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EFFECT OF THREE ORGANIC PLANT POWDER EXTRACTS ON STORABILITY AND QUALITY OF MAIZE GRAINS

BY

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EFFECT OF THREE ORGANIC PLANT POWDER EXTRACT ON STORABILITY AND QUALITY OF MAIZE GRAINS

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(M. Phil. POSTHARVEST TECHNOLOGY) DEGREE

BY

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JUNE, 2014

DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

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DEDICATION

I dedicate this research work to the Lord Almighty who granted me the grace to complete this work successfully.

I also dedicate this piece of work to my lovely wife Cynthia Gameli and my children who have been a real source of support and inspiration.

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ABSTRACT

An experiment was conducted at the laboratory of Mampong College of Teacher Education, Mampong, Ashanti Region to assess the effect of three organic plant powders on the storability and quality of maize grains. Three organic powders of neem seeds, orange peels, lemongrass, and a control with six dosages namely 5g, 10g, 15g, 20g, 25g, and 30g, were used as treatments. The design used was a 4x6 factorial in Complete Randomized Design with three replicates. Parameters studied included weevil survival, weevil mortality, grain damage and weight loss. The results from the study showed that the highest percentage weevil mortality was recorded for Neem, followed by lemongrass, citrus and control with means of 8.78 (76.38), 8.61 (73.7) and 2.14 (3.99), respectively. High dosages of the plant powder (15g and above) was effective in reducing the weevil population for all treatments except control. Neem seed powder at 10g was very effective in elimination the weevil population. The lowest percentage survived weevils of 3.11 (11.43) was recorded for neem powder at 30g and the highest percentage survived weevils was recorded for control with a mean of 5.26 (96.01). The lowest percentage damage of 1 (0) was recorded for neem powder at 30g and the highest percentage damage was recorded for control with a mean of 1.77 (2.13). Finally on weight loss of the stored grain, The mean percentage weight loss was highest for control (8.4), followed by citrus (6.74), lemongrass (5.7) and neem (3.64). Treating maize grains with organic plant extract would be useful in storing of maize.

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CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays*) is a cereal crop belonging to the family of Gramineae. It is a native of Central America from where it spread to Asia, Europe and Africa through the activities of traders and explorers (Addo-Quaye *et al*., 1993). Maize is an important staple food for human beings and animals. In Ghana, 20% of small producer households (1 million) depend on maize for primary income (WABS Consulting Ltd, 2008). It is a major cereal which is cultivated by a vast majority of rural household and in all parts of the country. In addition, it is also used as an important feed and fodder for animals. Maize is a rich source of starch (60-80%), protein (8-12%), fat (3-5%) and minerals (1-2%) (Addo-Quaye *et al*. 1993).

Maize is also regarded as versatile and with many uses since it can thrive in diverse climates; hence it is grown in many countries than any other crop. Aside from being one of the major sources of food for both human and animals, it is also processed into various food and industrial products such as starches, sweeteners and oil. Maize is the single largest source of calories (Vellegas, 2000).

More than half of the country's malnourished children live in the rural areas, maize grain is the main food mothers use to wean their babies and maize is single largest source of calories (Vellegas, 2000).

Maize is one crop which suffers much deterioration during storage in Ghana (Bani, 1991). Pests such as maize weevils infest the grain during storage and transportation. Grain infestation usually starts in the field when the moisture content of the grain has fallen to about 18 to 20%. Subsequent infestations in store result from the transfer of infested grain into store or from pest flying into storage facilities, probably attracted by the odour of the stored grains. In stored maize, heavy infestation of this pest may cause weight losses of as much as 30-40% (Casey, 1994). The chewing damage caused by the insect brings about increased respiration in the cereal which promotes evolution of heat and moisture which in turn provides favourable living condition for molds and other fungal species (*Aspergillus* and *Penicillium* spp.) leading to the production of mycotoxin such as aflatoxin (Effiong and Sanni, 2009). Subsequently, at very high moisture levels, microbial growth is favoured which ultimately give rise to depreciation and finally total loss (Dahiya, 1999). Globally a minimum of 10% cereals and legumes are lost after harvest (Boxall *et al*., 2002). Moulds are responsible for the reduction in nutritional value by enzymatic digestion producing unpleasant flavours and appearance, making feed lumps and reducing palatability of poorly stored maize (Lim *et al*., 2008).

Insect pests cause heavy economic losses to stored grains throughout the world and their impacts are more devastating in poor countries (Boxall *et al*., 2002). The maize weevils are among the most destructive crop pests (FAO, 1994). The feeding of these pests is responsible for deterioration in the nutrient quality of maize and contamination of the interior content by producing harmful compounds and allergens (Rajendran and Parveen, 2005).

In an attempt to control weevils, farmers use different formulations of inorganic synthetic insecticides for spraying or dusting. The farmers are predisposed to hazards associated with these formulations as they are not adequately protected when using these chemicals (FAO, 1991). Insecticide and related products employed in insect pests control, apart from being expensive has detrimental effects on users and a long term detrimental impact on the environment or ecosystem (David, 1993). About 50,000 people are accidentally poisoned annually by insecticides worldwide with a fatality rate of about 1% (WHO, 1979). A report from the National Academy of Sciences expressed concern about pesticides residue in children`s food (Persley 1996).

Over the years, many of these insect pests have developed resistance to the continued use of the same synthetic pesticides, a situation that leads to high insect pests population build-up (Schuz, 1986; Copping and Hewitt, 1998; Aggarwal *et al*., 2001). To reduce these risks associated with synthetic pesticides, alternative products are being sought by both farmers and consumers in controlling storage pests of maize. These plant extracts are biodegradable, locally reliable and are less expensive than conventional insecticides (Heinrich *et al*., 1979).

Over 16,000 plant species are reported to possess pest control properties (Brower's, 1983; Graigne *et al*., 1984). Some phytochemicals with pest control potential have been developed into commercial products (Jacobson, 1977). The use of plant derivatives for pest control was common in the tropics before the advent of synthetic pesticides (Saxena, 1987). It also reduced fungal attack and infestation on stored seeds and crops on the field. Research work done over the years have revealed that, some plant extracts possesses pesticidal properties and could therefore replace the hazardous synthetic products currently being used.

The objective of the study was to determine the effect of three organic plant powder extract on the storability and quality of maize grains.

The specific objectives were therefore to:

i. determine the percentage of survived weevils after application of plant powders,

ii. assess the efficacy of the three organic plants powders in controlling maize weevils in storage and

iii. determine the quality of maize grains in storage after the application of organic plant powder.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BOTANY AND PRODUCTION REQUIREMENTS OF MAIZE

Maize (*Zea mays*) is a cereal belonging to the family Gramineae. It is a native of Central America, from where it spread to Asia, Europe and Africa through the activities of traders and explorers (Addo-Quaye*et al*., 1993).It is a monoecians annual grass, which is cultivated twice in a year especially in the forest zones of Ghana during the two growing seasons (that is from March to June and from mid of July to September).It is the most popular of all grains in Ghana and grows in all parts of the country with the best yields coming from the forest and transitional zones (Awuku *et al*., 1993).

Various varieties developed besides the local varieties and cultivated in the country include "Dobidi", "Okomasa", "Aburotia", "Abelehi", "Nyankpala", "Safita" 2, "Golden crystal" and "La posta". These are improved high yielding varieties which have a shorter production cycle.

