KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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The Efficacy Of Ethanolic Root And Leaf Extract Of *Chromolaena Odorata* In Controlling *Sitophilus Zeamais* In Stored Maize

BY

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THE EFFICACY OF ETHANOLIC ROOT AND LEAF EXTRACT OF *CHROMOLAENA ODORATA* IN CONTROLLING *SITOPHILUS ZEAMAIS* IN STORED MAIZE

A thesis submitted to the school of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, as partial fulfillment of the requirement for the award of Master of Science, Crop Protection (Entomology) degree.

AMENGA DENIS ABUGRI

June 2011

DECLARATION

I hereby declare that this research work presented in this thesis is my own work and that, to the best of my Knowledge, it contains no material previously published by another person for the award of a degree in any other University, except where acknowledgement has been made in the text

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ABSTRACT

Sitophilus zeamais Motschulsky is among the important pests which attack stored maize. It is listed in addition to *Prostephanus truncatus* as the two most damaging species of maize in West Africa. In Ghana about 15% of maize grains harvested is lost to *S. zeamais*. A laboratory study was conducted at the Entomology laboratory of the Faculty of Agriculture of Kwame Nkrumah University of Science and Technology, Kumasi, to determine the efficacy of *Chromolaena odorata* (L) R. M. King and H. Robintson ethanolic root and leaf extract for *Sitophilus zeamais* control. The bioactivity of these extracts was assessed under average laboratory conditions of 26 °C and relative humidity of 80%. The leaf and root extracts at four dosage levels (0.0, 2.5, 5.0 and 10.0 ml) were mixed with 50 g of disinfested MAMABA maize variety in 750 ml plastic containers and the effect on insect mortality, progeny production and grain damage were assessed. The repellent action of these extracts at 0.0, 5.0, 10.0, 20.0 ml on *Sitophilus zeamais* was also evaluated. The leaf extract showed significant difference between 10.0 and 5.0 ml on one hand and 2.5 and control on the other hand. The 10.0 ml that recorded the highest mortality could inflict only as low as 8.75% after 7 days. There was no significant difference between the different levels of the root extract on mortality. The maize grain treated with the various dosage levels of the leaf extract showed much promise by significantly reducing the number of progeny produced by *S. zeamais* as compared with the control. Grain weight loss in leaf extract treated grains was dose dependent ranging from 3.51% in the highest dose to 11.34% in the control with significant differences. There were no significant differences in progeny production and grain weight loss with root extract treatments. Both the leaf and root extracts were not repellent to the weevil.

The correlation between grain weight loss and progeny production was very strongly positively correlated in the leaf extract effect.

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DEDICATION

This work is dedicated to my family especially, my wife Elizabeth Anobiga and my daughters Amenga Grace Awinpiini, Amenga Lilian Awinimi and Amenga Princess Awin-yam. Their love, encouragement and support inspired me in all my endeavours.

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CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea mays* L. sp. *mays*), known as corn in some countries, is a major staple crop in Ghana. It is cultivated in all the 10 regions of the country with the Eastern Region being the largest producer In terms of production, maize ranks third only after roots and tubers and plantain (MOFA, 2001). The Ministry of Food and Agriculture (MOFA), (2007) reported that, in 2006 1.2 million Mt tons of maize was produced from 793,000 ha.

Maize has three possible uses: as food, as feed for livestock and as raw material for industry (Morris, 2001; FAO, 2007). As food, the whole grain, either mature or immature, may be consumed in a multitude of ways which vary from region to region or from one ethnic group to the other. It may be processed to give a relatively large number of intermediary products, such as maize grits of different particle size, maize meal, maize flour and flaking grits.

Despite its importance much of the harvest is lost to insect pests during storage. Between 20 – 40 % losses have been attributed to insect pests in the tropics, including Ghana (Hill and Waller, 1990, Nuepane, 1995). Insect infestation results in weight losses and quality deterioration which constitute a threat to food security especially in developing countries like Ghana **(**Rouanet, 1992).

Sitophilus zeamais Motschulsky is one of the most important insect pests that attack stored maize (Bhatia 1976; Warui *et al.*, 1990). It has been reported that about 15% of maize grains harvested in Ghana is lost to *S. zeamais* (Youdeowei and Service, 1986).

Current control practice for the pest relies on synthetic chemicals (Redlinger *et al.*, 1988). These chemicals are associated with evolution of resistant strains, destruction of natural enemies and non target species, turning innocuous species into pests and contamination of food (http://www.ias.ac.in). The residue of the chemicals on the grain also poses health hazard to consumers (Mabbett, 2007).

Current research focus in stored products protection includes the development of non-chemical technologies which may eliminate the use of insecticides and have economic and health benefits for applicators, consumers and the environment (Murdock *et al.*, 1997; Elhag, 2000; Talukder and Howse, 2000). The use of natural methods of protecting harvested crops from insect damage is not only gaining prominence (Golob *et al.*, 1999) but is also generating positive results (Elhag, 2000; Ogunleye *et al.*, 2003; Obeng-Ofori and Dankwa, 2004; Ogunleye, 2006).

It is against this background that this study was conducted to find out the efficacy of *Chromolaena odorata* (L) R. M. King and H. Robintson for *S. zeamais* management.

The specific objectives are:

- To determine the efficacy of alcoholic leaf and root extracts of *Chromolaena odorata* in controlling *S. zeamais.*

- To determine the bioactivity of these extracts on reproduction of *S. zeamais*
- To determine the repellency effect of these extracts on *S. zeamais* and
- To determine the effects of these extracts on the weight loss of stored maize.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize production trends

Maize is widely cultivated throughout the world. It is cultivated between latitudes 50º north and south of the equator and from sea level to 3600 m elevation, in cool and hot weathers, with variable growing cycles (Morris, 2001). A greater weight of maize is produced each year than any other grain. The Portuguese introduced maize to Equatorial Guinea and Congo, from where it has become the staple grain crop for much of Sub Saharan Africa. (http://www.satake.co.uk).

Among the important pests which attack stored maize are *Sitophilus zeamais* Motschulsky, *Tribolium castaneum* Herbst, *Sitotroga cereallela* Oliv. (Bhatia 1976; Warui *et al.,* 1990) and *Prostephanus truncates* Horn. However the two most damaging species for maize are the maize weevil *S. zeamais,* and the larger grain borer (LGB), *P. truncatus* (http://www.cimmyt.org).

In West Africa the dominant insect pest are the Larger Grain Borer (LGB), *P. truncatus* and the maize weevil, *S. zeamais* (Vowotor *et al.,* 2005). It has been reported that about 15% of maize grains harvested in Ghana is lost to *S. zeamais* (Youdeowei and Service, 1986).

Maize has been cultivated in Ghana for several hundred years. It soon established itself as an important food crop after been introduced in the late 16th century. Today, maize is Ghana's most important cereal crop and is grown by the vast majority of rural households (Morris *et al.,* 1999). Production is however concentrated in the Forest-Savanna transition zone comprising the Ashanti, Brong-Ahafo and Eastern Regions, mainly in the Ejura-

Sekyeredumasi-Techiman-Wenchi area considered as the maize belt of Ghana (GGDP, 1991). It accounts for 50% - 60% of the country's cereal production. Maize is the most researched food crop in Ghana. This has led to the availability of varieties that are adapted to the country's agro-ecological zones. Over 12 improved varieties were released from 1979 to 1998. The release of these improved varieties and their production technologies contributed significantly to food security and national economy. For example, maize production in Ghana increased from an average of 296,700 tons per year in 1978-79 to over 1 million tons per year in 1997-98 (i e. 20 years later) (http://www.csir.org. gh). In 2006, about 1.2 million tons representing an increase of 1.5% over the previous year was produced from about 793,000 ha of land (MoFA, 2007). Initially, open-pollinated varieties (including Abelehi, Obatampa, Okomasa, Dorke SR and Dodzi) were developed to suit the smallholder-farmer preferences. Recently, hybrid varieties of Quality Protein Maize such as *Cidaba, Mamaba* and *Dadaba* have been developed that suit industrial uses such as for brewing, starch production and specialised foods and feed formulations. These varieties mature within 90 to 120 days (http://www.gains.org.gh). New varieties have recently been released to meet the demands of consumers and industry. The varieties are *Golden jubilee*, *Aziga*, *Etuto-Pibi*, and *Akposoe* (http://www.csir.org.gh).

2.1.2 Soil and climatic requirement for maize production.

Maize, although is best adapted to well drained sandy loam to silty loam soils, can be grown under other diverse conditions as well (http://www.ficciagroindia.com), ranging from fairly coarse sand to the heaviest of clay (Kochnar, 1986). It can be grown

successfully in soils whose pH ranges from 5.5 to 7.5. Maize requires considerable moisture and warmth from germination to flowering. It is a warm weather plant. Minimum soil temperatures of 10 to 13°C are required for maize germination and seedling growth. The ideal temperature requirement for germination is from 16°C to 32°C (Rouanet 1987). According to Sprague and Dudley (1988), optimum germination and emergence occurs when temperatures reach 20 to 22°C.

Wallace and Bressman (1937) reported that maize usually emerges in 8 to 10 days at an average temperature of 16 to 18°C, but it takes longer (18 to 20 days) at 10 to 13°C.

If the soil is wet enough and at an average temperature of 21°C, emergence may occur in 5 to 6 days (Shaw and Newman,1991).

It grows from sea level to 3600 m above sea level. In America where the highest yields are obtained, yield may vary from 2.5 to 6 tons per acre depending on the soil and its cultivation. Yields above 7 tons per acre have often been recorded (http://www satake. co.uk).

2.2 Constrains to maize production

The maize plant is quite hardy and adaptable to harsh conditions. In addition, it is a highly diverse crop, offering ample scope for genetically enhancing its tolerance to constraining factors. This not withstanding, production has been affected by certain factors which have led to decreased yields and high post harvest losses. These limiting factors include both biological and physical factors. Relevant physical variables are temperature and precipitation (BFAP, 2007) together with other traditional inputs such as labour, seed, fertilizer and irrigation. The declining soil fertility and the limited use of nitrogenous fertilizers are major challenges for maize production in sub-Saharan Africa.

In addition, periodic drought caused by irregular rainfall distribution has made farming a very risky endeavour for millions of small scale farmers who rely on rainfall to water their crops. Drought reduces maize yields by an average of 15% each year in sub-Saharan Africa. This is equivalent to at least US$200 million in lost grain. (http://www.iita.org).

Biological factors limiting maize production are diseases and pests. An array of diseases plagues maize growing areas in sub-Saharan Africa. These include downy mildew, rust, leaf blight, stalk and ear rots, leaf spot, and maize streak virus. Weeds including the parasitic witch weed (*Striga*) are major pests in sub-Saharan Africa and cause estimated cereal grain losses up to US$7 billion per annum. This adversely affects the lives of about 300 million people (http://www.iita.org). Maize is also attacked by a wide range of insect pests both in the field and in storage (Neupane *et al.,* 1991). Insect pests, including stem and ear borers, armyworms, cutworms, grain moths, beetles, weevils, grain borers, rootworms, and white grubs are also a great threat to the production of maize in Africa. Among the insect pests which attack stored maize are the maize weevil (*S. zeamais*), Rust-red flour beetle *(Tribolium castaneum* Herbst), Angoumous grain moth (S*itotroga cerealella* Oliv.) (Warui *et al.*1990) and the larger grain borer, *Prostephanus truncatus Horn* (http://www.cimmyt.org). In West Africa the dominant insect pests are *Prostephanus truncatus* and *S. zeamais* (Vowotor *et al.,* 2005). Almost all the insect pests of stored grains have a remarkably high rate of multiplication and within one season, they may destroy the grain and also leave behind undesirable odours and flavours (Neupane *et al.,* 1991). In Ghana, about 15 % of harvested maize is destroyed by *S. zeamais* during storage (Youdeowei and Service 1986).

2.3 Description and Biology of *Sitophilus zeamais*

Sitophilus zeamais belongs to the order Coleoptera and family Curculionidae (Hill, 1987). It is a tiny weevil measuring 3 to 3.5 mm long and has a dull brown colour. The prothorax and elytra are densely pitted with rows of microscopic circular holes (Norman, 1955; Jones *et al*,., 1966).

Sitophilus zeamais is a strong flier when conditions are conducive. They have a characteristic snout or rostrum which projects from the front of the head. *S. zeamais* has a biting mouth part which is located at the tip of the rostrum, and a pair of elbowed, clubbed antennae located at the base (http://sgrl.csiro.au). The larva, which feeds in the grain, is a white, legless thick-bodied grub (Norman, 1955; Jones, 1966). Initial infestations of maize by the adult weevil occur in the field (Adedire and Lajide, 2003), as soon as it reaches the roasting ear stage. Ovipositor however, does not begin until the ear becomes firm. At this stage, the female weevil bores minute holes in the grain surface using its mouth part in which the eggs are deposited. One egg is laid in each hole at a time; the hole is sealed with a mucilaginous material secreted by the female. The eggs are white and oval in shape, measuring about 0.7 mm by 0.3 mm, and each female may deposit as many as 5 eggs per day with a total of about 100 to 450 during its life span (Donald and Mills 1985; http://sgrl.csiro.au).

The egg hatches in 4 to 9 days, depending on the temperature and humidity. The larval stage lasts for 15 to 40 days, depending on the environmental temperature and humidity. The grub is white in colour with a brown head and strong jaws. After hatching, the small legless larvae feed on the endosperm of the grain passing through a number of instar

stages gradually increasing in size. The mature larva is about 4 mm long. Pupation occurs within the grain, and the pupal stage lasts for 3 to 6 days (Haines, 1991; ttp://sgrl. csiro.au). The newly emerged adult remains in the grain for a few days before it leaves it (Hugh 1988). Donald and Mills (1985), showed that under optimum laboratory conditions of 31 ºC and 14 percent moisture, maize weevils take from 30 to 40 days to develop from egg to adult. The life cycle is completed in about five weeks at 30 ºC and 70% RH (Haines, 1991; http://www.kznhealth.gov.za: Wikipidia, http://en.wikipidia). Hugh (1988), in his study, demonstrated that the weevil is unable to survive at temperatures above 42 ºC. The adults live for five to eight months. The weevil has a wide range of hosts among the grains in storage and in warm climates also in the field. Some of these hosts include sorghum and rice (Norman, 1955), and wheat (Haines, 1991).

