EFFICACY OF SELECTED PLANT OILS AND POWDERS FOR THE CONTROL OF MAIZE WEEVIL (*Sitophilus zeamais* Motsc*h.*) ON STORED MAIZE

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DEDICATION

This project work is dedicated to God Almighty for His provision, protection, wisdom, knowledge and His grace bestowed on me although the period of study. May His name be praised forever and ever, amen

DECLARATION

I declare that this dissertation is an original research work in the department of Agronomy, Delta State University, Abraka and has not been submitted anywhere for any degree

Aghomo Victor Obariagbon　　　　　　　　　　Date

CERTIFICATION

I certify that this work was conducted by Aghomo Victor Obariagbon of the Department of Agronomy, Faculty of Agriculture, Delta State University, Abraka, for the Award of M.Sc in Agronomy

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ABSTRACT

This study was conducted at the Teaching and Research Laboratory of Delta State University, Asaba Campus, Asaba. The objectives were to evaluate the efficacy of some locally available plant powders and oils for the control of *Sitophilus zeamais* (Mostchulsky) and to determine the duration the grains could be protected by the different treatments. Two treatments (-standard check T_{13} using Permetrin) and untreated control (T_{14}) were included and the experiments were replicated three times. The experimental period was 100 days. The plant powders used were *Azadirachta indica* and *Nicotiana tobacum*.The plant oils were Coconut, Mustard, Castor, Sesame, Groundnut, Olive and Soyabean oils. The experiments were laid-out in Completely Randomized Design with 14 treatments in the first and 9 in the second. Data were obtained from adult mortality, first generation adults, grain damage, weight loss and weevil perforated index (WPI). All plant powders and oils significantly ($P<0.05$) affected weevil mortality when compared to the untreated control (T_{14}). The results of the experiments revealed that all the treatments (plant powders and oils), were toxic to the insects. The plant powder Treatments recorded mean mortality values which ranged from 0.33 to 4.33 within 35 DAT. None of the plant powders caused 100% mortality at 35 DAT, while the oils recorded the death of the entire test insects irrespective of the concentration level at 28 DAT. There was no first generation adult from the nine plant oil treatments (oils and permetrin) over the exposure period, indicating the potency of the oils against *S. zeamais*. As a result, there were no perforated seeds, no weight loss and no damaged seeds. *N. tobacum* powder at 6g/150g of maize seeds and 2ml of castol oil is therefore recommended to farmers for maize seeds beetle control. The oils were more potent and were on par with the standard check (permetrin) and can be used in integrated pest management of maize beetles.

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INTRODUCTION
1.1 Background of the study

Maize (*Zea mays* L.) often referred to as 'corn, belongs to the family of Poaceae (Okonmah and Eruotor, 2012). The total land area sown and world production in 2013, was 232 million hectares of farmland and 1.02 billion tonnes of maize yield respectively, in which Nigeria produced 10.4 million tonnes from 5.2 million hectares of land (FAOSTAT 2013))

Maize is an important cereal crop grown in different parts of the world including Africa, serving as source of food and industrial raw materials (Abdurahman, 2009) Annual maize demand in sub-Saharan Africa is expected to double to 52 million tonnes by 2020 (CIMMYT, 2004).It is a staple cereal crop in many parts of Africa and it has replaced many traditional starchy foodstuffs, such as sorghum and millet, particularly in South Africa, Malawi, Zimbabwe, Kenya, and in considerable sections of Angola, Zambia, Tanzania, Mozambique, Cameroon, Benin, Togo, Ghana, Nigeria and Egypt (Purseglove, 1992).

In developed countries like Canada and the USA, maize is consumed mainly as a second cycle produce in the form of meat, eggs and dairy products, while in developing countries like Nigeria and Tanzania it is consumed directly as cooked or roasted corn etc and serves as staple food for over 200 million people (Negahban, 2007).

Maize provides about 20% of the world's food calories and 15% of all food crop protein (Meseret, 2011).In the report of IITA (2011), maize production is projected to double in the developing countries of the world in the year 2050 and its global production surpassing all crops by the year 2025.

Despite the global continuous increase in cultivated farmlands, production and demand for the crop is still relatively high, this is as a result of numerous production problems recognized as bio-physical factors in the world which has limited its continuous availability. (Sahsiad Igetu, 2009). However, maize production and storage is inhibited by a number of factors which include, attack by diseases and insect pests. Insect pests are the major threat, destroying between 20 to 50% of stored maize in most African countries (CABI, 2012**;** Dhliwayo and Pixley, 2003; Nukenine *et al,* 2002)

Food grain yield losses due to insect pests and diseases, are estimated to be between 5 – 10% (temperate regions) like Canada and 50-100% in tropical regions like Nigeria (Van Wyk, Van outshum and Geneke, 2009).Food and Agricultural Organization (2001) estimated that about 200 million tonnes of maize grains is lost every year due to damage inflicted by storage pest and improper storage practices by resource poor farmers of the developing countries. Global postharvest grain and pulse crops losses mainly due to insect pests, was estimated to be 10% Boxall, Brice, Taylor and Bancroft, (2002).

1.2 Maize beetle description

The maize beetle (*Sitophilus zeamais*), is a species of beetle in the family Curculionidae. (Proctor, 1971) It can be found in many tropical areas around the world.It is a major pest of maize (Meikle, Holst, Markham, 1999). This species attacks crops on the field and stored cereal products (Nardon, 2002). The maize beetle has a length of 2.5 mm to 4 mm. This small, brown beetle has four reddish-brown spots on the wing covers. It has a long, thin snout and elbowed antennae. It causes characteristic damage to maize by making holes of about1mm on the maize grains, in which the adult female deposits its eggs. The holes are sealed with a gelatinous waxy secretion. The eggs, larvae and pupal stages of the insect pest takes place within the grain after which, the emerging adult beetle comes out of the grains through the holes, leaving visible holes on the grains (Rees, 2004; Sahaf, Moharramipour and Meshkatalsadat, 2008). These holes predispose the grains to secondary pest infection. Maize beetle damage results directly in loss of food ready for consumption or loss of cash from farmers' pocket ready to buy other valuable resources for the family needs. Damage by maize beetle to maize grains also reduces the viability of the seeds as the larvae and adults consumes the embryo, thereby affecting maize production of farmers who plant saved grains (estimated to be 70% of all maize planted in Eastern and Southern Africa) as seed Boxall *et al* (2002).

Several methods are used in controlling insects of stored grains, these methods include, physical (smoking, sundrying, heating), cultural, biological (male insect sterilization, natural enemies, use of resistant grain varieties) and chemical (use of synthetic products)

Several workers have reported the success of wide scale use of synthetic insecticides, commencing with the use of organochlorines in the mid1940s, followed by the use of organophosphate, carbamates, pyrethroids etc. The over dependence on insecticides, was as a result of their quick action, relative ease of use and effectiveness in reducing pest populations and damages.

The use of synthetic insecticides in grain storage is an age long practice to control pests in general and stored product pests in particular. However, the incessant use of these synthetic insecticides resulted in a number of serious ecological, environmental, social agricultural consequences unforseen by man (Emosairue, 2012). These include;

i. Environmental contamination and pollution of water bodies.
ii. High mortality of beneficial and non target organisms such as fishes, birds, biological agents such as bees, predators and natural enemies.

iii. Secondary pest resurgence

iv. Emergence of pesticide resistant species

v. High pesticide residues in food and environment

vi. Biomagnification or bioaccumulation and the attendant consequences.

vii. Effect on the ozone layer, e.g methyl bromide which depletes the ozone layer

In addition, the increased public awareness and concern for environmental safety, increased regulatory constraints, high cost of purchase etc are some of the other limitations of synthetic insecticide use (Oppert, Ellis and Babcock, 2000). Thus, the search for eco-friendly, cost effective, easily available insect pest management options being intensified globally. This is to reduce the use of synthetic insecticides in pest management. Among the benign alternatives in pest management options, is the use of plant materials (leaves, stems, oils, barks, etc) to address the menace caused by insect pests in storage. Plant materials are as effective and benign tools with broad spectrum action against wide range of insect pest management (Mohammed, 2009).

1.3 Justification

The justification of the study is to develop crop protection strategies that will provide adequate wholesome food for humans and livestocks as well as preserve the quality of the environment.

1.4 Objectives

The main objective, was to evolve a sustainable strategy that will reduce damage of maize grains during storage by the maize beetle (*S. zeamais*) through the use of botanicals (plant powders or oils) that are of low cost to peasant farmers and also ensuring environmentally friendly approach.The specific objectives were to:

i. evaluate the effect of plant powders and their combinations for the control of maize beetle.
ii. evaluate the control of maize beetle using selected plant oils

CHAPTER TWO
REVIEW OF RELATED LITERATURES
2.1 Botanical Description of maize

Maize or corn (Zea mays) is a plant belonging to the family of Poaceae (Okonmah and Eruotor, 2012). It is cultivated worldwide being one of the most important cereal crops in the world. Maize is an important human nutrient and a basic element of animal feed and raw material for the manufacturing of many industrial products which include; corn starch, maltodextrins, corn oil, corn syrup etc. It is also being recently used as biofuel. Maize is a versatile crop and it is cultivated over a wide range of agro climatic zones. The suitability of maize to diverse environments is unrivalled by any other crop. It is grown from 58^{o}N to 40^{o}S, from below sea level to altitudes higher than 3000 m, and in areas with 250 mm to more than 5000 mm of rainfall per year (Shaw, 1988; Dowswell *et al,* 1996), maize growing cycle ranges from 3 to 13 months (CIMMYT, 2000). However the major maize producing countries are located in temperate regions of the world.Such countries include; United States of America, China, Brazil and Mexico.They account for 70% of global production, While Africa accounts for 6.5% of world production

The use of maize varies in different countries. In United State of America, Canada and other developed countries, it is used mainly to feed farm animals directly or sold to feed industries and also as a raw material for extractive fermentation industries (Morris, 1998; Galinat, 1988; Shaw, 1988, Mexico, 1994). In developing countries, its uses are variable. In Latin America and Africa, the main use of maize is for food while in Asia it is used for food and animal feed. In many countries, it is the basic staple food and an important ingredient in the diets of people.

Table 2.1: Maize production in Nigeria and USA

Year	Area harvested ('000ha)		Total production ('000t)		Yield (t/ha)	
	Nigeria	USA	Nigeria	USA	Nigeria	USA
1986	2,800,000	27,885,000	3550000	208,943,000	1.268	7.493
1987	3,408,000	24,080,000	4612000	181,142,000	1.353	7.523
1988	3,212,000	23,573,000	5268000	125,914,000	1.640	5.311
1999	3,423,000	28,525,000	5476000	239,549,000	1.600	8.398
2000	3,159,000	29,315,700	4107000	251,852,000	1.300	8.591
2001	3,283,000	27,829,700	4596000	241,875,000	1.400	8.673
2002	3,282,000	28,057,200	4898000	227,765,000	1.490	8.118
2003	3,469,000	28,710,300	5203000	256,227,000	1.500	8.925
2004	3,479,000	29,797,700	5567000	299,874,000	1.600	10.064
2005	3,589,000	30,399,000	5957000	282,261,000	1.660	9.285
2006	3,905,000	28,586,500	7100000	267,501,000	1.818	9.358
2007	3,944,000	35,013,800	6724000	331,175,000	1.705	9.458
2008	3,845,000	31,796,500	7525000	307,142,000	1.957	9.660
2009	3,350,560	32,168,800	7358260	332,549,000	2.196	10.338
2010	4,149,310	32,960,400	7676850	316,165,000	1.850	9.592
2011	6,008,470	33,986,300	9180270	313,918,000	1.528	9.237

Source: FAOSTAT, 2013

2.1.1 The Biology of *Z. mays*

Maize (*Z. mays* L) is a tall, monecious annual grass with overlapping sheaths and broad conspicuously distichous blades.The maize plants has staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelets occur in 8 to 16 rows, on a thickened, almost woody axis (cob). Maize ear is enclosed in numerous large foliaceous bracts and silks protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971).

The pollen of the maize plant is produced entirely in the staminate inflorescence and eggs, entirely in the pistillate inflorescence. Maize is pollinated by wind, self and cross pollination are usually possible. The pollen grains shed usually remains viable for about 10 to 30 minutes, when conditions are favourable to the plant; the viability of the plant is longer (Coe *et al,* 1988).

Each maize plant contains male and female reproductive organs. The tassels, the terminal flowers develops only male spikelets which grow in pairs with one spikelet being sessile, having no stalk, and the other pedicellate, a single blossom on a lean stalk Each tassel contains about twenty-five million pollen grains. The female inflorescence is the ear. Each ear of maize contains upwards of one thousand potential kernels. Like the male tassels, the ears also bear spikelets, with only one of the flowers developing. Each of these flowers has one ovary terminated by a long style known as the ‘silk. Fine hairs cover the end of the silks, this catches the pollen grains that is blowing in the wind. If the silk which will develop into one kernel is not pollinated, the kernels will not appear.The pollen grains that the silk catches are about $1/250^{th}$ of an inch in diameter and are barely visible to the naked eye.