Maize does well in warm area within latitude 50˚N and 40˚S of the equator with a well-distributed rainfall between 6000mm and 1200mm during the growing season. It needs deep well drained loamy soils which are rich in phosphate and nitrogen with high humus content and the pH ranging from 5.2 to 8.0 (Guy, 1987). Planting distance of 90cm by 60cm by 40cm by 60cm is used depending on the variety under cultivation (Awuku *et al*., 1993).

According to Spore (1992) maize production cycle is 90 to 120days and therefore does not disrupt growing of other crops. This makes it best enough to be usually intercropped with other crops like cocoyam, cassava, pepper, cowpea and others.

2.1.1 Importance of Maize

Maize is an important staple food for human being and animals. According to Addo-Quaye *et al*. (1993), it has an average composition of 13.2% water, 10.3% protein, 60.5% starch, 1.2% sugar and 2.5% crude fibre. It is primarily an energy giving food because of its high starch content.

The grains is processed into flour, which can be used to prepare local Ghanaian foods like “Banku”, “kenkey”, Akple” porridge, “Apraprasa” and others like bread and pastries. The grain is also used to feed monogastric such as pigs and poultry as the main source of energy while the plant also serves as fodder for ruminants (Addo-Quaye*et al*., 1993).

The starch is used in making ice cream, alcohol, beverages, cosmetics and adhesive, cooking oil, salad oil, glycerine, soap and pharmaceuticals can also be made from maize (Onwueme and Sinha 1991).

Maize is also used as non-food product and used in the manufacture of glue and starch. Industrialized countries have gone further in developing, maize as a raw material for chemical industries and have developed a wide range of products including fuel, ethanol and biodegradable substitute for plastic (Spore, 1997).

According to Addo-Quaye *et al*. (1993), the maize cob is used to manufacture corn cob pipes or pulverized and used as abrasive for removing carbon from airplanes. In the home, the cob serves as a source of fuel for cooking. The husk is also used in making paper for boxes.

2.1.2 Harvesting and Drying

Maize is ready for harvesting when the cobs are just beginning to drop or when the grain can no longer be scratched with the nail shucks are drying up (Guy, 1987).Harvesting is done by breaking the ear from the stalk using the hand with either cutlass or sickle. It can also be done by using a machine - combine harvesters, which depending on the type may just harvest just the ears or the grains directly (Appert, 1987). After harvesting the grains need to be dried to separate and remove free water from the solid matter to the level which is below that needed for mould growth in order to store the grains satisfactorily (Nicol *et al.*, 1997). This is done through natural drying using sun drying or artificial drying like photovoltaic solar energy like solar energy (Appert, 1987). In sun drying, the grains are laid out on a clean surface and stirred frequently until they are dried enough to store. Another way is to place the maize cob on a specially design crib for air current to blow over them and absorb the moisture from the grains (Nicol *et al.*, 1997).

2.2 METHOD OF STORAGE

According to Onwueme and Sinha (1991), the rate at which grains lives is governed principally by temperature, moisture content and availability of oxygen. By adjusting these parameters, grains can be stored for a longer period. This is generally done by drying the grains to a desirable moisture content of 11-14%. Moisture content is the single most important factors in storage of grains against damage by insects, mites, mould, bacteria among others.

2.2.1 Traditional Method

The small-scale farm mostly use locally available materials for building structures for storing durable crops such as maize. Some of these structures are platforms, cribs; barns ventilated granaries (Appert, 1987). Local maize varieties often have husks that cover the whole cob and keep it intact.This provides a good protection against insects and therefore maize of this kind is sometimes stored on barns in husks. However, the moisture content should not be more than 26% in order for growing mouldy (Hayma, 1995).For small amount of grain reserve, which are drawn upon frequently for daily food requirements the grains either or unthreshed is kept in containers such as bags, baskets, jars, gourds and drums (Appert, 1987).

Lowenberg-Deboer (nd) shared the views of Appert (1987) on the structures and platforms that are used by some countries in storing maize. He gave a vivid picture of this storage method which can be seen on figure 2.1

Fig. 2.1 Traditional methods of preserving maize in Ghana.

Source: http://ag.purdue.edu/economics_of_maize_storage_in_ghana

2.2.2 Improved Method

For maize production in large scale traditional storage method are generally unsuitable because of large quantities of crop to be kept. The use of improved cribs, bins and silo built with materials such as sawn timber, hollow brick, concrete and corrugated sheets may be appropriate (Nicol *et al*., 1997). Other materials such as plastic sacks, metals drums, reinforced concrete silos, stores and warehouses (Appert, 1987).

2.3 POST HARVEST LOSSES

These are losses, which occur between the completion of harvest and the moment of human consumption. Most short falls in food supply to the majority of people in developing countries have been attributed to post-harvest losses. Conservative estimates of losses are put to 30% of production in Ghana. An important economic aspect of post-harvest food losses is that the importation of food in substantial quantities places a burden in the foreign currency reserves of many countries (Bani, 1991).

2.3.1 Causes of Food Losses during Storage

Deterioration in quantity occurs soon after harvest. Insects attack, bacteria proliferation, mould growth and biochemical changes occur. Losses of carbohydrates, protein and vitamins result from the handling method adopted or not adopted by producers, middle agents and retailers (Workshop Reports, 1993).

Other causes of losses during storage reported by Hayma (1995) include inadequate drying after harvesting resulting in mould development especially in the production of chemical which can be carcinogenic particularly to animal such as poultry; premature drying before harvesting which cause shattering cracking or scorching of grains; chickens, rats and birds consuming and contaminating produce spread on the ground or on the platform to dry or store in open sided cribs; insects pest (beetles, weevils and moths) eating and multiplying in stored grains, this causes loss of foodstuffs and lowering of grade and of financial return when the produce is sold in markets; inefficient threshing and shelling methods, which exposes the produce to accelerated attack by pest; improper construction of containers allowing rains to penetrate and wet the produce and or enabling re-absorption of moisture, thus causing rotting and accelerating pest development.

2.4 SOME COMMON PESTS OF STORED MAIZE

Pests cause a lot of damage to stored maize through direct consumption, breaking of seeds coat and production of moisture, which encourages microbe development (Linblad and Druben, 1984). Pests produce heat, moisture, waste products and secretions which have adverse effects on the quantity of the grain and its susceptibility lead to further deterioration (WFP, 1994). According to Ashiamah (1992) rat, mice, insects and mould are present all year round in large numbers and are known to cause between 5-30% loss in stored grains.

2.4.1 Birds

In many tropical regions, birds are responsible for losses sometimes before and after harvesting. The most common species that prey on stored grains are sparrow, red-tailed queleas, Gendarmes, starlings, pigeons and weaverbirds. These birds are not only harmful particularly in terms of the amount of grains they consumes in feeding but also because they contaminate the grains, its packaging or even the storage premises with their dropping, feathers or various materials carried by them when building their nests (Appert, 1987).

2.4.2 Rodents

Rats and mice are the common rodent pests of stored products (grains). Man considers them as formidable crop pests because they feed on the same plant products as man and therefore compete directly with him (Linland and Druben, 1984). The fact that, they are found everywhere (e.g. in banks, under bushes, old abandoned machinery and in piles of wood or weeds on roof ceilings) their fertility, the extents of damage they cause and their ability to reach all sources of food make their control a difficult matter (Workshop Report, 1993). They are responsible for considerable percentages of losses throughout the post harvest period (Appert, 1987).

