Sudan University of Science and Technology

College of Graduate Studies

Insecticidal Effect of Some Botanical Formulations on Mortality of Red Flour Beetle *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae).

الأثر الإبادى لبعض المستحضرات النباتية علي خنفساء الدقيق الحمراء

Tribolium castaneum Herbst **(**Coleoptera**:** Tenebrionidae**)**

A thesis submitted in partial fulfillment of the requirements for the M. Sc. degree in plant protection

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الآيــة

قال تعالي:

مَانَ جُنُودُهُ مِنَ الْجِنِّ وَالإِنْسِ وَالطَّيْرِ فَهُمْ
حَتَّى إِذَا أَتَوْا عَلَى وَادِ النَّمْلِ قَالَتْ نَمْلَةٌ يَا أَيُّهَا يُوزَعُونَ (17)
خُلُوا مَسَاكِنَكُمْ لَا يَحْطِمَنَّكُمْ سُلَيْمَانُ وَجُنُودُهُ وَهُمْ لَا
(18) فَتَبَسَّمَ ضَاحِكًا مِنْ قَوْلِهَا وَقَالَ رَبِّ أَوْزِعْنِي أَنْ
َّتِي أَنْعَمْتَ عَلَيَّ وَعَلَى وَالِدَيَّ وَأَنْ أَعْمَلَ صَالِحًا
ضَاهُ وَأَدْخِلْنِي بِرَحْمَتِكَ فِي عِبَادِكَ الصَّالِحِينَ (19))

صدق الله العظيم

سورة النمل الآيات (17–19)

DEDICATION

TO my mother and father

To my dear brothers and sisters

To all my family

To all my teachers and friends with

love

&

respect

Nada

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All thanks are due to Almighty Allah (SWT) who gave me health and strength, and helped me tremendously to produce this work. I would like to express my thanks to my supervisor Professor. Awad Khalafalla Taha for his helpful assistance, guidance, patience and keen supervision during this work.

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Abstract

Laboratory experiments were conducted at the College of Agricultural Studies, Sudan University of Science and Technology, to evaluate the insecticidal effect of korobi *Nerium oleander* L, Damas *Conocarpus lancifolius* Engl and Mahogany *Khaya senegalensis* (Desr. A.Juss). against red flour beetle *Tribolium castaneum* Herbst.

Three formulations (powder, aqueous and ethanolic extract of each plant were used under three concentrations . Three concentrations from each plant (5%, 10% and 15%) were used in this study. The results showed that all concentrations of all tested plants in various formulations gave significantly higher mortality percentage than the control after 24hrs of exposure.

The highest concentration (15%) of Nerium leaves powder revealed only 38.4% mortality after 72 hrs of exposure, whereas, the same concentration of Nerium leaves aqueous and ethanolic extracts gave higher mortality percentage (48.4%). Meanwhile, the highest concentration of Damas leaves aqueous extract generated only 38.4% mortality after 72 hrs of exposure, whereas, the same concentration of Damas leaves ethanolic extract caused 41.7% mortality.

The obtained results also revealed that the highest concentration of Mahogany leaves powder, aqueous extract and ethanolic extract induced 25%, 31.7% and 55% mortality respectively after 72 hrs of application.

(ملخص البحث)

أجريت تجارب معملية بكلية الدراسات الزراعية, بجامعة السودان للعلوم والتكنولوجيا لتقييم الأثر الإبادي لنباتات ورد الحمير، الدمس و المهوقني ضد خنفساء الدقيق الحمراء *Tribolium castaneum* Herbst. تم استخدام ثلاثة تراكيز في هذه الدراسة (5%, 10% و15%).

استخدمت ثلاث مستحضرات (بدرة، والمستخلص المائى والإيثانولى) بثلاث تركيزات لكل نبات .

أوضحت النتائج المتحصل عليها أن كل التركيزات المختبرة من كل النباتات بمختلف مستحضراتها أعطت نسب موت عالية مقارنة بالشاهد بعد 24 ساعة من المعاملة.

أعطى أعلى تركيز (15%) من بدرة أوراق ورد الحمير فقط نسبة موت 38.4% بعد 72 ساعة من المعاملة, في حين ان نفس التركيز من المستخلص الإيثانولي والمائى لأوراق ورد الحمير أعطى نسبة موت عالية (48.4%). وفي سياق متصل, أعطى أعلى تركيز (15%) من المستخلص المائي لأوراق الدمس فقط نسبة موت 38.4 % بعد 72 ساعة من المعاملة، في حين ان نفس التركيز من المستخلص الإيثانولي لأوراق الدمس أعطي نسبة موت 41.7, %.

كما أوضحت النتائج المتحصل عليها أن أعلى تركيز (15%) من البدرة، المستخلص المائي و المستخلص الإيثانولي لأوراق المهوقني احدث نسبة موت (25%, 31.7% ,55%) بعد 72 ساعة علي التوالي.

CHAPTER ONE

INTRODUCTION

Cereal grains are used as a source of food in many countries. Dura *Sorghum bicolor* (L.) Moench is belong to family Poaceae. It is a common grains crop, within the region. In both advanced and subsistence agriculture, with about 75% of the world total sorghum acreage as a primary crop in subsistence agriculture (FAO,1979).

In the Sudan, Sorghum crop occupies about 40% of the Sudan cropped lands, about 90% is rain fed and lies mainly in what is known as the central rain lands extending from Kassala State in the East to North and South Kordofan in the West (Elkhaidir, 1982). However, the losses due to infestation by insects after harvest have been estimated at 5-10% (Anon, 1993). The losses vary according to the geographical location and climatic conditions within the country and it fluctuates between 5% in North to 20% in South (FAO, 1977). The majority of these losses are due to insects infestation (Ibrahim, 2001). Annual post-harvest losses resulting from insect damages, microbial deterioration and others factors are estimated to be 10-25% of worldwide production (Matthews, 1993).

In the Sudan insect pests of sorghum include stem borer *Chilo partellus* and *Sesamia cretica* Sorghum Aphids *Melanaphis sacchari* , Sorghum midge *Contarinia sorghicola* dura andat *Agonosciles pubscenes*, Shoot fly *Atherigona varia* soccata and African bollworm *Helicoverpa armigera*. This beside a number of Storage pests such as khapra beetle *Trogoderma granarium*, lesser grain borer *Rhizopertha dominica*, saw-toothed grain beetle *Oryzaephilus surinamensis*, store weevil *Sitophilus granarius* (Schmutterer, 1995).

Tribolium castaneum Herbst is considered as a major pest of stored grains. Control of these insects relies heavily on the use of synthetic insecticides and fumigants. But their widespread use has led to some serious problems including development of insect strains resistant to insecticides (Rachid, *et al.* 2006), toxic residues on stored grain, toxicity to consumers and increasing costs of application. However, there is an urgent need to develop safe alternatives that are of low cost, convenient to use and environmentally friendly. Considerable efforts have been focused on plant derived materials, potentially useful as commercial insecticides. Also the development of bioinsecticides has been focused as a viable pest control strategy in recent years (EL-Kamali, 2009).

Botanical insecticides are considered as an alternative to the synthetic chemicals for being biodegradable, pest specific, non-hazardous to human health and environment and leaving no toxic residue in nature (Amin e*t al.*, 2012).

Objective of the present study

This study was aimed to investigate the insecticidal effect of various extracts from three plants, namely korobi *Nerium oleander* L. Damas *Conocarpus lancifolius*, Mahogany *Khaya senegalensis* (Desr.) A.Juss. against red flour beetle *Tribolium castaneum* Herbst.

CHAPTER TWO

LITERATURE REVIEW

2.1. *Sorghum bicolor*. (L.) Moench

2.1.1 Taxonomy

Sorghum is a cereal of remarkable genetic variability. More than 22000 accession are present in the World Sorghum Collection India .This collection is used by plant breeders to improve the crop. Sorghum is difficult to classify, due to its wide diversity (Kimber, 2000).

Kingdom : Plantae

Division : Magnoliophyta

Class : Liliopsida

Sub class : Commelinidae

Order : Cyperales

Family : Poaceae (Grass)

Genus : Sorghum

Species : bicolor (L.) Moench

S.N : *Sorghum bicolor* (L.) Moench

2.1.2 Description

Sorghum is annuals, few are perennials. Cultivated and most weedy sorghum are non-rhizomatous, culms nodes are either glabrous or shortly tomentose. The inflorescence is contracted. The branches of the inflorescence are alternate. *Sorghum bicolor* includes all cultivated sorghums as well as a group of semi wild plants often regarded as weeds. Historical records and aracheological data have not been able to clearly state the origin and domestication of *Sorghum bicolor*. There are 571 recognized cultivars, however these cross readily without barriers of sterility or difference in genetic balance, therefore it makes sense to group them into a single. The leaves look much like those of maize, they sometimes roll over. A single plant may have more than two leaves. The flower head carries two types of flowers, one type has no stalk has both male and female part, and the other flower is stalked and is usually male (Amsalu and Endashaw , 1998).

2.1.3 Distribution

The largest diversity of cultivated and wild sorghum is in Africa (De Wet and Price, 1976). The great diversity of *S. bicolor* was created through disruptive selection and by isolation and recombination in the extremely varied habitats of Northeast Africa and the movement of people carrying these species throughout the continents (Miller, 1982). There seems to be no agreement that sorghum plants are African in origin but the domestication event may have taken place elsewhere and more than once when and how sorghum is a matter of conjecture (House, 1985).

suggested that sorghum has separate centers of origin. The wild race, aethiopicum, gave rise to races durra and bicolor, arundinaceum to guinea, and verticilliflorum to kafir. (De Wet and Huckabay ,1967). Dogget (1965) suggested that the diversity seen in the wild forms might reflect human manipulation and intervention associated with the selection of domesticated type.