As a result of their size and weight which is light, the pollen grains can be carried easily by the wind for long distances.The kernels that develop as a result of the pollination of the silk are firmly attached to the solid core of the ear, the cob. A matured kernel has three parts: the pericarp also known as thin shell, the endosperm or food storage organ, and the embryo or germ. The pericarp is a thin layer of maternal tissues that encloses the entire seed. The pericarp is usually colourless but can atimes be red, brown, orange, and cherry. These colours can appear in a variety of patterns especially in corn varieties common in parts of Mexico and Guatemala.

The endosperm or food storage organ consists primarily of starch, which is digested into sugar upon germination and growth. One primarily useful scientific trait is the microscopically thin outer-layer of the endosperm known as the aleurone (which can be in various shades of coluor).It is most useful in genetic studies of corn. Finally, the embryo or germ contains most of the fat, vitamins, and minerals. They can vary in colour, shape, and chemical composition. Also for a seed to germinate, it must contain a living embryo which has the capacity to stay alive for around three to five years. Though if kept in a cooled storage location, a corn seed has the potential to last for twenty-five years or more.

A unique characteristic of maize is that unlike most plants the kernels are completely enclosed by the outer layer known as the husk. These are leaf sheaths that tightly surround the kernels. The number of leaves in the husk is a direct result of the number of joints on the maize stalk. These husks thus prevent the dispersal of seeds by wind, birds, or other natural means.

Though maize is heavily reliant on humans for its survival, it is a self-pollinating plant. It disperses pollen from the male tassels to the female silks. Since maize is so easily cross-pollinated, new varieties continue to appear and the vast similarities and differences make them hard to classify. In fact, the number of varieties on record for maize far exceeds that of any other crop.

2.1.2 Types of maize

D**ent maize** this type of maize derived its name from the dent or depression that is visible when dried and matured. The dent is caused by the shrinking of the soft, floury starch within the hard starch which is contained to one side of the kernel. Most dent corn is yellow or white and it is used mainly as a livestock feed. White dent maize are a preferred food in Mexico, Central America, the Caribbean, and southern Africa. As such, it is the most produced type of corn and accounts for about 95% of all maize produced.

Flint corn this type of maize has a smooth kernel due to a limited to non-existent amount of soft starch contained within the hard endosperm. The colour ranges from white to deep red. It thrives in cool climates with wetter soil and performs better at higher altitudes. It matures earlier than other varieties. It stores more durably than other varieties because they are more resistant to fungi and insects .and the kernels absorb less moisture.

Flour corn It is like flint maize in size and shape but is mainly white or blue in colour. Soft and mealy starch dominates the endosperm so the kernel can easily be crushed into flour. It is cultivated mainly in the southwestern United States and Andean highlands of South America. One interesting characteristic of flour corn is that it is used for beer making in South America.

Sweet corn, It is easily recognized by their wrinkled kernels, which are typically white or yellow. The sweetness is as a result of a genetic defect in metabolism that prevents the sugars from being completely transformed into starch. It has a soft, sugary endosperm and thus it is bred especially for consumption in an immature state (James McCann, 2001). It is grown mainly in the United States.

Pod corn It is grown almost exclusively for scientific research in an effort to trace the genetic roots of maize. Each kernel of pod corn is enclosed in a husk

Popcorn It has small, hard kernels that contain high levels of starch in the endosperm. They are extremely hard kernels of the flint variety.When heated the water in the starch steam-pressure the endosperm to explode causing the small kernels to swell and burst producing an edible white flake, the most common are yellow and white.

2.1.3 Cultivation

Maize requires full sun, nutrient rich (specifically nitrogen) soil, and adequate amount of water. Land Preparation is by weeding, churning, generous composting is generally necessary. Due to the countless varietals that span across continents, different agricultural processes have been developed to nurture corn in a variety of vastly diverse climates. But in all of these regions some general characteristics remain the same when cultivating corn. These are that: corn should be protected from frost; crop rotation will generally produce a better yield due to the extremely high amount of nitrogen and other nutrients that corn extracts from the soil and that a rotational crop such as legumes would replenish the use of fertilizers, manure, or crop residue to enrich the soil.

Table 2.1 Maize weevil

Scientific classification	
Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Coleoptera
Family:	Curculionidae
Subfamily:	Dryophthorinae
Genus:	*Sitophilus*
Species:	***S. zeamais***
Binomial name: ***Sitophilus zeamais***	

Source: Motschulsky (1955).

2.2.1 Maize weevil description

The maize beetle (*Sitophilus zeamais*), is a species of beetle in the family Curculionidae. (Proctor, 1971) It can be found in many tropical areas around the world.It is a major pest of maize (Meikle, Holst, Markham, 1999). This species attacks crops on the field and stored cereal products (Nardon, 2002). The maize beetle has a length of 2.5mm to 4mm. This small, brown beetle has four reddish-brown spots on the wing covers. It has a long, thin snout and elbowed antennae (Mason, 2003).

2.2.2 Distribution

S. zeamais occurs throughout warm, humid regions around the world, especially in locations where maize is grown, Peng. Lin, and Wang, 2003) such countries include; United States of America, Brazil, Morocco, Spain Nigeria etc. It is also widely distributed throughout the agricultural areas of northern Australia where the crop is grown. (Mason, 2003)

2.2.3 Life cycle

The complete development time of this species averages 36 days. The female eats through the surface of the maize seeds, establishing a hole. It then deposits a small oval white egg, and covers the hole as it removes the ovipositor.The hole is sealed with a waxy secretion that creates a plug (Maceljski and Korunic, 1973). The plug quickly hardens and this provides the only visible evidence that the kernel is infested. Only one egg is laid inside each grain. When the egg hatches into a white, legless grub, it will remain inside the grain and begin to feed on the grain. The larvae will develop to a pupa while inside the grain and will then chew an exit outlet hole and emerge as an adult beetle. A single female may lay between300 to 400 eggs during her lifetime. The breeding conditions require a temperature range between 15 and 34 °C and at least 40% relative humidity.

When the adults emerge, the females of the beetlrs move to the surface of the stored maize grains and release sex pheromones, this substance attracts the males for mating purpose.

2.2.4 Host range

The maize beetle commonly attacks standing crops in particular, maize before harvest, storage. Although the maize beetle cannot readily breed in finely processed grains, it can easily breed in products such as macaroni and noodles, and milled cereals that have been exposed to excessive moisture.

2.2.5 Damage and detection

Early detection of infestation is difficult. As *S. zeamais* larvae feeds on the inside of individual grains. Infested grains contain holes through which adults have emerged. A possible indication of infestation in grain is when they are placed in water and they float to the surface (Mason, 2003). In large stores of grain, an increase in temperature may be detected. The most obvious sign of infestation is the emergence of adults.

2.3.6 Methods of Pest Management

2.2.6.1 Cultural practices

Infestation of maize beetle can be reduced by good store hygiene,:such as cleaning the store between harvests, removing and burning of infested residues, fumigating the store house to eliminate residual infestation and selecting only uninfested grains for storage. Harvesting the maize immediately after maturity will reduce the chances of attack by maize beetle. The use of resistant seed varieties also reduces the severity of infestation.

2.2.6.2 Physical control Sieving of the insect from the grains can reduce their population, but this method is labour intensive. The addition of inert dusts such as ash and clay to the grains can reduce insect population by causing the insects to die from desiccation (Coombs, Billings, Porter 1977).

2.2.6.3Biological pest control

This involves the use of various parasitoids (*Anisopteromalus calandrae*, *Cephalonomia tarsalis*, *Lariophagus distinguendus* and *Theocolax elegans*) are effective if they are introduced early in the storage period. Also the fungus *Beauveria bassiana* and bacterium *Bacillus thuringiensis* can be used as a biological insecticide to control maize beetle in stored maize CABI (2010).

2.2.6.4 Use of controlled atmosphere

Where the infrastructure is suitable, low oxygen and carbon dioxide level will create an atmosphere that can be used to control the insect.

2.2.6.5 Freezing and Heating

Freezing for several days and heating for hours have proved to be an effective method in controlling the insect pest.

2.2.6.6 Chemical control

Fumigation with phosphine or methyl bromide is very effective in large-scale store houses. Also grain stocks may be fumigated with phosphine which is also effective in controlling the insect pest. Pesticides are poisons and so are dangerous, as such. it is vital to adhere to all safety precautions on labels before use.

2.2.7 Insecticides

The use of insecticides is discouraged around food materials. Insecticides are supplementary to sanitation and proper storage. Household insecticides have no effect on insects within food packages. For extra protection, some treat seeds or grains before storage with dusts or sprays with synergized pyrethrins.

2.3 Methods of maize storage (Temporary Storage Methods of maize)

2.3.1 (i) **Aerial Storage**

Maize cobs, sorghum or millet panicles are sometimes tied in bundles, which are suspended from tree branches, ropes, or inside the house. This method of storage is not suitable for very small or very large quantities of maize and does not provide protection against the weather (if outside), insects, rodents, or thieves, may be a serious problem to this storage system or type.

(ii) **Ground storage,**

This method of storage is temporal, since the grains are exposed to all pests, including domestic animals, and the weather.This method is utilized only if the producer is compelled to attend to some other task, or lack means of conveying the grains to the homestead.

(iii) **Open Timber Platforms**

A platform consists mainly of a number of relatively straight poles laid horizontally on a series of upright posts. Grains are stored on platforms in heaps, woven baskets or in bags. In humid countries, fire may be lit under elevated platforms; these dry the produce and deter insects or other pests from infesting them.

2.3.2 Long-term maize storage methods

(i) **Storage baskets (cribs)**

In humid countries, where grains cannot be dried adequately prior to storage and needs to be kept well ventilated during the storage period, traditional granaries (cribs) are usually constructed. Under prevailing climatic conditions, most plant materials rot fairly quickly and most cribs have to be replaced every two or three years although bamboo structures may last up to 15 years, with careful maintenance.

(ii) **Calabashes, gourds, earthenware pots**

These small capacity storage containers are mostly used for storing seeds and pulse grains, such as cowpeas. They have small openings, they can be made airtight by sealing the walls inside and out with liquid clay and closing the mouth with stiff clay or a wooden cork.If the grain is dry (less than 12% moisture content); then there is usually no problem with this kind of storage,as they will store ptoperly without fear of spoilage.

(iii) **Jars**

These are large clay storage containers, whose shape and capacity varies from place to place. The upper part is narrow and closed with a flat stone or a clay lid: which is sealed in position with clay or other suitable materials. Generally, they are mainly kept in dwellings they serve equally for storing seeds and legumes so they can remain in good condition, they should not be exposed to the sun.

(iv) **Solid wall bins**

Such grain stores, are usually associated with dry climatic conditions, in it, it is possible to reduce the moisture content of the harvested grains to a satisfactory level simply by drying them under the sun. The base of a solid wall bin may be made of timber, earth or stone. Earth is not recommended because it permits termites and rodents to enter, better base is made of stone.

Mud or clay silos are either round or cylindrical in shape, depending on the materials used for its construction. Rectangular-shaped bins of this type are less common, because the uneven pressure of the grain inside causes cracking - especially at the corners. Clay, which is the basic material, varies in composition from one place to another.The type most commonly used for such construction work is obtained from termitaries, because the termites add a secretion which gives it better plasticity. The roof is usually made of thatched grass, with a generous overhang to protect the mud wall (s) from erosion. Where a side door or a detachable 'cap' is not provided, the roof has to be lifted for access to the bin. Such silos can serve for 30 to 50 years.

(v) **Underground Storage**

This storage system is practised in countries like India, Turkey, sahelian countries and southern Africa. This method of storage is used in dry regions where the water table does not endanger the contents. Conceived for long term storage, pits vary in capacity (from a few hundred kilogrammes to 200 tonnes)

The advantages of this method of storage are:

- few problems with rodents and insects;
- low cost of construction,compared to that of above-ground storage of similar capacity;
- ambient temperatures are relatively low and constant;
- hardly visible, and therefore relatively safe from thieves;
- no need for continuous inspection.

The disadvantages are:

- construction and digging are laborious and tasking;
- storage conditions,adversely affect viability.
- The stored grains can only be used for consumption;
- the grain can acquire a fermented smell after long storage;
- removal of the grain,is laborious and can be dangerous because of the accumulation of carbon dioxide in the pit, if it is not completely full;
- inspection of the grains,is difficult;
- risks of penetration by water is much and the grains at the top and in contact with the walls is often mouldy.