2.4.3 Damage Caused by Rodents

Single average-sized rat may consume at least 500g of maize alone per month. They render consumed grains, inedible and unsalable and also impair germination capacity of the grains. Their contamination with urine and droppings results in damage, which may be as twenty times as great as that resulting from feeding. They carry various pathogenic agents which may transmit typhoid, rabies, jaundice, yellow fever and others (Limblad and Druben, 1984).

2.4.4 Insects

Common insects pest that attacks maize in storage are moth larvae and weevils. Infestation often starts from the field prior to harvesting. In the case of serious infestation 90% of the grains may be destroyed within six months (Guy, 1987). They give terrible smell and taste in grains in which they live especially the adult of red beetle and grains mites (Bomrner, 1985). They reduce seed germinate significantly (Ghizadavu and Deac-Va, 1995) and promote mould development through production of water in respiration (Bommer, 1985).

2.4.5 Moulds

These are tiny organism found on grains. In warm and moist grains they germinate and produce tiny threads called hyphae. These hyphae penetrate through the seed coats of grains and attack the embryo. The kind of damage caused includes producing enzymes which inhibit seed germination and decreasing the quality of the grain for food and for market. Some mould produce toxic chemicals that can poison human beings and producing bad smell and changes that affect the colour of the grains (Linblad and Druben, 1984; Guy, 1987).

2.5 METHOD OF REDUCING POST HARVEST LOSSES

2.5.1 Indigenous Methods

Traditional pest control method is often effective in keeping down infestation level. Some farmers storing large grains and pulses will admix a smaller seed or sand with the grains to fill the inter-granular spaces. This effectively inhibits the development of brunched beetles or weevils (Parizer *et al.,* 1981). Other farmers use fire under their storage cribs to repel insects either thorough the effect of smoke or by keeping the grains dry. The admixture or overlay of ashes derived from another method affording protection against insects attack (Parizer *et al*., 1981).

In many countries, farmers believe that the addition of certain plants to store produce will deter insects. Leaves of the neem tree whose fruit have insecticidal properties, garlic, dry peel of citrus, dry lemongrass leaves are used for storing maize. Although they have a protective role, its real value remains to be established (Appert, 1987).

For rodents most farmers use chemical poison, traps and cats to reduce their population (FAO, 1983). This is because eradicating them completely is difficult and an expensive task when they are installed. People are afraid of the hazardous nature of the chemicals and therefore will not attempt their use at all. According to Grass and Gregg (1999), the use of chemicals is hazardous to operators and to the environment as well.

Traditionally most farmers rely on the effects of husk and select local varieties of grains that have low susceptibility to storage pest (Appert, 1987).

2.5.2 Modern Method

This is mostly concerned with the use of chemicals – insecticides, rodenticides and fumigants to control and check post-harvest losses. In Ghana, most farmers have come to accept the use of Actellic 25EC to treat their maize in storage (Awuku*et al*., 1993). This has proven effective in preventing and killing insect pests by some farmers.

According to Gwinner *et al*. (1990), as traditional means of pest control will be over changed with increasing production and stored quantities all over the world, efforts are being made to introduce changes to be traditional storage system by the use of insecticidal dusts which are mixed with the produce.

Damage and losses in untreated and pesticide treated maize on farm in Zimbabwe were estimated and found out that there was reduction in weight loss and amount of grain saved by grain protestants (pesticides) can be significant and the benefits justified the experiment on the grain protestants particularly for the storage of hybrid cultivates of maize susceptible to insects (Giga *et al*., 1992). There are also several studies on varietal resistance of crops to storage pests.

Gwinner *et al.* (1990), came out with a finding that, a large number of high yielding varieties coming on the market in context with the green revolution have proved to be more susceptible to infestation by storage pests than the local varieties. Resistant varieties should therefore have priority in breeding programme.

2.6 THE USE OF BOTANICALS IN STORAGE

Botanical pesticides are agricultural pest management agents which are based on plant extracts. In modern times these have been used as alternatives to synthetic chemicals in organic pest management. In an attempt to substitute unsustainable industrial pesticides with something more in line with organic agriculture, recent scientific research has turned to the biochemical properties of plants as a possible alternative to conventional chemical pesticides (Abate *et al*., 2000).

However, the practice of using plants and their extracts for pest management in agriculture have a long history among traditional farming peoples throughout the world. This also holds true with indigenous farming technique in Africa, the continent being home to some of the oldest continuing cultures on Earth (Abate *et al*., 2000).

In regard to the small scale farmer with limited economic resources, botanical pesticides seem to offer several benefits besides being an environmentally friendly pest management strategy. Ideally, botanical pesticides are locally available lowcost, non-toxic or at least less toxic and non-persistent in the environment (Ekbergzas, 2005).

Isman (2006) also reported pesticidal properties in Tephrosia a leguminous plant found both growing wild and in cultivation. The plant contains rotenone one of themain active compounds in Tephrosia based pesticides. The plant is very potent and toxic to aquatic life. Again, Pyrethrum an extract of *Tanacetum cineratiaefolium*is one of the world's most common plant derived pesticides for storage (Isman, 2006).

2.6.1Neemand Neem Products

Neem (*Azadirachta indica*) which belong to the family Meliaceae grows in arid and nutrient deficient soil and is a fast growing source of fuel wood. It has many commercially exploitable by-products and environmentally beneficial attributes. Although in Asia neem leaves are often used as fodder, the ecotype in West-Africa is ignored by cattle, sheep and even goats which make it easy to establish (Ayensu, 1980). The main use of neem is mostly for medicinal purpose, with few farmers using it for crop protection (Webster and Wilson, 1981).

Research conducted by the National Research Council in 1992 showed that azadirachtin, the active component of neem disrupts the metamorphosis of insect larvae. Gholz (1987) and Ayensu (1980) in independent works reported that, the seeds and leaves of neem contain chemicals which can drive away or kill insects. Bill (1999) also working on neem reported that neem can be used to repel ticks. Neem is also known to acts as feeding deterrent in insects (Warthen, 1979). Schaver and Schmutterer (1981) indicated that, various aphid species were sensitive to neem kernelextracts applied to the host plants through spraying or watering. They further reported that non-viable nymphs were produced after neem treatment and other nymph died due to difficulties during the molt. Schluter (1981) reported that neem extracts applied on insects made them black due to the presents of melanin. Schulz (1981) working on female locusts treated with neem extracts rendered them unable to reproduce. Kraus *et al.*(1981) indicated that, neem extracts have anti-feeding and growth disrupting properties.

Neem seed extracts are very effective in the control of many insects' pests. Unlike most of the presents insecticides available on the market, these extracts are non-poisonous to man and animals (Radwanski, 1977). Investigation into insecticidal properties of neem seed extracts were found to have active isolate which exhibit gustatory repellency (Pradhan and Jotwani, 1971). The ground seed contain more azadirachtin than the leaf and is used in India as an anti-helmitic. In a report of Saxena (1983), neem was found to be highly effective in reducing the survival of a plant hopper. According to Ladd *et al*. (1978) neem seed kernel extracts have now be found to act as feeding inhibitors for several insect species. Hoody (1986), reported that neem acts as a repellent.