2.1.4 Ecology

Sorghum is primarily a plant of hot, semi-arid tropical environments that are too dry for maize. It is particularly adopted to drought due to a number of morphological and physiological characteristics, including an extensive root system, waxy bloom on leaves that reduces water loss, and the ability to stop growth in periods of drought and resume it when the stress is relieved. A rainfall of 500-800mm evenly distributed over the cropping season is normally adequate for cultivars maturing in 3- 4 months. Sorghum tolerates water logging and can also be grown in areas of high rainfall. It tolerates a wide range of temperatures and is also grown widely in temperate region and at altitudes up to 2300 m in the tropics. The optimum temperature is 25-31C°, but temperatures as low as 21 C° will not dramatically affect growth and yield. (Balole and Legwaila, 2005).

2.1.5 Cultivation

In dry-land condition , seeds normally sown in rows, 75-100cm apart at a rate of 3-9kg/ha higher seed rates used for more humid areas. In good rainfall or under irrigation, seeds should be close drilled or broadcasted at a rate of 20-35kg/ha. This resulting in more leaf and less heavy stems, also obviating weeding. Seeds germinate best between 20-30C°, with poorer germination at higher or lower degrees. Seeded in rows like corn in most areas, usually spaced 10-14cm apart in rows, whereas profuse tillering varieties are spaced 30-45cm apart. Weeds control by chemicals or mechanical means is important as crop grows slowly in early stages. Cultivated or harrowed once after plant emergence and later as required. Usually 1-3 cultivations are necessary in tropics. Shallow cultivation is essential to prevent damage to surface roots. Constant rouging necessary for off-type plants before flowering for both open pollinated and hybrid seed production. (Reed, 1976).

2.1.6 Uses

Though sorghum is used largely for forage in the US, it is very important in the world`s human diet, with over 300 million people dependent on it (Bukantis, 1980). It is grown for grain, forage, syrup and sugar, and industrial uses of stems and fibers. Grain sorghum is a staple cereal in hot dry tropics. The threshed grain is ground into a wholesome flour and stalk used as animal feed. Sorghum, with large juicy stems containing as much as 10% sucrose, is used in the manufacture of syrup and also sugar can be manufactured from sorghum. Arubans make porridge and muffins from sorghum meal. Parched seeds are used as coffee substitutes or adulterant (Morton, 1981).

2.2 Rust red flour beetle *Tribolium castaneum* Herbst

2.2.1 Classification

Kingdom : Animalia

Phylum : Arthropoda

Class : Insecta

Order : Coleoptera

Family : Tenebrionidae

Genus : Tribolium

Species : castaneum

S.N : *Tribolium castaneum* Herbst

2.2.2 General Description

A serious secondary pest throughout the warmer parts of the world in food stores. The adult is rather flat oblong, reddish-brown in color and about 3-4mm long (Hill, 1975). Its antennae end in a three-segmented club. (Walter, 1990).These beetles can breed throughout the year in warm areas.(Plate. 1), (Plate. 2) .

Plate. 3 : Adult of Red flour beetle

Plate. 4: Larva of Red flour beetle

http://entenemdept.ufl.*edu*/creatures/urban/beetles/red.flour-beetle.htm

2.2.3 Distribution

Tribolium castaneum occurs all over the world wherever stored cereal products are found. It lives inside the buildings and may easily be carried from place to place in small quantities of food stuffs, this beetle is likely to be recorded from practically any part of the world. It is essentially an insect of warm climates (Good, 1936). The factors influencing distribution are numerous including the height, the temperature, the moisture content … etc, (Boon and Ho, 1995).

2.2.4 Host Range

Tribolium castaneum is a cosmopolitan pest which primarily attacks milled grain products, such as flour and cereals. Both adults and larvae feed on grain dust and broken grains, but not the undamaged whole grains and spend its entire life cycle outside grain kernels (Karunakaran *et al*., 2004). *T. castaneum* and *T.confusum* infest a wide range of commodities and products including barley, beans, biscuits, breakfast cereals, cacao, corn, cornmeal, cottonseed, dried fruits, drugs, flour, legume seeds, milk chocolate, millet, nuts, oats, peas, powdered milk, rice, rye, spices, sunflower seeds, wheat and wheat bran, herbarium and museum collections (Mason, 2003) .

2.2.5 Nature of damage

Infestation is apparent by the appearance of adults on the surface of the grain; there is extensive damage to previously holed or broken grains, or grain damaged by other pests. Damage is done by both larvae and adult (Hill, 1975).

Tribolium castaneum caused damage by feeding ability in addition to contamination of the grain or medium. Infestation by tenebrionids leads to persistent disagreeable odours in the commodity. This odour is due to the secretion of benzoquinones from a pair of abdominal defense glands, found in the adult of all species (Anonymous, 1986). In most cases the presence of insects in a grain bin indicates that moisture builds up and molds are also present. The combination of these three factors can greatly reduce the quality and value of grain (Doug, 2001).

In the Sudan, sorghum grain after harvest always has some broken and damaged kernels due to the threshing process, and damage is even greater when sorghum is threshed manually. About 20% of the kernels are recorded to be damaged (Saad, 1978).

2.2.6 Biology

The eggs are small, cylindrical and white. The female lays the eggs scattered in the produce. The larvae are yellowish-white, about 6mm long when fully grown. The head is pale brown, and the last segment of the abdomen has two upturned dark pointed structures. The larvae live and develop inside the grain till pupation. The pupa is yellowish-white, later becoming brown, dorsum hairy and the tip of the abdomen having two spine-like processes (Hill, 1975).

Female beetles lay 300 - 400 eggs directly into flour or other foods during a period of five to eight months (2-3eggs per day). Fully grown larvae transform into naked pupae without any form of protection. At the optimum temperature of $35C^0$, the development times for each stage were 3 days for eggs, 16 days for larvae and 4.5 days for pupae at RH 60-80% (Shazali and Smith, 1986).

Newly hatched larvae survive only if suitable food is readily available. The number of larval instars varies widely, depending on the individual, the environmental conditions and availability of food resources. Larvae are active, but generally hide within the food away from light (Abdelsamad *et al.*, 1988 and Mason, 2003).

Adults are very active, quickly running for cover when disturbed and can be found either on the surface or deep within the food ; males showed aggregation behavior, while females dispersed fairly uniformly. Egg to adult development time was about 26 days at 32-35C^{o} and >70% RH (Mason, 2003).

T. castaneum is a facultative predator and scavenger. Both adult and larvae of *T. castaneum* were known to prey on immature stages of the rice moth *Corcyra cephalonica*, a potential competitor within stored product environments. Adults and larvae are voracious predators of eggs and pupae, thus enhancing larval development or adult reproduction, thereby reducing competition for their progeny (Alabi *et al.,* 2008).

2.2.7 Control of stored grain pests

2.2.7.1 Non-chemical methods

These are particularly practices which are often effective in knocking down insect's infestation and should be encouraged and developed. They are :

2.2.7.1.1 Wood ashes

Mixing material with grain to prevent insect damage was first practical many years ago and had never been entirely abandoned (Richard, 1956).

2.2.7.1.2 Smoking

Some farmers stored sorghum, the head inside of their huts, suspended from the roof. Other farmers used the fire under their storage cribs for the same purpose (Gile, 1964).

2.2.7.1.3 Sunning

Exposing infested grain, in thin layers to the sun to minimize infestation were common practices in rural communities (Shazali, 1989).

2.2.7.1.4 Sanitation

To minimize the movement of insects from old grain and grain debris to new grain , thorough cleanup is necessary. At least 2 weeks before storing new grain, clean all grain and grain debris from within and around grain bins. Be thorough; sweep or vacuum bin floors and remove and destroy any grain and grain debris in combines, wagons and augers (Weinzierl and Higgins, 2008).

2.2.7.2 Chemical control

Both insecticides and fumigants such as methyl bromide and phosphine are used. The application of insecticides should be very limited because of health hazards and residue problem. Insecticides such as malathion may be used for spraying walls, floor and ceiling of warehouses or store room in order to kill a residual infestation. Grain fumigants are chemicals usually alone or in combination in vapour phase to control existing infestation. A light degree of air tightness should be manifested to obtain a complete kill (Robert Fadt, 1985).

2.2.7.3 Biological control

Tribolium castaneum was more susceptible to tape worms than *T. confusm*. There was only significant variation among strains and between sexes for both *Tribolium* spp. (Yan and Norman, 1995). Parasitism of the mite *Acarophenax lacunatus* led to a reduction in the number of *T. castaneum* larvae and adults, showing that the mite can affect populations of the beetle (Oliveira *et al*., 2006).

2.2.7.4 Use of natural botanical products for control of storage insects

The use of synthetic insecticides is associated with many problems, which were revealed only in recently years. These problems include insect resistance, resurgence of tread insects destruction of natural enemies and also lead to the environmental contamination. Besides, such insecticides cannot be used for treating pests on grains used for human and animals consumption because of toxicity of mammals (Jacobson *et al*., 1978)

Early records of information were raised by Srivastava and Awasthi (1958). Brich *et al*., (1993) revealed that, plants produce a wide range of defensive compound for defense against predators and pathogens. These compounds may protect the plant against pathogens and insect pests by acting as ovicides, repellents, antifeedents, antivirus vectoring activities and growth regulators.

Fifteen volatile compounds found in bay leaves *Laurus nobilis* L. and crushed bay leaves were tested as repellents against adult of *T.castaneum* when added to wheat flour, give positive result (Norasaim *et al*., 1986).

