain was observed in the treated grain with *V. amygdalina* was lower than that of the untreated control. Enobakhare and Law-Ogbomo (2002) also showed that *V. amygdalina* is an effective grain protestant against *S. zeamais*. *Prostephanus truncatus* was able to cause more damage to grains than *S. zeamais*. In the bioassay, due to the high

humidity some of the botanical extract treated grains except *V. amygdalina* were observed to be attacked by *Aspergillus flavus*. The inhibitory action by *V. amygdalina* was as a result of its secondary metabolites that are resistant to fungus as reported by (Ogbebor *et al.*, 2007).

The powder produced after ten weeks of storage differs in terms of plant and the type of insect. It was observed that *P. truncatus* produced more powder than *S. Sitophilus*. This might have been due to its robust nature, exploratory and ability to feed and breed in dry conditions and even in maize with 9% moisture content. (Cornelius *et al.*, 2008)

CHAPTER SIX

6.0 Conclusion and Recommendations

6.1 Conclusion

The study identified and assessed the bioactivity of six indigenous plants in the management of *S. zeamais* and *P. truncatus* in stored maize. The survey identified *A. indica*, *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalina*, *N. latifolia* and *M. charantia* as botanicals used by the farmers to manage insect pests in maize in the Volta Region. However, *A. indica* was not chosen because extensive work had already been carried out on it. The powders of the other six botanicals were toxic to *P. truncatus* and *S. zeamais* by reducing insect survival when applied at 5% and 10% concentration. *Vernonia amygdalina* was observed to be the most promising botanical in protecting maize grains against the two insects. The methanol extract of *V. amygdalina* contains insecticides, antifeedants, anti-ovipositor, ovicidal and repellent properties. Methanol extract of *V. amygdalina* at 0.2 g/ml caused mortality of 83.3% and 86.7% to *P. truncatus* and *S. zeamais* respectively through contact application after 96 hours. This was not significantly ($P < 0.05$) different from the standard (Actellic).

The mortality of insects in maize grains treated with methanol extract of *V. amygdalina* was very high compared to the control. The damage caused by insects to maize grains treated with *V. amygdalina* in a crib after 10 weeks was minimal in that it was not significantly different from Actellic. Few eggs were laid by both insects in treated maize grains with extract of *C. anisata*. There was total inhibition of adult emergence from eggs, larvae and pupa when grains were treated with extract of *V. amygdalina* and the standard

(Actellic). Repellency of extract of *C. anisata* (0.2 g/ml) to insects was highly significant to the standard. The presence of toxicants and growth inhibitors in *V. amygdalina* when applied to *P. truncatus* and *S. zeamais* suggest good potential for their use in storage pest management especially farm stored grains by peasant farmers. The study also established the scientific fact of the use of *V. amygdalina* as grain protectants by the farmers.

6.2 Recommendations

In spite of the potency of all the six indigenous plants against *P. truncatus* and *S. zeamais* in this study, further research is needed using other insect pests, in order to broaden its spectrum of action. Research must also be conducted to determine the toxicity of these plants in order to assess its potential hazards for consumers and the environment. Again, different solvents should be used for extraction of the chemical component from the plant. In order for this research to be beneficial to the society, it is hoped that NGOs and other Governmental Organisations would help to disseminate the outcome of the study to the various farmers in their communities. For sustainable production and utilization of these biopesticides, there must be year round cultivation of the plants since some of them are seasonal or almost in extinct. Finally, *N. latifolia* root extract was very soapy and used to wash all apparatus, it should therefore be investigated in order to be used in the soap industry.

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APPENDIX I

Appendix 1: Analysis of variance for repellency effect of methanol extract of (0.1 g/mL) *C. anisata*, *P. amarus*, *P. nitida*, *V. amygdalima* on *P. truncatus* and *S. zeamais*.

Variate: %_Repellency

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	9	3746.7	416.3	2.84	0.025
Residual	20	2933.3	146.7		
Total	29	6680.0			

Analysis of variance for repellency effect of methanol extract of botanicals (0.2 g/mL) on *P. truncatus* and *S. zeamais*.

Variate: %_REPELLENCY

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	9	2453.3	272.6	1.28	0.308
Residual	20	4266.7	213.3		
Total	29	6720.0			

**Analysis of variance for Contact toxicity of methanol extract of botanicals (0.1 g/mL)
by topical application to *S. zeamais* and *P. truncatus*.**

Variate: %_mortality

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	32333.3	2939.4	21.60	<.001
Residual	24	3266.7	136.1		
Total	35	35600.0			

**Analysis of variance for Contact toxicity of methanol extract of botanicals (0.2 g/mL)
by topical application to *S. zeamais* and *P. truncatus*.**

Variate: %_mortality

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	36475.0	3315.9	22.11	<.001
Residual	24	3600.0	150.0		
Total	35	40075.0			

**Analysis of variance for effect of methanol extracts of botanicals (0.1 g/mL) on
damage caused (powder) by *P. truncatus* and *S. zeamais* after 10 weeks of treatment.**

Variate: Quantity_of_powder

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	3232.870	293.897	46.68	<.001
Residual	24	151.107	6.296		
Total	35	3383.976			

Analysis of variance for effect of methanol extracts of botanicals (0.2 g/mL) on damage caused (powder) by *P. truncatus* and *S. zeamais* after 10 weeks of treatment.

Variate: Quantity_of_powder

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	3122.881	283.898	106.48	<.001
Residual	24	63.987	2.666		
Total	35	3186.867			

Analysis of variance for effect of methanol extracts of botanicals (0.1 ml/L) on eggs of *P. truncatus* and *S. zeamais*.