According to National Research Council (1992) Indians have traditionally crushed neem seeds and rubbed them into open wounds on cattle to eliminate maggot. Leuschner (1972) stated that, crude metabolic extracts of neem seeds had growth regulating effects on coffee bugs. Zanno (1974) confirmed that azadirachtin the active ingredient of neem have deterrent properties and growth disruptant effects on insects. Redfern*et al*. (1979) and Saxena and Pathak (1977) reported molting inhibition and finally death when nymphs were treated with azadirchtin. Report from Goyal*et al.* (1971) confirmed that the extracts from the neem tree have been tested and found to deter feeding by a large number of cutting and chewing insect types.

The extracts of seed kernels of neem when incorporated into diet or applied to plant leaves adversely affected the growth and development of a number of insect pest species. According to Morgan and Thornton (1973) neem seed appear to be the richest potent source of plant chemicals among the array of plants with pesticidal properties neem stands out for use as pesticides in terms of economic feasibility for the resource poor farmers in developing countries. The special qualities of neem such as drought tolerance, rapid growth and ability to thrive on marginal soils increase the advantages of the use of neem (Adhikary, 1980). Similarly, Sowunmi and Akinusi (1983) protected maize seeds from attack by weevils using 1% and 2% neem kernel powder Ogunwolu and Odunlami (1996) also protected cowpea seeds for five months with neem seed powder.

Iubijaro(1983) and Yusuf *et al*. (1998) also reported that, neem seed powder reduced ovipositon and inhibition of F1 progeny emergence of maize weevils. The bioactivity of crude or commercial, pesticide from the seeds, twigs and stem barks of neem trees against over 700 pest and disease pathogens has been documented (Finar, 1986; Hellpap and Dryer, 1995). According to Mohammed (2005) brown blotch disease of cowpea was significantly reduced from 3.6 to 2.1 severity index with no scorching observed as a result of application of neem leaf extract. According to Akou-Edi (1984) neem seed powder and oils are effective in repelling and killing maize weevils.

2.6.2 Importance and Uses of Citrus Peel Powder

Citrus belong to the family Rutacea (Ceiba-Geigy, 1975) although the history of its cultivation shows that it must have originated from South-Eastern Asia. The crop is an aromatic, broad-leaved, evergreen tree native to tropical and subtropical regions, varying from 3-5m tall for lime and up to 10m for grapefruit cultivars. It does well in warm climates where there are suitable soils which are slightly acidic (Karikari, 1971) and have sufficient moisture to sustain the tree (Ceiba-Geigy, 1975). The fruit is a berry with leathery pericanp, which has numerous oil sacs in its tissue (Rice *et al*., 1993). Apart from the export of the fruits and juice for vitamin "C" flowers, leaves and stems of all species of citrus contain several essential oils which are important on the international market (Leslie, 1957.)

According to Don-Predro (1985) cowpea treated with powder of citrus peels was able to control *Callosobruchus maculates* (F) exposed to it. Tripathi *et al*. (2003) also stated that, essential oil derived from orange peels is known to have toxic seeding deterrent and poor development effects on larger grain borer, rice weevils and red floor beetle. The orange peel oil has also been report to have toxicity towards *Culex pipiens* according to Mwaiko and Savael (1992) and cowpea weevils by El-Sayed and Abdel-Razak, (1991).

Furthermore, Weinzierl and Henn (1992) reported that, orange peel oil and powder has fumigant action against fleas. Karr and Coats (1988) also stated that, orange peel powder and oil has fumigant action against house hold insects and rice weevils. Sharaby (1988) also reported that orange peel oil have toxic effect on weevils due to d-limonene. Belmain and Stevenson (2001) also reported that effective use of citrus peel powder, against legume pests. Similarly, Levinson *et al*. (2003) also reported that, orange peel oil at 1ml suppressed ovipasition of mediterianin fruit fly. Keita *et al.*(2001) reported that, the mode of the action of fumigant toxicity of essential oil against insects might be the inhibition of acetylcholinesterase. Lee *et al*. (2003) also reported fumigant action of orange peel oil against weevils. Odeneyi *et al*. (2000) also put it that, citrus peel powder caused mortality of weevils. Owoade (2008) also confirmed that the use of the powder could have resulted to death in the tendency of the powder to block the spiracle of insect's thus impairing respiration leading to the death of insects. Okonkwo and Okoye (1996) noted that the powder inhibited adult emergence of maize weevils. It was also confirmed by Onu and Sulyman, (1997) that the plant volatile essential oils of fruits peels of some citrus species have insecticidal properties against stored grains insect pests. Experiment conducted by Intekhab and Aslam (2009) confirmed that, sweet orange is a medicinal plant prescribed as traditional medicine to treat diverse illness. Han (1998) confirmed through an experiment that sweet orange peel has also been used as insect repellent, antibacterial and larvicide. According to Omomouwajo *et al*. (2005) put it that essential oil of citrus also has fumigant toxicity against mosquitoes.

2.6.3 Importance and Uses of Dry Lemongrass Powder

Lemongrass (*Cymbopogon citratus*) is a genus of about 55 species of grasses. It is a native to warm temperate and tropical regions of the oil world and Oceania. It is found in many parts of Ghana. It is mainly grown as an ornamental plant. However, lemongrass has many other uses such as a beverage crop use in herbal tea because of its sharp lemon flavour; as a perfume in soaps and as medicine to treat various health ailments, including acne athlete`s foot, flatulence, muscle aches and scabies (Athens, 2002).

Furthermore, Schaneberg and Khan (2002) revealed that bioactivity studies have shown that the various components of this essential oil contain antimicrobial, antifungal, antibacterial and mosquito repellent properties. Natural Resources Industries (NRI) (2001) also indicated that citral isolated from the lemongrass is used in the manufacturing of vitamin `A` because of those desirable attributes, lemongrass oil is of great use and value in the agriculture sector especially for the protection of stored agricultural products, such as the staple food crop, maize. According to Ong *et al*. (1998) citral in the lemongrass was able to kill larger grain borer. Kamanula *et al*. (2002) confirmed that lemongrass was used to control larger grain borer in storage. Tripeth *et al*. (2001) indicated that toxicity value of lemongrass on larger grain borer was due to linalool it contains. Phillips *et al*. (1995) also demonstrated that linallol, active ingredient of lemongrass was effective against larger grain borer.

2.7 MAIZE WEEVIL

The maize weevil is distributed in tropical environments but becoming established in temperate environments where it was reported in Ontario, Canada.The maize weevil is commonly associated with feeding on corn, rice and other raw or processed cereals. It infests standing crops before the harvest. The maize weevil is closely related to the rice weevils (*Meikle et al*., 1999).

Figure 2.2: Maize Weevil

Source: Aggie- horticulture.tamu.Edu, 2013

2.7.1 Life Cycle of Weevil

The complete development time for the life cycle of these weevils averages 36 days. The female maize weevil chews through the surface of the grain, creating a hole. She then deposits a small oral white egg and covers the hole as the ovipositor is removed, with a waxy secretion that creates a plug (Maceljski and Korunic, 1973). The plug quickly hardens, and leaves a small raised area on the seed surface. This provides the only visible evidence that the kernel is infested. Only one egg is laid on inside of each grain, a white, legless grub. It remains inside and begins feeding on the grain. The larvae will pupate while inside the grain, then chew a circular exit hole (Proctor, 1971) and emerge as an adult weevil. A single female's may laid between 300 to 400 eggs during her life time. Adults can live for 5 to 8 months (Peng *et al.*, 2003).