1.2 Historical background to the use of natural pesticides

Plants are composed of chemical substances. Some of these chemicals are not directly beneficial to the growth and development of the plant. These secondary compounds have usually been regarded as part of the plants' defense against plant-feeding insects and other herbivores Rosenthal and Janzen, (1979). The pesticidal properties of many plants have been known for a long time and natural pesticides based on plant extracts such as rotenone, nicotine and pyrethrum have been commonly used in pest control during the earlier half of this century. However, after the Second World War, their relevance was lost, with the entrant of synthetic organic chemicals. The organic chemicals are concentrated products, with high knock-down effect on pest organisms. The chemicals can be produced in large quantities relatively cheaply and they rapidly substituted most other pesticides in the 1950s.

The use of organochlorines like DDT and organo-phosphorous compounds, led to hazardous effects on the environment and humans. In response, concerted efforts were made to strengthen the integrated pest management approach where chemical control (if necessary), should be incorporated with other methods like crop sanitation, resistant varieties and biological control. Furthermore, attention was geared towards the development of alternative chemicals, example, is the isolation and identification of pyrethrins from the Pyrethrum plant, *Chrysanthemum cinerariifolium,* (from which pyrethroids was synthesized). These broad-spectrum insecticides have reduced persistence and toxicity (in relation to organochlorines and organophosphorous compounds) spread over the world in the seventies.

In addition to pesticide contamination of the environment and human health risks, other aspects of synthetic chemical effects, includes misuse of non-selective chemicals can wipe out the natural enemies and induce problems with development of resistance to such insecticides. About 450 pest species of insects and mites have now developed resistance to one or more major synthetic pesticides Georghiou, (1986). The yearly utilization of pesticides in developing countries, was estimated at 600 000 tonnes in 1988 with a drastic increase of 184% during 1980-1884 in Africa alone WHO, (1990). Because pyrethroids and other newly developed pesticides are expensive, many of the harmful but cheaper ones such as DDT are still being used in many parts of the world today.

As a key to synthesize a chemical compound which then could be produced industrially today, there is considerable interest among biochemists and botanists to screen plants for secondary chemical compounds, which could be used for developing medicals and pesticides, particularly in the tropical rain forests where plant species are numerous but threatened with extinction (Downum *et al*, 1993). However, it is an expensive and tedious process to isolate and identify the active ingredients of plants and to produce them in formulations which can be commercialized. Natural pesticides, are not uniform products, but consist of different active ingredients which often vary in concentration from sample to sample. This makes toxicological tests difficult and costly to run Latum and Gerrits, (1991). Therefore one can expect that the interest of the chemical industry in developing new bio-pesticides is rather limited.

2.4 Insect pests of stored grains in hot climates

The grain beetle (Curculionidae) are well-known as major primary pests of stored cereal grains. They are able to establish themselves on whole, undamaged grains of maize, sorghum, rice and wheat so long as the grains are not exceptionally dry. However, *Sitophilus zeamais* is the dominant species on maize.

2.4.1 Pest status

The status of any particular insect pest may vary between different commodities, different varieties of the same commodity, different climatic regions and agro-industrial systems and between different socio-economic groups. It is affected by the form, by the environmental conditions and by consumer attitudes.

Most storage insects, especially the important pests, are able to survive and multiply rapidly on well-dried grains. However, grains dried to below 12% moisture content, inhibits the development of most species of insects to some extent and on exceptionally dry grain (<8% moisture content) the grain beetle, for example, are insignificant pests. The grain borers remain of considerable importance at these low moisture content levels, the "khapra" beetle (*T. riumgrana*) becomes increasingly important.This insect,assumes major pest status and dominance over almost all other storage insects at the very low moisture contents (down to about 4%) which equates to the extremely low humidities (< 20% relative humidity) that characterises the most arid climates and, also, the insect ecosystem created by stored malting barley which is usually dried to this very low level and is not uncommonly imported into the tropics.

2.4.2 Factors affecting the development and control of pests

Grain moisture content considerably affects pest status but it is not a factor which can be cost-effectively manipulated in most situations to achieve sufficient control of insect pests. Cost-effective drying is a common practice and can achieve control of moulds and will lessen the problems of insect infestation; in particular it will greatly reduce the spectrum of pest species. However, it will not prevent significant damage by one or more of the major insect pests.

Insect development and population growth rates are more dramatically affected by temperature and the developmental limits are more clearly defined and generally applicable. Upper limits for development and survival vary to some extent between species, with the grain borers more resistant than the grain beetle.

2.4.3 The insect resistance problem

The development by pests of acquired resistance or increased tolerance to pesticides is now a well-known pest management problem in the world. There is general agreement that the rate of resistance development in any particular pest species and to any particular pesticide, is to some extent susceptible to control (i.e. management). Possibilities for the containment of resistance include sustained improvements in application techniques, where acceptable pesticide dosage rates, remain effective and the adoption of alternative pesticides or other control measures where the degree of resistance to a particular pesticide prohibits its use. Continued monitoring of resistance, in field populations, is also necessary.

2.5 Botanicals as Grain Protectants

Losses caused by insects, include not only the direct consumption of kernels, but also accumulation of exuviae, webbing, and cadavers. High levels of the insect detritus may result in grains that are unfit for human consumption and loss of the food commodities, both, in terms of quality and quantity. Insect infestation induces changes in the storage environment, may cause warm moist “hotspots” this provides suitable conditions for storage fungi that causes further losses.

2.5.1 The Potency and Limitations of Plant-Based Pesticides (Botanicals)

Pests are one of the most serious challenges facing crop production in the world presently. There are many ways to controlling or eliminating pests. Every pest management options, has certain limitations. The use of plants and plants-based products to controlling pests in developed and developing countries, is well known and prior to the discovery of synthetic pesticides, plants or plant-derived products were the only pest controlling means available Owen, (2004).. Sometimes plant materials were chopped, grounded into powders or liquids and applied on crops as crop protectants, some of these traditional botanical pest control methods are still being used presently, especially by farmers who are not yet heavily influenced by modern technology and pest controllers who are environmentally conscious. For self defense, many plants generate chemicals that are toxic to pests and since these naturally occurring pesticides are derived from plants, they are called Botanical pesticides or simply Botanicals.

2.5.2 Developments That Limited The Use Of Botanicals.

Prior to the the Second World War, Botanical pesticides were commonly used globally to protect crops from pests, most especially insect pests. However, just before the war, a highly effective synthetic insecticide known as, dichlorodiphenyltrichloroethane (DDT) an organochlorine insecticide was discovered and introduced for use.This changed the trend of pest control worldwide. Based on its cheapness, easy application and most importantly, long-lasting effect; other synthetic insecticides followed shortly which quickly replaced botanicals in the market and greatly slowed the research and development of natural botanical compounds. Unfortunately, these synthetic insecticides,target nervous system common to human and other animals and can be toxic to fish species,non target .organisms and the environment

Some synthetic pesticides or chemicals have been suspected and confirmed to be carcinogenic and toxic to mammals even at very low doses. Environmental pollution, pest resistance to pesticides, lethal effect to non-target organisms in the agro-ecosystem, pest resurgence and direct toxicity to users, have all been attendant consequences of the development and use of synthetic pesticides (Prakash *et al*, 2008). Awareness of the potential health and environmental hazards of many synthetic pesticides, the observation of more and more resistance of pests to synthetic pesticides, in addition to the fact that the industry may not have enough resources to continually develop and supply the market with new products exactly when needed to replace the old, have triggered interest in plant derived pesticides (Isman, 2006).

2.5.3 Efficacy of Some Botanicals

Plant based insecticides have been used for many centuries among resource poor farmers in developing countries like Nigeria, to control insect pests of field and stored produce, but their potentials was initially limited and ignored.Some of these plant species, possess one or more useful properties, which acts as, antifeedant, fast knock down, repellency, flushing action, , broad-spectrum of activity, biodegradability and ability to reduce insect resistance.

In storage pest control, a lot of work have been carried out to investigate the efficacy of powder of *C. frutescens* (chill pepper) on the survival of insect pest,including *S. zeamais* and *C. maculatus*, Asawalam et al. (2007) reported *C. frutescens* to have shown 75% mortality of *S .zeamais* 33 days after treatment. The results indicated that *C. frutescens* effectively protected maize grains against beetle attack. It exhibited fumigant mode of action since it has a characteristic pungent smell and pepperish in nature. *A. cepa and P. guineense* were tested and found to be effective in controlling insect pests of stored grains. Abdullahi and Muhammad (2004) assessed the toxic potentials of some plant powders on survival and development of *C. maculatus* and recorded 100% mortality 8 days after treatment when *P. guineense* (Ashanti or Benin pepper) was used at the rate of 1 g/ 50 g cowpea seeds. Asawalam *et al.* (2007) also recorded 79% (highest) mortality of *S. zeamais* treated with *P. guineense* on maize grains Danjumma *et al*. (2009) also found that *A. sativum* is effective in killing adult *S .zeamais* and recorded 96.67% mortality at the rate of 2.0 g/ 50 g maize grains. The mode of action of these two plant powders may be due to fumigant and anti-feedant effects. *A. sativum* powder contains allicin as the major constituent.

Reported Cases Of Controlling Stored Insect Pests With Soil Plant Oils

The use of plant oils in stored product protection, has been researched upon by various researchers (Obeng-Ofori,1995, Mohiuddin *et al, 1987,* Lale, 1991).Plant based insecticides (oils) have been used for many centuries among resource poor farmers in developing countries like Nigeria to control insect pests in fields and stores .Some of these plant oils, possess one or more useful properties, which acts as, antifeedant, fast knock down, repellency, flushing action, , broad-spectrum of activity, biodegradability and ability to reduce insect resistance.

In storage pest control, a lot of work have been conducted to investigate the efficacy of groundnut oil and palm oil against *callosobruchus maculatus* to assess first generation adult, damaged seeds, insect mortality and effect on grain germination.

It was reported that groundnut oil when applied at 20mls per 50g of grains completely inhibited first generation adults' *C. maculatus* at one day and fourteen days after adult insects' removal from grains.While Palm oil applied at the same concentration level, significantly reduced first generation adults compared to the control treatment.It was reported further that on damage assessment, cowpea grains treated with both plant oils at the two levels (5 and 10mls) showed significant differences ($P<0.05$) in the reduction of damage caused by the test insect. But complete protection of cowpea grains was achieved at 10mls with groundnut oil

At a higher concentration of 20mls/50g of grains, groundnut oil completely inhibited first generation adults when applied at the rate of 20mls per 50g of grains. Most of the insects that emerged were found dead from the treatments. This implies the ability of the oils to act as suffocating materials with the possibility of preventing respiration. (Obeng-Ofori, 1995). The complete protection of grains from damage by the beetles achieved with groundnut oil implies the presence of oviposition deterrence and repellent properties in the oils. The effect of plant oils on insect development could have been caused by physical properties of coating and blocking of respiration rather than by specific chemical effect (Abulude, Ogunkoya, Ogunleye, Akinola and Adeyemi 2007). The non emergence of insects from treatments comprising of groundnut oil, could be as a result of the effect of arachidonic acid that is present in groundnut and could also have been responsible for the mortality of insect which inhibited further development (Lale, 2002).Plant oils are generally reported to exert certain actions such as ovicidal action against insect pests of storage products. (Don-Pedro, 1989).The application of coconut oil has been observed to be effective against *C.maculatus* and *C.sinensis* for storage duration of up tp six months. It is also found to be effective when applied to rice to protect it against *R.dominica* and *S.cerealella* (Doharrey, Katiyar and Singh 1990). The oils were observed not to affect seed germination; this affirms non-adverse effect on grain chemistry.

The Efficacy of Palm kernel, Coconut and Eucalyptus oils against Rice beetle

The results obtained from the study involving evaluating the efficacy of Palm kernel, Coconut and Eucalyptus oils against rice beetless, indicates that the mean mortality rates of adult *Sitophilus oryzae* differs in their level of concentrations at post treatments. The results also indicated that the oil of *Eucalyptus camaldulensis* was the most effective among the plant oils evaluated and had the fastest insecticidal effect on the insect pests in less than 10 minutes of application, while the least effective of the oils evaluated was coconut oil. This finding corroborates some other findings on the evaluation of plant oils as botanical grain Protestants' where they were also found to be effective against storage beetles (Okparaeke, Bunmi 2006). The results also corroborate the observations of (Onolemhemhem and Oigiangbe, 2001) who recorded 100% mortality of adult *callosobruchus maculatus* in cowpea seeds treated with groundnut oil. This mode of action could be as a result of the oil coating formed on the treated cowpea grains which hindered contact between the grains and the weevils; this led to starvation and increase in the rate of mortality. It was noted that the three oils:Palm kernel, Coconut oil and Eucalyptus were effective as contact treatments against *Sitophilus oryzae*.The efficacy decreases from *Eucalyptus camaldulensis* to Palm kernel oil and Coconut oil which was subsequently dependent on the concentration level of the oils.