Numerous extracts of different plant species have been screened and many alkaloid curnarin and terpenoid compound has been isolated from them. The role of such compounds in inhibiting the feeding of many phytophagus insects has been confirmed. Recently, over 2000 plant species were reported to possess toxic properties out of which very little were exploited for pest control purposes (Schmutterer, 1995).

The Sudan with its different geographical zones is considered as one of the richest countries in its flora, which can provide unlimited sources of active agents with high potentialities that can help in insect control programmers. Examples of promising chemical source plants in Sudan include Neem tree *Azadirachta indica* A. Juss, "Usher" *Calotropis procera J.*; Fenugreek "Hilba" *Trigonella foemun* and garlic *Allium sativum L.* (Siddig, 2009).

2.3 korobi *Nerium oleander* L.

2.3.1 Classification

Kingdom : Planate

Order : Gentianales

Family : Apocynaceae

Genus : Nerium.

Species : oleander

S.N : *Nerium oleander* L.

2.3.2 Description

Nerium oleander (Plate. 5). is an evergreen shrub reaching four meters in height. Leaves are 10 to 22 cm long, narrow, untoothed and short-stalked, dark or grey-green in colour. Some cultivars have leaves variegated with white or yellow. All leaves have prominent mid rib, are "leathery" in texture and usually arise in groups of three from the stem. The plant produces terminal flower heads, usually pink or white, however, 400 cultivars have been bred and these display a wide variety of different flower colour: deep to pale pink, lilac, carmine, purple, salmon, apricot, copper, orange and white (Huxley, 1992). Flowers are about 5 cm in diameter and five-petalled. The throat of each flower is fringed with long petal-like projections. Occasionally double flowers are encountered amongst cultivars. The fruit consists of a long narrow capsule 10 to 12 cm long and 6 to 8 mm in diameter; they open to disperse fluffy seeds. Fruiting is uncommon in cultivated plants. The plant exudes a thick white sap when a twig or branch is broken or cut (Pearn, 1987). The fruits are a long narrow capsule 5–23 cm long, which splits open at maturity to release numerous downy seeds. (Pankhurst, 2009).

Plate. 6 : *Nerium oleander* L.plant

2.3.3 Distribution

Nerium oleander L. is either native or naturalized to a broad area from Mauritania, Morocco, and Portugal eastward through the Mediterranean region and the Sahara (where it is only found sporadically), to the Arabian peninsula, southern Asia, and as far East as Yunnan in southern parts of China. (Bingtao *et al*., 2009). It typically occurs around dry stream beds. *Nerium oleander* L. is planted in many subtropical and tropical areas of the world. On the East Coast of the US, it can be planted as far north as Virginia Beach, Virginia, while in California and Texas it is naturalized as a median strip planting. Also oleander distributed originally in the Mediterranean region , subtropical Asia, and the Indo-Pakistan subcontinent but is now growing in many parts of the world such as Australia, USA, China, and Middle East countries (Derwich *et al.*, 2010).

2.3.4 Toxicity

Nerium oleander L. has historically been considered a poisonous plant because some of its compounds may exhibit toxicity, especially to animals, when consumed in high amounts. Among these compounds are oleandrin and oleandrigenin, known as cardiac glycosides, which are known to have a narrow therapeutic index and can be toxic when ingested. Toxicity studies of animals administered oleander extract concluded that rodents and birds were observed to be relatively insensitive to oleander cardiac glycosides (Szabuniewicz, 1972). Other mammals, however, such as dogs and humans, are relatively sensitive to the effects of cardiac glycosides and the clinical manifestations of "glycoside intoxication" (Hougen *et al*., 1979). This plant has potential toxic effect after ingestion. All parts of oleander are toxic containing oleandrin, oleandrigenin, and other cardiac glycosides. Toxic exposure of humans and different species of domestic animals *to N. oleander* L. cardenolides occurs commonly throughout the geographic regions where this plant grows (Abbasi *et al.*, 2013).

Toxicity studies that have been conducted in dogs and rodents administered oleander extracts by intramuscular (IM) injection indicated that on an equivalent weight basis, doses of an oleander extract with glycosides ten times in excess of those likely to be administered therapeutically to humans are still safe and without any "severe toxicity observed" (Langford and Boor, 1996).

2.4 Damas Conocarpus lancifolius Engl.

Family Combretaceae comprises about 20 genera and about 600 species found in tropical and subtropical regions of the world. The family has few genera with great economic value, an useful timber is obtained from some species belong to it and other species has medicinal importance. Damas *Conocarpus lancifolius* Engl is one of the most important species in this family (Pandey and Misra, 2008).

2.4.1 Classification

Kingdom : Plantae

Phylum : Tracheophyta

Class : Magnoliopsida

Order : Myrtales

Family : Combretaceae

S. N. : *Conocarpus lancifolius* Engl.

2.4.2 Description

Damas *Conocarpus lancifolius* Engl. (Plate. 7). is an evergreen tree that grows up to 20 m in height and 60 - 250 cm or more in diameter. However, it is believed that the larger trees have now been almost entirely felled. Whereas it is usually a multi-branched tree in its natural habitat, trees planted in the Sudan formed a single, straight stem (NAS, 1983). Bark is grey-brown, fissured and the leaves are smooth and shiny, about 10 cm long, narrowing towards the base (lanceolate), in dense spirals. Flowers are yellow-green, in round heads on branched stalks, slightly fragrant and its fruit exist in dry, round, greenish heads, cone-like, containibng tiny, scale-like hard seeds (Bein *et al*., 1996).

2.4.3 Distribution

Natural stand of Damas are found beside intermittent watercourses of northern Somalia and in the southwest part of the Arabian Peninsula. Some of these streams are salty and some sulphurous. The tree is also cultivated in Somalia, as it is in Djibouti, Sudan, Kenya, north and south Yamen, and Pakistan. A small plantation has been established in Sudan Khashm El-girba arboretum. About 10000 trees have been planted successfully in limestone near Mombasa, Kenya (NAS, 1983).

Plate. 8: *Conocarpus lancifolius* plant.

2.4.4 Economic importance

Conocarpus lancifolius Ingl is multipurpose; wood which is the main product is used domestically for house construction, firewood and excellent charcoal. Commercially timber was more useful formerly; it was cut and exported from Somalia to Arabia for dhow construction. Other potential uses include wood based board. Bark may be a useful source of tannins (Booth and Wickens, 1993).

The tree is evergreen and its foliage makes a good fodder, also it is a good shade and roadside tree. It is used as wind breaks around irrigated agricultural areas and for avenue planting. A drought-resistant species, *C. lancifolius* is one of the more promising trees for trials in arid areas. It is recommended for a variety of soil types including saline soils, and yields excellent charcoal and valuable wood (NAS, 1983).

Information on the importance of *C. lancifolius* in its native distribution areas relative to other species with similar wood , fuel and forage uses is lacking hence it is difficult to assess its importance. However Somali tribe owing the Damas (Tugs) dry river valleys (wadis) containing *C. lancifolius* have restricted cutting because of the threat of overexploitation (Booth and Wickens, 1993).

2.4.5 Environmental Requirements

Damas grows best in areas where the mean annual temperature ranges from 20°c -30°c, but where the maximum summer temperature has reached 50°c. The tree grows from sea level up to about 1000 m. The rainfall in its natural habitat is generally between 50 mm and 400 mm, but the tree grows mainly along seasonal watercourses. It can be grown in plantations in areas with less than about 400 mm but grows well only if irrigated or within reach of groundwater. It withstands drought conditions for several months when irrigation fails. Damas does well on deep soils ranging from pure sand to clays and loams, but has difficulty on shallow soils. It will tolerate moderately saline soils (NAS, 1983).

Damas trees are often dominant in dry river valleys (wadis) in Somalia. It is now cultivated as it is one of the fastest growing trees in very dry areas. It tolerates sandy, saline and coral soils (Bein *et al*., 1996).

2.5 Mahogany *Khaya senegalensis* (Desr.) A.Juss.

2.5.1 Classification

Kingdom : Plantae

Division : Magnoliophyta

Class : Magnoliopsiada

Order : Sapindales

Family : Meliaceae

Genus : *Khaya*

Species : *Senegalensis*

S. N : *Khaya senegalensis* (Desr.) A.Juss.

2.5.2 Description

Khaya senegalensis (Plate. 9). is an important multipurpose tree in its natural range in sub-Saharan Africa. It is particularly valued for timber, fuel wood and medicinal purposes as well as being a popular shade and amenity tree (CAB International, 2000). In its natural habitat it is a medium-sized to large tree (up to 30 m) with a wide crown. In cultivation as an exotic it can grow up to more than 35 m high and up to 1½ m in diameter (Ker and Gaméné, 2003). Cultivated timber tree can reach to 30 m in height with pinnate leaves 25cm long, the leaflets are oblong to 10cm long, loose sprays of white flowers and 4-valved woody capsules with winged seeds (Robertson, 1989).

Timber of *K. senegalensis* is highly valued because of its beautiful figurative grain and its rich reddish mahogany browns color (TRADA, 2004).

2.5.3 Distribution

Khaya senegalensis is a tree belongs to the family meliaceae, is native of West Africa (Senegal) and extends to Sudan and Uganda (Keay, 1989), and it is widely distributed in the Savannah region, Mali, Northern Nigeria, Northern Cameroon and Northern Uganda (FAO, 1986).