Variate: INSECTS_EMERGENCE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	167.6389	15.2399	28.88	<.001
Residual	24	12.6667	0.5278		
Total	35	180.3056			

Analysis of variance for effect of methanol extracts of botanicals (0.2 ml/L) on eggs of *P. truncatus* and *S. zeamais*.

Variate: INSECT_EMERGERNCE

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	192.2222	17.4747	39.32	<.001
Residual	24	10.6667	0.4444		
Total	35	202.8889			

Analysis of variance for effect of methanol extracts of botanicals (0.1 g/mL) on larvae of *P. truncatus* and *S. zeamais*.

Variate: Insect_emergence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	102.9722	9.3611	21.06	<.001
Residual	24	10.6667	0.4444		
Total	35	113.6389			

Analysis of variance for effect of methanol extracts of botanicals (0.2 g/mL) on the larvae of *P. truncatus* and *S. zeamais*.

Variate: Insects_Emergence

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	116.0000	10.5455	11.50	<.001
Residual	24	22.0000	0.9167		
Total	35	138.0000			

Analysis of variance for effect of methanol extracts of botanicals (0.1 g/mL) on the Pupae of *P. truncatus* and *S. zeamais*.

Variate: Insect_Emergency

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	168.9722	15.3611	20.48	<.001
Residual	24	18.0000	0.7500		
Total	35	186.9722			

Analysis of variance for effect of methanol extracts of botanicals (0.1 g/mL) on the Pupae of *P. truncatus* and *S. zeamais*.

Variate: Isects_Emergency

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	179.5556	16.3232	30.93	<.001
Residual	24	12.6667	0.5278		
Total	35	192.2222			

Effect of methanol extracts of botanicals (0.1 g/mL) on damage caused by *P. truncatus* and *S. zeamais* after 10 weeks of treatment.

Variate: %_Grain_Damaged

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	580.01	52.73	3.59	0.004
Residual	24	352.90	14.70		
Total	35	932.91			

Effect of methanol extracts of botanicals (0.2 g/mL) on damage caused by *P. truncatus* and *S. zeamais* after 10 weeks of treatment.

Variate: %_Grain_Damage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
TRT	11	486.079	44.189	9.46	<.001
Residual	24	112.121	4.672		
Total	35	598.201			

APPENDIX II

QUESTIONNAIRE

BIOACTIVITIES OF SIX INDIGENOUS GHANAIAN PLANTS IN MANAGING *SITOPHILUS ZEAMAI* AND *PROSTEPHANUS TRUNCATUS* IN STORED MAIZE IN VOLTA REGION.

This research is purposely for academic exercise and all information given shall be used for the stated objective. All information given would be treated as confidential.

Section A–Demography (Farmers Only)

Please fill in or tick [] where applicable.

1. Name of the interviewer:
2. Date of interview:
3. District:
4. Place of interview:
5. Sex of farmer : Male [] Female []
6. Age of farmer: Under 21[] 21-40 [] 41-60 [] above 60[]
7. Marital status: Single[] Married [] Widowed [] Divorced [] Separated []
8. Number of dependents:
9. What is your educational level? None [] Primary [] JHS/JSS [] Middle school[]
Secondary [] Technical/ Vocational [] Certificate [] Diploma/ Degree [] higher []
10. How long have you been farming?
11. Do you do any other kind of work apart from farming? Yes [] No []
12. If yes please specify.....
13. Indicate your monthly income from the other activity? [GH¢]

Section B Type of Crop and Storage

1. What other crops do you cultivate aside maize? Cowpea[] Cassava [] Rice []
Yam[] Others []
2. Which of the food crops do you grow in large quantity? Maize [] Cowpea []
Cassava[] Yam [] Rice[] Others []
3. Which season do you mostly grow your maize? Major [] Minor []
4. What type of farming system do you practice? Subsistence [] Commercial []
5. What variety (ies) of maize do you mostly cultivate?
6. At what stage do you harvest your maize? Green matured [] Dried matured []
Droop dried others []
7. Please explain why you harvest at that stage?

-
8. What method of harvesting do you use? Mechanical [] Manual []
 9. Do you store your maize? Yes [] No []
 10. If yes, what is/are the reason(s) for the storage?
 -
 11. In which form do you store your maize? Cob (with husk) [] Cob (without husk) [] Shelled grains [].
 12. Which type of storage facility do you use? Crib [] Barn [] Warehouse [] Others []
 13. Why do you choose the above storage facility?

The use of synthetic insecticide and bioinsecticides to store products (maize)

1. Do you use insecticides to store your maize grains? Yes [] No []
2. If yes, how long have you been using the insecticide?
3. What type of pesticide do you use to store your maize? Synthetic pesticide [] Botanicals [] Both synthetic and botanicals []
4. State the reason(s) for using the selected type of pesticide above.
.....
.....
5. List the various types of botanicals that you use to store grains.
.....
.....
.....
.....
6. In what form do you use the botanicals to store the grains? Powder [] Aqueous [] Raw leaves [] Tablets [] Others []
7. How long (months) do you store your grains?
8. Estimate the percentage of loss of grain at the end of the storage period when botanicals are used. < 10% [] 10-20% [] 21-30% [] 31-40% [] 41-50% [] >50% []
9. Which type of botanicals do you think is most effective in controlling pest of stored maize?
-
10. State the reason for your answer
-
11. Where do you acquire your botanicals?
-