Efficacy of Lime Peel Oil in Protecting Stored Maize against Adult Maize Beetles (*Sitophilus zeamais:* Motschulsky)

The use of plant extracts in the control of stored products insects is an age long practice (Qi and Burkholder, 1981). Oils are mainly used in insect pest control because they are relatively efficacious against virtually all life stages of insects (Nezan, 1983; Adedire, 2002; Don-Pedro, 1989, 1990). Lime peel oil was reported to give good and effective control of adult maize beetle (*Sitophilus zeamais*) in the store. Lime peel oil may have been very potent because of the odour they emit which may have exerted toxic effect by inhibiting normal respiratory activity of the weevils, thereby resulting in asphyxiation and subsequent death of insects (Adedire and Ajayi, 1996).

Essential oils of plants are highly lipophilic and they have the ability to penetrate the cuticle of insects. This may be another reason for the potency of the extracts. The plant material apart from its odour, may have acted as a contact poison. The toxicity of the oil may be attributed to the presence of limonene, terpenine, sinensal, neral octanal tridecanal chemical which were reported to have some insecticidal properties (Kabir, 2008). The results of the study was similar to that reported by Asawalam and Emosairue (1990) who reported the use of essential oil from *Vernonia amygdalina* and ashes of certain medicinal plants. These substances have been reported to be toxic against adult maize beetles (*S.zeamais).* Furthermore, neem (*Azadirachta indica* A. Juss), cotton seeds and yellow oleander (*Thevetia peruviana*) oils were also discovered to be toxic against maize beetles (*S. zeamais* Motschulsky).

Several plant products were also reported to be effective against insects including *Callasobruchus maculatus* (Sathyaseelan *et al*., 2008). These plant oils have been reported to possess insecticidal properties. Plants produce essential oils that have been found to possess insecticidal activities to various species of insect pest. (Ukeh, 2008). Essential oils from many herbs and spices have also been reported to have fumigant and toxic effect (Rice and Coats, 1994; Regnault-Roger and Hamraoui, 1995). Shaaya *et al.* (1991, 1997), A number of essential oils from spices showed fumigant toxicity to stored-product insects. Alkofahi *et al*. (1989) reported that coconut oil when applied to rice protected it against lesser grain borer (*Rhizopertha Dominica*).

Similarly, Neem oil when applied at 0.5, 1.0 and 2.0% v/w was found to cause 100% mortality of the beetle (*Callasobruchus maculatus*) after 2 days of treatment (Ram and Gopal, 2000). The finding from the study indicated that oils from plants were effective in protecting stored product from insect infestation

2.5.4 Mode of Action of Some Botanicals on Target Pest and Effects on Adult Mortality

Toxicity, either through fumigation or direct contact, is usually the major action of plant powders against adult insects in the laboratory tests Rajapakse, (2006) A powder of *C. sinensis* peels was found to be effective on the mortality of *Z. subfasciatus* Dawit and Bekelle, (2010). They recorded 67% mortality of *Z. subfasciatus* when the beans were treated with 15g of sun dried powder of orange peels. Also, there was significant reduction in generation emergence of the insect. The effect of leaf powder of *J. curcas* on the mortality of *C. maculatus* was assessed by Umar (2008).

2.5.4.1 Repellency effects

In terms of Repellency, Parugrug and Roxas (2008) worked on the insecticidal action of five plant materials against maize beetles, *S. zeamais* and found that at 24 hours of exposure, ratings of 7.00 (High Repellency) were recorded in powdered *A. indica and carbaryl*, whereas *Cymbopogon citratus* (lemon grass) had repellency rating of 5.80 (Moderate Repellency) at the same hour. *C. sinensis* peel powder was also found to be effective in repelling *Z. subfasciatus* on (*phaseolus vulgaris),* haricot bean seeds Dawit and Bekelle, (2010).

2.5.4.2 Ovicidal effects

When the plant powders reduce adult longevity and agility, the number of eggs laid will be lower as well. Moreover, the mechanical effect of large quantities of powders themselves could have effect on oviposition Rajapakse, (2006).

Adult emergence

Botanical powders often reduce the emergence of adult beetles from the seed Rajapakse, (2006). Some of these powders were found to have effect on adult emergence of insect pests attacking stored grains such as cowpea and maize. Abdullahi and Muhammad (2004) recorded 40.9% adult emergence of *C. maculatus* on cowpea treated with *P. guineense,* while Asawalam and Emosairue (2006) and Asawalam *et al*. (2007) recorded 10.0% and 5.0% adult emergence of *S. zeamais* on maize treated with the same plant powder respectively. *C. frutescens and N. tabacum* were also reported to affect adult emergence of *S. zeamais* on maize grains revealing 10.0% and 12.0% emergence respectively.

2.6 Advantages of Botanicals over Synthetic Chemicals

Plant-derived pesticides have many advantages when compared with synthetics pesticides.

- Botanical pesticides generally possess low mammalian toxicity thereby creating little or no health hazards and environmental pollution.
- There is practically no risk of developing pest resistance to plant-derived pesticides if prepared in natural forms as they are made up of a mixture of active principles.
- There are no adverse effects on plant growth, seed viability and cooking quality of the grains.
- They are less hazardous to non-target organisms and pest resistance has not yet been reported except in synthetic pyrethroid.
- Botanical pesticides are less expensive (especially in their crude form) and easily available because of their natural occurrence
- Farmers can easily and cheaply produce these plant materials for their use unlike synthetics whose cost is generally on the high side.

2.7 Limitations on the Use of Botanicals

- The use of some natural compounds in the protection of grains, requires them to be applied in high concentration or quantities which often exceeds the threshold of acceptable flavour to the consumers (Nazer *et al*, 2005)..
- The discovery process for botanical pesticides is more cumbersome as compared to their synthetic counterparts,
- Sheer negligence due to influx of synthetics.

Other constraints/limitations to their development, includes; quality control, raw material availability, standardization of extraction methods, potency variations, shelf life and specific bioefficacy all of which combine to pose more treat on the effective adoption of botanicals as a competent pest control measure.

There should be comcerted efforts on the search for active natural products from plants as alternatives to conventional insecticides since most researches have proved that plant materials and local traditional methods are much environmentally safer than chemical insecticides. The constraints are very surmountable if the needed commitment is given individually and collectively.

2.8 Some Important Phytochemicals with Insecticidal Properties

2.8. 1 Azadirachtin

The neem tree, *Azadirachta indica,* is the most promising example of plants currently being used for pest control. This holy tree in India, from where it originated now has a global distribution throughout the tropics and the world. It is used for many purposes, such as shade tree, poles for construction, medicine, tooth sticks and as a source of insecticide National Research Council, (1992). Since the early seventies, many research have been conducted on the pesticidal properties of the neem tree and the results have been published in proceedings from three international neem conferences Schmutterer and Ascher, (1981; (1984 and 1987).

Although the active ingredients in the neem, such as the azadirachtin, are known, it has not been possible to synthesize these complex compounds. Stable formulations of purified extracts are commercialized (Margosan and others) and distributed in several countries.

2.9 Pesticides Effects on Human Health

Pesticides cover a wide range of compounds including fungicides, insecticides, herbicides, rodenticides, moliuscicides, nematicides, e.t.c. They are designed to kill and because their mode of action is not specific to one species, they often kill or harm organisms other than the target pests, including humans. The World Health Organization (WHO) estimated that there are about 3 million cases of pesticide poisoning each year and up to 220,000 deaths do occur mainly in developing countries like Nigeria The application of pesticides,is often not very precise and unintended exposure occurs to other organisms in the area where pesticides are applied. Pesticides exposure can cause a range of neurological health effects such as, loss of coordination, reduced speed of response to stimuli, altered or uncontrollable mood etc. These symptoms are often very subtle and may not be recognized by the medical community as a clinical effect.

Pesticide formulations, contains "active" and "inert" ingredients. Active ingredients are what kill the pest and inert ingredients help the active ingredients to work more effectively. These "inert" ingredients may not be tested as thoroughly as active ingredients and are seldom disclosed on product labels. Solvents, which are inert ingredients in many pesticide formulations may be toxic if inhaled or absorbed by the skin.

2.10 Dangers of synthetic pesticide

The synthetic pesticide DDT was widely used in urban aerial sprays to control urban mosquitoes, gypsy moth, Japanese beetle and other insects in the 1940's. By 1972, DDT was banned from the United States due to widespread development of resistance to DDT and evidence that DDT use was increasing preterm births and also harming the environment. DDT was found to cause behavioral anomalies and eggshell thinning in populations of bald eagles and peregrine falcons. Although DDT is banned in the US and many other countries, DDT continues to be manufactured and applied in underdeveloped nations where some of the US food supply is grown.

Durban, one of the most common pesticides used in households, schools, hospitals and agriculture was banned in 2000 by the USEPA due to unacceptable health risk, especially to children. Toxicology studies have found out that exposures to Dursban early in life may affect the function of the nervous system later in life.

2.10.1 Types of synthetic pesticide

There are many classes of synthetic pesticides. The main classes consist of organochlorines, organophosphates, carbamates, and pyrethroids. Exposure to pesticides can cause acute (short term) or chronic (long term) effects on animals and humans, especially in the reproductive, endocrine, and central nervous systems within days after exposure ends as acetylcholine levels return to normal.

Some organophosphates have a delayed neurological reaction characterized by muscle weakness in the legs and arms. The human toxicity of organophosphates caused a decline in their use and spurred the search for new alternatives.

2.10.1.1 Organochlorines

Acute ingestion of organochlorine insecticides can cause loss of sensation around the mouth, hypersensitivity to light, sound and touch, dizziness, tremors, nausea, vomiting, nervousness and confusion.

In 1975, over 70 workers manufacturing Kepone, an organochlorine insecticide, in Hopewell, Virginia, developed a variety of neurological symptoms.The most prominent of which became known as the "Kepone shakes." The workers' symptoms started about 30 days after their first exposure to Kepone. Subsequent testing also revealed decreases in sperm count and motility. In 1976, Kepone was discontinued and substituted with organophosphates.

2.10.1.2 Organophosphates and Carbamates

Acute organophosphate and carbamate exposure causes signs and symptoms such as increased salivation, perspiration, narrowing of the pupils, nausea, diarrhea, decrease in blood pressure, muscle weakness and fatigue. These symptoms usually decline within days after exposure ends as acetylcholine levels return to normal. Some organophosphates also have a delayed neurological reaction characterized by muscle weakness in the legs and arms. The human toxicity of organophosphates caused a decline in their use and spurred the search for new alternatives.

2.10.1.3 Pyrethroids

Among the most promising alternatives to organophosphates are synthetic pyrethroids. However, pyrethroids can cause hyper-excitation, aggressiveness, uncoordination, whole-body tremors, and seizures. Acute exposure in humans usually resulting from skin exposure due to poor handling procedures, usually resolves within 24 hours. Pyrethroids can cause an allergic skin response, and some pyrethroids may cause cancer, reproductive or developmental effects, or endocrine system effects.

Presently, there are more than 500 species of insects and mites that are resistant to some form of pesticides. As a result of the increasing resistance, countries have started applying more products, combine pesticides, increase applications, or substitute with more toxic replacement.

Benefits of Pesticides

The followings are the benefits of the use of pesticides;

Improving productivity

The primary benefit of pesticidal use, is the higher yield and better quality of food crops' Tremendous benefits have been derived from the use of pesticides in forestry, public health and the domestic sphere and of course in agriculture. . Pesticides have been an integral part of the process by reducing losses from weeds, diseases and insect pests that can markedly reduce the amount of harvestable produce. Warren (1998) also drew attention to the spectacular increases in crop yields in the United States in the twentieth century. Webster *et al* (1999) stated that "considerable economic losses" would be suffered without pesticide use and quantified the significant increases in yield and economic margin that results from pesticide use. Moreover, in the environment, most pesticides undergo photochemical transformation to produce metabolites which are relatively non-toxic to both humans and the environment (Kole *et al*, 1999).

Protection of crop losses/yield reduction

In medium land, rice even under puddle conditions during the critical period warranted an effective and economic weed control practice to prevent reduction in rice yield due to weeds that ranged from 28 to 48%, based on comparisons that included control (weedy) plots Weeds reduce yield of dry land crops (Behera *et al*, 1999) by 37–79%. Severe infestation of weeds particularly in the early stage of crop establishment, ultimately accounts for a yield reduction of 40%. Herbicides provided both an economic and labour benefit.