2.5.4 Uses

In its natural range *K. sengalensis*. provides cattle fodder, edible and cosmetic oils, medicinal products shade and shelter as well as providing fuelwood and valuable timber. In Mali, Niger and parts of the Sahel Alaag *K. sengalensis*. rates highly as an agroforestry tree species, based on farmers' preferences market demand and potential for genetic improvement (Franzel *et al*. 1996). As an exotic, it is valued for both amenity applications and timber production (Ker and Gaméné, 2003). The wood is used for a variety of purposes. It is often used conventionally for carpentry, interior trim, and construction. Traditionally the wood was used for dugout canoes, household implements, djembe, and fuel wood. The bitter tasting bark is used for a variety of medical purposes; it is taken against fever caused by malaria, stomach complaints, and headaches. It is applied externally to cure skin rashes, wounds, or any abnormality. It has been exported from West Africa (Gambia) to Europe since the first half of the 19th century and has been exploited heavily for its timber. It is now used more locally, and is planted ornamentally as a roadside tree. *K. senegalensis* is commonly used by the local people in Nigeria for the treatment of dysentery, mucous diarrhea and wound infections. The leaves and the barks were screened for their phytochemical properties and antimicrobial activity (Makut *et al*., 2008). The bark was used as abortifacient, and to treat malaria fever, colic, phagedenic ulcers, blennorrhea, dermatitis and urticaria, anemia, sickle cell disease; roots treated diarrhea, jaundice, headaches; leaves for treated amenorrhea, smallpox, lumbago, rheumatism and flowers treated gastritis (Arbonnier, 2002).

Plate. 10: *Khaya senegalensis* plant.

CHAPTER THREE

MATERIALS AND METHODS

These experiments were conducted at the College of Agricultural Studies, Sudan University of Science and Technology (SUST) to evaluate the efficacy of different leaves extract of korobi *Nerium oleander* L, Damas *Conocarpus lancifolius* Engl and Mahogany *Khaya senegalensis* (Desr.) A.Juss., against the red flour beetle *Tribolium castaneum* Herbst.

3.1 Insect rearing

The red flour beetle *Tribolium castaneum* Herbst was collected form infested flour brought from the market and reared in plastic cages in laboratory of the Department of plant protection. The insect culture was maintained in the laboratory to provide regular supply of test insects for the experiments.

3.2 Preparation of leaves powder

Leaves of all tested plants were collected from Shambat area and brought to the laboratory where they were shade- dried for 10 days and then ground by an electric blender. The powders of all plants were kept in glass jars under room temperature until use.

3.3 Preparation of aqueous extracts

Aqueous extracts were prepared for each plant as follows : 10, 20 and 30 gram of the fine powder from each plant were placed in a conical flask and dissolved in 200 ml of distilled water and the solution was shaken for 10 minute then left over night. And hence each solution was shake well and filtered after 24hours by a filter paper to give solution of 5, 10 and 15% concentration.

3.4 Preparation of Ethanol extracts

Extraction processes were conducted at the Environment and Natural Resources Research Institute (ENRRI) National Research Center. Fifty grams of each of the previously prepared powder of each plant were placed in a thimble unit and it was placed in a Soxhelt Plate (6) extractor apparatus and the extraction was made with 300 ml the ethanol for each sample. The extraction continued for six hours, and the ethanol solvent was removed off the crude extract by Rotary Plate (7) evaporator. The obtained extracts were stored in a refrigerator until used for the experiments.

3.5 Testing of the effects of the plant powder

Twenty grams of grind Sorghum grain seeds were weighted and placed in plastic pots. The leaves powders of each plant were tested at 1, 2, 3 grams to obtain the (5%, 10%, 15%) (W/W) concentrations and were added to the plastic pots containing sorghum grain. Twenty newly emerged adults of *T. castaneum* were then introduced in each of the plastic pot and each treatment was replicated three times. Also twenty newly emerged adults were used as control in which only sorghum is used. The number of dead insects in each plastic pots was counted after 24,48and 72 hours of exposure.

3.6 Testing the effects of Aqueous extracts

Twenty gram of grind sorghum grain were dipped in a desired concentration of aqueous extract for one hour and allowed to dry for one hour and placed in plastic pots. Twenty newly emerged adults of *T. castaneum* were placed in each plastic pot for the experiments. Each treatment was replicated three times. The number of dead insects was recorded after 24, 48 and 72 hours of application

Plate (6): Soxhelt extractor apparatus

Plate (7): Rotary Evaporator

3.7 Testing the effects of Ethanolic extraction

Twenty gram of grind sorghum grain were dipped in a desired concentration of ethanolic extract for one hour of all tested plants and allowed to dry for one hour and placed in plastic pots. Twenty newly emerged adults of *T. castaneum* were placed in each plastic pot for the experiments. Each treatment was replicated three times. The number of dead insect was recorded after 24, 48 and 72 hours of exposure(Plate. 8).

3.8 The standard insecticide (Cypermethrin)

A standard insecticide Cypermethrin 25% E. C. was used as standard for comparison with effect of botanical extract.

3.9 Statistical analysis and Experimental Desgin

Complete Randomize Design (CRD) was applied for exppriments. Data were analyzed according to analysis of variance (ANOVA); means were used for means separation using MSTATC software program(Gomez and Gemez 1984).

Plate. 8 :Experimental Desgin

CHAPTER FOUR

RESULTS

4.1 Effect of Nerium against red flour beetle

As seen in Table (1), Fig. (1, 2 and 3) and appendices (1, 2 and 3) the results showed that, all tested concentrations of Nerium gave significantly higher mortality percentage than the control after 24 hrs of exposure. It can also be noted that the lowest concentration (5%) of powder, aqueous and ethanolic extracts of Nerium generated 10%, 6.7% and 6.7 % respectively after 24 hrs of application and there is no significant different between all formulation. The highest concentration (15%) of powder, aqueous and ethanolic extracts of Nerium scored 20%, 25% and 36.7% respectively after 24 hrs of application and there is no significant different between all formulations of Nerium used in this study and the same trend continued for 48 and 72 hrs of expose. However, the standard insecticide Cypermethrin generated higher mortality percentage of 86.7% throughout the experimental period.

Table. 1: Effect of Nerium against red flour beetle *Tribolium castaneum*

Formulation		Mortality (%)		
		Exposure time (hrs)		
	Concs. (%)	24	48	72
Powder	5	10 (15.0) d	26.7 (30.7) b	16.7 (23.9) e
	10	15 (22.0) cd	25 (29.7) b	21.7 (27.5) de
	15	20 (26.1) bcd	36.7 (36.9)b	25 (29.9) de
Aqueous extract	5	6.7 (14.7) d	23.4 (28.8) b	31.7 (34.2) cde
	10	11.7 (19.9) cd	26.7 (30.7)b	25 (29.7) de
	15	25 (29.9) bc	43.4 (41.1) b	31.7 (34.0) cde
Ethanolic extract	5	6.7 (14.7) d	20 (26.5) b	48.4 (44.0) bc
	10	26.7 (31.0) bc	23.4 (28.8) b	40 (47.9) b
	15	36.7 (36.9) b	41.7 (40.1) b	55(39.2) bcd
Standard		86.7 (72.3) a	86.7 (72.3) a	86.7 (72.3) a
Control		0 (0.0) e	0 (0.0) c	0 (0.0) f
SE±		3.31	3.05	16.7 (23.9) e
C. V. (%)		30.36	22.63	21.7 (27.5) de

Means followed by the same letter are not significantly different at (P<0.05). brackets are transformed according to arcsine transformation.

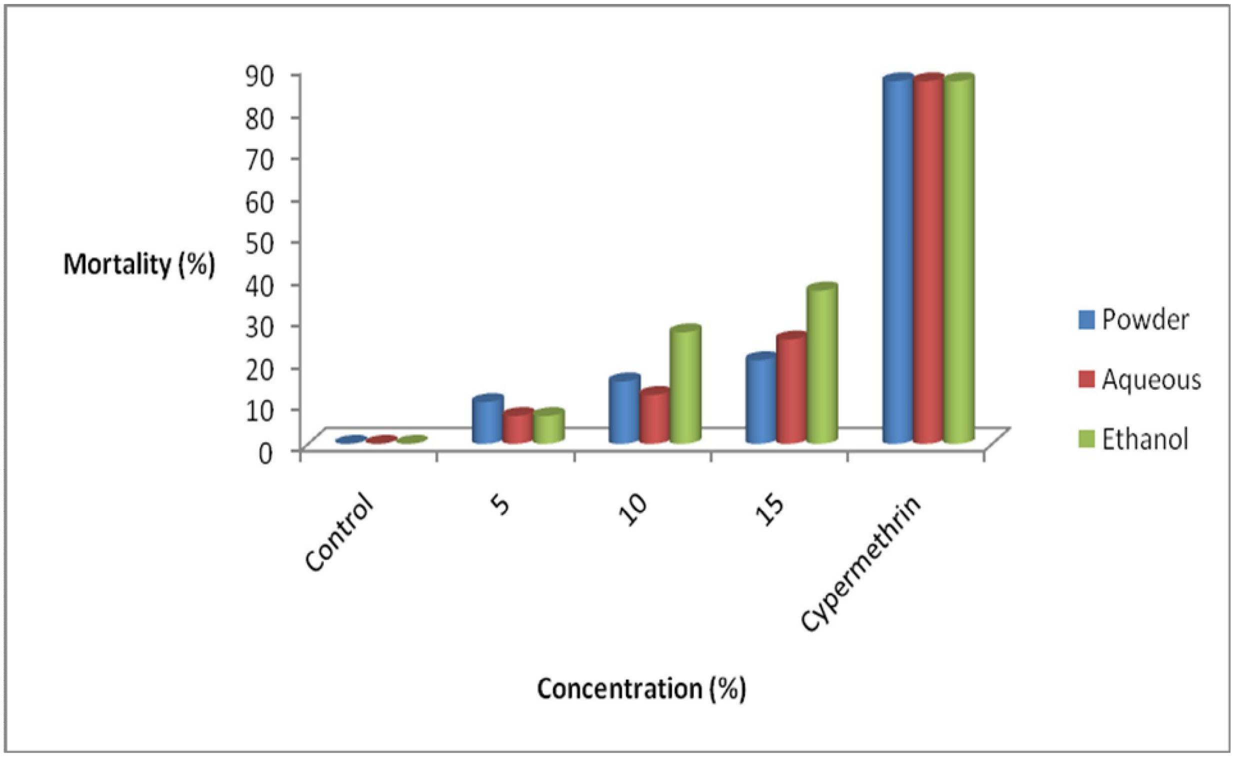

Fig. 1 : Effect of Nerium against flour beetle *Tribolium castaneum* after 24 hrs.

