بسم الله الرحمن الرحيم

Sudan University of Science and Technology

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Evaluation of the Effect of Some Plant Extracts on Khapra Beetle *Trogoderma granarium* Everts. (Coleoptera: Dermestidae).

تقويم أثر فاعلية بعض المستخلصات النباتية على خنفساء الخابرا khapra Beetle *Trogoderma granarium* Everts. (Coleoptera: Dermestidae)

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DEDICATION

TO THE SOUL OF MY MOTHER

AYMAN

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First of all, I render my gratitude and praise to the Almighty; ALLAH who offered me the health, determination and the ability to undertake this work. Also my all thanks and appreciation to my father, who was supportive me in my life.

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Table of contents

CHAPTER FOUR: RESULTS

List of tables

List of figures

List of plates

Abstract

Laboratory studies were carried out to determine the effects of some indigenous plant extracts on the larvae of Khapra beetle, *Trogoderma granarium* Everts.The lethal, antifeedant and repellency activity of powders and aqueous extracts of eight plants (e.g., Basil *Ocimum basilicum*, Henna *Lawsonia inermis*,, Senna *Cassia senna*, Lantana *Lantana camara* , Datura *Datura alba*, Usher *Calotropis procera* ,Chili *Capsicum frutescens* and Jatropha *Jatropha curcas*.) were evaluated.

Results revealed that at the three doses applied 10%,15% and 20%, all plants tested have played some potential insecticidal effect but *C. procera* , *J. curcas* and *D. alba* had the most high lethal and antifeedant effect on the 3rd larval instar of *T.granarium*. The highest percentages of dead larvae (5.87, 5.00 and 4.50) were scored at 30th day with concentration 20% of Usher, Jatropha and Datura respectively. Also, from the results, it is becoming evident that Datura and Jatropha displayed some potential as anti-feedants to the larvae.

On the other side the repellency action of these plants was more effective against the pest .It was increased with increase in concentrations of the extract applied. However, Leaves water extract at 10% in *C.procera* showed the lowest repellency percentage (29.17%) class II, while the higher repellency effects were obvious at higher concentration 20% in *J.curcus*(77.15%) class IV.

In the Weevil perforation index experiments (WPI), plant extracts of Datura, Usher and Jatropha were evaluated for their activity on *T. granarium*, in the ratios of 10%, 20%, and 30% (w/w).This test allows plant materials with strong, weak or negative grain protectant effects to be detected. The results showed that, Of the 3 plants screened, *Datura alba* showed the best grain protectant effects, with a WPI value of (24.63) at dose of 30% (w /w).

In other experiments, treatments comprised application of mixed proportions of best two effective plants, leave powder extracts of Usher (U) and fruit powder

extracts of Jatropha (J), at three doses 10%, 15% and 20%. The treatments were arranged in a completely randomized design (CRD) with three replications . Treatment concentrations were added to test containers with (10 g) dry Sorghum seeds, admixed with (10) 3rd instar larvae of *T. granarium*. Insecticidal effects of the plant mixture combinations at the 1st day and 10th day showed no significant difference ($p>0.05$) at all concentrations. However, there was significant difference ($p<0.05$) in the mortality of the insects as the time of exposure increased at 20th day and 30th day compared to control. The results also showed that, the more the concentration of Jatropha extract, the more will be its effect on larval mortality.

Based on the results of this study, Powder extracts of *C.procera*, *J. curcas* and *D. alba* could be used in IPM program for control of *T.granarium*.

ملخص الدراسة:

تم أجراء التجارب المعملية لتقييم فاعلية بعض مستخلصات النباتات المحلية على يرقات خنفساء الخابرا تحت ظروف المعمل وتشمل الأثر القاتل ، المانع للتغذية والأثر الطارد للمساحيق والمستخلصات المائية لثمانية نباتات (الريحان ، الحنة، السنمكة، اللانتانا، السيكران، العشر، الشطة والجاتروفا).
أظهرت النتائج أن الجرعات الثلاث المستعملة 10 %، 15 %و 20 %، قد أحدثت بعض الخصائص السمية في كل النباتات المختبرة على الحشرة المستهدفة.