Vector disease control

Vector-borne diseases are most effectively tackled by killing the vectors. Insecticides are often the only practical way to control the insects that spread deadly diseases such as malaria, resulting in an estimated 5000 deaths each day Ross, (2005).

Quality of food

In countries of the first world, it has been observed that a diet containing fresh fruit and vegetables far outweigh potential risk from eating very low residues of pesticides in crops. Brown, (2004). Increasing evidence (Dietary Guidelines, 2005) shows that eating fruits and vegetables regularly reduces the risk of cancers, high blood pressure, heart disease, diabetes, stroke, and other chronic and heart diseases.

2.11 Human Harm

There are three types of harmful effects that can be caused by pesticides: acute effects, delayed effects, and allergic effects.

Acute effects are injuries or illnesses that appears immediately after exposure to these chemicals. The effects are usually obvious and reversible if appropriate medical care is given immediately

Delayed effects are illnesses or injuries that do not appear immediately. These include cancer.

There are over 160 synthetic pesticides that are listed to be possible carcinogens. Many of these pesticides are still in use presently. Pesticides have been known to cause lymphoma, leukemia, breast cancer, asthma, and other immune system disorders.

Allergic effects are harmful effects that some but not all people develop in reaction to substances.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of experimental site

The study was conducted at the Teaching and Research Laboratory of Delta State University, Asaba Campus.Asaba Campus lies between the coordinates of Latitude 6°14′N and Longitude 6°49′E. Asaba is located in the tropical climate region with a mean annual rainfall of 1,500-2,000mm, mean annual temperature of 23.7°C – 37.3°C, mean humidity of 77.2% and monthly sunshine of 4.8 bars (NIMET, 2011).

3.2 Maize grain variety used for the Experiments

Clean and well sieved grains of dent maize (*Zea mays indentata*) were used for the experiments. The maize grains were procured from Asaba local market. The seeds were frozen at -4°C for four days, to sterilize it. The essence of this is to kill any live insect(s) that may be present. The grains sourced were not previously treated with insecticide.They were properly dried and used to rear *S. zeamais* this is to ensure uniform population of the test insect. The grains were sorted manually and only large grains were used for the study.

3.3 **Collection and preparation of botanicals (Plant powders and oils)**

Fresh and matured leaves of both plant materials were used for the experiment. Neem leaves (*Azadirachta indica* A. Juss) was obtained fresh but tobacco leaves (*N. tobaccum* L) was sourced dried. The purified botanical oils were purchased from the supermarket.The leaves were air and shade dried until they were totally dried. The leaves were grinded using a blender and sieved through a 0.25 mm mesh to obtain uniform particle size which is similar with the procedures followed by Araya (2007) and Parugrug and Roxas (2008). The resulting powders were kept separately in containers and stored at room temperature until when needed. The quantity of powder mixed with the maize grains was calculated on weight by weight basis, i.e. weight of powder to weight of grains. The volume of the botanical oil mixed with a given quantity of maize grains was calculated also. Synthetic insecticide (permethrin) was used as the standard/synthetic check.

3.4 Rearing of *S. zeamais*

S. zeamais were cultured in the laboratory and maintained at a temperature of 26-27 ^{0}C and relative humidity of 65-70% at the Department of Forestry Laboratory. Infested maize grains were procured from the market and the adult *S.zeamais* were allowed to oviposite in a container of clean and uninfested maize.The parent adults were then removed after 20 days by sieving the grains with a 2.0mm sieve.The beetles that subsequently emerged, were used for the bioassays.

3.5 Treatments and experimental design

There were fourteen (14) treatments in the first experiment which were replicated three times and arranged in completely randomized design (CRD). There were two controls in the experiment (the untreated and the standard/synthetic check using permethrin) for comparison. Treatments used were in powdered form (for the botanicals) and liquid form (for the oils). Each treatment was measured and introduced (mixed with maize grains) in appropriate ratios in each jar. The adult insects reared were introduced to each replicate (i.e. 10 unsexed weevils/150g of maize grain).

Experiment 1: Evaluating *A indica,N.tobacco* plant powders and their combinations for the control of maize beetle. (*S.zeamais)*

The various treatments used for the first experiment and their weight by weight concentration to 150g of maize seeds were:

i. T_1 = Tobacco powder – 1%w/w concentration
ii. T_2 = Tobacco powder – 2% w/w concentration
iii. T_3 = Tobacco powder – 3% w/w concentration
iv. T_4 = Tobacco powder - 4% w/w concentration

v. T_5 = Neem leaf powder – 2.5% w/w concentration

vi. T_6 = Neem leaf powder – 5.0% w/w concentration

vii. T_7 = Neem leaf powder – 7.5% w/w concentration

viii. T_8 = Neem leaf powder-10% w/w concentration

ix. T_9 = Neem powder (2.5%) w/w+Tobacco powder (1%)

x. T_{10} = Neem powder (5.0%) w/w +Tobacco powder (2%)

xi. T_{11} = Neem leaf powder (7.5%) w/w + Tobacco powder (3%)

xii. T_{12} = Neem leaf powder (10%) w/w + Tobacco powder (4%)

xiii. T_{13} Permethrin insectide (standard check)

xiv. T_{14} Control (untreated control).The control is a jar of maize seeds without treatment application.

The number of treatments = 14

The number of replicates = 3.

The experimental design used is Completely Randomnized Design (CRD)

Experiment 2: Evaluating selected plant oils for control of maize weevils on stored maize

In experiment 2, the treatments were arranged in Completely Randonmized Design (CRD). Selected oils used for this Experment were:

i. Groundnut oil (*Arachis hypogea*)
ii. Coconut oil (*Cocos nucifera*)
iii. Castor oil (*Ricinus communis*)
iv. Sesame oil (*Sesamum indicum*)
v. Soybean oil (*Glycine max*)
vi. Olive oil (*Olea europaea*)
vii. Mustard oil *(Sinapis hirta)*

This experiment consists of nine treatments and the oils were admixed with a kiligram of maize grain in 10, 15 and 20mls of plant oils respectively.

3.6 Bioassay procedures in Experiment 1.

Tobacco powder of the following concentrations 1.5, 3.0, 4.5 and 6.0g which corresponds to 1, 2, 3 and 4% w/w concentration of 150g of maize seeds were weighed and each added to 150g of healthy uninfested maize seeds in one-litre plastic jars and admixed with 1.5, 3.0, 4.5 and 6.0g of powdered tobacco leaves (T_1, T_2, T_3, T_4). 3.75g, 7.50g, 11.25g and 15.0g of neem leave powder (T_5, T_6, T_7, T_8), corresponding to 2.5, 5.0, 7.5 and 10% w/w concentration of maize grains were weighed and added to 150g of clean uninfested maize grain and their combinations (T_9, T_{10}, T_{11}, T_{12}).

The oil treatments were admixed in 1ml, 1.5mls and 2mls to each plastic jar containing 150g of maize grains. The jar contents (treatments and maize grains), were shaken thoroughly for a while to ensure uniform distribution of the botanical powders and the oils. Then, 10 newly emerged adult beetles of the same age were collected from reared culture of insects in the laboratory and introduced into each jar. After introduction of the predetermined adult insects into each experimental jar;the following data were collected; adult mortality, first generation adult emergence, seed damage, weight loss,weevil/beetle perforated index (WPI) and calculated as described below;

$$\text{Percentage seed damage} = \frac{\text{no of perforated grains}}{\text{Total number of grains}} \times 100$$

$$\text{Weight loss} = \frac{\text{initial weight-finalweight}}{\text{initial weight}}$$

$$\text{Weevil Perforated Index (WPI)} = \frac{(\text{\% treated maize grains perforated})}{(\text{\% control maize grains perforated})} \quad 100$$

When WPI>50=negative protectant of plant material tested (strongly infested by beetles)

When WPI<50=positive protectant (inhibiting beetles infestation)

3.6.1 Adult maize beetle mortality test

Adult maize beetle mortality was assessed on 7, 14, 21, 28, 35 days , after exposure of the beetles to the treatments. Adult beetles were considered dead when no response was observed when poked gently with an entomological pin. The data on each assessment day was summed up and Percentage adult mortality was calculated following the method described by Parugrug and Roxas (2008) using the following formula:

$$\text{Percentage mortality} = \frac{\text{Number of dead insects}}{\text{Total number of insects}} \times 100$$

3.6.2 First Adult Generation count

Twenty (20) days after the introduction of insects to each experimental jar, all dead and alive insects were removed from each jar and the seeds were returned to their respective containers to further assess first adult generation emergence. First adult generation count was made on the 35^{th}- 40^{th} days after adult beetles were introduced. Inspection of the adults was made on each assessment day by displaying the seeds on paper and sieving the contents of the jars, the plant powder and emerged beetles passed through the sieve and counting of newly emerged adults was carried out.

3.6.3 Damaged seeds (perforated seeds)

Damaged seeds were assessed 100 days after adult introduction by counting the total number of seeds in a jar and counting the ones with holes. The damaged seeds were expressed in percentage;

Perforated seeds = number of seeds in a jar-undamaged seeds

$$\%\ \text{perforated seeds} = \frac{\text{perforated seeds}}{\text{Total seeds in a jar}} \times 100$$

3.6.4 Grain weight loss

Percentage weight loss was assessed by measuring the initial and final weight of the grain as described by Ileke and Oni (2011).

$$(\%) \text{ loss in Weight} = \frac{(\text{Initial weight-Final weight}) \times 100}{\text{Initial weight}}$$

3.6 5: Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) and significant mean differences were separated by Duncan Multiple Range Test (DMRT) using SAS (2010) package

CHAPTER FOUR

RESULTS

4.1 Effects of different dosages of *A.indica, N. tobacum* plant powders and their combinations on the mortality of *Sitophilus zeamais (*Coleoptera: Curculionidae) on stored maize.

The effect of different dosages of *A.indica, N. tobacum* plant powders and their combinations on the mortality of *S .zeamais* on stored maize, is presented in table 4.1a, while table 4.1b showed the percentage mortality of *S. zeamais*.

At 7 days after treatment (DAT), there were various mortalities which ranged from 0.33 to 1.67 beetles in the plant treatments.This translates to 3.33 to 16.7% mortality (Table 4.1b).Treatment T_{113} (The synthetic check) recorded the highest mortality of 10 beetles,this was followed by treatment T_4.Treatment T_4 (6g of *N.tobacum*) showed superiority over other treatments by recording the second highest mean mortality value of 1.67 beetles,while Treatments T_1 (1.50g of *, N.tobacum*), T_5 (3.75g of *A.indica*) and T_9 (1.50g of *N.tobacum* + 3.75g of *A.indica*) recorded the least value of 0.33 beetles. Treatment T_{14} (The untreated control) recorded no death of beetles,while Treatment T_{13} indicated the death of the entire test insects (100% mortality) within the first 7 DAT.The same trend occured on the 14^{th}, 21^{th}, 28^{th} and 35^{th} DAT.At 35 DAT, none of the plant powders recorded 100% mortality.

Similarly, at the 14^{th} DAT, there were gradual increase in mortality of beetles which resulted in varied differences in mortality among the treatments.Treatment T_{13} (synthetic check), recorded the highest mortality value of 10 beetles, this was followed by Treatment T_4 (6.0g of *N. tobacum*) which recorded a mean mortality value of 2.00, it was followed by Treatment T_3 (4.5g of *N.tobacum*), Treatment T_7 (4.5g of *N.tobacum* + 11.25g of *A.indica*) and Treatment T_8 (6.0g of *N.tobacum* + 15g of *A.indica*) with value of 1.67 beetles each The lowest mean mortalities were recorded in Treatments T_5 (3.75g of *A.indica*), T_6 (7.50g of *A.indica* and T_9 (1.50g of *N.tobacum* + 3.75g of *A.indica*) (Table4.1), with value of 0.67 beetles each. Treatment T_{14} (untreated control) recorded no mortality and the same trend continued till the 35^{th} DAT

At 21 DAT, the same trend of performance on mortality were recorded as concentration of plant powder and exposure period increased.This was followed by corresponding increase in mortality.However,Treatment T_{13} recorded total moetality, it was followed by Treatment T_4 (6g of *N.tobacum*) which showed superiority among the treatments as it recorded mortality value of 3.00 beetles, followed by Treatments T_3 (4.5g of *N.tobacum*) and T_2 (3.0g of *N.tobacum*) which indicated 2.67 deaths of beetles.Treatment T_5 (3.75g of *A.indica*) recorded the least mortality of 1.00 beetles among the treatments with plant powders (Table4.1a). However, it should be noted that treatment, T_3, (4.5g of *N.tobacum*) and T_2 (3.0g of *N.tobacum*), showed no significant differences ($P > 0.05$) in the test insect mortality.