2.4 Pest status of *S. zeamais*

McFarlane (1990), stated that 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 may also vary between biotypes of the same insect species due to differences in the capacity to cause grain damage. In addition pest status may vary due to adaptations to other foodstuffs (Holloway, 1986).

Maize varietal characteristics have been reported to influence the preharvest infestation of maize cobs by *S. zeamais* (Floyd and Powell, 1958; Giles and Ashman, 1971; Schulten, 1976). Appert (1987) and Adebiri and Lajide (2003) observed that initial infestations of maize occur in the field just before harvest. However the extent of

infestation of the cobs at this stage is greatly affected by the degree of coverage of the cobs by the sheath leaves. Cultivars that produce sheathing leaves completely enclosing the entire cob are better protected against the weevil. Storage of cobs in the sheath, which does not significantly impair the grain drying rate in ventilated cribs, therefore reduces the status of *S. zeamais* as a pest and will be beneficial where weevils are the main threat (Dick, 1988). Even without the sheath, grains on the cob are considerably less susceptible to weevil attack than the shelled grains (Kossou *et al.*, 1992).

Larval development of grain weevils on stored grain and for that matter their status as pest depends on grain size (which is generally a varietal attribute) since the entire pre-adult live within one kernel.

2.5 Factors affecting development and control of *S. zeamais*

Factors affecting the development and control of insect pests have been comprehensively reviewed in "Grain storage techniques, Evolution and trends in developing countries", FAO Agricultural services bulleting No. 109 (FAO, 1994).

Firstly, the status of storage insect pests is affected in different ways by the moisture content of the grain. Many storage insects are able to multiply rapidly on well-dried grain, but lowering moisture content greatly reduces the spectrum of pest species. Grain dried to below 12% moisture content inhibits the development of most species and on exceptionally dry grain (<8% moisture content) the grain weevils, for example, are insignificant pests. At 14% moisture content of maize the attainment of pest status of *S. zeamais* is optimized.

Secondly, temperature and humidity exert considerable dramatic effect on insect development and population. The developmental limits of insects are more clearly

defined and generally applicable. With temperature, upper limits for development and survival vary to some extent between species. Grain borers are more resistant than grain weevils, but temperatures above 45°C are eventually fatal to all storage insects. At 50°C most species will die quite quickly, within a matter of hours (Evans, 1987).

For most storage insects, the optimal temperature for development is around 30ºC with relative humidity of 40 to 80 %. Within a fairly narrow range of 5 – 10 ºC around the optimal temperature the development of most insects is quite rapid. The developmental period is prolonged when the temperature nears 20 ºC resulting in considerable decline in population growth. Insect development is almost negligible and pest status is consequently greatly reduced when temperature is around 17 ºC or less. However, even at 15 ºC some species are able to continue feeding, to some extent, so that grain damage may very slowly increase.

Dormancy is induced at temperatures below 10 ºC (http://www.fao.org). Storage of grain at very low temperatures would therefore suppress infestation and ensure safety of the grain. Even though it may not completely eradicate the pest it would suppress infestation. Storage at such low temperatures in the tropics such as Ghana would require cold storage facilities, something that is beyond the means of peasant farmers. It is noteworthy that even in cold storage (at 6 - 9 ºC) some of the important insect pests of stored grain can survive longer than one year (Wohlgemuth, 1989). In such a case resurgence may occur when conditions become warmer.

Thirdly, insect pest require oxygen for respiration. Hyde *et al.* (1973) reported that most storage insects will die when the oxygen in the storage atmosphere falls to 2%. Gradual depletion of oxygen in the storage atmosphere can be attained by maintaining air-tight

conditions of grain storage. This will ensure the gradual consumption of oxygen in the storage atmosphere through respiration by the insects. When infestation is light this process may take 6-8 weeks, however when infestation is heavy the process may be much quicker. It has been reported that insects may adapt to low oxygen tension resulting in strains with enhanced resistance to sub-optimal levels as low as about 1% (Donahaye, 1990).

Fourthly, the development and control of insect pests in storage can also be influenced by the physical disturbance of the grain. Physical disturbance of grain can reduce live grain weevil infestation considerably thus retard its further development (Joffe, 1963). Physical disturbance of grain can be accomplished by turning it from one elevator bin to another, by mechanical high-speed impact in the entoleters included in the processing line of many grain mills or through vigorous violent shaking of small quantities of grain held in small pots and gourds.

Insect behavioural patterns can also impact on the development and control of insect pests. Behaviour patterns such as oviposition and feeding behaviour, locomotory behaviour and diapause exhibited by some insects can undermine the effectiveness of control measures. For example diapause may postpone population development in the Kharpa beetle, *Trogoderma granarium* Everts, while locomotory avoidance has been observed in *T. castaneum* (Wildey, 1987).

Storage management according to McFarlane (1988) greatly influences pest development and control. It encompasses decisions upon the location of stores, storage periods and the quality control objectives for stored commodities. All of these have substantial

implications for pest management and are components of the complex interactive network of actors affecting loss reduction in grain storage.

Also, some socio-economic factors affect the acceptability of control measures. Modern techniques, especially those involving the application of synthetic insecticides to stored grain, are especially prone to consumer sensitivity. However, many traditional techniques also face similar problems. The use of wood ash and other non-toxic 'natural' grain protectants may not be acceptable in all circumstances, not even to all those people at the small farm level in developing countries who are often supposed to prefer such treatments (http://www.fao.org).

2.6 Losses and damage caused by *Sitophilus zeamais*

S. zeamais jeopardizes food security by ruining grain saved for home consumption and also making it impossible to store any surplus grain *(*htpp://www.cimmyt.org).

Unless the problem of storage is solved satisfactorily the sad reality of hungry millions may continue even with substantial increase in production (htpp://www.ikisan.com).

S. zeamais also destroys seeds kept for planting in subsequent season(s).

S. zeamais whether adult or larvae, feed on grain endosperm and/or the germ. Endosperm feeding results in grain weight loss, reduction in nutritive value and deterioration in end-use. Damage to the germ results in reduction in seed germination, while both types of feeding reduce seed viability and vigour.

There is also damage due to excrement contamination, empty eggs, larval moults, empty cocoon and adult corpses. Maize weevils are also known to carry and transmit diseases such as *Aspergilus flavus, Fusrium verticillioides* and *Penicillium islandicum* and others

(http://www.kznhealth.gov.za). Insect respiration within grain increases moisture content and generates heat creating conducive atmosphere for the development of fungi. Microflora damage grain by: (i) damp grain heating, which causes caking and fermentation; (ii) reducing food value as a result of degradation of starch and protein, mycotoxin production and production of musty, unappetizing odour: and

(iii) jeopardizing its ability to germinate through injury to the germ (http://www.fao.org). Damage by a single insect, in terms of actual food consumption (through feeding by both the larvae and adult (http://www.kznhealth.gov.za), is generally quite little; it amounts to only 10 to 20 mg per insect during the larval feeding stage. It is the capacity for very rapid population growth; however, that makes insect infestation a major cause of food loss in storage (Mcfarlane, 1989).

2.7 Control of *Sitophilus zeamais*

Pest control involves any measure deliberately initiated by man to prevent, reduce or eliminate the harm caused by pest animals. Any action that kills, or prevents the increase or distribution of pest organisms is considered pest control. Although some control measures are accomplished in nature by natural factors including predatory, parasitic or disease causing organisms, several applied measures are commonly practiced to control insects or other pests. These measures include cultural, physical, mechanical and legal, biological and chemical (including botanical control methods).

2.7.1 Cultural control of *S. zeamais* in stored maize

Cultural control may entail either preventive or curative measures or both. As a start for any successful cultural control, it should be borne in mind that an intact grain is essential for successful storage. Sinha *et al.* (1988) observed that whole grains of wheat were less susceptible to insects than crushed seeds.

Preventive measures as a cultural control option in grain storage entails cleaning the storage structure, sealing of cracks, crevices and holes present in the floors and cleaning of shelled before use. Furthermore, proper staking of the filled bags is done for proper hygiene and sanitation to prevent insect damage in the ware house.

Curative measures on the other hand, are measures taken to minimize infestation or eliminate insect pests in the stored maize. This is usually achieved by the use of physical, mechanical and ecological control measures. (htpp://www.ikisan.com).

2.7.2 Physical control

This employs the use of chemically inert materials such as ashes, sand, powders, seeds or other materials to eliminate or make the survival of pest difficult (Golob and Webley, 1980). These materials are usually used in large quantities to fill the interstitial space in grain bulks so as to provide a barrier to insect movement. In addition the abrasive nature of such materials may be damaging to the insect cuticle leading to dehydration and death thereby effecting control.

Other physical methods employed by farmers to control insect pests at the farm level are smoking, thermal disinfestations (where the grain is spread out in a thin layer on the ground /platform exposed to the sun for several days) and hermetic storage in which the

grain is retained in sealed, airtight containers such as clay pots, metal bins or specially manufactured polysacks to effect control.

Traditionally clay pods were used but this has evolved to metal bins and more recently special polythene containers such as "super grain bags".

"Super grain bags" are ultra-violet resistant PVC airtight membranes fitted with extruded airtight zipper fasteners to form hermetically sealed containers. The material has a low enough permeability to air so that after a few days (typically a week to ten days at room temperature) primarily due to insect respiration, the oxygen is depleted to a level (typically 1-2%) which cannot sustain insect life, while the carbon-dioixide level rises very substantially. This essentially creates an asphyxiating process resulting in death of insects. The low level of oxygen also prevents growth of fungi and aflatoxin (http://grainpro.com). Donahaye (1990) however, reported increased tolerance by insects to low oxygen tensions in controlled storage atmosphere. This notwithstanding, insect adaptability to such constraints on fundamental biotic requirement such as aerobic conditions will be relatively limited (FAO, 1997).

In Nigeria, Emebiri and Nwufo (1990) reported on effective control of *S. zeamais* and *Tribolium castaneum* in maize through use of *trona*, a crystalline carbonate/bicarbonate that occurs naturally in several parts of Africa. Termite mound soil has also been reported to cause a high degree of adult mortality in *S. zeamais* (Firdissa and Abraham, 1999).

2.7.3 Biological/Biotechnical Control

Biological control has been recognized as an important component of integrated pest management strategies for field crops and stored product commodities.

McFarlane (1989) indicated the possible application of conventional biological control techniques in stored-grain pest control including control by the use of predators, parasites, insects pathogens and sterile males, the use of pheromones for pest monitoring, mating disruption or to enhance mass trapping and the use of resistant crop varieties.

2.7.3.1 Use of parasites and insect pathogens

Studies by Kassa (2003) demonstrated the possible successful control for *S. zeamais* on stored and infested cereals using dustable powder formulation of conidia of *Beauveria bassiana* and *Metarhizium anisopliae* isolates. He however indicated the need to evaluate an optimized and economic production system and the most suitable formulation that would optimize its application, efficacy and storage characteristics as well as the persistence after application.

Lariophagus distinguendus is an ectoparasitoid of several beetle species that feed on durable stored products. Its potential for the control of *S. zeamais* was assessed in stored maize. The parasitoid significantly reduced the emergence of *S. zeamais* in stored maize. (Charles Adarkwa http://www.tropentag.de).

2.7.3.2 Use of resistant cultivars for control of insects.

Painter (1951) recognized three types of varietal resistance to insect pests viz non-preference, antibiosis and tolerance. Non-preference is the situation whereby a plant may not be preferred for oviposition, food, shelter or combinations of these. Non-preference is usually attributed to morphological, physiological or biochemical factors in the plant. For example in wild V*icia* spp, thick cuticle present in these species impedes the penetration

of the stylets of first instar nymphs of both *Aphis fabae* and *Acrythosiphon pisum.* Hairiness of the plant also hinders the settling and feeding of these aphids (Anon, 1988). Similarly, hairy- leaf varieties of wheat are attacked significantly less often by the cereal leaf beetle *Qulema melanopus (*Coleoptera: Chrysomelidae*)* (Webster and smith., 1975).

Antibiosis is the situation where the biology of an insect is adversely affected when it feeds on a particular host plant. This may take the form of reduced fecundity and longevity. Painter (1951) stated that antibiosis may occur as a result of the deleterious effects of specific chemicals, lack of specific food materials or differences in quantities of food available. It has been shown by Sinden *et al.,* (1979) that the presence of glucoside in *Solanum chacoener* makes the plant resistant to attack by the Colorado beetle *Leptinotarsa decemlineata*.

Tolerance is the situation in which the plant possesses the ability to grow and reproduce or repair injury to a marked degree although it supports a population that can injure a susceptible host. It has been shown by Hill, (1987) that vigorously growing sorghum could withstand considerable stalk borer damage with no apparent loss of yield.

During storage, individual grains do not possess the capacity to tolerate damage by growth and reproduction or repair of injury. Thus, resistance to post-harvest insect attack would be attributable to the interrelated component factors of antibiosis and nonpreference (http://www.fao.org). Biological control by the use of resistant variety generally retards the increase of infestation and grain damage, thereby prolonging the period in which damage remains relatively low.

2.7.4 Chemical control

2.7.4.1 Use of Synthetic Insecticides

This entails the reduction of pest population or prevention of pest damage by the use of chemicals to poison them or repel them from specific areas. Chemical control measures are more popular and effective. They may be used as prophylactic treatments to prevent insect infestation and cross infestation or as curative treatments to kill all insect stages residing in the produce (htpp://www.ikisan.com). For stored grain, contact insecticides and fumigants are the most commonly used chemicals among small-scale farmers (http://www.fao.org; Rai *et al*., 1987; Gwinner *et al*., 1996).

Recommended contact insecticides for stored-grain are either organophosphorus compounds, such as fenitrothion, malathion and pirimiphos methyl, dichlorvos and methacrifos or pyrethroids which include Pyrethrin/piperonyl butoxide, bioresmethrin, phenothrin and permethrin. Methyl bromide and phosphine are the only fumigants commonly used on a world-wide scale (FAO, 1985).