من هذه النباتات المختبرة أظهرت نباتات العشر، الجاتروفا والسيكران فاعلية أكثر و أحرزت أعلى نتائج في درجة السمية بالإضافة إلى العمل كمانع تغذية للطور اليرقي الثالث لخنفساء الخابرا. وقد سجلت هذه النباتات أعلى نسبة موت في اليرقات في اليوم 30 بتركيز 20% بنسب (5.87 ، 5.00 و 4.50) على التوالي. كما أوضحت النتائج أن السيكران و الجاتروفا قد أظهرا بعض الخصائص كمانع تغذية لليرقات. في الجانب الآخر أوضح اختبار الأثر الطارد أن لهذه النباتات الثلاث كفاءة عالية في طرد الآفة. هذه الفاعلية زادت مع زيادة التركيز وأوضحت النتائج أن تركيز10% من المستخلص المائي لنبات العشر اظهر اقل نسبة اثر طارد (29.17%) حيث صنف في الدرجة الثانية ، فيما اظهر أعلى تركيز من نبات الجاتروفا (20%) أعلى نسبة اثر طارد (77.15%) حيث صنف في الدرجة الرابعة .

بالنسبة لاختبار مؤشر ضرر الحشرة (WPI) ،{الذي يستخدم لتقييم المستخلصات النباتية من حيث فاعليتها في حماية الحبوب المخزونة (قوية ، ضعيفة أو سلبية)}، تم تقييم فاعلية مستخلصات نباتات السيكران والعشر والجاتروفا بنسب 10%، 20% و 30% (وزن / وزن) ودراسة تأثيرها على يرقات خنفساء الخابرا. أوضحت النتائج أن من النباتات الثلاث المختبرة أظهر السيكران أفضل النتائج في حماية الحبوب المخزونة (WPI =24.73)عند التركيز 30 % (وزن / وزن).
في تجارب أخرى، تم اختبار مخلوط أكثر نباتين فاعلية (العشر: الجاتروفا) وتم خلط مستخلصاتهما (بودرة أوراق العشر وبودرة ثمار الجاتروفا) بنسب متباينة. تم استخدام ثلاث جرعات 10 %، 15% و 20% . تم إضافة الخليط إلى أوعية اختبار تحتوى (10 جم) من بذور الذرة ، تم إدخال (10) يرقات من خنفساء الخابرا (الطور اليرقي الثالث) إلى أوعية الاختبار. أجريت التجارب باستخدام التصميم العشوائي الكامل (CRD) بثلاثة مكررات. أظهرت النتائج في اليوم الأول واليوم العاشر عدم وجود فرق معنوي ($p>0.05$) في جميع التركيزات. غير أنه كان هناك فرق معنوي ($p<0.05$) في معدل الموت بالنسبة

لليرقات بزيادة فترة التعرض في اليوم 20 و اليوم 30 مقارنة مع الشاهد كما أظهرت النتائج أيضا أنه كلما زاد تركيز مستخلص الجاتروفا، أكثر ازداد تأثيره على معدل موت اليرقات.

بناء على نتائج هذه الدراسة ، اتضح انه يمكن استخدام المستخلصات النباتية للعشر، الجاتروفا والسيكران في مكافحة يرقات خنفساء الخابرا ضمن برامج المكافحة المتكاملة .

CHAPTER ONE

INTRODUCTION

INTRODUCTION

Sudan is the largest agricultural country in Africa, with an area of 200 million fedans that can be cultivated. This area, coupled with huge amounts of water resources and the diversified agricultural environments enabled the production of different agricultural commodities. Cereal crops, oil crops and all types of horticultural produce are grown successfully.

Sorghum (Dura) is serving as a staple food crop for millions of the poorest and most food-insecure people in the semi-arid tropics of Africa, Asia and Central America. The crop is genetically suited to hot and dry agro-ecologies where it is difficult to grow other food grains. These areas are frequently drought-prone and characterized by fragile environments. In Sudan, sorghum is the staple food for most people lived in the country which ranks first, followed by wheat and millet. It is produced by the traditional farming sector for subsistence. It is particularly important in the west and south of the country. Total area under sorghum reached 10 million fedans in the season 2000/2001, 63.6% of which is rainfed, 35% irrigated and only 1.4% by floods. Sorghum and millet coupled with wheat constitute the main staple food of the country and hence play a vital role in food security.