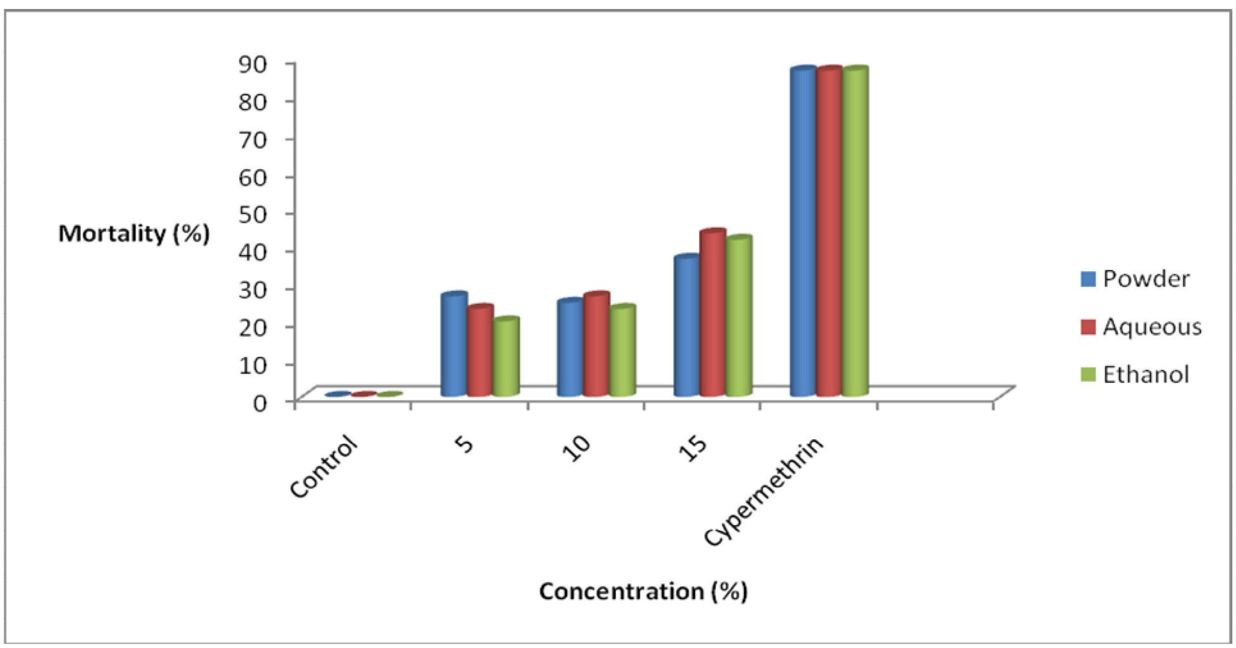

Fig. 2: Effect of Nerium against flour beetle *Tribolium castaneum* after 48 hrs.

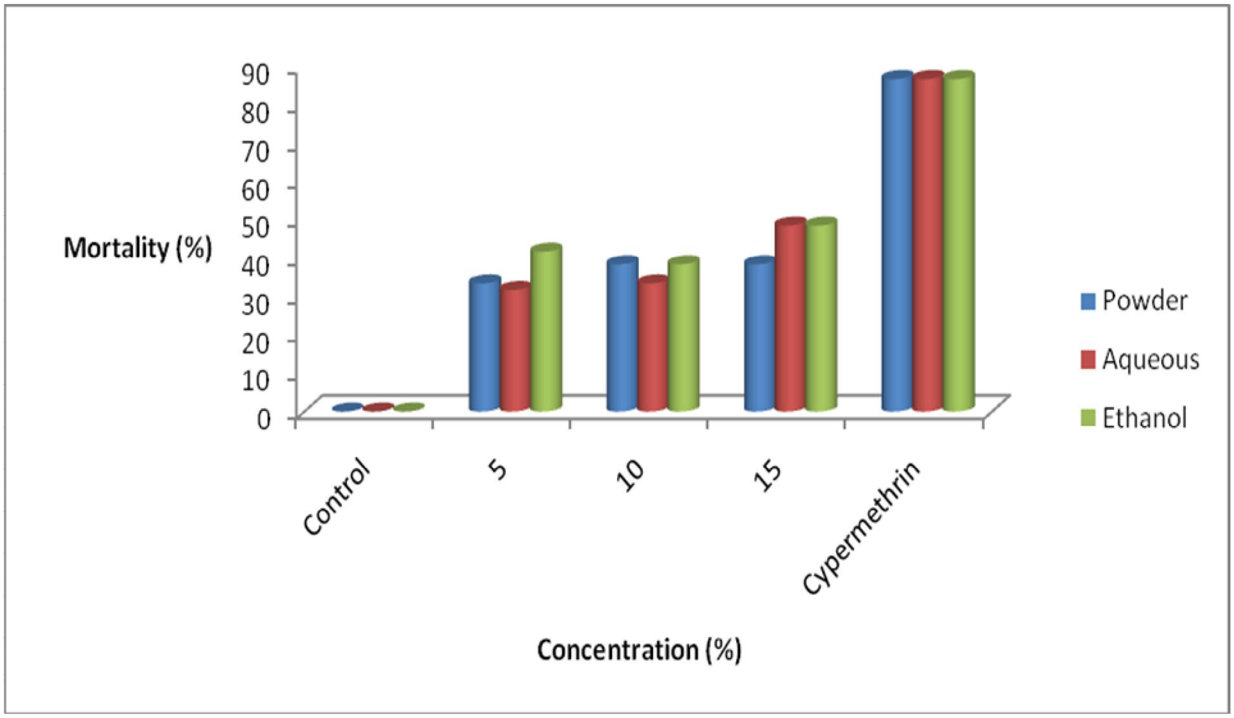

Fig. 3 : Effect of Nerium against flour beetle *Tribolium castaneum* after 72 hrs.

4.2 Effect of Damas against red flour beetle

The data presented in Table (2) and Fig (4, 5 and 6) and appendices (4, 5 and 6) revealed that all tested concentrations gave significantly higher mortality percentage than the control after 24 hrs of exposure. It is interesting to note that the lowest concentration (5%) of all formulations of Damas revealed 16.7 %, 15% and 13.4% mortality after 24 hrs of exposure with no significant difference between various formulations. Similarly there is no significant difference between the highest concentrations (15%) of various formulations of Damas used this study, in fact it scores 21.7%, 31.7% and 21.7% mortality, respectively.

The lowest concentration (5%) of ethanolic extract of Damas generated 36.7% mortality after 48 hrs of exposure, whereas, the highest concentration (15%) of Damas powder and aqueous extract scored and 25% and 38.4% mortality with no significant difference from the lowest concentration (5%) of ethanolic extract and the same trend continued for 72 hrs of exposure as in Table (2) and Fig (5and 6). Whereas, the standard insecticide Cypermethrin revealed higher mortality percentage of 86.7% throughout the experimental period.

Table. 2: Effect of Damas against red flour beetle *Tribolium castaneum*.

Formulation	Concs. (%)	Mortality (%) Exposure time (hrs) 24	48	72
Powder	5	16.7 (23.9) bc	11.7 (19.9) d	21.7 (27.5)
	10	8.4 (16.6) c	11.7 (19.3) d	23.4 (28.2)
	15	21.7 (27.7) bc	25 (29.9)bcd	40 (39.1)
Aqueous extract	5	15 (22.6) bc	18.4 (25.0) cd	25 (30) c
	10	21.7 (27.1) bc	28.4 (31.7) bcd	30 (33.2)
	15	31.7 (34.2) bc	38.4 (38.2) bc	38.4 (36.2)
Ethanolic extract	5	13.4 (21.1) bc	36.7 (37.1) bc	36.7(38.1)
	10	16.7 (23.2) bc	43.4 (41.1) b	48.4 (44.0)
	15	21.7 (36.1) b	38.4 (38.2) bc	41.7 (40.2)
Standard		86.7 (72.3) a	86.4 (72.3) a	86.7 (72.3)
Control		0 (0.0) d	0 (0.0) e	0 (0.0) d
SE±		3.28	3.19	3.04
C. V. (%)		35.24	22.84	20.10