In general, protection of maize cobs with chemicals is not as effective as protection afforded to insecticide-treated grain. However some control of infestation is possible even with the sheath intact with some insecticides like pirimiphos-methyl (Golob and Mawulo, 1984). It has also been demonstrated that protection is obtained by applying permethrin, phoxim, trichlorfon and diazinon as spray to maize cobs with husks intact (Golob and Hanks, 1990; Langune-Tejeda, 1991).

Use of insecticides may sometimes be disadvantageous because of the problems they create. For instance, the use of synthetic insecticides which are in wide use recently (Redlinger *et. el.*, 1988) is hampered by procurement cost, evolution of resistant strains,

destruction of natural enemies and non target species, turning innocuous species into pests and contamination of food (Obeng-Ofori *et al.*, 1997; Russel, 1978). Studies have indicated that some stored product pests are resistant to some insecticides. For instance, *S. zeamais* and *S. oryzae* have been found to be resistant to both malathion and pirimiphos-methyl (Sayaboe and Acda, 1990). There have also been repeated indications that certain insects have developed resistance to phosphine which is widely used today (Taylor, 1991). It has been recently reported that at least 447 species of insects and mites and 200 species of plant pathogens and 48 species of weeds are now resistant to chemicals (http://www.ias.ac.in).

2.7.4.2 Use of Botanicals

Current research focus in stored products protection is to minimize or eliminate the use of synthetic insecticides and have economic and health benefit to applicators, consumers and the environment (Murdock *et al.*, 1997; Elhag, 2000; Talukder and Howse, 2000). The use of botanicals is seen to be an effective alternative and suitable for small holder farmers for preserving stored grain from insect damage.

Plants are known to possess secondary chemical compounds which are used as a part of the plant's defense against plant-feeding insects and other herbivores (http://www. ias.ac.in/currsci; Swain, 1977; Lupina and Chipps, 1987). These secondary compounds, which have no known function in photosynthesis, growth or other aspects of plant physiology, confer on plant materials or their extracts some insecticidal activity (http://www.fao.org; http://www.new-ag.info)

Some of the secondary metabolites are merely the end products of aberrant biosynthetic pathways and other excretory products. Some of these substances belonging to various categories (terpenoids, alkaloids, glycosides, phenols, tannins etc.) affect insects in several ways. Some of such plant products affect nerve axons and synapses e.g. pyrethrins, nicotine and picrotoxinin; muscles e.g. ryanodine; respiration e.g. rotenone and mammein; hormonal balance; e.g. juvenile and moulting hormone analogues and antagonist; reproduction e.g. b asaron and behaviour e.g. attractants, repellents and antifeedants (http://www.ias.ac.in; Bell *et al.,* 1990).

Botanical pesticides represent an important potential for integrated pest management programmes in developing countries as they are based on local materials (Bekele *et al.,* 1997).

Plant materials with insecticidal properties provide small scale farmers with chemicals that are locally and readily available, affordable, relatively less poisonous and less detrimental to the environment for pest control (Niber, 1994; Talukder and Howse, 1995).

Botanicals, such as neem and hot pepper, have been used for generations throughout Africa, Asia and the Americas (http:///www.new.ag.info).

A survey conducted in some parts of Ghana identified 26 different species which are used by farmers as grain protectants. The most common being *Chromolaena odorat*a (Siam weed), *Azadirachta indica* (neem) and *Capsicum annum* (Chilli pepper). Insecticidal activity against insects other than those of stored grain pest has been reported in more than 980 other plant species (http://www.fao.org).

There has been considerable interest among scientists to screen plants for secondary chemical compounds with pesticidal activity (Pathak and Krisna, 1991). Many researchers are attempting to validate the efficacy of traditional storage protectants, while others among other reasons are seeking effective plant species which would be readily available in the local environment for farmer use (Weaver *et al.,* 1991)

Available published information on the use of plant materials, extracts and oils for the control of stored product pests show that a large number of plant species from a wide range of families have been evaluated (FAO, 1999). Jacobson (1989) suggested that the most promising botanicals were found in the families of Meliaceae, Rutaceae, Asteraceae, Annonaceae, Labiatae and Caellaceae.

The plant species that have been investigated are frequently those used locally, within individual countries, as culinary spices or in traditional medicine. Among the plant families investigated to date, one showing enormous potential is the Piperaceae (Dodson *et. al.,* 2000). They have also been traditionally used as spices in most parts of the world and as pesticides (Sighamony *et al.,* 1986; Miyakado *et al.,* 1989; Pathak and Krisna, 1991).

Currently only products from a few plant species have found widespread use as insecticides and in commercial production. These include Rotenone from *Derris elliptica* and *Lonchocarpus species,* Pyrethrum from *Chrysanthemum cinerariaefolium* and azadirachtin from neem (http://www.fao.org)

Kis-Tamas (1990) proposed that prospective plants with desirable characteristics for use in pest control would probably be that the plant is perennial, easy to grow and not expensive to produce. The plant should also show no potential to become weeds or host

for plant pathogens and should if possible, offer complementary economic uses. In addition, the insecticidal product should effectively control the range of pests encountered in local storage situations, be safe to use, pose no environmental hazard, be easy to extract, formulate and use with available skills

Studies conducted to evaluate *Vitex negundo* L (langundi) leaves both as whole dried leaves and powdered form against *S. zeamais* showed that whole dried leaves checked *S. zeamais* population for 90 days (Bhulyah, 1988), while 5% of the leaf powder reduced fecundity of adult female weevils. In a similar study, Javier and Morallo Rejesus (1982) reported that ground black pepper used against weevils was as effective as malathion and residually toxic for 2 to 4 months against *Oryzaephilus surinamensis* L., *Rhyzopertha dominica* and *Tribolium castaneum.*

Ground products of some local spices (*Piper guineense*, *Allium sativum*, *Afromomum melequaeta*, *Xylopia aethiopica* and *Tetrapleura tetraptera*) were applied as direct admixtures to test their ability of protecting stored maize against infestation by *S. zeamais*. *Piper guineense* caused significant mortality of weevils while *Afromomum melequata* and *P. guineense* were repellent to the weevils. There was a significant reduction in damage caused by the weevils. Progeny production was also significantly adversely influenced by *P. guineense* (Udo, 2005).

Eugenol from *Eugenia aromatica* and *Ocimum suave* were found to be repellent to *Sitophilus zeamais;* Hildecarpan from Tephrosias an antifeedant against *Maruca testulalis* and retenoids and rotenone are very potent antifeedants against a number of lepidopterans (Hassanali and Lwande, 1989).

Treatment with leaves from *Eucalyptus globules*, *Schinese molle*, *Datura stramonium*, *Phytolacca dodecandra* and *Lycopersicum esculentum* caused high adult weevil mortality for *S. zeamais* (Firdissa and Abraham, 1999).

2.7.4.2.1 *Chromolaena odorata*

Chromolaena odorata (L) R. M. King and H. Robintson (Asteraceae) is a Neotropical plant (Gautier, 1992). According to Voigt (1845*), C. odorata* was introduced to Calcutta botanical gardens in 1845. From this original point of introduction as an ornamental, it spread throughout Southeastern Asia into parts of Oceania and into West and Central Africa (Gautier, 1992). It was accidentally introduced to Nigeria in 1937 (Bennett and Rao 1968; Ivens, 1974; Munniapan and Marutani, 1988). Hall *et al.* (1972) reported that the weed was first discovered in Ghana in 1969 and by 1991 it had colonized about 67% of the total land area of the country (Timbila and Braima, 1996).

Chromolaena odorata contains diverse range of secondary chemicals including flavonoids, terpenoids and alkanoids (Talapatra *et al*., 1974; Biller *et al.,* 1994). In China, analysis of the volatile oil from *C. odorata* identified 33 components with terpenoid compounds in the majority. The main terpenoid compounds are trans-caryophyllene (16.22%), A-cardinene (15.53%), a-capaene (11.32%), caryophyllene oxide (9.42%), germacrene-D (4.86%) and humulene (4.23%). Similar work in Thailand identified 22 constituents. The major constituents were prejeijerene (17.6%), germacrene D (11.1%), a-pinene (5.6%), o-cadinene (4.9%) and geijerene (Nisit *et al*., 2006).

In another independent study, Toan-Thang *et al.* (2001) identified the presence of phenolic acids (protocatechuic, p-hydroxybenzoic, p-coumaric, ferulic and vanillic acids)

and complex mixtures of lipophilic flavonoid aglycones (flavanones, flavonols, flavones and chalcones) in the crude ethanol extracts of the leaves of Chromolaena *odorata*.

Nisit *et al.* (2005) investigated the chemical constituents of the aerial part extract of *C. odorata* after separation and purification. Six flavanoids were obtained including 3,5,4`-trihydroxy -7-methoxyflavanone; 5,7,3 trihydroxy -5- methoxyflavanone and 3,5,7-tridroxy-methoxyflavanon.

Biller *et a*\. (1994) as cited by Timbila (2005), reported that *Chromolaena odorata* contains a mixture of pyrrolizidine alkaloids (PAs) with the major components being rinderine and intermedine plus other PAs in smaller quantities all occurring exclusively as N-Oxides with the highest concentration occurring in the roots and in the flowers but absent in the leaves.

Caryophyllene and germacrene-D which have been reported to be major constituents in *Lantana camara* leaf has been established to possess insecticidal activity against *Dactynotus carthami* (Patil *et al.,* 1997), repellent towards bees, mosquitoes and cattle flies, (Attri and Singh, 1978) and ovipositional against *Callosobruchus maculatus* (Adebayo and Gbolade, 1994). Coumarine a constituent of *C. odorata* is also well known to possess insecticidal properties (www.rareorganics.com).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The experiments were conducted at the Entomology laboratory of the Faculty of Agriculture of Kwame Nkrumah University of Science and Technology, Kumasi.

3.2 Experimental design

The experimental design used was completely randomized design (CRD).

3.3 Maize variety

Twenty kilogrammes of shelled untreated Mamaba maize variety was obtained from a seed grower at Asuoyeboa, a suburb of Kumasi. Basal insect infestations in the maize were disinfested by deep freezing for two weeks (Kossou *et al.*, 1992). The maize was then air dried under a screen to prevent possible re-infestation by insects. The moisture content of the maize samples was determined before each laboratory experiment.

3.4 Preparation of botanical materials.

Fresh leaves and roots of *chromolaena odorata* were collected from the arable farm of the Faculty of Agriculture of Kwame Nkrumah University of Science and Technology, Kumasi. The leaves and roots (chopped up into pieces to facilitate drying) were dried in a well ventilated area at room temperature for 2 weeks. The dried leaves and roots were milled into powder using Christy and Norris Junior ® laboratory mill. Three hundred and

fifty grams each of the leaf and root powders were soaked separately in 1,400 ml (1:4 W/V) of ethanol contained in 2,000 ml plastic containers for 96 hours. The leaf and root extracts were strained using a clean fine muslin cloth. The extracts were stored in plastic containers at room temperature in the insectary as stock solution and used for the study.

3.5 Insect culture

Adult *S. zeamais* used for the study were raised from a stock maintained at the insect laboratory of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi. Two hundred unsexed adult *S. zeamais* from the stock were introduced into a plastic container, sealed with a clean fine muslin cloth, holding 1,000 g of the disinfested maize grain. The insects were allowed to oviposit for ten days before they were sieved out and the container sealed again with the cloth to prevent possible escape and/or reinfestation. The F_1 adults that emerged were introduced onto a sample of the test maize and the resulting F_2 emerged weevils were used for the various experiments. The culture was maintained under average temperature of 26ºC and relative humidity of 80%.

3.6 Mortality Test and Progeny emergence assessment

Fifty grams of maize grain were introduced into 750 ml plastic containers. Varying volumes or dosages of *C. odorata* leaf and root extracts (0.0, 2.5, 5, and 10.0 ml) were introduced onto the 50 g maize in the plastic containers and vigorously shaken every 30 minutes for 2 hrs to ensure uniform distribution of the extract over the grain surface. The treated maize was allowed to stand for two hours for the alcohol solvent to evaporate

before the introduction of the weevils. Ten pairs of sexed 5-10 days old adults staved for 24 hrs were then introduced into each plastic container. The plastic containers were covered with muslin cloth sandwiched between two wire mesh. Each treatment was replicated four times. The experiment was arranged in a completely randomized design in the laboratory.

The number of dead insects in each plastic container was counted after 1, 2, 3, 4, 5, 6, and 7 days to estimate maize weevil mortality. Insects were certified dead when there was no response to prodding of the abdomen with a sharp pin.

Maize weevil mortality was assessed as:

(Number of dead insects/Total number of insects) x 100

To account for death by natural conditions other than the effect of the plant extracts data on percentage adult weevil mortality was corrected using Abbott's (1925) formula thus:

PT = (PO-PC) / (100-PC)

Where, PT = Corrected mortality (%),

PO = Observed mortality (%)

PC = Control mortality (%)

After mortality count on the 7th day, all insects were sieved out of the plastic containers and their contents kept at an undisturbed area in the laboratory for 6 weeks for progeny development from any eggs laid. Emergence count of F_1 generation commenced on the 21st day after infestation and was terminated after 34 days of counting to prevent overlapping of generations.

3.7 Repellency test

A modified Mohan and Field (2002) technique for assessing repellents and attractants in stored products as adopted by Ansah (2009), was used. Plastic bottles measuring 18 cm x 4 cm (height and base diameter respectively) with 2 mm holes created at intervals of 1.5 cm x 1 cm (horizontally and vertically respectively) all round the surface were used. Two hundred grams of shelled maize treated with varying volumes of *C. odorata* leaf and root extracts (0.0, 5, 10.0 and 20.0 ml) were put into the plastic bottles. This was placed in a plastic cup measuring 5 cm x 6 cm (height and base diameter respectively) with holes at the base. The setup was placed in a petri dish filled with water (Fig 3.6.A).