Gadarif State (Eastern Sudan) is the most important region for sorghum production where about 5-6 million feddans are cultivated on an annual basis. Large scale farming where agricultural machinery is used characterizes this region. Farm size in this region averages at about 1500 feddans. The dominant varieties grown are the traditional Feterita types e.g. *Arfa Gadmek, Abdalla Mustafa* and *Korolo. Tetron* and *Dabar* are grown on a limited scale. Sorghum grown in this region is used for commercialization purposes and is sold mainly in the local markets, with some of it for export. In the Gadarif area, the principal

variety is Feterita which is relatively high in protein content and hence preferred by exporters. Sorghum in the irrigated schemes accounted for 35% of total sorghum production (Hamid 2006).

After harvest and before the consumption or export, grains of sorghum are transported to town markets where they are displayed in the open (Zariba) until May each year. Unsold sorghum during the rainy season is shifted to stores made up of mud and wood. Then these grains usually stored for variable periods under different conditions.

However, during storage the grains are attacked by insects, rodents, birds and other pests. They are attacked also by micro organisms. High losses occur by these pests. Insects are main pests which cause great proportion of damage. They often cause extensive damage to stored grains and grain products, amounting to 5-10% loss in temperate regions and 20-30% in the tropical regions (Nakakita, 1998). FAO estimated the annual losses in storage grain due to insects as amounting to 13 million tons. Different species of insects are responsible for the yield reduction of grains, beetles and moths are predominant (Khan and Mannan, 1991).

The heavy post-harvest losses and quality deterioration caused by storage pests are a major problem facing agriculture in developing countries (Adedire and Ajayi,1996). The protection of stored grain and seeds against insect pests has been a major problem in the development of agriculture.

Synthetic pesticides have traditionally been used as grain protectants across the globe. They have great potential in pest control, especially in terms of efficacy during emergency situations.

Chemicals used for controlling store pests have resulted in many problems, such as toxicity of the treated food grains ultimately creating some sanitary and phytosanitary problems, lethal effects on non-target organisms (Ajayi & Lale,2000); ozone layer depletion, high costs of chemicals, resistance of pests to pesticides and harmful effects on human beings (Gao, *et al.* 2008). Other

problems include poor knowledge of application; cost, non-availability, genetic resistance and hazard to health have necessitated the search for humanly safe, ecologically tolerable and relatively cheap control measures (Adedire & Ajayi, 1996 & Akinkurolere, *et al,* 2006)). In the developed countries, conventional fumigation technology is currently being scrutinized for many reasons such as ozone depletion potential of methyl bromide and carcinogenic concerns with phosphine (Adedire, 2002).

These problems caused by synthetic pesticides and their residues have increased the need for residue-free grain, effective biodegradable pesticides with greater selectivity.

One solution to these problems might be to totally replace synthetic chemicals with compounds, which occur naturally in plants. These alternative strategies have included the search for new types of pesticides which are often effective against a limited number of specific target species, are biodegradable into nontoxic products and are suitable for use in integrated pest management programs (IPM). Most of these plant products are cheap, readily available, edible and ecologically safer means of controlling insect pest infestations of stored cereal and grains especially in the tropics.

The use of botanical pesticides is now emerging as one of the prime means to protect crops and their products and the environment from pesticide pollution. Botanicals have been used for centuries and were widely used in the United States until the 1940s and 50s when synthetic pesticides were introduced. Botanicals have many advantages, eg., it is degrade more rapidly from sunlight, air, and proper moisture than most chemical pesticides, and are, therefore, considered relatively environment friendly and less likely to kill beneficial species than synthetic pesticides with longer environmental retention, Botanicals act quickly to stop feeding of insect pests and often cause immediate paralysis or cessation of feeding and most botanicals are not toxic to plants, except insecticidal soaps.