Further increase in mortality was recorded at the 28^{th} DAT.Mortality ranged from 1.33 to 3.67 beetles with varied significant differences ($P > 0.05$) among the treatments.The highest mean mortality was recorded in Treatment T_{13},this was follwed by Treatment T_4 (6.0g of *N.tobacum*) with a value of 3.67 beetles which was significantly different ($P < 0.05$) from treatments dosaged with plant powders.The lowest mean death of beetles among the treatments with plamt powders, was recorded in Treatment T_9 (1.50g of *N.tobacum* + 3.75g of *A.indica*) with mean mortality value of 1.33 beetles.

Similar trend of performance were observed at the 35^{th} DAT. Both powders and their combinations could not completely knock off the test insects as the highest mean mortality value in plant treatments was recorded in treatment T_4 (6.0g of

N.tobacum) with a value of 4.33 beetles.This was followed by treatments T_3 (4.5g of *N.tobacum*),T_2 (3.0g of *N.tobacum*),T_1 (1.50g of *N.tobacum*) and T_8 (15g of *A.indica*) with mean mortality values of 3.67, 3.33, 3.00 and 3.00 beetles respectively.There were no significant differennces ($P > 0.05$) in mortality in Treatments T_7 (11.25g of *A.indica*), T_{11} (4.5g of *N.tobacum* + 11.25g of *A.indica*) and T_{12} (6.0g of *N.tobacum* + 15.0g of *A.indica*) with mean mortality value of 2.67 beetles.

Treatments T_5 (3.75g of *A.indica*) and T_9 (1.50g of *N.tobacum* + 3.75g of *A.indica*) recorded the least mortality value of 2.00 beetles.It does appear however ,that the toxicity of the powders at various levels could not cause further mortality with increase in duration of application.It was observed that treatment T_{12} (6.0g of *N.tobacum* + 15.0g of *A.indica*) indicated mean mortality value as was recorded on the 28 DAT. None of the powders and their combinations indicated total mortality at the 35th DAT.

Table 4.1a Effect of *A.indica,N.tobacum* plant powders and their combinations on the mortality of *Sitophilus zeamais* (Motsch.)on stored maize

		Days after treatment				
Treatment	**Dosage (g)**	**7**	**14**	**21**	**28**	**35**
T_1	1.50	0.33^{ef}	0.67^{cd}	2.33^{bcd}	2.67^{bcde}	3.00^{cde}
T_2	3.00	1.00^{cde}	1.33^{bc}	2.67^{bc}	3.00^{bcd}	3.33^{cd}
T_3	4.50	1.33^{bcd}	1.67^{bc}	2.67^{bc}	3.33^{bc}	3.67^{bc}
T_4	6.00	1.67^{b}	2.00^{b}	3.00^{b}	3.67^{b}	4.33^{b}
T_5	3.75	0.33^{ef}	0.67^{cd}	1.00^{f}	1.67^{ef}	2.00^{f}
T_6	7.50	0.67^{def}	0.67^{cd}	1.33^{ef}	2.00^{def}	2.33^{ef}
N_7	11.25	1.00^{cde}	1.00^{bcd}	1.33^{ef}	2.33^{cdef}	2.67^{def}
N_8	15.0	1.00^{cde}	1.33^{bc}	2.00^{cde}	2.67^{bcde}	3.00^{cde}
T_9	3.75+1.50	0.33^{ef}	0.67^{bc}	1.00^{f}	1.33^{f}	2.00^{f}
T_{10}	7.50+3.00	1.00^{cde}	1.00^{bcd}	1.33^{ef}	1.67^{ef}	2.33^{ef}
T_{11}	11.25+4.50	1.33^{bcd}	1.67^{bc}	1.67^{def}	2.00^{def}	2.67^{def}
T_{12}	15.0+6.00	1.67^{bc}	1.67^{bc}	2.00^{cde}	2.67^{bcde}	2.67^{def}
T_{13}(Synthetic check)		0.00^{f}	0.00^{d}	0.00^{g}	0.00^{g}	0.00^{g}
T_{14}(Untreated)		10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.1b: Mean Percentage mortality of *Sitophilus zeamais* treated with *A.indica, N.tobacum* plant powders and their combinations

The mean percentage mortality of *S.zeamais* treated with *A.indica, N. tobacum* plant powders and their combinations, is presented in Table 4.1b.

At 7 DAT, percentage mortality ranged from 0 to 100%.The highest percentage mortality was recorded in Treatment T_{13} (synthetic check) with a value of 100% (Table 4.1b), this was followed by Treatments T_4 and T_{12} with percentage mortality value of 16.7%.Treatments T_{12} (15.0g of *N.tobacum*+6.0g of *A indica)*, T_{11} (11.25g of *A.indica*+4.5g of *N.tobacum*) and T_3 (1.5g of *N.*tobacum) came next with value of 13.3%, 13.3%. It was followed by Treatments T_1 and T_9 with percentage value of 3.33%.There were no significant differences (P>0.05) in Treatments T_7, T_8 and T_{10} with mean percentage mortality value of 10.0%. There were also no significantt difference (P>0.05) in Treatment T_1, T_5 and T_9 with mean percentage mortality value of 3.33. Treatment T_{14} (untreated control) indicated the least percentage mortality with a value of 0.0%.

Similarly, at the 14DAT, there were gradual increase in percentage mortality among the treatments.The synthetic check (T_{13}) and untreated control (T_{14}) followed the same trend of performance till 35 DAT.There were no percentage mortality increase in Treatments T_6, T_7, T_{10} and T_{12} (Table 4.1b), they retained same values as obtained at 7 DAT.There were no significant differences (P>0.05) in Treatments T_1, T_5, T_6, and T_9 (Table 4.1b). Also there were no significant differences (P>0.05) in Treatments T_3, T_8, T_{11} and T_{12} and T_2.The synthetic check indicated 100% percentage mortality within 7 DAT and the same trend continued throughout the experiment. At 21 DAT, there were higher performance among the treatments evaluated, with Treatment T_4 indicating 30.0% mortality next to the synthetic check (T_{13}) (Table 4.1b).Treatments T_1 and T_9 indicated the least percentage mortality value next to the untreated control with mean value of 10.0%.There were no significant differences (P>0.05) in Treatments T_5 and T_9 with mean percentage value of 10.0%,Treatment T_2 and T_3 with mean percentage value of 26.7% and T_6, T_7, T_{10} with mean percentage mortality value of 13.3%.There was no percentage increase in Treatment T_{11} (Table 4.1b) as it recorded the same percentage mortality value as was obtained at 14 DAT.

Further increase in performance was recorded at the 28 DAT with a .Similar trend as observed in percentage mortality. At 21 DAT.Treatment T_4 indicated the second highest percentage mortality value of 36.7% next to the synthetic check (T_{13}) with percentage mortality value of 100% (Table 4.1b).The least percentage mortality value among the evaluated powders was recorded in Treatment T_9 with percentage mortality value of 10.0%.There were no significant differences ($P>0.05$) in Treatment T_1,T_8 and T_{12} with mean percentage mortality value of 26.7%.

However, at 35DAT, Treatment T_4 recorded the second highest percentage mortality value of 43.3% among the evaluated plant powders evaluated. Treatments T_5 and T_9 recorded the lowest percentage value next to treatment T_{14} (untreated control) with a value of 20%.There were no significant differences ($P>0.05$) in Treatments T_5 and T_9, Treatments T_1 and T_8 and Treatments T_7, T_{11} and T_{12}. At the end of 35 DAT, none of the plant treatments indicated 100% mortality, as the highest percentage mortality among the plant treatments was recorded in Treatment T_4 with a value of 43.3% (Table 4.1b)

Table 4.1b: Mean Percentage mortality of *Sitophilus zeamais* treated with selected plants powder and their combinations (%)

		Days after treatment				
Treatment	**Dosage (g)**	**7**	**14**	**21**	**28**	**35**
T_1	1.50	3.33 ^{ef}	6.70 ^{cd}	23.3 ^{bcd}	26.7 ^{bcde}	30.0 ^{cde}
T_2	3.00	10.0 ^{cde}	13.3 ^{bc}	26.7 ^{bc}	30.0 ^{bcd}	33.3 ^{cd}
T_3	4.50	13.3 ^{bcd}	16.7 ^{bc}	26.7 ^{bc}	33.3 ^{bc}	36.7 ^{bc}
T_4	6.00	16.7 ^{b}	20.0 ^{b}	30.0 ^{b}	36.7 ^{b}	43.3 ^{b}
T_5	3.75	3.33 ^{ef}	6.70 ^{cd}	10.0 ^{f}	16.7 ^{ef}	20.0 ^{f}
T_6	7.50	6.70 ^{def}	6.70 ^{cd}	13.3 ^{ef}	20.0 ^{def}	23.3 ^{ef}
T_7	11.25	10.0 ^{cde}	10.0 ^{bcd}	13.3 ^{ef}	23.3 ^{cdef}	26.7 ^{def}
T_8	15.0	10.0 ^{cde}	13.3 ^{bc}	20.0 ^{cde}	26.7 ^{bcde}	30.0 ^{cde}
T_9	3.75+1.50	3.33 ^{ef}	6.70 ^{bc}	10.0 ^{f}	13.3 ^{f}	20.0 ^{f}
T_{10}	7.50+3.00	10.0 ^{cde}	10.0 ^{bcd}	13.3 ^{ef}	16.7 ^{ef}	23.3 ^{ef}
T_{11}	11.25+4.50	13.3 ^{bcd}	16.7 ^{bc}	16.7 ^{def}	20.0 ^{def}	26.7 ^{def}
T_{12}	15.0+6.00	16.7 ^{bc}	16.7 ^{bc}	20.0 ^{cde}	26.7 ^{bcde}	26.7 ^{def}
Synthetic check		0.00 ^{f}	0.00 ^{d}	0.00 ^{g}	0.00 ^{g}	0.00 ^{g}
Untreated		100.0 ^{a}	100.0 ^{a}	100.0 ^{a}	100.0 ^{a}	100.0 ^{a}

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.2 Effects of *A.indica, N. tobacum* plant powders and their combinations on first generation adult emergence at 40 DAT

The effect of plant powders on first generation adult emergence at 40 DAT is presented in Table 4.2. The result revealed that the treatments showed positive performances in adult emergence. There were high significant differences ($P<0.05$) in adult emergence with Treatment T_{14} (untreated control) indicating a significantly higher emerged beetles than other treatments with mean adult emergence value of 74.3 beetles, this was followed by Treatments T_9 and T_{10} with mean values of 32.4 and 26.5 beetles respectively.Minimum adult emergence were recorded in Treatment T_{13} (synthetic check) and Treatment T_4 with mean values of 0.00 and 6.00 beetles respectively.There were no significant differences ($P>0.05$) in treatment T_1 and T_6 and T_5 andT_{10}. It does appear that the treatments gave better performance when applied singly than when combined (Table 4.2)

Table 4.2: Effect of *A.indica, N. tobacum* plant powders and their combinations on adult emergence at 40 DAT

Treatment	Adult emergence
T_1	22.4^{cd}
T_2	14.2^{e}
T_3	9.30^{f}
T_4	6.00^{g}
T_5	26.3^{c}
T_6	23.2^{cd}
T_7	19.4^{d}
T_8	14.6^{e}
T_9	32.4^{b}
T_{10}	26.5^{c}
T_{11}	19.1^{d}
T_{12}	15.20^{e}
Synthetic check	0.00^{h}
Untreated	74.3^{a}

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.3 Effect of *A.indica,N. tobacum* plant powders and their combinations on Weight loss on stored maize infested by *S.zeamais* (Motsch)

The effects of different dosages of **A.indica,N. tobacum** plant powders and their combinations on weight loss on stored maize seeds, is presented in Table 4.3. There were significant difference (P>0.05) in weight loss among the treatments evaluated. The mean values obtained ranged from 0.00g to 82.33g.The highest and least weight loss were recorded by Treatment T_{13} (synthetic check) and Treatment T_{14} (untreated control) with values of 0.00g and 82.3g respectively.There were high positive performance in all the plant treatments, with treatment (T_4) indicating a weight loss value of 1.33g and treatment T_9 recording a weight loss value of 28.0g which is significantly higher (P<0.05) than other treatments with plant powders evaluated.It does appear that weight loss is concentration dependent as increase in concentration resulted in corresponding decrease in weight loss (Table 4. 3).