Ten pairs of unsexed 2 to 3 weeks old adults starved for 24 hours were introduced into the treated maize samples through a long stem funnel. A cage made up of a wooden frame of 21 cm x 18.5 cm x 18.5 cm wide with the sides covered by plastic mesh (Fig 3.6.B) was inverted over the setup to prevent the escape of insects repelled out of the treated maize in the bottles and also to prevent insects not included in the experiment coming into contact with the set up. Each setup had a control in which untreated maize was used. The *S. zeamais* that moved out of the plastic bottles into the water contained in the Petri dish or on the outside surface of the bottle or on the inside surface of the cage inverted over the setup were deemed repelled away by the extracts and therefore counted. Counting was done at 1, 2, 12 and 24 hours after infestation. Abbot's correction formular was used to eliminate random departures by the insect.

Fig 3.6 A:

Figure Fig 3.6.B:

A modified Mohan and Field apparatus for assessing repellence of *C. odorata* extracts against *S. zeamais*

3.8. Damage Assessment

Damage assessment was carried out on treated and untreated grains after two months of storage. Samples of 100 grains were taken from each jar and the number of damaged grains (grains with characteristic holes) and undamaged grains counted and weighed. Percentage weight loss was calculated, using FAO (1985) method as follows:

% Weight loss = [(UaN)-(U +D)] / UaN x 100

Where, U= Weight of undamaged fraction in the sample

N = Total number of grains in the sample

Ua = Average weight of undamaged grain

D = Weight of damaged fraction in the sample.

3.9 Data Analysis

All percentage with more than 40% range were arcsine transformed (Sine $^{-1}$ ((x+0.5/100). While count data were square root transformed √(x+0.5) (Clewer and Scarisbrick, 2001). GenStat Release 7.2 Discovery Edition (2007) Computer package was used to analyse variances and least significant differences (LSD) were used to separate means that showed significant differences at Probability level of 5% ($P \leq 0.05$).

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of ethanolic root extract of *C. odorata* on percent *S. zeamais* mortality after 96 hours (4 days)

Figure 4.1 shows the percent mean mortality of *S. zeamias* after 96 hours in maize grains treated with different volumes of ethanolic root extract of *C. odorata.*

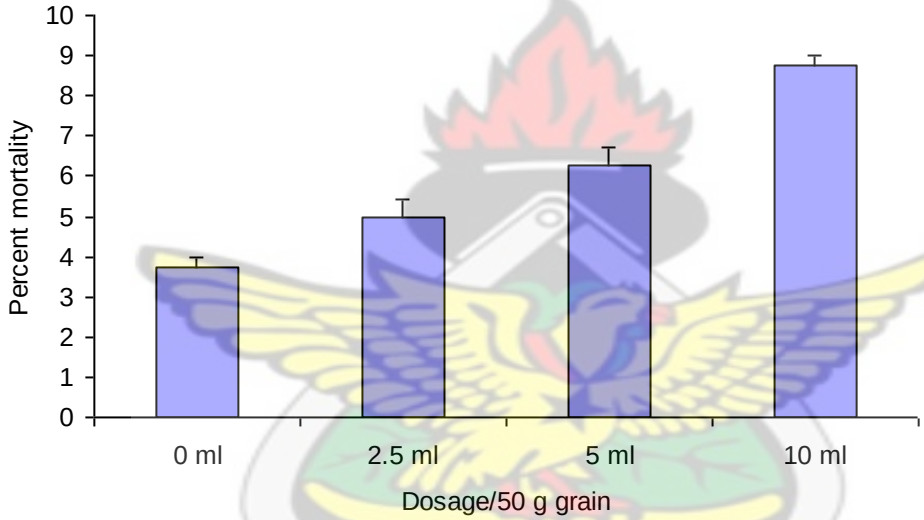

Figure 4.1: Mean percent mortality of *S. zeamais* after 96 hours in maize grain treated with different dosage levels of ethanolic root extract of *C. odorata*.

Bars indicate standard error of means (SEM)

Between the various dosage levels applied there were no significant differences in the percent mortality of the insects after 96 hours ((4 days) of exposure.

4.2 Effect of ethanolic root extract of *C. odorata* on *S. zeamais* mortality after 7 days

Figure 4.2 shows the mean percent mortality of *S. zeamias* in maize grains treated with different dosage levels of ethanolic root extract of *C. odorata* after 7 days.

Similar to the results of 4 days of exposure, there were no significant differences in weevil mortality between the different dosage levels of the ethanolic root extract after seven days exposure to the treated grain.

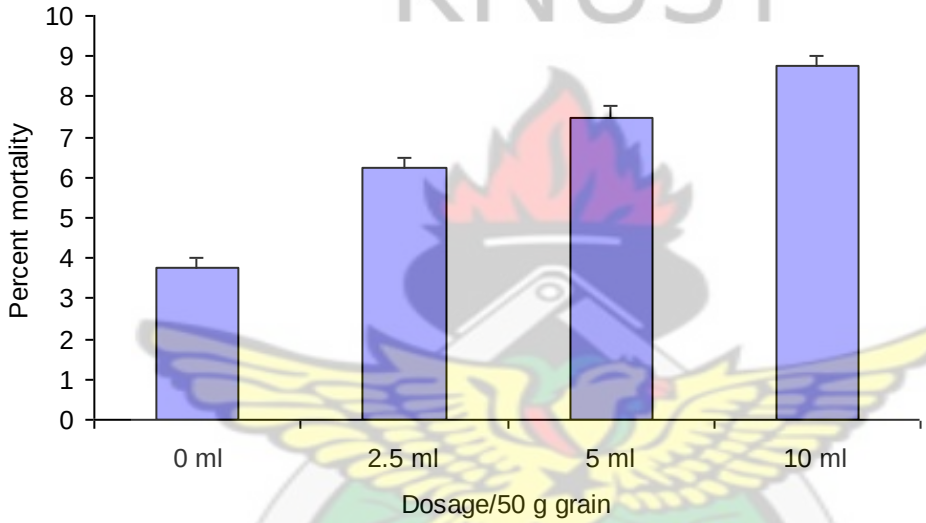

Figure 4.2: Mean percent mortality of *S. zeamais* after 7 days in maize grain treated with different dosage levels of *C. odorata* ethanolic root extract.

Bars indicate standard error of means.

4.3 Effect of ethanolic leaf extract of *C. odorata* on percent *S. zeamais* mortality

Figure 4.3 shows the percent mortality of *S. zeamias* after 4 days in maize grains treated with different dosage levels of ethanolic leaf extract of *C. odorata*.

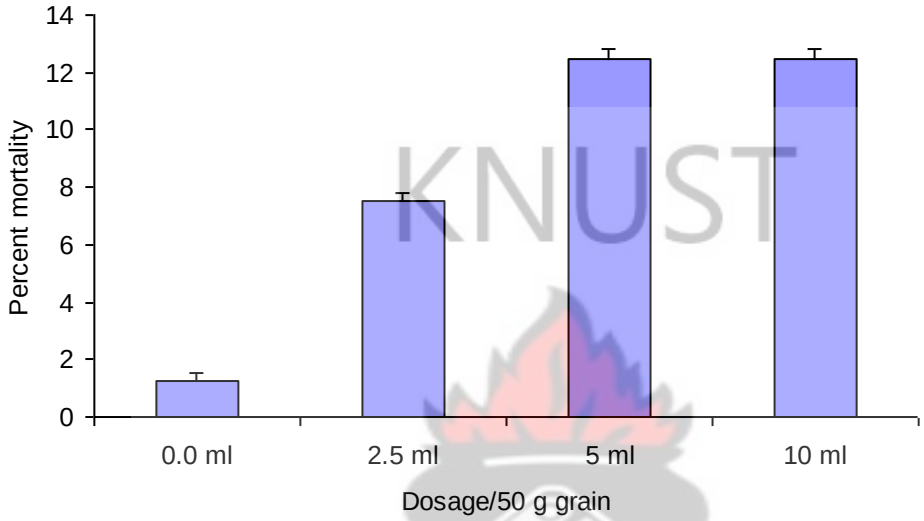

Fig 4.3: Mean percent mortality of *S. zeamais* after 4 days in maize grain treated with different dosage levels of *C. odorata* ethanolic leaf extract.
The error bars represent standard error of means.

There were no significant differences in toxicity between the5 ml and the 10 ml dosage levels of *C. odorata* ethanolic leaf extract to the insects after 4 days exposure to the treated grain. However, the differences between the5 ml and 10 ml on one hand and the 2.5 ml and the control on the other hand as shown in Figure 4.4 were Significant. The differences between the 2.5 ml and the control were also significant.

4.4 Effect of ethanolic leaf extract of *C. odorata* on *S. zeamais* mortality after 7 days

Figure 4.4 shows the mean percent mortality of *S. zeamias* after 7 days in maize grains treated with different volumes of ethanolic leaf extract of *C. odorata*

Similar to the results obtained from 4 days of exposure there were significant ($P < 0.05$) differences in weevil mortality between the different dosage levels of extract after one week exposure The *C odorata* leaf extract at 10 ml and 5 ml dosage levels exhibited significantly greater mortality than the 2.5 ml and the control (untreated grain). Also, the grain treated with 2.5 ml dosage level inflicted significant level of *S. zeamais* mortality ($P < 0.05$) than the control.

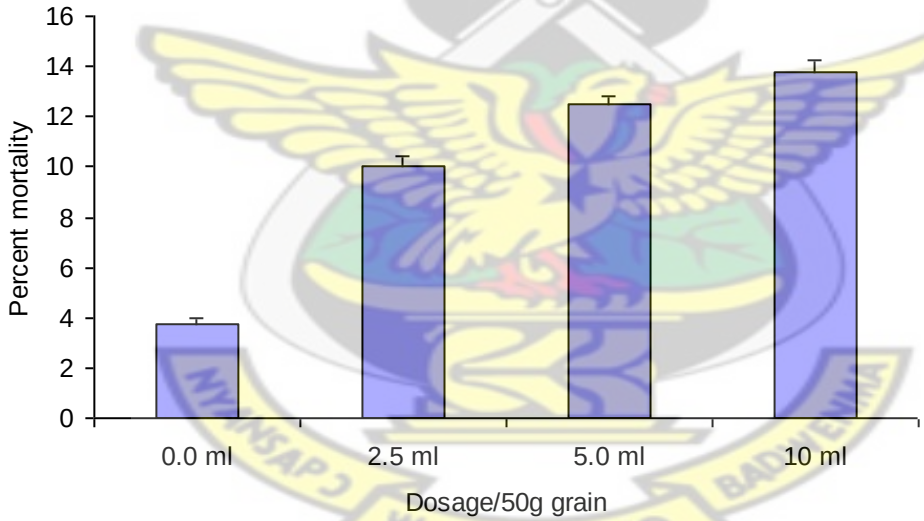

Fig 4.4: Percent mean mortality of *S. zeamais* after 7 days in maize grain treated with different dosage levels of ethanolic *C. odorata* leaf extract.

The error bars represent standard error of means.

4.5 Effect of ethanolic leaf extract of *C. odorata* on *S. zeamais* Progeny development

The number of progeny produced by *S. zeamais* in untreated grains and grains treated with different dosage levels of ethanolic leaf extract of *C. odorata* are shown in Figure 4.5. The first batch of emergence was recorded from 5 ml and 10 ml treated grain lots at 26 days after infestation (DAI) but emergence occurred in all treatments on the 27th DAI. Peak emergence occurred in the 5th week (as depicted by the steepness of the graphs slopes) with the control recording the highest emergence. Emergence then reduced greatly until the 8th week when it stopped.

Significantly greater number of progeny was produced by *S. zeamais* in the untreated grains compared with the grains treated with the highest dosage levels of ethanolic leaf extract. The two highest dosage levels of the ethanolic leaf extract of *C. odorata* significantly reduced the number of progeny produced by the weevil compared to the 2.5 ml and the control.

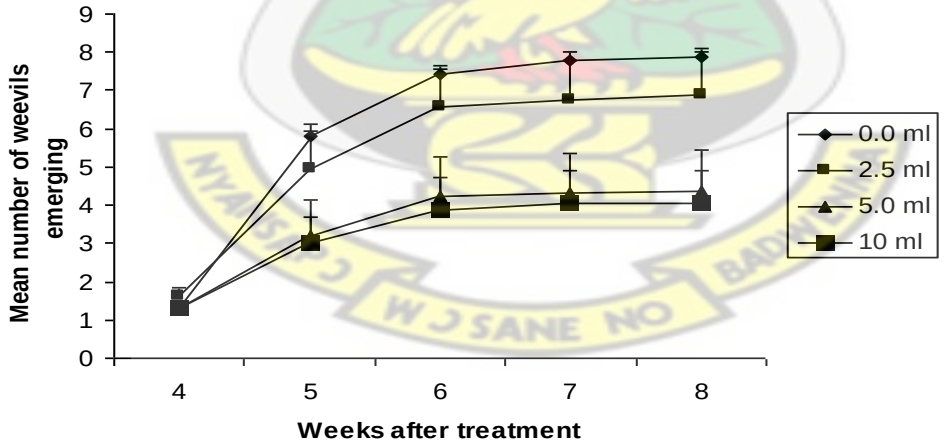

Figure 4.5: Mean number of *S. zeamais* that emerged in maize grain treated with different dosage levels of ethanolic *C. odorata* leaf extract for 8 weeks of storage.

The error bars represent standard error of means.

4.6 Effect of ethanolic root extract of *C. odorata* on *S. zeamais* Progeny development

The number of progeny produced by *S. zeamais* in untreated grains and grains treated with different dosage levels of root extract of *C. odorata* is shown in Figure 4.6. There were no significant differences in the number of progeny produced by *S. zeamais* in the various dosage levels of ethanolic *C. odorata* root extract used. All the levels of root extract of *C. odorata* did not significantly reduce the number of progeny produced by the weevil as compared with the control (Fig. 4.8).