Botanicals generally act in one of two ways: either as a contact poison when sprayed on the insect, or as a stomach poison when applied to the plant and eaten by the insect. More than 1000 species of plants have been reported to have chemicals in leaves, stems, flowers, seeds and roots which have insecticidal property, only a few of them have been used for practical insect control on a commercial scale in the past (Shahid, 2003). The use of plants as repellents is very old but has not received the necessary attention for proper development (Isman, 1997). Botanicals are processed into various forms: dusts and powders made from ground and dried plant parts; pure chemicals isolated from plants; and plant extracts or resins. These extracts and resins are formulated as liquid concentrates or impregnated on to dusts or wettable powder.

Control of stored grain insect pests attacking food grains is also a difficult job particularly in bag storage where still jute bags are important receptacles for the storage of grains.

Khapra beetle (*T. granarium* Everts) is a storage insect pest which occurs mainly on cereals and cereal products, oil seeds (especially groundnut which is the primary host to the insect) and oil cakes, pulses and pulse products, Khapra beetle has observed as major pest which has the tendency to reduce seeds to a powdery form over a period of time, when left uncontrolled.

Though several works had been done on the use of plant materials in stored product protection, it is necessary to evaluate plant products in economic formulations which will be efficient. Farmers are accustomed to use Plant powder formulations because it is cheap since organic solvents are not available.

Objectives

In view of the recently increased interest in developing plant origin insecticides as an-alternative to chemical insecticide, this study was undertaken to assess the toxicant potential, repllent activitay and antifeedant effect of the extracts from certain plants against khapra beetle *T. granarium* to determine the

response of this pest to different doses of these plants, and also to test the extracts effect of more than one plant against khapra beetle.

The study aimed at developing insecticides using plant material that are economical, safe and locally available in sudan, and it is also essential that appropriate technology transfer system is developed to promote a direct preparation of traditional pesticides at the farm level for those resource-poor farmers who have no access to commercial pesticides or organic solvents to extract plant material or can not afford them.

CHAPTER TWO
LITERATURE REVIEW

LITERATURE REVIEW

2.1 Khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae)

The khapra beetle, *T. granarium* Everts, has a number of "Synonyms"*: T. afrum* Priesner, *T. khapra* Arrow, and *T. quinquefasciata* Leesberg. It is a cosmopolitan, multivoltine and polyphagous pest throughout the tropics (Hill, 1983; Hill and Waller, 1988; Odeyemi, 1989). This pest is one of the world's most feared stored-product pests and considered to be the most destructive stored product pest (Burges, 2008; Mark *et al*., 2010). Khapra beetle feed on almost any dried plant or animal matter but prefers grain and cereal products, particularly wheat, barley, oats, rye, maize, rice, flour, malt, various leguminous and sorghum (Haines, 1991; Lowe *et al*., 2000; El Nadi *et al*., 2001; CAB, 2004). It is a pest of stored groundnut seeds in Nigeria (Howe, 1952; Prevett, 1964; Odeyemi, 1989; Odeyemi and Daramola, 2000). It also occurs on other products such as empty sacks and gum… etc. which is probably accidental due to cross-infestation (Haines, 1991; Lale, 2002).

The pest had been given status as an A2 quarantine organism for EPPO (EPPO, 2007). Besides it is considered as a pest of quarantine concern for CPPC, COSAVE, JUNAC, NAPPO and OIRSA.

In Sudan, this beetle is now distributed in most parts of the country as a major pest of store grains and it is considered a national pest (Anonymous, 2001-2009)

2.1.1 Distribution

The Khapra beetle is native to the Indian sub-continent and now a serious pest of stored grain in most parts of the world (Konemann, 1993). Harris (2009) stated that, this pest is originally occurred in India, and spread to Africa, Europe, South America and East Asia.