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

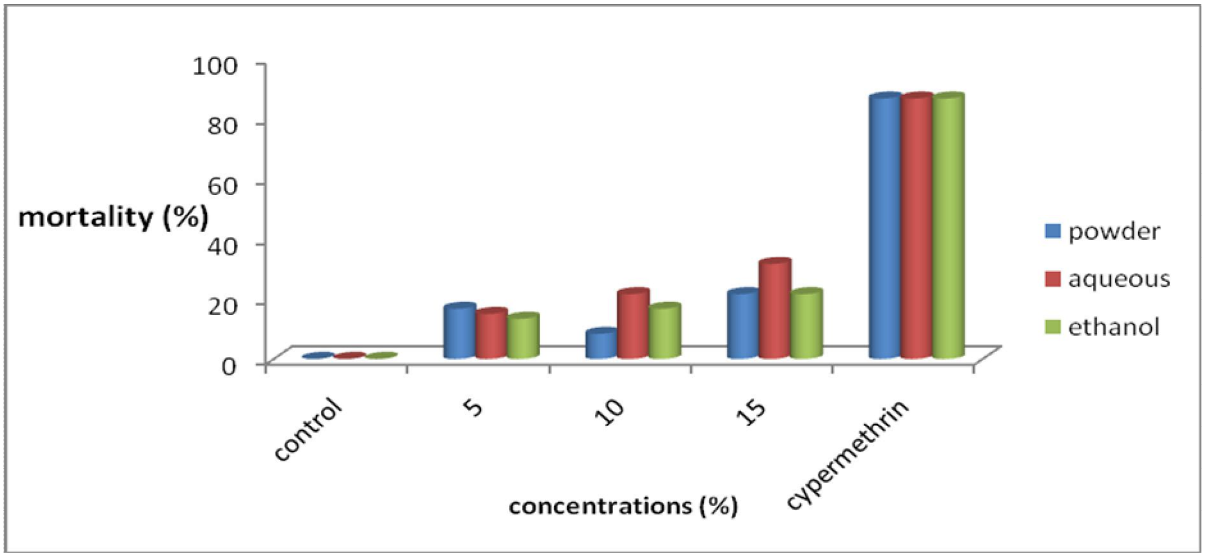

Fig. 4: Effect of Damas against red flour beetle *Tribolium castaneum* after 24 hrs.

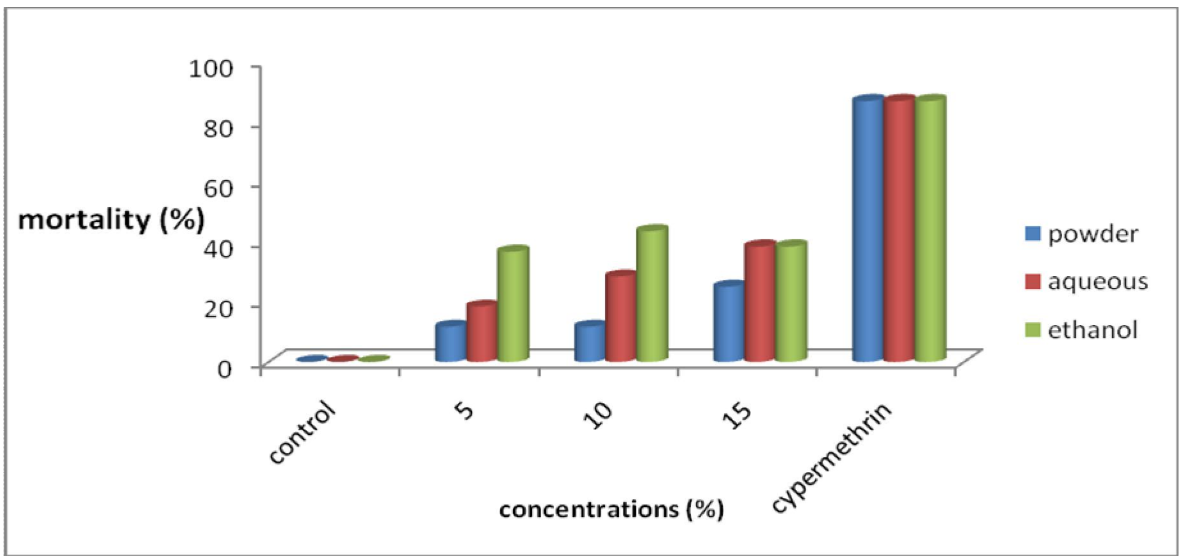

Fig. 5: Effect of Damas against red flour beetle *Tribolium castaneum* after 48 hrs.

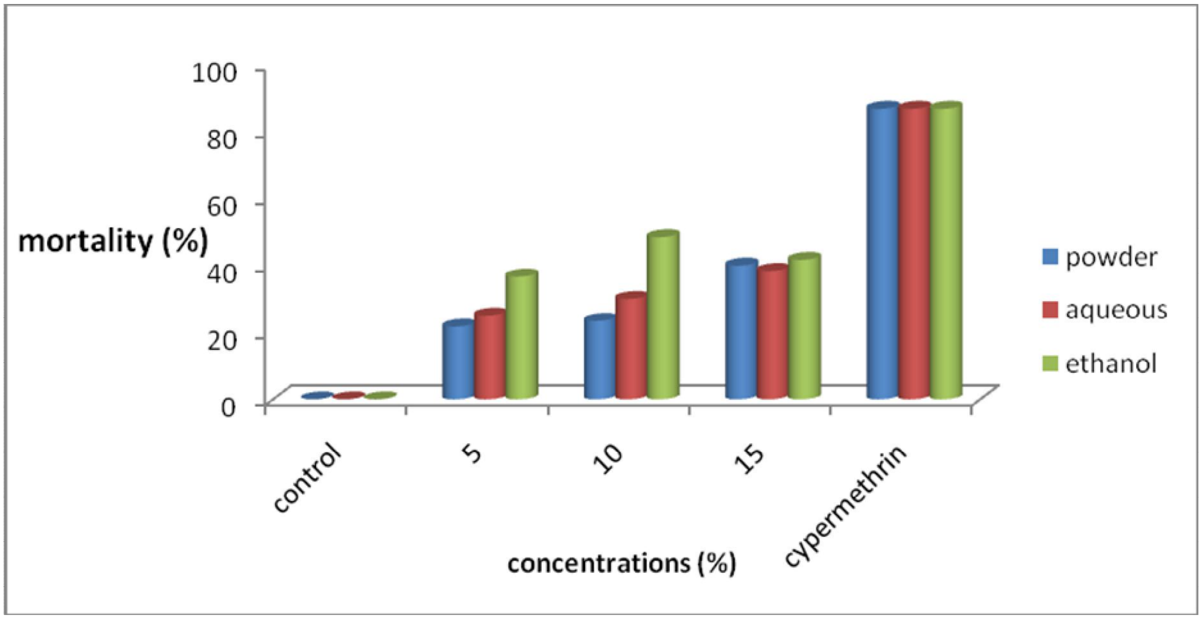

Fig. 6: Effect of Damas against red flour beetle *Tribolium castaneum* after 72 hrs.

4.3 Effect of Mahogany against red flour beetle

The results exhibited in Table (3) and Fig. (7) and appendices (7, 8 and 9) Showed that that there is no significant difference between the lowest concentration (5%) of all formulations of mahogany after 24 hrs of exposure. The results also revealed that there is no significant difference between the lowest concentration (5%) of aqueous extract of mahogany and 15% concentration of ethanolic extract of the same plant and the trend continued for 48 hrs of application as in Table (3) and Fig.(8).

As seen in Table (3) and Fig. (9) the results showed that there is no significant difference between the highest concentration (15%) of aqueous extract of mahogany and the same concentration of mahogany leaves ethanolic extract after 72 hrs of exposure. However, the standard insecticide Cypermethrin generated higher mortality percentage of 86.7% throughout the experimental period.

Table. 3:Effect of Mahogany against red flour beetle *Tribolium castaneum*

Formulation	Concs. (%)	Mortality (%) Exposure time (hrs) 24	48	72
Powder	5	11.7 (19.9)b	16.7 (23.9) b	16.7 (4.1) e
	10	18.4 (25.3)b	30 (33.0) b	21.7 (4.6)
	15	26.7 (31.0) b	36.6 (36.9) b	25 (5.0) de
Aqueous extract	5	15 (22.6) b	23.4 (28.8) b	31.7 (5.7)
	10	11.7 (19.3) b	21.7 (27.3)b	25 (5.0) de
	15	11.7 (19.9) b	23.4 (28.8) b	31.7 (5.6)
Ethanolic extract	5	16.7 (23.7) b	30 (33.1) b	48.4 (7.0) b
	10	20 (26.1) b	35(36.0) b	40 (6.4) bc
	15	11.7 (19.9) b	26.6 (30.8)b	55 (7.4) b
Standard		86.7 (72.3) a	86.7(72.3) a	86.7 (9.3) a
Control		0 (0.0) c	0 (0.0) c	0 (0.7) f
SE±		3.06	3.02	3.13
C. V. (%)		24.52	23.59	19.27

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

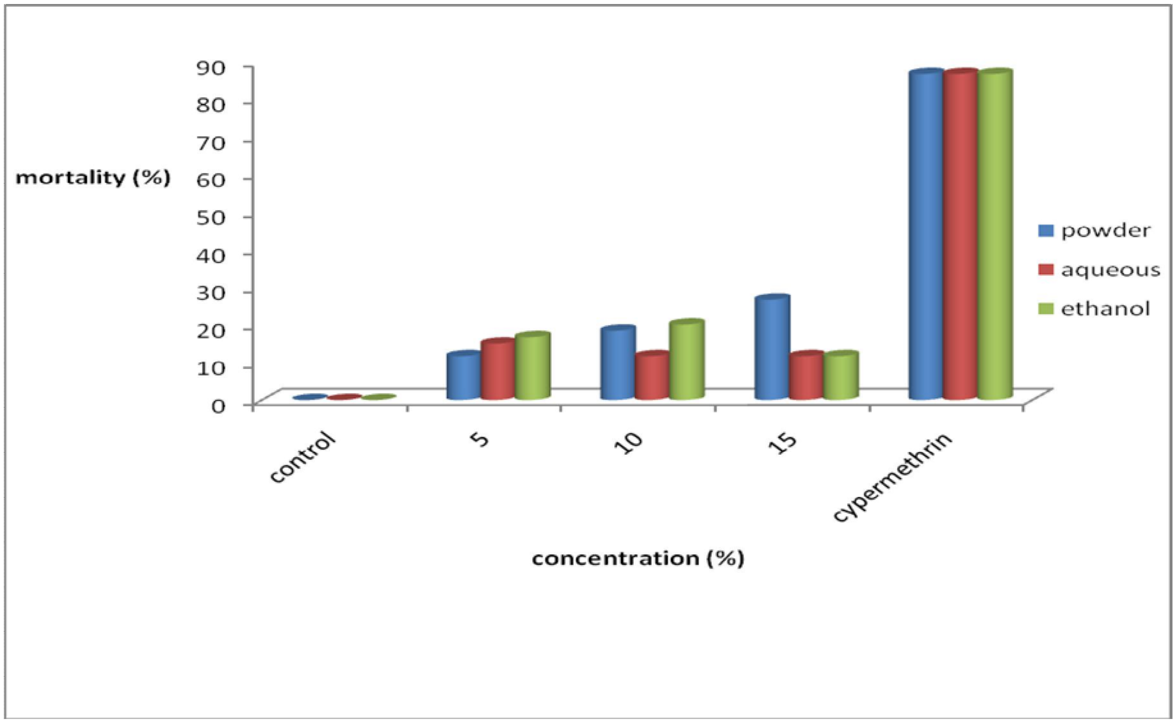

Fig. 7: Effect of Mahogany against red flour beetle *Tribolium castaneum* after 24 hrs.