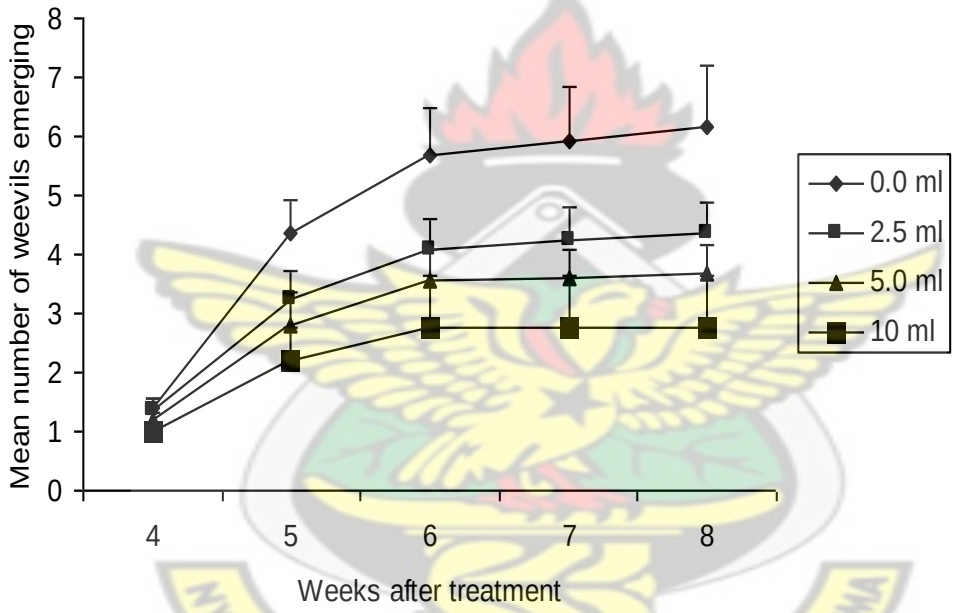

Figure 4.6: Mean number of *S. zeamais* that emerged in maize grains treated with different dosage levels of ethanolic root extract of *C. odorata* after 8 weeks of storage. The error bars represent standard error of means.

4.7 Effect of ethanolic leaf extract of *C. odorata* treatment on grain weight loss

Weight loss caused by *S. zeamais* to treated and untreated grains is shown in Figure 4.7. Weight loss was dose dependent with significant differences. The weight loss of 11.34% in the control was significantly greater than losses of 5.46% and 3.51% in the 5 ml and 10 ml dosage levels respectively. However treatment at 2.5 ml/ 50 g grain also suffered significant weight loss compared with the grains treated with 10 ml of leaf extract.

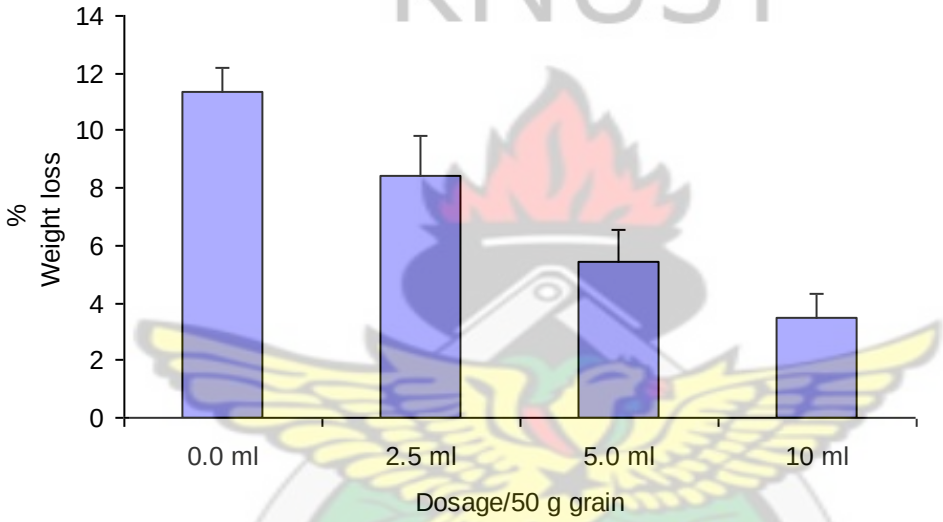

Figure 4.7: Percent weight loss caused by *S. zeamias* damage of maize grains treated with different dosage levels of ethanolic leaf extract of *C. odorata* after 8 weeks of storage

The error bars represent standard error of means.

4.8 Effect of ethanolic root extract of *C. odorata* treatment on grain weight loss

Weight loss caused by *S. zeamais* to treated and untreated grains with ethanolic root extract of *C. odorata* is shown in Figure 4.8. Analysis of variance shows that there were no significant differences ($P < 0.05$) in weight loss between the treatments. The 2.5 ml dose level treated grain lot suffered the highest weight loss of 10.37% whilst the grain lot treated with the highest dose level (10 ml) offered the maximum protection resulting in the lowest weight loss of 5.21, the non significant difference notwithstanding.

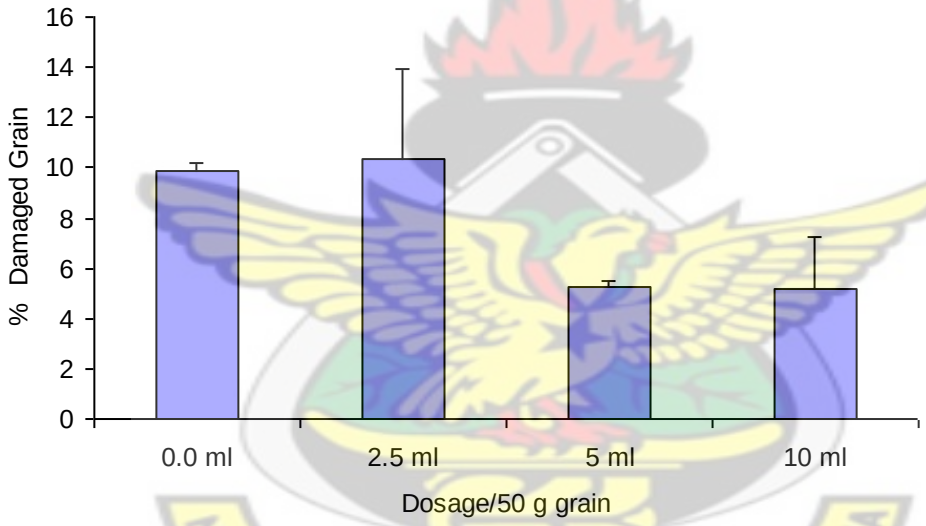

Figure 4.8: Percent weight loss caused by *S. zeamias* damage of maize grains treated with different dosage levels of ethanolic root extract of *C. odorata*.

The error bars represent standard error of means.

4.9 Correlation between grain weight loss and progeny production in stored maize treated with ethanolic *C. odorata* leaf extract.

Figure 4.9 shows the correlation between grain weight loss and progeny production in stored maize treated with *C. odorata* leaf extract.

The results of this study showed a very strong positive correlation between grain weight loss and weevil progeny produced. Ninety-six percent (96%) of the variation in grain weight loss was related to the variation in weevil progeny produced.

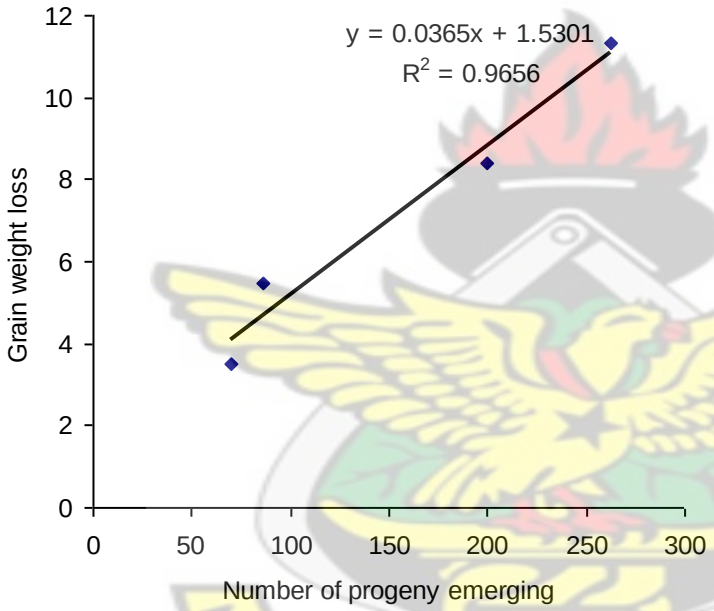

Figure 4.9: Correlation between grain weight loss and progeny produced in stored maize treated with *C. odorata* leaf extract.

4.10 Correlation between grain weight loss and progeny produced in stored maize treated with *C. odorata* root extract.

Figure 4.10 shows the correlation between grain weight loss and progeny produced in stored maize treated with *C. odorata* root extract.

In this study, 51 % of the variation in the maize grain weight loss was explained by the variation in weevil progeny produced in the stored maize treated with *C. odorata* root extract.

The correlation between grain weight losses and variation in weevil progeny produced was positively correlated.

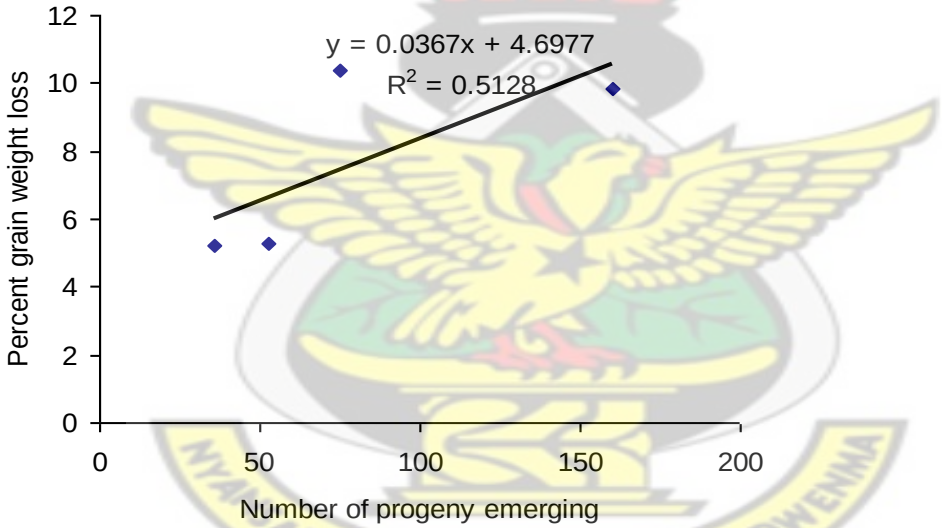

Figure 4.10: Correlation between grain weight loss and progeny production in stored maize treated with *C. odorata* leaf extract.

4.11 Repellence effect of ethanolic root extract of ***C. odorata*** **on *S. zeamais.***

Figure 4.11 represents the mean repellence values of *S. zeamais* on maize grain treated with different dose levels of ethanolic root extract of *C. odorata*. The highest number of the pest was repelled during the first one hour of introduction onto the maize grains. The lowest repellence of 3.33% was observed in the untreated maize while the highest repellence of 8.88% was found in the highest dosage of 20 ml. However, the analysis of variance indicated that the differences were not significant.

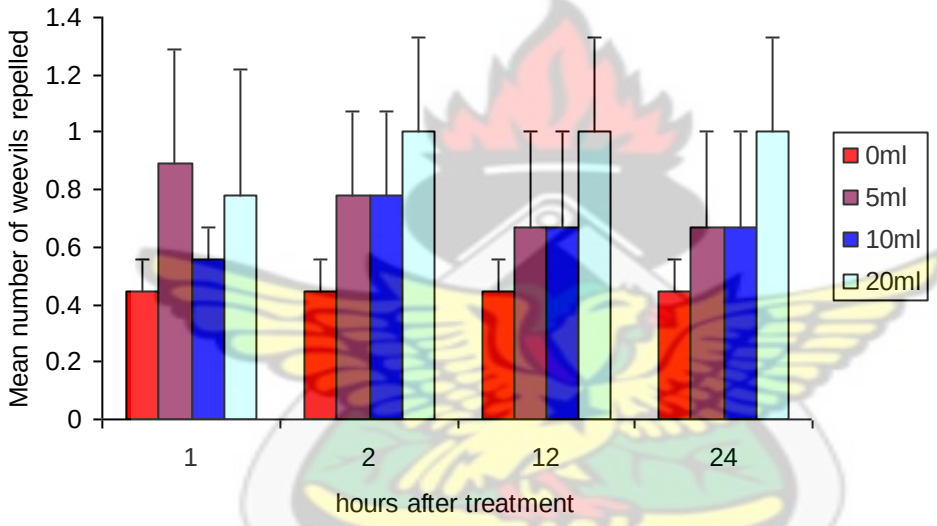

Figure 4.11: Cumulative mean repellence of *S. zeamais* in maize grain treated with different dosage levels of *C.* ethanolic root extract for 24 hours period.

The error bars represent standard error of means.

4.12 Repellence effect of ethanolic leaf extract of *C. odorata* on *S. zeamais.*

Figure 4.12 represents cumulative mean repellence of *S. zeamais o*n maize grain treated with different dosage levels of *C. odorata* ethanolic leaf extract for 24 hours period. Analysis of variance indicated there were no significant differences between the responses to the four dosage levels tested.