When the adults emerge, the females move to a high surface and release sex pheromones to attract males.

2.7.2 Description of the Maize Weevil

The maize weevil has a length of 2.5mm to 4mm (Proctor 1971). This small brown weevil has four reddish brown spots on the wing covers (elytra). It has a long, thin snout and elborved (antennae) (Maceljski and Korunic, 1973). Maize weevil appears similar to the rice weevil, but has more clearly marked spots on the wing covers and is somewhat larger (Peng*et al*., 2003).

2.7.3 Damage Caused By the Maize Weevil

Weevils are classified among the most destructive storage pests. The feeding habits of these pests are responsible for deterioration in the nutrient quality of maize and contamination of the interior content by producing harmful compounds and allergens (Rajenedran and Parvean, 2005). The activities of these pests, changes in ecological factors like variations in temperature and humidity favours fungal growth on stored maize (Effiong and Sanni, 2009). The most common fungi involved belong to the Aspergillus and Penicillum species. The moulds are responsible for reduction in nutritional value by enzymatic digestion, producing unpleasant flavours and appearance, making feed lumps and reducing palatability of poorly stored maize (Lim *et al*., 2008). Both weevil infestation and mould growth caused considerable increase in the moisture content of stored maize grains, with moulds having greater effect. The increase in moisture content dilutes the dry mater yields of maize grains stored locally. Both weevil infestation and mould growth increased organic matter content, with weevil. Infestation having greater effects than moulds this also implied that more inorganic or mineral composition of the grains was probable lost due to pest infestation (Barney *et al*., 1991). Pest infestation had a large effect on depleting the crude lipid content of grains during storage. According to FAO (1994) moulds usually attack grains following primary weevil infestation. Furthermore, when weevils feed on grain, they produce heat and moisture (Youdeowei and Service, 1983) which alters the micro environment of the infested grains leading to leaching away of mineral elements. Weevil infestation reduces the protein content of the maize grains.

Figure 2.3: Damage Caused By the Maize Weevil

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION OF THE STUDY AREA

The experiment was conducted in the laboratory of Mampong College of Teacher Education, Mampong in the Ashanti Region.

3.2 SOURCE OF THE EXPERIMENTAL MATERIALS

Dried Obaatanpa maize was obtained from the Grains Development Board, Kumasi, Ashanti Region. Neem seeds were obtained from the Savanna Agricultural Research Institute (SARI) in Tamale, Northern Region. Orange peels were collected from an orange seller in Mampong in Ashanti Region. Fresh and matured leaf blades of lemongrass were also obtained from Mampong.

3.3 PREPARATION OF PLANT POWDER EXTRACTS

3.3.1 Orange Peel Powder

Fresh peels of *Citrus sinensis* of 5kilograms were dried under shade. The dried peels were pounded into powder using mortar and pestle. The powder was then sieved using a wire mesh of size 0.2mm to obtain a fine powder. The active ingredient found in citrus and believe to be effective in controlling insect is citric acid.

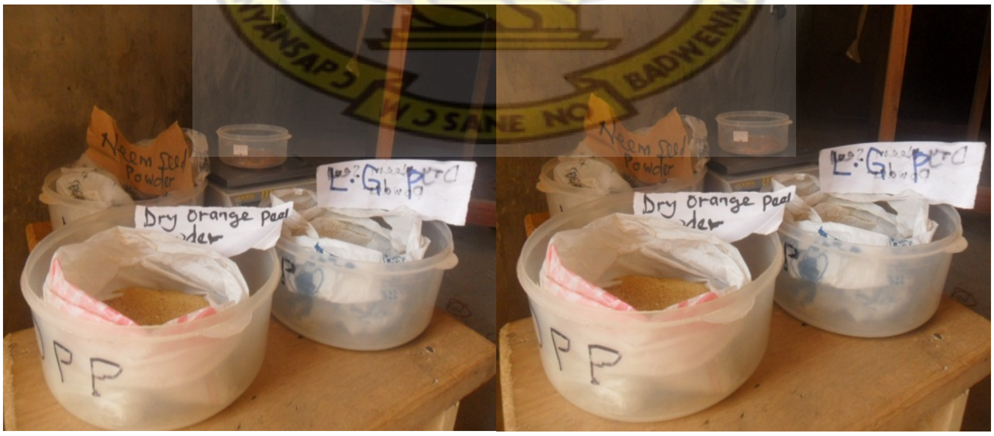
3.3.2 Neem Seed Powder

Ripe neem fruits of 5kilograms were de-pulped after which drying was done under shade. Dry seeds were pounded into powder using a mortar and pestle. The powder was sieved using a wire mesh of size 0.2 mm to obtain a fine powder. The main active ingredients found in neem are azadirachtin and limonoids.

3.4.3 Lemongrass Powder

Five kilograms of fresh leaves of the lemongrass were air-dried under ambient conditions until it was crispy. The dried leaves were pounded into powder using a mortar and pestle. The powder was sieved using a wire mesh of size 0.2 mm to obtain a fine powder. The active ingredients found were citronella, citronellol, myrcene and linalool

Figure 3.1: Dry Plant Extracts Powders

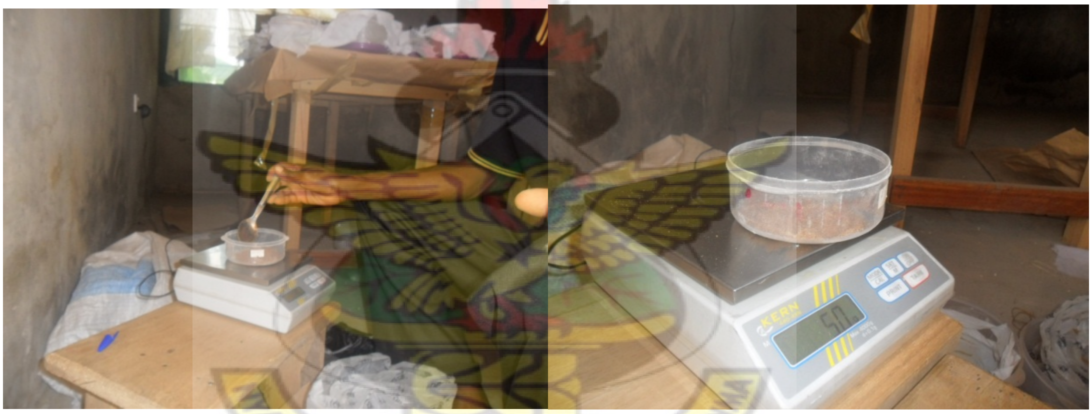


Source: Experimental Set-Up

3.4 PRE-TESTING OF PLANT POWDER EXTRACTS

Pretesting of the three plant powders extract was conducted for two weeks to see the efficacy of the powders produced. Different amount of the powder, thus, 5g, 10g, 15g, 20g, 25g, and 30g were measured using an electronic balance scale and were separately introduced into small plastic containers. Thirty (30) healthy maize weevils were introduced into each container after which it was shaken to get the powder unto the weevils. These containers were then covered with a muslin cloth to facilitate proper aeration and prevent entry of other insects. Observation was done daily.