Table 4.3a: Effect of *A.indica,N. tobacum* plant powders and their combinations on weight loss in stored maize at 100 DAT

Treatment	Mean weight (g)	Weight loss (g)
T_1	138.33^{ab}	11.67^{c}
T_2	146.33^{a}	3.67^{e}
T_3	147.33^{a}	2.67^{ef}
T_4	148.67^{a}	1.33^{efg}
T_5	140.67^{a}	9.33^{d}
T_6	143.67^{a}	6.33^{de}
T_7	145.00^{a}	5.00^{def}
T_8	144.33^{a}	5.67^{de}
T_9	122.00^{abc}	28.00^{b}
T_{10}	143.00^{a}	7.00^{d}
T_{11}	144.00^{a}	4.02^{e}
T_{12}	145.67^{a}	4.33^{e}
Untreated	67.33^{c}	82.33^{a}
Synthetic check	150^{a}	0.00^{h}

Means with the same aiphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.3b Mean percentage weight loss on stored maize infested by *S.zeamais* 100 DAT

The mean percentage weight loss result on stored maize infested by *S.zeamais,* is presented in Table 4.3b.There were high significant differences ($P<0.05$) in percentage weight loss among the treatments.The highest and least percentage weight loss were recorded in Treatment T_{13} (synthetic check) and TreatmentT_{14} (untreated control) with values of 44.89 and 0.00 respectively.Treatment T_4

indicated a percentage weight loss next to Treatment T_{13} (synthetic check) with a mean value of 0.89%,this was followed by Treatment T_3 with a value of 1.78%.There were no significant differences ($P>0.05$) in Treatments T_7 and T_8 .Also, there were no significant difference ($P>0.05$) in Treatments T_2 and T_{12} and in Treatments T_6 and T_{10}.It does appear that weight loss and percentage weight loss were concentration dependent (Table 4.3a and 4.3b).The higher the concentration, the lower the weight loss recorded.

Table 4.3b: Mean percentage weight loss of stored maize infested by *S.zeamais* at 100 DAT

Treatment	% weight loss
T_1	7.78^c
T_2	2.45^e
T_3	1.78^f
T_4	0.89^g
T_5	6.22^{cd}
T_6	4.22^{cde}
T_7	3.33^d
T_8	3.78^d
T_9	25.33^b
T_{10}	4.67^{cde}
T_{11}	4.00^{de}
T_{12}	2.88^e
T_{13} Synthetic check	0.0^h
T_{14} Untreated	44.89^a

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.4 The effect of *A.indica, N.tobacum* plant powders and their combinations on damaged seeds at 100 DAT

The results of the effect of *A.indica, N.tobacum* plant powders and their combinations on damaged maize seeds at 100 DAT,is presented in Table 4.4a.The result showed that there were high significant differences ($P<0.05$) in the treated maize seeds evaluated. TreatmentT_{14} (untreated control) indicated the highest seed damage of 560.0 seeds which is significantly higher than other treatments evaluated.This was followed by treatment T_1 and T_5 with value of 68.33damaged seeds each, while the least damage seeds were recorded in the treatment combinations of T_{10}, T_{11}, T_{12} and T_{13} (synthetic check) with mean values of 15.3, 15.0and 14.3 and 0.0 respectively Apart from Treatment T_{13} (synthetic check) which showed no damaged seeds,, the treatment combinations of T_{10}, T_{11}, T_{12} with mean values of 15.3, 15.0 and 14.3 respectively,gave better performance than when the treatments were applied singly. It does appear that the treaments when combined were more efficatious than when applied singly.

Table 4.4a:

4.4 The effect of *A.indica, N.tobacum* plant powders and their combinations on damaged seeds at 100 DAT

Treatment	**Mean damage (g)**
T_1	68.33^{b}
T_2	20.67^{ef}
T_3	18.00^{efg}
T_4	16.67^{fg}
T_5	68.33^{b}
T_6	30.67^{c}
T_7	26.67^{def}
T_8	27.33^{de}
T_9	29.33^{d}
T_{10}	15.3^{fg}
T_{11}	15.0^{g}
T_{12}	14.3^{g}
Synthetic check	0.00^{h}
Untreated	560^{a}

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.4b Mean percentage of damaged seeds at 100 DAT

The result of the mean percentage of damaged maize seeds at 100 DAT is shown in Table 4.4b. The percentage damaged seeds ranged from 0.00 to 100%, with treatment T_{13} (synthetic check) recording a value of 0.00 and treatment T_{14} (untreated control) recording a value of 100%. All the treatments proved superior over the untreated control during the storage period.There were high significant differences ($P<0.05$) in percentage damage, with the untreated control indicating 100% which is significantly higher than other treatments.Treatments T_4 and T_{12} recorded the least damaged seeds next to the synthetic check with values of 2.98 and 3.05 respectively.There was no significant differences between treatment T1 and T_5, Treatment T_7 and T_{10} and treatment T_3 and T_{11}

Table 4.4b: Mean percentage of damaged seeds at 100 DAT

Treatment	% damage
T_1	12.20^b
T_2	3.70^e
T_3	3.21^{ef}
T_4	2.98^f
T_5	12.20^b
T_6	5.47^c
T_7	4.76^{de}
T_8	4.88^d
T_9	5.24^{cd}
T_{10}	4.70^{de}
T_{11}	3.09^{ef}
T_{12}	3.05^e
Synthetic check	0.00^h
Untreated	100^a

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

4.5 Weevil/beetle perforated index (WPI) on *A.indica, N.tobacum* plant powders and their combinations at 100 DAT

The result of the effect of different dosages of *A.indica, N.tobacum* plant powders on weevil/beetle perforated index is presented in Table 4.5.Treatment T_{14} (untreated control) recorded the highest WPI of 100, followed by Treatment T_1,Treatment T_4 recorded the least WPI of 14.3 which is next to T_{13} (synthetic check) that recorded WPI of 0.00.When WPI is >50, it implies a negative protection of stored material and when <50, it implies a positive protection of plant material stored.Treatment T_1

and Treatment T_{14} (untreated control) recorded a negative protection effect, while other treatments have positive protection effect on the stored material (Table 4.5)

Table 4.5: Weevil perforated index (WPI) on *A.indica, N.tobacum* plant powders and their combinations at 100 DAT

Treatment	Weevil perforated index (WPI)
T_1	68.3
T_2	20.7
T_3	18.0
T_4	14.3
T_5	39.0
T_6	30.7
T_7	26.7
T_8	27.3
T_9	29.3
T_{10}	21.3
T_{11}	17.3
T_{12}	14.3
Synthetic check	0.00
Untreated	100

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (P>0.05) level of probability using DMRT

Experiment 2

4.6 Effect of different dosages of selected plant oils on the mortality of *Sitophilus zeamais* on stored maize.

The results of the effect of different dosages of selected plant oils on the mortality of *Sitophilus zeamais* on stored maize, is presented in Table 4.6a

At 7 days after treatment (DAT), the result obtained showed performances of different oils on the mortality of adult *S. zeamais.*The lowest mortality was recorded at 1.0 ml of sesame oil with a value of 6.66 which was significantly lower ($P<0.05$) than all the other oils evaluated. Castor oils at 2.0, olive oil,soyabean oil, coconut oil all at (2.0)mls) and Treatment T_{13} (synthetic check) exerted the highest level of mortality on the test insect.However,it does appear that the mortality of the insects,is concentration dependent (Table 4.6a)

Similarly, at 14 DAT, 8.33 mortality was recorded for sesame oil and mustard seed oil at 1ml concentration level which were significantly lower ($P<0.05$) than all other oils evaluated .For all other oils and Treatment T_{13} (synthetic check), the mean mortality of *S.zeamais* ranged from 8.67 to 10.0 at different concentrations but indicated no significant differences ($P>0.05$)

Same trend of performance was obtained at 21 DAT in all the treatments, where all the different oils exerted almost complete or absolute mortality on the test insects except at lower dosage of 1.0 (mls) where sesame, groundnut, soyabean and coconut oils recorded 9.00, 9.67, 9.0, 9.33, 9.0, 9.69 and 9.33 mean values respectively, which showed no significant differences ($P>0.05$). At dosage rate of 2.0mls all the oils evaluated indicated 100% mortality including Treatment T_{13} (synthetic check).

As the days progresses, the ability of the *S. zeamai*s to withsstand the treatments became completely weakened. At 28 and 35 DAT all the oils tested and the synthetic check indicated 100% mortality of the insect irrespective of the dosage applied.It does appear however, that apart from being concentration dependent, the potency and effectiveness of the oils may be linked to duration of treatment.

Table 4.6a: Effect of different dosages of selected plant oils on the mortality of *Sitophilus zeamais* on stored maize

Plant oils	Dosages (mls)	Days after treatment				
		7	**14**	**21**	**28**	**35**
Castor oil	1.0	9.33^{abc}	9.67^{ab}	10.0^{a}	10.0^{a}	10.0^{a}
	1.3	9.66^{ab}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}
	2.0	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}
Sesame oil	1.0	6.66^{e}	8.33^{d}	9.66^{ab}	10.0^{a}	10.0^{a}
	1.5	8.66^{bcd}	9.67^{ab}	10.0^{a}	10.0^{a}	10.0^{a}
	2.0	9.33^{ab}	9.33^{c}	10.0^{a}	10.0^{a}	10.0^{a}
Groundnut oil	1.0	8.33^{cd}	9.66^{ab}	9.67^{ab}	10.0^{a}	10.0^{a}
	1.5	8.66^{bcdr}	9.67^{ab}	10.0^{a}	10.0^{a}	10.0^{a}
	2.0	9.66^{ab}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}
Mustard seed oil	1.0	7.66^{de}	833^{d}	9.06^{ab}	10.0^{a}	10.0^{a}
	1.5	9.33^{abc}	9.67^{ab}	10.0^{a}	10.0^{a}	10.0^{a}
	2.0	9.66^{ab}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}
Olive oil	1.0	8.33^{cd}	8.67^{bc}	9.33^{abc}	10.0^{a}	10.0^{a}
	1.5	9.33^{abc}	9.67^{cd}	10.0^{a}	10.0^{a}	10.0^{a}
	2.0	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}
Soya bean oil	1.0	8.33^{cd}	8.67^{cd}	9.66^{ab}	10.0^{a}	10.0^{a}
	1.5	9.33^{abc}	9.67^{ab}	9.67^{ab}	10.0^{a}	10.0^{a}
	2.0	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}	10.0^{a}

Coconut oil	1.0	8.33[cd]	8.67[bc]	9.33[abc]	10.0[a]	10.0[a]
	1.5	9.33[abc]	9.67[ab]	10.0[a]	10.0[a]	10.0[a]
	2.0	10.0[a]	10.0[a]	10.0[a]	10.0[a]	10.0[a]
Synthetic check		10.0[a]	10.0[a]	10.0[a]	10.0[a]	10.0[a]
Untreated		0[e]	0[d]	0[e]	0[d]	0[d]

Means with the same alphabet(s) on the same column and under the same heading are not significantly different at (p>0.05) level of probability using DMRT

4.6b: Mean percentage mortality of *S. zeamais* (Mostch) treated with selected plant oils and Permethrin at 7, 14, 21, 28 and 35 days after treatment

The effects of different dosages of selected plant oils on the mortality of *Sitophilus zeamais* on stored maize is presented in Table 4.6b. At 7 days after treatment (DAT), the results obtained showed performance of the different oils on the percentage mortality of adult *S.zeamais.* The lowest percentage mortality was recorded at 1.0ml of sesame oil with a value of 66.66% which was significantly lower (P<0.05) when compared to other oils evaluated.Castor oil at 2.0mls, olive oil, soyabean oil,coconut oil all at (2.0) mls) and the synthetic check exerted the highest level of percentage mortality on the test insect. However, it does appear that the mortality of the insect is concentration dependent (Table 4.6b).

Similarly, at 14 DAT, 83.33% was recorded for sesame oil and mustard seed oil which were significantly lower (P<0.05) than all other treatments evaluated. For all other oils and the synthetic check, the mean percentage mortality of *S. zeamais* ranged from 86.67% to 100% at different concentrations but indicated no significant differences (P>0.05)

Same trend of performance was obtained at 21 DAT in all the treatments where all the different oils exerted almost complete or absolute mortality on the test insects, except at lower dosage of 1.0 ml where sesame, groundnut, soyabean and coconut oils recorded 90%, 96.67%, 90%, 93.33%, 90%, 96.69% and 93.33% mean values respectively, which showed no significant differences (p>0.05). At dosage rate of 2.0 mls, all the oils evaluated indicated 100% mortality including the synthetic check.

As the day's progresses, the ability of the *S. zeamai*s to withstand the treatments became completely weakened. At 28 and 35 DAT, all the oils tested and the synthetic check indicated 100% mortality of the test insect irrespective of the dosage applied. It does appear however, that apart from being concentration dependent, the potency and effectiveness of the oils may be linked to duration of treatment.