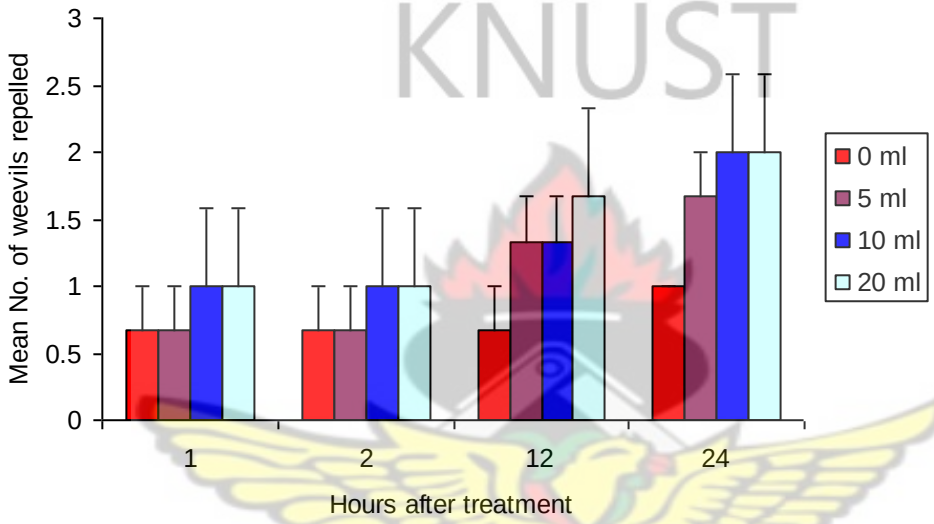

Figure 4.12: Mean cumulative repellence of *S. zeamais* in maize grain treated with different dosage levels of ethanolic *C. odorata* leaf extract for 24 hours period.

The error bars represent standard error of means.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of ethanolic extracts of *C. odorata* on *S. zeamais* mortality

The results showed that the ethanolic extracts of *C. odorata* root were not effective for the control of *S. zeamais*. Even the leaf extracts that showed some killing power, inflicted as low as 8.75% mortality on *S. zeamais*. However the extracts cannot be discounted completely as it exerted some degree of mortality on the *S. zeamais.* This perhaps indicated that, a much higher dose may exhibit greater potency. On the other hand, other appropriate alternative solvents (method of extraction) may enhance the efficacy of the leaf extracts as a protectant for maize against the maize weevil (Makanjuola, 1989; Ogunleye, 2000).

Plant terpenoids and phenolic acids have been reported to be toxic to insects. For example, *Lantana camara* which has been reported to possess, in major quantities, terpenoids such as caryophyellene and germacrene D exhibited insecticidal activity against *Dactynotus carthamii* (Patil *et al.* 1997, http://www.rareorganics.com/ coumarins_wri.html). *Chromolaena odorata* has also been reported to possess terpenoids including caryophyellene and germacrene (Nisit *et al.*, 2006) and phelonic acids such as coumarine D in major quantities (Toan-Thang *et al.* 2001).

Asawalam *et al*. (2006) and Mbah and Okorokwo (2008) reported that leaf powder *of C. odorata* caused 69% and 64% mortality of *S. zeamais* respectively. In this study, mortality of *S. zeamais* ranged from 3.75% to 8.75% for all the different treatments indicating that the populations of *S. zeamais* were not appreciably controlled at the doses of ethanolic extracts of *C. odorata*.tested.

Several reasons could be adduced for the ineffectiveness of ethanolic extracts *C. odorata* to control *S. zeamais* in this study. It has been established that different climatic, soil, and seasonal conditions can affect the type and quantity of the components isolated from extracts. It is probable also that the age of the plant, type of solvent used in extraction and quantity of extracts used among others could have affected the efficacy of the extracts used in this study. Asawalam *et al.* (2006) and Mbah and Okorokwo (2008) used *C. odorata* powder which might have contributed to the higher mortality recorded in their studies since the abrasive nature of such materials may be damaging to the insect cuticle leading to dehydration and death (mechanical control), in addition to the insecticidal effect.

5.2 Effect of ethanolic extracts of *C. odorata* on *S. zeamais* Progeny development

The results obtained from this study demonstrated that both the leaf and root extracts of *C. odorata* can suppress progeny production (egg production) of *S. zeamais*. Suppression of ovipositional activity could be attributed to the presence of caryophyllene and germacrene D (Adebayo and Gbolade, 1994). Adebayo and Gbolade (1994) reported that *Lantana camara* which contains caryophyllene and germacrene D in large quantities exhibited some ovipositional suppression on *Callosobruchus maculatus.*

5.3 Effect of ethanolic extracts of *C. odorata* on weight loss of grains

This study indicated that the root extracts of *C. odorata* did not provide effective protection of the stored grain against damage by *S. zeamais*. However, the leaf extracts significantly protected the stored maize against *S. zeamais* up to two months of storage. The efficacy of the leaf extracts against weevil damage agrees with the findings of Mbah and Okorokwo (2008) that *C. odorata* leaf powder was as effective as Actellic powder in protecting stored maize against *S. zeamais*. Weight loss in stored maize grain was related to the number of insects present (Asawalam and Hassanali, 2006).

Although, the mode of action of these plant materials are not yet fully known, these extracts negatively affected oviposition rate, fertility of eggs or larval growth and development of hatched eggs or a combination of two or all of these factors (Bell *et al*, 1990; http://www.ias.ac.in/currsci/jan.25/articles22.htm) resulting in fewer number of insects in the treated grains.

5.4 Repellence effect of ethanolic extracts of *C. odorata* on *S. zeamais*

Both the ethanolic root and leaf extracts of *C. odorata* did not significantly repel the weevil relative to the control. Caryophyllene and germacrene-D are major constituents in *Lantana camara* and the essential oils have also been reported to repel bees, mosquitoes and cattle flies (Attri and Singh, 1978). The results of this study seek to suggest that *C. odorata* extracts do not repel *S. zeamais*.

Pharmacophagous sequestration of pyrrolizidine alkaloids (PAs) in *C. odorata* by *Zonocerus variegatus* was suggested by Boppre´ (1986). Furthermore chemoecological studies by Timbilla (2005) established that pyrrolizidine alkaloids such as rinderine and

intermedine (PAs) served as attractants to the African grasshopper, *Z. variegatus*. This study however could not conclude whether the non-repellence of S. *zeamais* by the *C. odorata* extracts was the result of the attractant activity of the PAs as in the case of Z. *variegatus* or otherwise.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study has shown that:

1. The ethanolic root extracts of *C. odorata* was not significantly toxic to the maize weevil at the dosage levels tested.
2. The ethanolic leaf extract on the other hand effected a better control of the weevil; however the percentage of weevil survival (> 91%). in the highest dosage i.e. 10 ml was still very high and capable of inflicting economic damage.
3. Both the root and leaf extracts did not repel the weevil significantly.
4. The leaf extracts reduced emergence of the weevil and also reduced grain weight loss, but same was not true for the root extracts.
5. The leaf extracts might be of practical use to farmers if it is used to reduce weevil multiplication (reproduction) thus reducing number of insects feeding and hence weight loss of grain.

6.2 Recommendations

Dried leaves and roots of *C. odorata* were used for the study. This might have resulted in the loss of volatile oils. It will therefore be necessary to test freshly harvested *C. odorata* materials. Further studies should also be conducted with higher dosages of the extracts. Again, different solvents should be used for extraction and the plant material should tested in various forms for example, leaf powder and paste.

REFERENCES

Adebayo, T. and Gbolade, A. A. (1994). Protection of stored cowpea from *Callosobruchus maculatus* using plant products. Insect Science and its Application 15: 185-189.

Adedire, C.O. and Lajide, L. (2003). Ability of extracts of ten tropical plant species to protect maize grains against infestation by the maize weevil, *Sitophilus zeamais*, during storage. Nigeria Journal of Experimental Biology 4:175-179.

Annon (1988). Plant breeding an integrated discipline, Abstract Selwyn College, Cambridge Walllbourne. Association of Applied biologist 97 pp.

Ansah, K.D. (2009). Effect of Smoke from *Senna siamea* (Lambk) on *S. zeamais* (Mot.) in stored maize. MSc Dissertation submitted to The Department of Crop Science, Faculty of Agric, Kwame Nkrumah University of Science Technology. 88 pp.

Appert, J. (1987). The Storage of Food: Grains and Seeds. Macmillan Publishers Ltd., London, 146 pp.

Asawalam E.F., Emosairue S.O., Ekeleme F. and Wokocha R.C. (2006). Insecticidal effects of powdered ports of eight Nigerian plant species against maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidea), Abstract. Nigeria Agricultural Journal 37:106-113.

Asawalam E.F. and Hasanali, A. (2006). Constituents of the Essential oil of *Vernonia amyddalina* as Maize Weevil Protectants. Tropical and Subtropical Ecosystems 6:95-102.

Attri, B.S. and Singh, R.P. (1978). A note on the biological activity of the oil of *Lantana camara* L. Indian Journal of Entomology 39: 384-385.

Bathia, S.K. (1976). Resistance to insects in stored grains. Tropical stored product information 31. 21 pp.

Bekele, A.J., Obeng-Ofori, D. and Hassanali, A**. (**1997). Evaluation of *Ocimum kenyense* (Ayobangira) as source of repellents, toxicants and protectants in storage against three major stored product insect pests, Journal of Applied Entomology 121: 169 –173.

Bell, A.E., Fellows, L.E. and Simmonds, S.J. (1990). Natural products from plants for the control of insect pests. E. Hodgson & R.J. Kuhr, eds. safer insecticide development and use. Maecel Dekker, USA.

Bennett, F.D. and Rao, V.P. **(**1968). Distribution of an introduced weed *Eupatorium odoratum* Linn (Compositae) in Asia and Africa and possibility of its biological control. PANS (C) 14: 277-281.

Bureau for Food and Agricultural Policy (BFAP). 2007. Modeling the Economic impact of climate change on the South African maize industry. BFAP Report No. 2007-2.

Bhulyah, I.M. (1988). Evaluation of leaves of Lagundi (*Vitex negundo* Lin.) as corn seed protectant against the corn weevil, *Sitophilus zeamais* Motsch. M.Sc. Thesis Central Luzon State University, Nueva Ecija, Philippines.

Biller, A. Boppre M., Witte, L. and Hartmann, T. (1994). Chemistry and Chemical Ecology of Pyrrolizidine alkaloids in *Chromolaena odorata,* Phytochemistry 35: 615- 619.

Boppre' M (19896) Insects pharmacophagously utilizing secondary plant substances (Pyrrolizidine alkaloids). Naturwissenschaften 73: 17-26.

Boppre M. (1983) Leaf scratching-A specilised behaviour of danaine butterflies for gathering secondary plant substances. Ocologia 59: 414-416.

Charles Adarkwa , Daniel Obeng -Ofori, Sabine Proyell, Matthias Scholler, Christoph Reichmuth, Carmen Buettner: Potential of the parasitic wasp, *Lariophagus distinguedus* (Forster) (Hymenoptera:Pteromalidea)as a biological Control Agent for *Sitophilus zeamais* Motschulsky (Coleoptera:Curculionidae) in stored Maize.

Clewer, A.G. and Scarisbrick, D.H. (2001). Practical Statistics and Experimental Design For plant and Crop Science. John Wiley Sons, Ltd, Baffin's Lane, Chichester, West Sussex P019IUD, England. 219-225.

Consultative Group on International Agricultural Research (CGIAR) (1997). (Newsletter) Volume 4, Number 2.

Dick, K. (1988). A review of insect infestation of maize in farm storage in Africa with special reference to the ecology and control of *Prostephanus truncatus.* Overseas Development Natural Resource Development Institute Bulletin No. 18, v+42 pp.

Dodson, C.D., Dyer, L.A.., Searcy, J., Wright, Z. and Letuorneau, D.K. (2000). Cenocladamide, a diydropyridon alkaloid from *Piper cenocladum*. Phytochemistry 53:51-54.

Donahaye, E. (1990). Laboratory selection of resistance by the red flour beetle *Tribolium castaneum* (Herbst) to an atmosphere of low oxygen concentration. Phytoparasitica, 18(2): 189-202.

Donald, A. W. and Mills, R. B. (1985). Stored grain insects. Fundamentals of Applied Entomology. R.E. Pfadt.(ed) Fourth Edition 567-569 pp.

Elhag, E.A. (2000). Deterrent effects of some botanical products on oviposition of the cowpea bruchid, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). International Journal of Pest Manage 46(2):109-113.

Emebiri, L.C. and Nwufo, M.I. (1990). Effect of trona (urao) on the survival and reproduction of *Sitophilus zeamais* and *Tribolium castaneum* on stored maize. Agriculture, Ecosytem and Environment 32: 69-75.

Evans, D. E. (1987). The influence of ate of heating on the mortality of *Rhyzopertha dominica* (F.) (Coloeptera: Bostrichidae). Journal of Stored Product Research 23, 73-77.

FAO (1985). Prevention of post Harvest Food Losses. Training Series No. 10 (122), Rome. 120 pp.

FAO (1997). http://www.fao.org/inpho/maize (Internet information Accessed on 23 August, 2007)

FAO (1994) Agriculture Series, No. 27. ISSN 0081-4539. Food and Agriculture Organization of the United Nations Rome.

FAO Agricultural Services Bulletin No. 17, Food and Agricultural Organization of the United Nations, Rome, v+71 pp.

Firdissa, E. and Abraham, T. (1999). Effects of some botanicals and other materials against the maize weevil (*Sitophilus zeamais* Motsch.) on stored maize. In CIMMYT & EARO, Maize Production Technology for the Future: Challenges and Opportunities. Proc. 6th Eastern and Southern Africa Regional Maize Conf., 21- 25 Sept. 1998. Addis Ababa, CIMMYT.

Floyd, E.H. and Powell, J.D. (1958). Some factors influencing the infestation of corn in the field by the rice weevil, Journal of Economic Entomology 51: 23-26.

Gautier, L. (1992). Taxonomy and distribution of a tropical weed, *Chromolaena odorata* (L.) R. King and H. Robinson. Candollea 47: 645-662.

Ghana Grains Board Programmne (GGBP), (1991). Maize Improvement, 1992 Annual Report of Ghana Grains Development project, Crops Research Institute, Kumasi, Ghana. 145 pp.

GenStat Release 7.2 Discovery Edition. Iawes Agricutural Trust (Rothamsted Experimental station)

Giles, P.H. and Ashman, F. (1971). A study of preharvest infestation of maize by *Sithophilus zeamais* Motsch. (Coloeptera: Curculionidae) in the Kenyan Highlands. Journal of Stored Products Research 7: 69-83

Golob, P. and Webley, D.J. (1980). The use of plants and minerals as traditional protectants of stored products. G138, Natural Resources Institute, Kent, UK.