Figure 3.2: Dosage of Plant Extracts



Source: Experimental Set- Up

3.5 EXPERIMENTAL DESIGNS

A 4x6 factorial in Complete Randomized Design was used (CRD) for the experiment. Each treatment was replicated three (3) times. In all, there were 24 different treatment combinations used in the experiment

3.6 TREATMENTS

Four (4) different plant powder extracts included orange-peel powder, lemongrass powder, neem seed powder and a control where no plant powder was applied to the grains. For the dosage of powder, 5g, 10g, 15g, 20g, 25g, and 30g, were applied to 500 grains.

3.7 APPLICATION OF TREATMENTS

Five hundred (500) grains of maize were placed in small plastic container. The different amount of each plant powder extract (5g, 10g, 15g, 20g, 25g, and 30g) was applied to each container. Thirty healthy (30) maize weevils were introduced into each container. The mixture was thoroughly mixed and then covered with muslin cloth. The setup was stored for 8 weeks and observation was done weekly.

Figure 3.3: Applications of Treatment

Source: Experimental set- up

3.8 PARAMETERS STUDIED

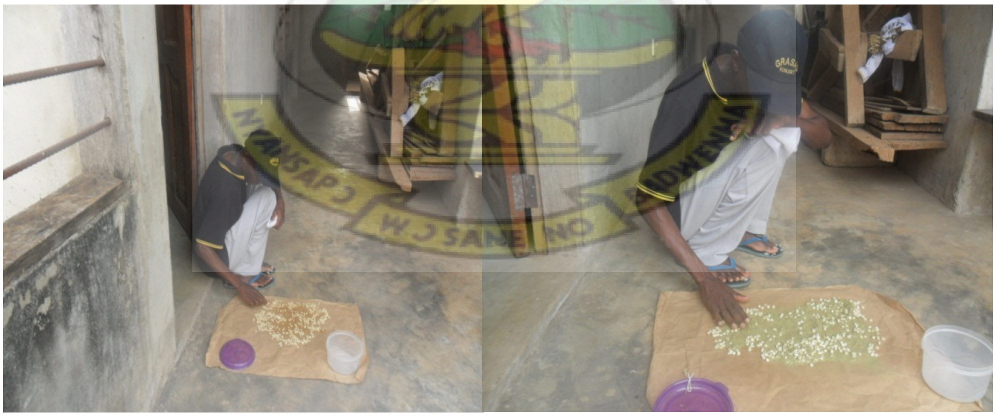
3.8.1 Weevil Survival

The number of weevils alive were counted and recorded. This was done by observing and counting weevils that were alive at weekly. The survived weevil was estimated at the end of the storage period and was expressed as a percentage.

3.8.2 Weevil Mortality (%)

The number of dead weevils were counted and recorded. This was done observing and counting dead weevils at weekly. Weevil mortality was determined at the end of the storage period and was expressed as a percentage.

Figure 3.4: Counting dead Weevil



Source: Experimental set- up

3.8.3 Grain Damage

Weevil damage was assessed at the end of the storage period. The number of grains with holes was counted as damaged through weevil feeding. Grain damage was expressed as a proportion of the total number of seeds. (Adedire and Ajayi, 1996).

$$GrainDamage(\%) = \frac{Number\ of\ treated\ grains\ wh\ holes}{Totalnumberof grains} x\ 100$$

3.8.4 Weight Loss (%)

Monthly weight loss in each treatment and control was determined from 100g batches of grains in each container as follows: Odeyemi and Daramola (2000)

$$\text{Percent weight loss} = \frac{(Wu \times Nd) - (Wd \times Nu) \times 100}{Wu(Nd + Nu)}$$

Where;

Wu = Weight of undamaged grains

Nu = Number of undamaged grains

Wd = Weight of damaged grains

Nd = Number of damaged grains

3.8 DATA ANALYSIS

The data collected were subjected to Analysis of Variance (ANOVA) using GenSTATversion 9. Means were separated using Lsd (5%).The count data were transformed using square root transformation [√(x+1)] in order to stabilize the variance, where x represent any number.

CHAPTER FOUR

4.0 RESULTS

Table 1: Percentage weevil mortality of maize grains treated with varying dosages of plant powder extracts

Plant extract	Percentage weevil mortality						
	weight of plant extract						
	5g	10g	15g	20g	25g	30g	Mean
Citrus	7.03 (48.57)	8.21 (66.51)	8.85 (77.3)	9.04 (80.63)	9.21 (83.81)	9.30 (85.4)	8.61 (73.7)
Lemongrass	7.87 (61.11)	8.53 (71.75)	8.83 (76.98)	9.09 (81.59)	9.14 (82.54)	9.24 (84.29)	8.78 (76.38)
Neem	8.25 (67.14)	8.84 (77.14)	9.11 (82.06)	9.29 (85.4)	9.41 (87.62)	9.46 (88.57)	9.06 (81.32)
Control	2.85 (7.14)	2.31 (4.44)	2.51 (5.4)	2.28 (4.29)	1.36 (1.11)	1.55 (1.59)	2.14 (3.99)
Mean	6.5 (45.99)	6.97 (54.96)	7.33 (60.44)	7.42 (62.98)	7.28 (63.77)	7.39 (64.96)	

Lsd (5%) - Weight of plant extract (W) = 0.24

Lsd (5%) - Plant extract (E) = 0.19

Lsd (5%) - WxE = 0.48

CV (%) = 7.5

There were significant differences ($p<0.05$) in the percentage weevil mortality among treatments (Appendix 1). A mean percentage weevil mortality of 9.06 (81.32) was recorded for Neem which was the highest, followed by lemongrass, citrus and control with means of 8.78 (76.38), 8.61 (73.7) and 2.14 (3.99), respectively. Among the citrus powders, 30g application had the highest percentage mortality of 9.30 (85.4) and 5g application had the lowest percentage weevil mortality of 7.03 (48.57). For the Lemongrass powder applications, 5g had the least percentage mortality of 7.87 (61.11) and 30g application had the highest with a percentage mortality of 9.24 (84.29). Neem powder application at 30g had the highest percentage application of 9.46 (88.57) and 5g application was the least with percentage mortality of 8.25 (67.14). The mean of control showed the lowest percentage mortality of 2.14 (3.99) among all the treatments (Table 1).

Table 2: Percentage survived weevils among maize grains treated with different dosages of plant powder extract

	Percentage survived weevils						
	Weight of plant extract powder						
Plant extract	5g	10g	15g	20g	25g	30g	Mean
Citrus	4.63 (51.43)	4.20 (33.49)	3.81 (22.7)	3.66 (19.37)	3.47 (16.19)	3.37 (14.6)	3.86 (26.30)
Lemongrass	4.34 (38.89)	4.03 (28.25)	3.83 (23.02)	3.60 (18.41)	3.55 (17.46)	3.45 (15.71)	3.8 (23.62)
Neem	4.18 (32.86)	3.82 (22.86)	3.58 (17.94)	3.36 (14.6)	3.17 (12.38)	3.11 (11.43)	3.54 (18.68)
Control	5.22 (92.86)	5.25 (95.56)	5.24 (94.6)	5.25 (95.71)	5.29 (98.89)	5.28 (98.41)	5.26 (96.01)
Mean	4.59 (54.01)	4.33 (45.04)	4.11 (39.56)	3.97 (37.02)	3.87 (36.23)	3.8 (35.04)	