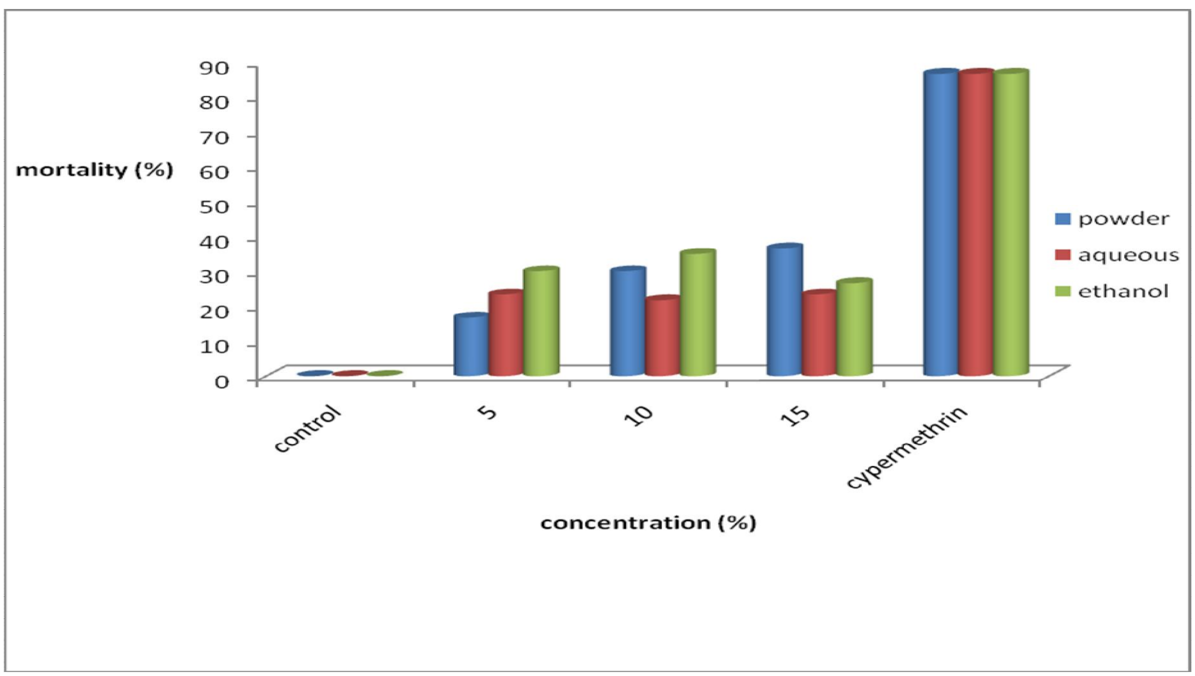

Fig. 8: Effect of Mahogany against red flour beetle *Tribolium castaneum* after 48 hrs.

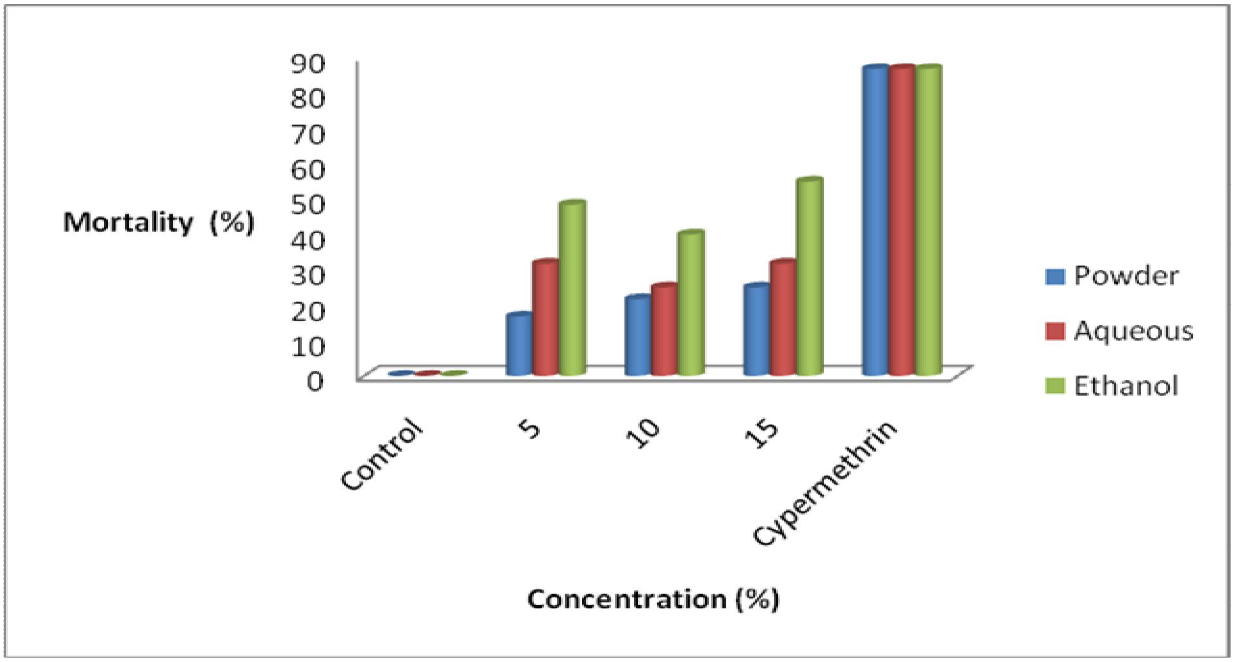

Fig. 9: Effect of Mahogany against red flour beetle *Tribolium castaneum* after 72 hrs.

CHAPTER FIVE

DISCUSSION

In the last four decades many botanical formulations have proven to be potent and effective as many as conventional synthetic pesticides even at low concentrations. In fact, botanical insecticides have drawn great attention as major control agents in organic farming.

There is a renewed interest amongst scientists to study the bioactivity of plant extracts against stored-grain insect pests (Stoll, 2000).

This study was aimed to evaluate the incecticidal effect of powder, aqueous and ethanolic extracts of Nerium, Damas and Mahogany against red flour beetle *T. castaneum*. The obtained results showed that all tested concentrations of Nerium in various formulations gave significantly higher mortality percentage than the control after 72 hrs. The highest concentration (15%) of powder, aqueous and ethanolic extracts of Nerium scored 38.4%, 48.4% and 48.4% respectively. Similar results were obtained by Lokesh, *et al.* (2010) who found that the Nerium have larvicidal effect against the mosquito larvae belong to four genera namely *Anopheles; Aedes; Culex* and *Culiseta.*

The highest concentration (15%) of powder, aqueous and ethanolic extracts of Damas generated 40%, 38.4% and 41.7% respectively after 72 hours of exposure. Feeny (1970) reported that tannin content in Oak leaves inhibits the growth of winter moth (*Operophtera brumata*) caterpillars and causes death. The results obtained in this study may also be attributed to the tannin content in *C. lancifolius* leaves.

All concentrations of mahogany ethanolic extract gave significantly higher mortality percentage than the powder and aqueous extract of mahogany after 72 hrs of application. In fact, 5%, 10% and 15% concentrations of mahogany leaves ethanolic extract score 48.4%, 55% and 40% mortality respectively. This agree with Yakubu and Nda (2012) who found that mahogany leave and seeds powder extracts caused a significantly higher mortality percentage of *Tribolium confusum* on stored pearl millet. Bamaiyi, *et al*. (2007) also found that the seeds oil and powder of mahogany have a lethal effect against cowpea beetle *Callosobruchus maculatus* Fab. Similar finding was obtained by Shaalan, *et al*. (2006) who reported that, mahogany have a larvicidal effect against *Culex annulirostris*.

CONCLUSION AND RECOMMENDATIONS

This study clearly demonstrates that all tested plants in various formulations have insecticidal effect on of the red flour beetle. However, all formulations of Nerium seem to be much more toxic than the different formulations of Damas and Mahogany.

Based on the above mentioned results, powder, aqueous and ethanolic extract of Nerium, Damas and Mahogany can be recommended to be used as a control agent for *T. castaneum*. However, further experiments should be conducted to evaluate the effects higher concentrations of these plants with other organic solvents and also on other insect pests. Finally, a comprehensive study should be conducted to specify the active ingredients in each plant extract.