Golob, P. and Muwalo, E. (1984) Pirimiphos-methyl as a protectant of stored maize cobs in Malawi. International Pest Control, July-August 94-96.

Golob, P. and Hanks, C. (1990) Protection of farm-stored maize against infestation by *Prostephanus truncatus* (Horn) and *Sitophilus* species in Tanzania. Journal of Stored Product Research, 26(4): 187-198.

Golob, P.S., Moss M.., Fidgen, H. and Evans, C. (1999). The Use of Spices and Medicinals as Bioactive Protectant for Grains. F.A.O., Rome, 239pp.

Gwinner J., Harnish R., Muck O. (1996): Manual on the Prevention of Post Harvest Grain Loss. GTZ, Eschborn.

Haines, C. P. (1991). Insects and Arachids of Tropical Stored Products. Their Biology and Identification, a Training Manual. Natural Resource Institute. 246 pp.

Hall, J.B., Kumar, R. and Enti, A.A (1972). The obnoxious weed *Eupatorium odoratum* (Compositae) in Ghana. Ghana Journal of Agricutural Science 5: 75-78.

Hassanali, A. and Lwande, W. (1989). Insecticides of plant origin (eds Arnason J. T., Philogene, B. J. R. and Morand P.), ACS Symposium Series 367, American Chemical Society, Washington DC, pp.78-98.

Hill, S. D. (1987). Agricultural Insect Pests of the Tropics and their Control. 2nd edition Cambridge University Press 33-50 pp.

Hill, D. S. and Waller, J. M. (1990). Pests and Disease of Tropical Crops (U.K.) Field Handbook Longman Scientist and Technical; 1990. 432 p.

Holloway, G. J. (1986). The potency and effect of phototoxins within yellow split peas *(Pisum sativum*) and adzuki bean (*Vigna angularis*) on survival and reproductive potential of S*itophilus oryzae* (L.) (Coleoptera: Curculionidae). Bulleting of Entomology Research 76(2); 287-295.

Hugh, D. (1988). Sorghum. Tropical Agricultural series. Longman Scientific and Technical (Publishers) New York pp 329 pp.

Hyde, M.B., Baker, A.A., Ross, A. C. and Lopez-Cesar, O. (1973). Airtight grain storage.

Ivens, G.W. (1974). The problem of *Eupatorium odoratum* L. in Nigeria. PANS 20: 76–82.

Jacobson, M. (1989) Botanical pesticides: past, present and future. Arnason, J.T., Philogene, B.J.R. and Morand, P., eds. Insecticides of Plant Origin. ACS Symposium Series, 387, pp. 1-10. Washington DC, USA.

Janick, J., Schery, R.W., Wood, F.W. and Ruttan, W.V., (1981) Plant Science. An introduction to world crops. Third Edition pp.532-533. Freeman and Company, San Francisco.

Javier, P.A. and B. Morallo-Rejesus.1982. Isolation and bioassay of insecticidal principles from black pepper (*Piper nigrum* L.) against three stored grain insects. In: Progress in Grain Protection Proc. 5th Annual Workshop in Grains Post Harvest Technology. pp. 45-59.

Joffe, A. (1963). The effect of physical disturbance or "turning" of stored maize on the development of insect infestation. South African Journal of Agricultural Science 6(1): 5564.

Jones, F.G.W. and Jones M.G. (1966). Pest of Field Crops. Edwards Arnolds (Publishers) Ltd. London pp 305-310.

Kassa, Adane (2003), Development and testing of mycoinsecticdes based on submerged spores and aerial conidia of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisoplae* (Deuteromycotina: Hyphomycetes) for control of locusts, grasshoppers and storage pests.

Kéita, S.M., Vincent, C., Schout, J.P., Arnason, J.T., Belanger, A. (2001). Efficacy of essential oil of *Occimum bacilicum* L. and *Occimum gratissimum* L. applied as an insecticidal fumigant and powder to control *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Stored Product Research 37(4):339-349.

Kis-Tamas, A. (1990) Study on the production possibilities of botanical pesticides in Developing African countries. UNIDO, Vienna, Austria.

Kochnar, S.L. (1986). Tropical Crops: A Textbook of Economic Botany. Macmillan Publishers, Hong Kong. 88-95 pp.

Kossou, D. K., Bosque-Perez, N. A. and Mareck, J. H. (1992). Effects of shelling maize on the oviposition and development of *Sitophilus zeamais* Motschulky. Journal of Stored Products Research 28 (3): 187-192.

Langunes-Tejeda, A. (1991) Evaluation of Technical and non-technical method to control *S. zeamais* in grains. Journal Maize abstracts. 308-309.

Lupina T. and Cripps H. (1987). The photoisomers of piperine. Journal Analytical Chemistry, 70(1): 112- 113.

Mabbett, T. (2007). Feed your crops and fight the pest : African farming March/April pp. 19 – 20.

Makanjuola, W.A., 1989. Evaluation of extracts of neem (Azadiracta indica A. Juss) for the control of some stored products pest. Journal of Stored Products Research 25(4): 231-237.

Mbah, O.I. and Okorokwo, M.O. (2008). An assessment of two plant product efficacy for the control of the maize weevil (*Sitophilus zeamais* Motschulsky) in stored maize. African Journal of Agricultural Research 3(7): 494-49.

McFarlane, J.A. (1989). Guidelines for pest management research to reduce stored food losses caused by insects and mites. Overseas Development and Natural resources Institute Bulletin No. 22. Chatham, Kent, UK.

McFarlane, J.A. (1990). Differences between some strains of stored –grain beetles in their capacity to cause grain damage: possible implications for the management of pesticide resistance. Tropical Science Series 30:357-371.

Miyakado, M, Nkayama, I and Ohno, N. (1989). Insecticidal unsaturated isobutylamides from natural products to agrochemical leads. Arnason J.T., Philogene, B.J.R. and Morand, P., eds. American Chemical Society, Washington, USA.

MOFA (Ministry of Food and Agriculture), (2007). Annual Food Situation Report 2006.

MoFA (Ministry of Food and Agriculture), (2001). Agriculture in Ghana. Facts and Figures, Statistics, Research and information Directorate.

Mohan, S. and Field, P.G. (2000). A simple Technique to Assess Compounds that are Repellent or Attractive to Stored Product Insects. Journal of stored Product Reseacrch 38: 23-24. IITA/JIRCAS Publication, IITA, Ibadan, Nigeria, 302-312

Morris, M. L. (2001) Assessing the Benefits of International Maize Breeding. Research: An overview. Of Global Maize impact study: In Pingali, P. L. (ed). CIMMYT 1999-2000. World maize facts and trends. Meeting world maize needs: Technological Opportunities and Priorities for the public sect. Mexico. D.F. CIMMYT . 25-27.

Morris, M.L., Tripp, R. and Denkyi, A. A., (1999) Adoption and Impacts of Improved maize production technology. A case study of the Ghana Grains Development Project. Economic Programme paper 99-01. Mexico D.F: CIMMYT.

Munniapan, R. and Marutani, M. (1988) Ecology and distribution of C*hromolaena odorata* in Asia and the Pacific. In: Munniapan R (ed.) Pro. First International Workshop on Biological control of *C. odorata.* Agricutural Experimental Station University of Guam, 21-24.

Murdock, L.L., Shade, R.E., Kitch, L.W., Hnesing, W., Moar, O.L., Chamblish, E.E., Wolfson, J.L. (1997). Post Harvest Storage of Cowpea in Sub-Saharan Africa. In: Singh, B.B., Mohan Raji F.R., Dashel K.E., *et. al.*, editors. Advances in Cowpea Research. IITA, Ibadan, Nigeria: IITA/JICAS Publication; 1997. 302-312 pp.

Neupane, F. P. (1995).Review of Agricultural entomology country profile- Agricultural entomology in Nepal. CAB, International.

Neupane, F. P., S. M. Shrestha., R.B. Thapa and T.B. Adhikari (1991). Crop protection (Nepal). Institute of Agric and Animal science, Rampur, Chitwan, Nepal.

Niber, T.B. (1994). The ability of powders and slurries from ten plant species to protect stored grain from attack by *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae) and *Sitophilus oryzae* L. (Coleoptera: Curculionidae). . Journal of Stored Products Research 30 (4): 297 – 301.

Nisit P., B. Liawruangrath, S. Liawruangrath, A. Baramee, A. Apisariyakul, J. Korth and J.B.Bremner (2006). Constituents of the essential oil from aerial parts of *Chromolanena odorata* from Thailand, Natural Products Research, 20: 636-640.

Nisit P., S. Liawruangrath, J. B.Bremner, B. Liawruangrath, (2005). Chemical constituents and biological activities of *Chromolaena*. Chiang Mai Journal of Science 32(2): 139-148

Norman, A.G. (1955). Corn and Corn Improvement. Academic Press Inc (Publishers) pp 149-150.

Obeng-Ofori, D., Reichmuth, C.H., Bekele, A.J. and Hassanali, A. (1997). Biological activity of 1,8 cineole, a major component of essential oil of *Ocimum kenyense* (Ayobangira) against stored product beetles. Journal of Applied Entomology 121: 237-243.

Ogunyele, R.F., (2000). Effectiveness of some plants against *Callosobruchus maculatus* (F) (Coleoptera: Bruchidea). Applied Tropical Agriculture 5(1):72-76.

Ogunleye, R.F., (2006). Comparative effectiveness of Cypermethrin and *Zanthoythum zanthoxyloides* (LAM) for the control of the cowpea foliage pest, *Ootheca mutabilis* (Salbergy). Journal of Ultra Scientist of Physical Sciences 18(1):9-14.

Onwueme, I.C. and Sinha, T.D. (1991). Field crop production in tropical Africa, CTA, Ede, p. 480.

Osagie, A.U. and Eka, O.U. (1998). Nutritional Quality of Plant Foods. Post Harvest Research Unit, University of Benin, Benin. 34 -41 pp.

Painter, R.H. (1951). Insect resistance in crop plants. Macmillan, New York, 520 pp.

Pathak, P.and Krisna, S.S. (1991). Post-embryonic development and reproduction in *Cocyra cephalonica* on exposure to Eucalyptus and Neem volatiles Journal of Chemical Ecology 17: 12.

Patil, R.K., Rayar ,S.G., Basappa, H., Hiremath, I.G. and Patil, B.R. (1997). Insecticidal property of indigenous plants against *Dactynotus carthamii,* H.R.L. and its predator, *Chrysoperla carnea* L. Journal of Oilseed Research 14(1): 71-73.

Purseglove, J.W. (1992). Tropical Crops: Monocotyledons. Longman Scientific and Technical, New York. pp. 300-305.

Rai, R. S., Lal, P. and Srivastava, P.K. (1987) Impregnation of Jute bags with insecticide for protecting stored food grains.Pesticides 21(8): 39-42.

Redlinger, L.M., Zettler, J.L., Davis, R. and Simonaitis, R.A. (1988). Evaluation of Pirimiphos methyl as a protectant for export grain. Journal of Economic Entomology 8:718-721.

Rouanet, G. (1987). The Tropical Agriculturalist-Maize. Macmillan Press Ltd London and Basingstoke. 1-4 pp.

Rouanet, G (1992). Maize. The Tropical Agriculturist, CTA, Macmillan, London.

Russel G.E. (1978) Plant breeding for pest and disease resistance. Butterworths and Co. Ltd. London- Buston, 293-323 pp.

Sayaboe, P.D. and Acda, M.A. (1990). Resistance of the major Coleopteran pests of stored grains to malathion and pirimiphos methyl. Review of Agricultural Entomology 18: 653-660

Schulten, G. G. M. (1976). Insect in stored maize ears. Abstract on Tropical Agriculture, 2(6): 9-17.

Shaw, R.H. and Newman, J.U. (1991). Weather Stress in the Maize Crop - National Maize Handbook US (available at http://www.agcom.purdue.edu/ AgCom/ Pubs/ NCH/NCH-18.html, 7/11/2008)

Sighamony, S., Anees, I., Chandrakala, T.S. and Osmani, Z. (1986) Efficacy of certain indigenous plant products as grain protectants against *Sitophilus oryzae* (L.) and *Rhyzopertha dominica* (F.). Journal of Stored Product Research 2(1): 21- 23

Simmonds, N. W. (1976). Evolution of crop plants pp. 128-136. Longman Group Ltd. London.

Sinden. Sinha, R.N., Demianyk, C. J. & Mckenzie, R.I.H. (1988). Vulnerability of common wheat cultivars to major stored product beetles. Canadian Journal of Plant Science 68(2): 169-174

Sinha, R. N., Demianyk, C. J. and McKenzie, R. I. H. (1988). Venerability of common wheat cultivars to major stored-product beetles. Canadian Journal Plant Science 68(2): 337-343.

Sprague, G.F. and Dudley, J.W. (1988). Corn and Corn Improvement. 3rd Edition. American Society of Agronomy, Inc. Madison, U.S. pp 578 – 638.

Swain, T. (1977) Annual Review of Plant Physiology 28:479-501. (Volume publication date June 1977) DOI:10.114/annurev.pp.28.060177.002403.

Talapatra, S. K., Bhar, D. S. and Talapatra, B. (1974). Flavonoid and terpenoid-constituents of *Eupatorium odoratum*. Phytochemistry, 13: 284–285.

Talukder, F.A. and Howse, P.E. (1995). Evaluation of *Aphanamaxis polystachya* as a source of repellents, antifeedants, toxicants and protectants in storage against *Tribolium castaneum* (Herbst). Journal Stored Product Research 31: 55 – 61.

Talukder, F.A. and Howse, P.E. (2000). Isolation of secondary compounds from *Aphanamidis polystachygas* as feeding deterrents against adult *Tribolium castaneum* (Coleoptera:Tenebroidae Journal of Plant Diseases and Protection 107(5): 498-504.

Taylor R. W. D. (1991). Resistance to grain fumigants and future prospects for their use. Pesticides Outlook 2(2): 22-24.