Lsd (5%) - Weight of plant extract (W) = 0.11

Lsd (5%) - Plant extract (E) = 0.09

Lsd (5%) - WxE = 0.23

CV (%) = 3.4

There were significant differences ($p<0.05$) between the interaction of weight of plant powder extract and different plant powders (Appendix 2) for the percentage survived weevils. The lowest percentage survived weevils of 3.11 (11.43) was recorded for neem powder at 30g and the highest percentage survived weevils was recorded for control with a mean of 5.26 (96.01). Among, citrus powder application, percentage survived weevils grain was highest for 5g citrus powder and lowest for 30g citrus power with a value of 4.63 (51.43) and 3.37 (14.6), respectively. Lemon grass powder at 5g produced the highest percentage survived weevils of 4.34 (38.89) and at 30 g resulted in the lowest percentage survived weevils of 3.45 (15.71). Among the neem powder treatments, the highest percentage survived weevils of 4.18 (32.86) was recorded for Neem at 5g and the lowest percentage survived weevils of 3.11 (11.43) was recorded for Neem at 30g. The highest mean percentage survived weevils of 5.26 (96.01) was recorded for control, this was followed by citrus, lemongrass and neem with a mean of 3.86 (26.30), 3.8 (23.62) and 3.54 (18.68), respectively. Generally, the highest mean percentage survived weevils of 4.59 (54.01) was recorded for the 5g plant powders, followed by 10g, 15g, 20g, 25 and 30g with means of 4.33 (45.04), 4.11 (39.56), 3.97 (37.02), 3.87 (36.23) and 3.8 (35.04), respectively (Table 2).

Table 3: Effect of weevil infestation on percentage damage of maize grain treated with plant extracts at different concentrations

	Percentage damaged grain						
	Weight of plant powder						
Plant extract	5g	10g	15g	20g	25g	30g	Mean
Citrus	1.43 (1.06)	1.33 (0.78)	1.36 (0.86)	1.23 (0.52)	1.16 (0.35)	1.14 (0.30)	1.27 (0.65)
Lemongrass	1.4 (0.95)	1.40 (0.95)	1.14 (0.31)	1.17 (0.36)	1.09 (0.2)	1.09 (0.18)	1.21 (0.49)
Neem	1.17 (0.37)	1.11 (0.23)	1.09 (0.2)	1.06 (0.12)	1.03 (0.07)	1 (0)	1.08 (0.17)
Control	1.79 (2.2)	1.74 (2.04)	1.67 (1.79)	1.72 (1.96)	1.87 (2.50)	1.82 (2.30)	1.77 (2.13)
Mean	1.45 (1.15)	1.39 (1)	1.31 (0.79)	1.29 (0.74)	1.29 (0.78)	1.26 (0.70)	

Lsd (5%) - Weight of plant extract (W) = 0.08

Lsd (5%) - Plant extract (E) = 0.07

Lsd (5%) - WxE = 0.16

CV (%) = 7.5

There were significant differences ($p<0.05$) between the interaction of weight of plant powder extract and different plant powders (Appendix 3) for the percentage damage grain. The lowest percentage damage of 1 (0) was recorded for neem powder at 30g and the highest percentage damage was recorded for control with a mean of 1.77 (2.13). Percentage damaged grain was highest for 5g citrus powder and lowest for 30g citrus power with a value of 1.43 (1.06) and 1.14 (0.30), respectively. Lemon grass powder at 5g and 10g produced the highest percentage damage of 1.4 (0.95) each and at 30 g resulted in the lowest percentage damage of 1.21 (0.49). Among the neem powder treatments, the highest percentage damage of 1.17 (0.37) was recorded for Neem at 5g and the lowest percentage damage of 1 (0) was recorded for Neem at 30g. The highest mean percentage damage of 1.77 (2.13) was recorded for control, this was followed by citrus, lemongrass and neem with a mean of 1.27 (0.65), 1.21 (0.49) and 1.08 (0.17), respectively. Generally, the highest mean percentage damage of 1.45 (1.15) was recorded for the 5g plant powders, followed by 10g, 15g, 20g, 25 and 30g with means of 1.39 (1), 1.31 (0.79), 1.29 (0.74), 1.29 (0.78) and 1.26 (0.70), respectively (Table 3).

Table 4: Percentage weight loss of maize grains treated with varying dosages of plant powder extracts

	Percentage weight loss						
	Weight of plant extract powder						
Plant extract	5g	10g	15g	20g	25g	30g	Mean
Citrus	7	6.8	6.74	6.69	6.66	6.52	6.74
Lemongrass	5.9	5.8	5.72	5.7	5.68	5.38	5.7
Neem	3.9	3.8	3.75	3.69	3.43	3.28	3.64
Control	9	8.49	8.4	8.2	8.2	8.1	8.4
Mean	6.44	6.22	6.16	6.07	6	5.82	

Lsd (5%) - Weight of plant extract (W) = 0.03

Lsd (5%) - Plant extract (E) = 0.02

Lsd (5%) - WxE = 0.05

CV (%) = 0.5

There were significant differences among percentage weight loss of the various treatments (Appendix 4). The mean percentage weight loss was highest for control (8.4), followed by citrus (6.74), lemongrass (5.7) and neem (3.64).

With regards to the weight of plant powder of citrus, 5g had the highest weight loss and the lowest weight loss was recorded for 30g. The highest weight loss of 5.9 was recorded for lemongrass at 5g and the lowest of 5.38 was recorded for lemongrass at 30g. Also, among the neem powders, the highest weight loss was recorded for 5g and the lowest for 30g with percentage weight loss values of 3.9 and 3.64, respectively. Generally, 5g plant powders had the percentage highest weight loss and 30g plant powders had the lowest percentage weight loss with means of 6.44 and 5.82, respectively (Table 4).

Table 5: Correlation of percentage weevil mortality, damaged grains, weight loss and survived weevils

	Weevil mortality (%)	Damaged grains (%)	Weight loss (%)	Survived weevils (%)
Weevil mortality (%)	1			
Damaged grains (%)	-0.89	1		
Weight loss (%)	-0.763	0.83	1	
Survived weevils (%)	-0.99	0.91	0.78	1

Weevil mortality had a strong negative correlation with percentage damaged grain, percentage weight loss and number of surviving weevils with a correlation coefficient of -0.89, -0.76 and -0.99. Percentage damaged grain was strongly correlated with percentage weight loss and percentage survived weevils with a correlation coefficient of 0.83 and 0.91, respectively. There was a strong positive correlation of 0.78 between percentage weight loss and percentage survived weevils (Table 5).

CHAPTER FIVE

5.0 DISCUSSION

5.1 WEEVIL SURVIVAL

The study showed that the maize grains treated with the plant extracted powder recorded low weevil survival. Out of the three plant extract used, maize seeds treated with neem seed powder had less weevils surviving compared to those seeds treated with lemongrass and citrus peel powders. The control treatment as was expected had almost all the weevils surviving since there was no application of the plant powder extract.

On the other hand, plant powder dosages 15g and above was more effective in controlling the weevils than lower dosages (5g and 10g). This means that the high dosages of plant powder extract use were able to protect the grains and disrupt the feeding activities of the weevils hence the small number weevils surviving as seen in the three plant extracts used.

It was observed that increasing the dosage of lemongrass powder to 20g and above completely killed the weevils. Citrus peel powder was effective with dosages 15g and above whereas in neem seed powder, the effectiveness of the powder was seen when the dosage was increased from 10g and above. This shows that using very high dosages of the plant powder extract was an effective way of controlling the maize weevils in storage.