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APPENDICES

Appendix (1) Effect of Nerium against red flour beetle after 24 hours.

Formulation	Concs.(%)	Mortality (%) R1	R2	R3	Mean
Powder	5	0 (0.0)	10 (18.4)	20 (26.6)	10 (15.0) d
	10	5 (12.9)	20 (26.6)	20 (26.6)	15 (22.0) cd
	15	10 (18.4)	25 (30.0)	25 (30.0)	20 (26.1) bcd
Aqueous extract	5	5 (12.9)	5 (12.9)	10 (18.4)	6.7 (14.7) d
	10	10 (18.4)	10 (18.4)	15 (22.8)	11.7 (19.9) cd
	15	20 (26.6)	25 (30.0)	30 (33.2)	25 (29.9) bc
Ethanolic extract	5	5 (12.9)	5 (12.9)	10 (18.4)	6.7 (14.7) d
	10	20 (26.6)	30 (33.2)	30 (33.2)	26.7 (31.0) bc
	15	20 (26.6)	40(39.2)	50 (45.0)	36.7 (36.9) b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0(0.0)	0 (0.0)	0 (0.0)	0 (0.0) e

Means followed by the same letter are not significantly different at (P<0.05). brackets are transformed according to arcsine transformation.

Appendix (2) Effect of Nerium against red flour beetle after 48 hours.

Formulation	Concs.(%)	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	15 (22.8)	25 (30.0)	40 (39.2)	26.7 (30.7) b
	10	15 (22.8)	30 (33.2)	30 (33.2)	25 (29.7) b
	15	20 (26.6)	40 (39.2)	50 (45.0)	36.7 (36.9)b bcd
Aqueous extract	5	20 (26.6)	20 (26.6)	30 (33.2)	23.4 (28.8) b
	10	15 (22.8)	25 (30.0)	40 (39.2)	26.7 (30.7)b bcd
	15	30 (33.2)	50 (45.0)	50 (45.0)	43.4 (41.1) b
Ethanolic extract	5	15 (22.8)	25 (30.0)	20 (26.6)	20 (26.5) b
	10	20 (26.6)	20 (26.6)	30 (33.2)	23.4 (28.8) b
	15	30 (33.2)	45 (42.1)	50 (45.0)	41.7 (40.1) b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) c

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (3) Effect of Nerium against red flour beetle after 72 hours.

Formulation	Concs.(%)	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	20 (26.6)	35 (36.3)	45 (42.1)	33.4 (35.0) b
	10	25 (30.0)	50 (45.0)	40 (39.2)	38.4 (38.1) b
	15	25 (30.0)	40 (39.2)	50 (45.0)	38.4 (38.1) b
Aqueous extract	5	30 (33.2)	35 (36.3)	30 (33.2)	31.7 (34.2) b
	10	20 (26.6)	30 (33.2)	50 (45.0)	33.4 (34.9) b
	15	40 (39.2)	50 (45.0)	55 (47.9)	48.4 (44.0) b
Ethanolic extract	5	40 (39.2)	35 (36.3)	50 (45.0)	41.7 (40.2) b
	10	40 (39.2)	30 (33.2)	45 (42.1)	38.4 (38.2) b
	15	35 (36.3)	50 (45.0)	60 (50.8)	48.4 (44) b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) c

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (4) Effect of Damas against red flour beetle after 24 hours.

Formulation	Concs .(%)	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	20(26.6)	10 (18.4)	20(26.6)	16.7 (23.9) bc
	10	10 (18.4)	5 (12.9)	10 (18.4)	8.4 (16.6) c
	15	20(26.6)	20(26.6)	25 (30.0)	21.7 (27.7) bc
Aqueous extract	5	10 (18.4)	15 (22.8)	20(26.6)	15 (22.6) bc
	10	10 (18.4)	20(26.6)	35 (36.3)	21.7 (27.1) bc
	15	30 (33.2)	30 (33.2)	35 (36.3)	31.7 (34.2) bc
Ethanolic extract	5	10 (18.4)	20(26.6)	10 (18.4)	13.4 (21.1) bc
	10	5 (12.9)	25 (30.0)	20(26.6)	16.7 (23.2) bc
	15	10 (18.4)	20(26.6)	35 (36.3)	21.7 (36.1) b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) d

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (5) Effect of Damas against red flour beetle after 48 hours.

Formulation	Concs.(%)	Mortality (%) R1	R2	R3	Mean
Powder	5	10 (18.4)	10 (18.4)	15 (22.8)	11.7 (19.9) d
	10	5 (12.9)	10 (18.4)	20 (26.6)	11.7 (19.3) d
	15	20 (26.6)	25 (30.0)	30 (33.2)	25 (29.9)bcd
Aqueous extract	5	10 (18.4)	20 (26.6)	25 (30.0)	18.4 (25.0) cd
	10	15 (22.8)	30 (33.2)	40 (39.2)	28.4 (31.7) bcd
	15	30 (33.2)	40 (39.2)	45 (42.1)	38.4 (38.2) bc
Ethanolic extract	5	30 (33.2)	30 (33.2)	50 (45.0)	36.7 (37.1) bc
	10	40 (39.2)	60 (50.8)	30 (33.2)	43.4 (41.1) b
	15	50 (45.0)	30 (33.2)	35 (36.3)	38.4 (38.2) bc
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.4 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) e

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (6) Effect of Damas against red flour beetle after 72 hours.

Formulation	Concs.	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	15 (22.8)	20 (26.6)	30 (33.2)	21.7 (27.5) c
	10	10 (18.4)	25 (30.0)	35 (36.3)	23.4 (28.2) c
	15	30 (33.2)	40 (39.2)	50 (45.0)	40 (39.1) bc
Aqueous extract	5	25 (30.0)	25 (30.0)	25 (30.0)	25 (30) c
	10	35 (36.3)	25 (30.0)	30 (33.2)	30 (33.2) bc
	15	30 (33.2)	35 (36.3)	40 (39.2)	38.4 (36.2) bc
Ethanolic extract	5	25 (30.0)	35 (36.3)	55 (47.9)	36.7(38.1) bc
	10	50 (45.0)	60 (50.8)	35 (36.3)	48.4 (44.0) b
	15	50 (45.0)	35 (36.3)	40 (39.2)	41.7 (40.2) bc
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) d

Means followed by the same letter are not significantly different at (P<0.05). brackets are transformed according to arcsine transformation.

Appendix (7) Effect of Mahogany against red flour beetle after 24 hours.

Formulation	Concs.(%)	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	10 (18.4)	15 (22.8)	10 (18.4)	11.7 (19.9)b
	10	15 (22.8)	20 (26.6)	20 (26.6)	18.4 (25.3)b
	15	20 (26.6)	30 (33.2)	30 (33.2)	26.7 (31.0) b
Aqueous extract	5	10 (18.4)	15 (22.8)	20 (26.6)	15 (22.6) b
	10	5(12.9)	10 (18.4)	20 (26.6)	11.7 (19.3) b
	15	10 (18.4)	10 (18.4)	15 (22.8)	11.7 (19.9) b
Ethanolic extract	5	25 (30.0)	10 (18.4)	15 (22.8)	16.7 (23.7) b
	10	20 (26.6)	30 (33.2)	10 (18.4)	20 (26.1) b
	15	10 (18.4)	15 (22.8)	10 (18.4)	11.7 (19.9) b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) c

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (8) Effect of Mahogany against red flour beetle after 48 hours.

Formulation	Concs.(%)	Mortality (%)			
		R1	R2	R2	Mean
Powder	5	10 (18.4)	20 (26.6)	20 (26.6)	16.7 (23.9) b
	10	20 (26.6)	30 (33.2)	40 (39.2)	30 (33.0) b
	15	20 (26.6)	40 (39.2)	50 (45.0)	36.6 (36.9) b
Aqueous extract	5	20 (26.6)	20 (26.6)	30 (33.2)	23.4 (28.8) b
	10	15 (22.8)	15 (22.8)	35 (36.3)	21.7 (27.3)b
	15	20 (26.6)	20 (26.6)	30 (33.2)	23.4 (28.8) b
Ethanolic extract	5	40 (39.2)	25 (30.0)	25 (30.0)	30 (33.1) b
	10	45 (42.1)	40 (39.2)	20 (26.6)	35(36.0) b
	15	35 (36.3)	30 (33.2)	15 (22.8)	26.6 (30.8)b
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7(72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) c

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.

Appendix (9) Effect of Mahogany against red flour beetle after72 hours.

Formulation	Concs.(%)	Mortality (%)			
		R1	R2	R3	Mean
Powder	5	10 (18.4)	20 (26.6)	20 (26.6)	16.7 (23.9) e
	10	30 (33.2)	15 (22.8)	20 (26.6)	21.7 (27.5) de
	15	30 (33.2)	20 (26.6)	25 (30.0)	25 (29.9) de
Aqueous extract	5	25 (30.0)	35 (36.3)	35 (36.3)	31.7 (34.2) cde
	10	25 (30.0)	15 (22.8)	35 (36.3)	25 (29.7) de
	15	20 (26.6)	35 (36.3)	40 (39.2)	31.7 (34.0) cde
Ethanolic extract	5	60 (50.8)	50 (45.0)	35 (36.3)	48.4 (44.0) bc
	10	65 (53.7)	55 (47.9)	45 (42.1)	40 (47.9) b
	15	40 (39.2)	45 (42.1)	35 (36.3)	55(39.2) bcd
Standard		80 (63.4)	80 (63.4)	100 (90.0)	86.7 (72.3) a
Control		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0) f

Means followed by the same letter are not significantly different at ($P<0.05$). brackets are transformed according to arcsine transformation.