Timbilla, J.A. and Braima, H.(1996) A survey of introduction, distribution and spread of *Chromolaena odorata* in Ghana. In: Prasad UK, Muniappan R, Aeschliman JP, de Foresta H (eds). Distribution , ecology and management of *Chromolaena odorata*. Proceedings of third international *Chromolaena* workshop. Abidjan, Cote D'Ivoire. November, 1993. 6-18.

Timbilla J.A. (2005). Integrated management of the African grasshopper, *Zonocerus variegat*us (L) (Orthoptera: Pyrgomorphidea) in Ghana. Biological and chemoecological studies: A Thesis submitted for the degree of Doctor of Philosophy. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Toan-Thang PHAN, Lingzhi WANG, Patrick SEE, Renee Jacqueline GRAYER, Sui-Yung CHAN and Seng Teik LEE, "Phenolic Compounds of *Cromolaena odorata* Protect Cultured Skin Cells from Oxidative Damage: Implication for Cutaneous Wound Healing", Biological and Pharmaceutical Bulletin, 24: 1373-1379 (2001).

Udo, I. O.(2005). Evaluation of the potential of some local spices as stored grain protectants against the maize weevil *Sitophilus zeamais* most. (Coleoptera: Curculionidae) Journal of Applied Sciences & Environmental Management 9(1): 165-168 pp.

Voigt, J.O. (1845). Hortus suburbanus Calcuttensis, Bishop's College Press, Calcutta.

Vowotor, K. A., Meikle, W. G., Ayertey , J. N. and Markham, R. H. (2005). Distribution of and Association between the Larger Grain Borer *Prostephanus Truncatus* (Horn) (Coleoptera:Bostrichidae) and the Maize weevil *Sitophilus zeamais* (Motschulsky). (Coleoptera: Curculionidae) in maize stores. Journal of Stored Product Reseach 41: 498-512.

Wallace, H.A. and Bressman, E.N. (1937). Corn and Corn Growing. John Wiley and Sons, New York.

Warui, C.M., Kega, V.M. and Onyango, R.(1990). Evaluation of an improved pyrethrum formation in the control of maize pest in Kenya. Review of Agricultural Entomology 18:15-17.

Weaver, D.K., Dunkel, F.V., Ntezurubanza, L., Jackson, L.L. and Stock, D.T. (1991). The efficacy of linalool, a major component of freshly- milled *Ocimum canum* Sims (Lamiaceae), for protection against post-harvest damage by certain stored product coleoptera. Journal of Stored Product Research 27(4): 213-220.

Webster J. A. and Smith D. H. (1975). Resistance to cereal leaf beetle in wheat density and length of leaf. Crop Science 15:199.

Wildey, K. B. (1987).Repellency of insecticide formulations to rust-red flour beetles *Tribolium castaneum* (Herbst). In: Stored Products Pest Control (Lawson, T. J. ed.), Proceedings of the Symposium of the British Crop Protection Council, Reading, U K, 1987: BCPC Monograph No. 37:187-196.

Wohlgemuth, R (1989). Longevity of stored products insects in grain in cold-storage warehouse. Anzeiger fur—Schadliingskunde, Pflanzenschutz, 62(6): 114-119.

Youdeowei, A. and Service, M.W. (1986). Pest and Vector Management in the Tropics. ELBS and Longman Group Ltd. 39 pp.

http://edocs.ub.uni-frankfurt.de/volltextte/2008/10936 (Internet information accessed on 11/6/08).

http://en.wikipedia.org/wiki/Mealie (Internet information accessed on 21/11/08)

http://grainpro.com (Internet information accessed on 04/11/09).

http://sgrl.csiro.au/storage/insects/beetles_moths/sitophilus-species.html(Internet information accessed on 15/9/09).

http://www.aatf-africa.org. (Internet information accessed on 19/6/09).

http://www.cimmyt.org/resources/archive/what_is_cimmyt/annual_reports/ar97/htm/AR97. (Internet information accessed on 17/12/08).

http://www.csir.org.gh./index1.php?linkid=65&archiveid=35&page=1&adata=16/08/200 (Internet information accessed on 70/09/10).

Htt// www.fao. Org/docrep/T1838E/ti838E.htm (Internet information accessed on 11/6/10).

http://www.fao.org /docrep/to395e/TO395E03, htm (Internet information accessed on 5/6/10).

http://www.fao.org/docrep/x2230E/x2230e04.htm (Internet information accessed on 13/3/09).

http://www.faqs.org. (Internet information accessed on 2/6/09).

http://www.ficciagroindia.com/about-us/about-us.htm. (Internet information accessed on 11/6/08).

http://www.ficciagroindia.com/production-guidelines/field-crop/maize/area.htm (Internet information accessed on 27/6/08).

(http://www.gains.org.gh). (Internet information accessed on 4/8/09)

http://www.ias.ac.in/currsci/jan.25/articles22.htm (Internet information accessed on 23/6/08).

http://www.iita.org/cms/details/print-article.aspx?articleid=273&zoneid=63 (Internet information accessed on 8/10/09).

htpp://www.ikisan.com/links/ap_maizeStored%20Grain%20Pests.shtml (Internet information accessed on 28/11/09).

http://www.kznhealth.gov.za(Internet information accessed on 29/9/10).

http:///www.new.ag.info/00-3/focuson/focuson4.html (Internet information accessed on 5/30/09).

http://www.rareorganics.com/coumarins_wri.html (Internet information accessed on 12/8/10).

http://www.satake.co.uk/cereal_milling/maize_origin.htm (Internet information accessed on 19/3/09).

http://www.tropentag.de)/2007/proceedings/node500.htm (Internet information accessed on 22/6/09).

Wikipidia, http://en.wikipidia .0rg/wiki/Sitophilus (Internet information accessed on 2/6/08).

APPENDICES

Appendix 1: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality one day after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.2500	0.4167	2.14	
Treatment level	3	0.7500	0.2500	1.29	0.337
Residual	9	1.7500	0.1944		
Total	15	3.7500			

Appendix 2: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality two days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.1875	0.3958	1.16	
Treatment level	3	2.1875	0.7292	2.14	0.165
Residual	9	3.0625	0.3403		
Total	15	6.4375			

Appendix 3: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality three days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	2.0000	0.6667	1.71	
Treatment level	3	2,5000	0.8333	2.14	0.165
Residual	9	3.5000	0.3889		
Total	15	8.0000			

Appendix 4: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality four days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.6875	0.5625	1.11	
Treatment level	3	2.1875	0.7292	1.44	0.295
Residual	9	4.5625	0.5069		
Total	15	8.4375			

Appendix 5: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality five days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.0000	0.3333	0.86	
Treatment level	3	2.5000	0.8333	2.14	0.165
Residual	9	3.5000	0.3889		
Total	15	7.0000			

Appendix 6: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality six days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.6875	0.2292	0.80	
Treatment level	3	2.1875	0.7292	2.56	0.120
Residual	9	2.5625	0.2847		
Total	15	5.4375			

Appendix 7: General Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* mortality seven days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.6875	0.2292	0.80	
Treatment level	3	2.1875	0.7292	2.56	0.120
Residual	9	2.5625	0.2847		
Total	15	5.4375			

Appendix 8: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality one day after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.5000	0.1667	0.75	
Treatment level	3	3.5000	1.1667	5.25	0.023
Residual	9	2.0000	0.2222		
Total	15	6.0000			

Appendix 9: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality two day after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.1875	0.0625	0.18	
Treatment level	3	8.1875	2.7292	8.02	0.007
Residual	9	3.0625	0.3403		
Total	15	11.4375			

Appendix 10: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality three day after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.1875	0.0625	0.18	
Treatment level	3	12.6875	4.2292	12.43	0.001
Residual	9	3.0625	0.3403		
Total	15	15.9375			

Appendix 11: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality four day after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.1875	0.0625	0.16	
Treatment level	3	13.6875	4.5625	11.53	0.002
Residual	9	3.5625	0.3958		
Total	15	17.4375			

Appendix 12: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality five days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.7500	0.2500	0.47	
Treatment level	3	12.2500	4.0833	7.74	0.007
Residual	9	4.7500	0.5278		
Total	15	17.7500			

Appendix 13: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality six days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.6875	0.2292	0.45	
Treatment level	3	9.6875	3.2292	6.37	0.013
Residual	9	4.5625	0.5069		
Total	15	14.9375			

Appendix 14: General Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* mortality six days after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.5000	0.5000	0.90	
Treatment level	3	9.5000	3.1667	5.70	0.018
Residual	9	5.0000	0.5556		
Total	15	16.0000			

Appendix 15: Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* emergence from stored maize after four weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.66121	0.22040	2.55	
Treatment level	3	0.31150	0.10383	1.20	0.364
Residual	9	0.77930	0.08659		
Total	15	1.75200			

Appendix 16: Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* emergence from stored maize after five weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	10.530	3.510	1.33	
Treatment level	3	22.520	7.507	2.84	0.098
Residual	9	23.755	2.639		
Total	15	56.805			

Appendix 17: Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* emergence from stored maize after six weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	15.820	5.273	2.32	
Treatment level	3	36.352	12.117	5.32	0.022
Residual	9	20.496	2.277		
Total	15	72.668			

Appendix 18: Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* emergence from stored maize after seven weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	17.122	5.707	2.58	
Treatment level	3	40.000	13.333	6.03	0.016
Residual	9	19.910	2.212		
Total	15	77.032			

Appendix 19: Analysis of variance on effect of alcoholic leaf extract of *C. odorata on S. zeamais* emergence from stored maize after eight weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	17.699	5.900	2.71	
Treatment level	3	41.987	13.996	6.43	0.013
Residual	9	19.595	2.177		
Total	15	79.28			

Appendix 20: Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* emergence from stored maize after four weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	0.30260	0.10087	1.34	
Treatment level	3	0.38839	0.12946	1.73	0.231
Residual	9	0.67514	0.07502		
Total	15	1.36613			

Appendix 21: Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* emergence from stored maize after five weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	1.340	0.447	0.31	
Treatment level	3	10.138	3.379	2.34	0.142
Residual	9	12.998	1.444		
Total	15	24.476			

Appendix 22: Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* emergence from stored maize after six weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	2.137	0.712	0.30	
Treatment level	3	18.003	6.001	2.56	0.120
Residual	9	21.126	2.347		
Total	15	41.267			

Appendix 23: Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* emergence from stored maize after seven weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	2.605	0.868	0.33	
Treatment level	3	21.326	7.109	2.70	0.109
Residual	9	23.713	2.635		
Total	15	47.643			

Appendix 24: Analysis of variance on effect of alcoholic root extract of *C. odorata on S. zeamais* emergence from stored maize after eight weeks.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	3.153	1.051	0.37	
Treatment level	3	14.555	8.185	2.90	0.094
Residual	9	25.425	2.825		
Total	15	53.132			

Appendix 25: Analysis of variance on effect of alcoholic leaf extract of C. *odorata* on weight loss of stored maize.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum					
Treatment level	3	140.763	46.921	8.45	0.003
Residual	12	66.653	5.554		
Total	15	207.416			

Appendix 26: Analysis of variance on effect of alcoholic leaf extract of C. *odorata* on weight loss of stored maize

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	17.175	5.725	1.04	
Treatment level	3	140.763	46.921	8.53	0.005
Residual	9	49.477	5.497		
Total	15	207.416			

Appendix 27: Analysis of variance on effect of alcoholic root extract of C. *odorata* on weight loss of stored maize

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum					
Treatment level	3	95.48	31.83	1.66	0.228
Residual	12	229.87	19.16		
Total	15	325.35			

Appendix 28:Analysis of variance on effect of alcoholic root extract of *C. odorata* on weight loss of stored maize

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	3	100.66	33.55	2.34	
Treatment level	3	95.48	31.83	2.22	0.156
Residual	9	129.21	14.36		
Total	15	325.35			

Appendix 29: General Analysis of variance on repellence effect of alcoholic root extract of C. *odorata on S. zeamais* one hour after treatment

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	0.3831	0.1915	0.72	
Treatment level	3	0.2189	0.0730	0.28	0.841
Residual	6	1.5869	0.2645		
Total	11	2.1889			

Appendix 30: General Analysis of variance on repellence effect of alcoholic root extract of C. *odorata on S. zeamais* two hours after treatment

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	0.8755	0.4378	3.00	
Treatment level	3	0.5199	0.1733	1.19	0.391
Residual	6	0.8755	0.1459		
Total	11	2.2709			

Appendix 31: General Analysis of variance on repellence effect of alcoholic root extract of C. *odorata on S. zeamais* twelve hours after treatment

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	0.49249	0.24625	3.86	
Treatment level	3	0.51985	0.17328	2.71	0.138
Residual	6	0.38305	0.6384		
Total	11	1.39540			

Appendix 32: General Analysis of variance on repellence effect of alcoholic root extract of C. *odorata on S. zeamais* twenty four hours after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	0.49249	0.24625	3.86	
Treatment level	3	0.51985	0.17328	2.71	0.138
Residual	6	0.38305	0.06384		
Total	11	1.39540			

Appendix 33: General Analysis of variance on repellence effect of alcoholic leaf extract of C. *odorata on S. zeamais* one hour after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	17.820	8.910	3.55	
Treatment level	3	5.489	1.830	0.73	0.571
Residual	6	15.076	2.513		
Total	11	38.385			

Appendix 34: General Analysis of variance on repellence effect of alcoholic leaf extract of C. *odorata on S. zeamais* two hours after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	4.117	2.059	0.69	
Treatment level	3	10.979	3.660	1.23	0.378
Residual	6	17.840	2.973		
Total	11	32.936			

Appendix 35: General Analysis of variance on repellence effect of alcoholic leaf extract of C. *odorata on S. zeamais* twelve hours after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	5.496	2.748	0.50	
Treatment level	3	16.481	5.494	1.00	0.454
Residual	6	32.943	5.490		
Total	11	54.920			

Appendix 36: General Analysis of variance on repellence effect of alcoholic leaf extract of C. *odorata on S. zeamais* twelve hours after treatment.

Source of Variation	DF	SS	MS	VR	F. pr
Rep stratum	2	1.372	0.686	0.11	
Treatment level	3	18.538	6.179	1.00	0.455
Residual	6	37.067	6.178		
Total	11	56.977			