Bill (1999) reported that there were about 2000 species of plants which produce chemical substances that act as repellent, poisonous, phagos restrainer, ovicide and can affect the insects' hormonal system.

Appert, (1987) reported that the leaves of neem tree garlic, dry peel of citrus, dry lemongrass leaves are used for storing maize by farmers who believe that these plants could deter storage insects.

Sowunmi and Akinusi (1983) indicated that maize seeds could be protected from attack by weevils using 1% and 2% neem kernel powder. Ogunwolu and Odunlami (1996) on the other hand protected cowpea seeds for five months with neem seed powder.

Tripathi *et al*. (2003) also reported that the essential oil derived from orange peels is known to have toxic seed deterrent and poor development effects on larger grain borer, rice weevils and red floor beetle.

Schaneberg and Khan (2002) working on lemongrass bioactivity studies, showed that the essential oil extracted had antimicrobial, antifungal, antibacterial and insect repellent properties. Ong *et al*. (1998) in their work found that the active component found in lemongrass, citralol was effective in killing larger grain borer.

It can therefore be concluded that the three organic plant extract used for the study contains active substances that were effective in killing the weevils, thereby reducing their population throughout the storage period.

5.2 WEEVIL MORTALITY

Weevil mortality was high in seeds treated with the plant extract than in the control as was seen in the study conducted. Maize seeds treated with neem seed powder recorded high weevil mortality than seeds treated by lemongrass and citrus peel powders. The control treatment had more weevils surviving than dead as was expected.

Higher plant dosages on the other hand were effective in controlling the weevils than lower dosage (5g). It was observed from the experiment that high dosages of the plant extract resulted in high weevil mortality. Trends seen in weevil mortality were inversely correlated with weevil survival as high weevil mortality resulted from low weevil survival and vice versa. It was also observed that increasing the dosage of lemongrass powder from 20g and above completely killed the weevils.

Citrus peel powder was effective at 15g and above of the powder applied. Neem seed powder was even highly effective at dosages as low as 10g and above. Hence, it can be said that the higher the dosage applied, the more effective it becomes, thus the higher mortality seen in the weevil population.

Webster and Wilson (1981) reported that neem is mostly used for medicinal purpose with few farmers using it for crop protection. Gholz (1987) and Ayensu (1980) also reported that both the seeds and leaves of neem contain chemicals which can drive away or kill insects.

The National Research Council (1992) showed that azadirachtin, the active component of neem disrupts the metamorphosis of insect larvae. Akou-Edi (1984) indicated that neem seed powder and oils were effective in repelling and killing maize weevils.

Orange peel oil and powder had been reported to have fumigant action against fleas (Weinzierl and Henn, 1992), house hold insects and rice weevils (Karr and Coats, 1988).Lee *et al*. (2003) reported that orange peel oil had fumigant action against weevils.

Sharaby (1988) also reported that orange peel oil have toxic effect on weevils due to d-limonene. Onu and Sulyman, (1997) pointed out that plant volatile essential oils of some citrus species peels had insecticidal properties against stored grains insect pests. Belmain and Stevenson (2001) on the other hand found out that citrus peel powder was effective against legume pests.

Phillips *et al*. (1995) also demonstrated that linallol, the active ingredient of lemongrass was effective against larger grain borer. Kamanula *et al*. (2002) concluded that lemongrass could be used in controlling the larger grain borer in storage.

5.3 GRAIN DAMAGE AND WEIGHT LOSS

In terms of grain damage, minimal damage from weevils was recorded in the grains treated with the three plant powder extracts. Grain damage was very low in seeds treated with neem seeds powder. The low values recorded can be attributed to the high mortality of the weevils to the plant extract application since low numbers of weevils are ineffective in causing substantial damage in storage. Casey (1994) reported that where there was a heavy pest infestation in stored maize, weight loss as much as 30-40% could be recorded.

The higher dosage of the plant powder may also have resulted in the low grain damage seen. The higher the dosage (10g to 30g), the lower the grain damage (1.7% to 1.2%) as compared to the 5g of the powder applied (2.1% grain damage).

Since grain damage and weight loss are related, the higher the grain damage, the higher the grain loss and verse vice. It can be inferred from the results that the low weight loss observed can be attributed to the low grain damage recorded. This is because, as the number of alive weevils reduces in the grains in storage, the amount of damage caused to the grains also reduces as there is less feeding. Hence the lower weight loss observed.

Ladd *et al*. (1978) reported that neem seed kernel extracts have been found to act as feeding inhibitors for several insect species.

Kraus *et al.* (1981) also reported that neem extracts have anti-feeding and growth disrupting properties. This could possibly explain why grain damage and weight loss recorded in grains treated with neem was very low.

The orange peel oil wastoxic to *Culex pipiens* (Mwaiko and Savael, 1992)and cowpea weevils (El-Sayed and Abdel-Razak, 1991). Odeneyi *et al*. (2000) indicated that application of citrus peel powder caused mortality of weevils. Owoade (2008) confirmed that the use of the powder could have resulted in death and the tendency of the powder to block the spiracle of the insects.

Tripeth *et al*. (2001) working on lemongrass found linalool, an active compound which was toxic to larger grain borer. This explains the low percentage of damaged grains recorded.

Thus the plant powders may have impaired respiration activity of the weevils leading to their death, hence the less damage and weight loss recorded in the treated seeds.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

The results showed that the tree plant powder extracts were more effective at higher dosage of 20g, 25g and 30g. It was also observed that the quality of the maize grains was better in grains stored with neem seed powder followed by lemongrass powder in that other. The three plant powder indicates that higher dosage is more efficient in management of pests. Again, when the plant powders were applied to maize grains in storage, there were significant reductions in maize damage and weight loss.

6.2 RECOMMENDATION

It is recommended that further studies should be conducted using higher dosages for long term storage.

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APPENDIX 1

Variate: percent_dead_weevils_T

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plant_extract	3	603.00655	201.00218	2399.23	<.001
weight_of_powder	5	7.57041	1.51408	18.07	<.001
plant_extract.weight_of_powder	15	15.63876	1.04258	12.44	<.001
Residual	48	4.02133	0.08378		
Total	71	630.23706			

APPENDIX 2

Variate: PERCENT_SURV_WEEVIL_T

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plant_extract	3	32.52598	10.84199	566.76	<.001
weight_of_powder	5	5.41210	1.08242	56.58	<.001
plant_extract.weight_of_powder	15	2.23694	0.14913	7.80	<.001
Residual	48	0.91823	0.01913		
Total	71	41.09324			

APPENDIX 3

Variate: Percentage_damaged_grains

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plant_extract	3	41.04439	13.68146	179.65	<.001
weight_of_powder	5	1.83012	0.36602	4.81	0.001
plant_extract.weight_of_powder	15	2.70316	0.18021	2.37	0.012
Residual	48	3.65551	0.07616		
Total	71	49.23319			

APPENDIX 4

Variate: PERCENT_WEIGHT_LOSS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
plant_extract	3	213.674206	71.224735	68284.70	<.001
weight_of_powder	5	2.693344	0.538669	516.43	<.001
plant_extract.weight_of_powder	15	0.501711	0.033447	32.07	<.001
Residual	48	0.050067	0.001043		
Total	71	216.919328			

EXPERIMENTAL SET-UP