Table 4.6b: Mean percentage mortality of *S. zeamais* (Mostch) treated with seven plant oils and Permethrin 7, 14, 21, 28 and 35 days after treatment (%)

Plant oils	Dosages (mls)	Days after treatment				
		7	14	21	28	35
Castor oil	1.0	93.3^{abc}	96.7^{ab}	100.0^{a}	100.0^{a}	100.0^{a}
	1.3	96.6^{ab}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
	2.0	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Sesame oil	1.0	66.6^{e}	83.3^{d}	96.6^{ab}	100.0^{a}	100.0^{a}
	1.5	86.6^{bcd}	96.7^{ab}	100.0^{a}	100.0^{a}	100.0^{a}
	2.0	93.3^{ab}	93.3^{c}	100.0^{a}	100.0^{a}	100.0^{a}
Groundnut oil	1.0	83.3^{cd}	96.6^{ab}	96.7^{ab}	100.0^{a}	100.0^{a}
	1.5	86.6^{bcd}r	96.7^{ab}	100.0^{a}	100.0^{a}	100.0^{a}
	2.0	96.6^{ab}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Mustard seed oil	1.0	76.6^{de}	83.3^{d}	96.6^{ab}	100.0^{a}	100.0^{a}
	1.5	93.3^{abc}	96.7^{ab}	100.0^{a}	100.0^{a}	100.0^{a}
	2.0	96.6^{ab}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Olive oil	1.0	83.3^{cd}	86.7^{bc}	93.3^{abc}	100.0^{a}	100.0^{a}
	1.5	93.3^{abc}	96.7^{cd}	100.0^{a}	100.0^{a}	100.0^{a}
	2.0	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Soya bean oil	1.0	83.3^{cd}	86.7^{cd}	96.6^{ab}	100.0^{a}	100.0^{a}
	1.5	93.3^{abc}	96.7^{ab}	96.7^{ab}	100.0^{a}	100.0^{a}

	2.0	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Coconut oil	1.0	83.3^{cd}	86.7^{bc}	93.3^{abc}	100.0^{a}	100.0^{a}
	1.5	93.3^{abc}	96.7^{ab}	100.0^{a}	100.0a	100.0^{a}
	2.0	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}	100.0^{a}
Synthetic check		100.0^{a}	100.0^{a}	100.0^{a}	100.0a	100.0a
Untreated		0.0^{e}	0.0^{d}	0.0^{e}	0.0^{d}	0.0^{d}

Means with the same aiphabet(s) on the same column and under the same heading, are not significantly different at (p>0.05) level of probability using DMRT

4.7 Effect of selected plant oils on weight loss, first generation adultemergence and damaged seeds.

The selected plant oils at the end of the experiment, inhibited first generation adult emergence.This occured as a result of total mortality on the test insect.There was no weight loss in all the oil treatments at all concentration levels, the insects could not bore holes into the grains to feed on the internal content of the maize seeds which would have resulted in weigt loss.There were no damaged seeds in all the treatments at all concentration levels.

CHAPTER FIVE

5.0 DISCUSSION

5.1: Effects of different *A.indica,N.tobacum* plant powders and their combinations on the mortality of *Sitophilus zeamais (*Coleoptera: Curculionidae) on stored maize.

The result of the study on effect of **t** *A.indica,N.tobacum* plant powders and their combinations on the mortality of *Sitophilus zeamais* on stored maize ,showed that the response of *Sitophilus zeamais* on stored maize was found to be dependent on concentration.There were significant differences (P>0.05) in beetle mortality on the plant powders evaluated.Adult mortality increased with increase in concentration.The study revealed that some of the plant materials despite not giving very high mortality of *S. zeamais,*were effective in performance than the untreated control. This finding agrees with the report of (Owusu-Akyaw, 1991) who reported that some local plants and plant parts do not only exhibit insecticidal properties, but also antifeedant properties that inhibit the activities of *S. zeamais*. According to some early research work done on similar botanical plant materials, it was reported that varying degrees of successes were recorded on the insecticidal, repellent and antifeedant properties of the botanicals on *S. zeamais* (Bekele,1997; Obeng-Ofori *et al,* 2005; Udo 2005; Arannilewa *et al,* 2006 and Assawalam *et al,* 2006).

However, *Nicotiana tobacum* gave the highest performance at the concentration level of 6.00g/150g as it caused the second highest mortality of the beetles next to the synthetic check that recorded total mortality of the test insect.It performed better when compared to *Azadirachta indica* and their combinations on the maize beetles.This finding may suggest an antagonistic effect of the two treatments when combined.This finding supports earlier report by (Lale, 2002); Stoll,1988) that *N. tobacum* possesses contact stomach and respiratory poisoning properties attributed to the active constituent nicotine. Simillar effects of plant materials as crop seeds protectants have been observed in the treatment of cowpea and maize grains against maize beetles (Asawalam *et al,* 2007) It has been observed and reported that the insecticidal property of any plant material, would depend on the active constituents of the plant material (Ofuya and Dawodu, 2002; Adedire and Ajayi 1996).

However, the results obtained from the study, disagreed with (Danjumma *et al,* 2009) who reported that 2.0 g of *N. tabacum* applied in 50g of maize grains resulted in 100% mortality of *S. zeamais*, as findings from this study revealed that the best perfomance of *N. tobacum* of 6.0 g/150 kg of maize seeds indicated 43.3% adult mortality at 35 DAT

5.2 Effect of *N.tobacum, A.indica* plant powders and their combinations on first generation adult emergence on *Sitophilus zeamais* at 40 DAT

The result on the effect of *N. tobacum, A.indica* plant powders and their combinations on first generation adult emergence on *S. zeamais* showed that treatment T_{14} (untreated control) recorded the highest number of adult beetles emergence. Adult emergence from both the treated and untreated maize grains commenced from the 40th day after treatment on the average. This indicates that the total developmental period (TDP) of the maize beetles S. *zeamais* is estimated to be 40days on the average.This finding agrees with the work of Perugrug and Roxas (2008) who reported 39 days for total development period of *S. zeamais.*

The reduction in the first generation adults in the treated grains, may be due to increased adult mortality, ovicidal and larvicidal properties of the tested plant powders, confirming the findings of *Selase* and Getu (2009) and Bamaiyi *et al* (2007) who reported that the active ingredient persistence in plant powders, declines after 40 DAT.This finding is also simmilar to that of Asmare (2002) who observed that the killing effect of botanicals is not acute as chemical insecticides in the first week after treatment. Adanre and Abraham (1995) reported that there are differences among botanicals in speed of action within a month of storage period, i.e some botanicals with different rates caused high mortality at 42 days after treatment. Also, plant powders often reduce the emergence of adult beetles from the seed. Rajapakse, (2006) reported that some plant powders have effect on adult emergence of insect pests attacking stored grains such as cowpea and maize.

However, *A. indica* may have been potent because of the strong odour emmited, thereby disrupting normal respiratory activities of the beetles resulting in asphyxiation and subsequent death .Adedire *et al* (1996) reported that the effectiveness of *A. indica* and *N. tobacum,* is dependent on dosage and exposure period. It was observed that the high significant differences on the emergence of adult *S. zeamais* on treated and untreated maize seeds indicates that insecticidal materials tested had significant effects on the developmental stages of insects which in turn affects emergence.

The weakening of adult beetles by botanical powders may make them lay fewer eggs than normal, leading to less hatchability to larvae and final metamorphosis to adults. Different botanical effectiveness at higher dosage to various storage insect pests have been reported by several authors; Adedire and Lajide, 2003;Negahban *et al*, 2007; Oni and Ileke, 2008; Shahaf *et al*., 2008; Ileke and Oni, 2011).

5.3: Effect of *A. indica, N. tobacum* plant powders and their conbinations on weight loss in stored maize infested with *Sitophilus zeamais* at 100 DAT

Observations from the result showed that there were significant differences (P>0.05) in weight loss on treated maize seeds.All the treated maize seeds gave better performance than the untreated. The finding from the study agrees with the report of Okonkwo and Okoye (1996) who reported that percentage weight loss was related to the population of adult *S zeamais*. *N. tobacum* at 6.00g/150g of maize seeds gave the best result of 1.33 and 0.59% of weight loss and percentage weight loss respectively.

However, *A .indica* like *N. tobacum,* decreases in weight loss with increase in concentration. The same trend also occured with the treatment combinations. Percentage weight loss also decreased with increase in concentration of plant powders. The weight loss of untreated maize grains (44.89%) infested with *S. zeamais,* could be a good index for assessing loss and waste during storage. Such often affects the nutritional quality and consumers acceptability of the maize grains (Lajide *et al,* 1998).

5.4 Effect of *A.indica, N. tobacum* plant powders and their combinations on weevil/beetle perforated index (WPI) on stored maize infested with *Sitophilus zeamais* at 100 DAT

The result on WPI showed that WPI ranged from 0.00 to 100.WPI in the untreated was observed to be 100, indicating total damage to stored maize grains. Treatment T_1 and T_{14} (untreated) recorded a WPI of 68.3 and 100 respectively.The finding is in line with (Fatope *et al* 1995) who reported that when WPI >50, it indicates a negative protection of plant materials tested (strongly infested by beetles) and when WPI < 50, it indicates a positive protection of plant material tested (inhibiting beetle infestation). However, it was observed that all other treated maize seeds gave a WPI that is less than 50, indicating a positive protection of plant material, thereby minimizing damage by beetlel infestation.

5.5 Effects of different dosages of selected plant oils on the mortality of *Sitophilus zeamais* on stored maize

The result obtained from the study showed that all the plant oils were toxic to the test insect .The finding agrees with the report of (Fekadu,*et al* ,2012) that

Ethiopian and Mustard seed oils tested, caused 100% and 95% mortality of *Sitophilus zeamais* respectively.

The seven plant oils, groundnut; sesame, castor, olive, mustard, soyabean and coconut oil, exhibited toxicity to adult beetle, inhibition of first generation emergence. As a result, there was no damage to the grains throughout the storage period similar to the standard check. The toxicity of these oils may be due to their active components responsible for the insecticidal properties against the beetles. The effectiveness of these oils may be through their impact on the breathing system of the insects through blockage of spiracles, preventing oxygen inhalation there by leading to death of the beetles.Similar findings on toxicity of plant oils on beetles was reported by (Cooping and Menn 2000) who revealed that death of storage insects was due to asphyxia when oils are applied to grains during storage.

CHAPTER SIX

6.0 Summary, Conclusion, Contribution to Knowledge and Recommendations

6.1 Summary

A laboratory study was conducted at Delta State University, Asaba campus to evaluate the effect of *A. indica*,, *N. tobacum* plant powders,their combinations and seven plant oils in the control of *S.zeamais* on stored maize.The specific objectives of the study were: to evaluate the effect of plant powders for the control of *S.zeamais*, to evaluate the control of maize beetles using selected plant oils. Both Experiments were arranged in Completely Randomnized Design and each treatment was replicated three times. Data was collected on parameters such as; mortality, first adult generation emmergence and damage indices. Data obtained were analyzed using analysis of variance (ANOVA) and the means were separated by Duncan Multiple Range Test (DMRT). The results showed that all the treatments were significantly ($P<0.05$) superior when compared to the untreated control.

6.2 Conclusion

The results obtained from the study showed that *A indica,N. tobacum* plant powders, their combinations and plant oils tested against *S. zeamais* showed insecticidal activity. All the plant treatment levels, singly or combined (botanical powders), caused varying degree of mortality in maize beetles, reduced number of emerged adults as well as weight loss of the grains. Results obtained from the study further revealed the potentials of *N. tobacum* as plant derived insecticide against maize beetles.Although, variations were observed in their effectiveness against the maize beetless. The plant oils caused complete mortality of the test insect and recorded no firstgeneration adult emergence, weight loss and seed damage.

The botanicals (powders and oils) could find a place in integrated pest management (IPM) strategies of *S. zeamais*, which needs to be investigated, especially where concern is on environmental, food safety and on replacing toxic insecticides. Also work in this regard should continue to obtain information regarding its practical effectiveness under natural conditions to protect the stored products without adverse side effects. Hence, there is a scientific rationale for the incorporation of these botanical powders and oils into the grain protection practice of resource-poor farmers

6.3 Recommendations

1. This study has proved that plant oils are better in the storage of maize grains against *Sitophilus zeamais* than plant powders.
2. Findings from the study revealed that plant oils can effectively store maize seeds against *Sitophilus zeamais* for a period of 100 days.
3. Results from the study equally showed that *Nicotiana tobacum* when applied singly, is more toxic to *Sitophilus zeamais*.

6.4 Contribution to Knowledge

1. The plant powder *Nicotiana tobaccum,* was found to be more effective in controlling *S.zeamais* than *A. indica* as observed in the results
2. The plant oils with dosage level of 20 mls/kg were the most effective in controlling *S.zeamais* on stored maize seeds, as results obtained showed no weight loss, mortality, perforated seeds and first generation adult emergence.
3. The experiment with the plant oils, established the fact that maize seeds can be stored effectively for a period of 100 days

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