It occurs under dry hot conditions predictably in areas which, for at least four months of the year, have a mean temperature higher than 20°C and a relative humidity below 50 %. It is especially prevalent in certain areas of the Middle East, Africa, and South Asia, and is also found in certain specialized warm habitats in temperate countries, e. g. (maltings in Britain) (Haines, 1991). Its endemic zone extends from Burma to West Africa and is limited by the 35° parallel to the north and the equator to the south. In Africa the pest was recorded in Algeria, Burkina Faso, Mali, Mauritania, Morocco, Niger, Senegal, Somalia, Nigeria (mainly in the north), Egypt, Libya and Sudan (CAB 2004; EPPO 2005).

Stoll (2000), reported that the eggs of *T. granarium* are laid on the store products, such as cereals, peanut, pulses herbs and manufactured products of grain, legumes and oil seeds. Freeman (1974) reported that, this beetle breeds most rapidly under hot, dry conditions and has a potential for spread. These spreads around the world in international trade are shown by its regular interception on oil cake and other products imported into Great Britain from Burma, Sudan, Senegal, India and Nigeria. Priesner (1951) wrote that, *T. afrum* was a major pest of grain in Egypt and Sudan. In Sudan, darling (1959) mentioned six primary spacies *T.granarium* , *Sitophilus oryzae* (L.), *Rhyzopertha dominica*(F.), *Sitotroga cerealella* (Oliv.), *Corcyra spp and Ephestia* spp, were found in humid areas ,Upper nile ,Bahr Elgazal, Equatoria, Nuba mountains, Red sea and central rain lands. *T. granarium* and, *R. dominica* were also found in dry Northen parts of sudan (Darling, 1959 and Ibrahim, 2001).

The problem of preventing the beetle's spread is further compounded by its ability to survive for several years in the larval stage with little or no food, and its habit of hiding in cracks and crevices. And also Because of its refuge seeking behavior, it is extremely difficult to eradicate this insect from premises or transport facilities, and the existence of a special type of recurrent dormancy in

the larval stage enables populations to exploit times of food abundance and to survive long periods of deprivation (Bell and Wilson, 1995).

2.1.2 Classification

Class: Insecta

Order: Coleoptera

Super family: Dermestoidea

Family: Dermestidae

Genus: *Trogoderma*

Species: *granarium*

2.1.3 Identification

The genus *Trogoderma* in recent years has been reported to include 117 species (Mroczkowski, 1968), 115 species (Beal, 1982), 130 species (Háva, 2003) and 134 species (Háva, 2011). There are many other species of *Trogoderma* yet to be described.

Eggs: milky white when first laid turning pale yellowish to brown with age, cylindrical, 0.7 by 0.22 mm long with one end rounded and the other pointed, and bearing spine-like projections (Harris, 1984; Haines, 1991; Barak, 1995; and Pasek, 1998).

Larvae: yellowish to bright brown during the first instar, changing to reddish-brown or golden brown in the last stage; clothed with fine setae, and tufts or/of barbed setae on each side of the terminal abdominal segments like a tail-shape. Larvae bear characteristic body hairs: (1) simple hairs in which the shaft bears many small, stiff, upwardly directed processes, and (2) barbed hairs with a constricted shaft in which the apex is a barbed head as long as the preceding 4-segmented-like constrictions (Hadaway 1956; Anonymous 1981).

The length in the first stages is 1.6 mm reaching up to 6 mm at the final instar; the body width is 0.25 to 0.3 mm (Pasek, 1998).

Pupa: is of exarate type, average length being 3-5 mm and 5 mm for male and female respectively (Hadaway, 1956).

Adult:

Male: Small, oblong-oval, about 1.8 to 3.0 mm long and 0.9 to 1.7 mm broad, reddish-brown, thorax usually dark brown, pubescent. The hairs trap the dust of the destroyed grain giving a dirty appearance.

Female: lighter in color and larger than male. Head small and deflexed with a median ocellus present between the compound eyes; antennae 11-segmented, antennal club very distinct consisting of 3 - 5 segments. The antennae fit into ventral grooves in the vertex (Harris, 1984; Haines, 1991; Pasek, 1998). Buss and Fasulo (2006) stated that, the adults are oblong-oval beetles, approximately 1.6 to 3.0 mm long by 0.9 to 1.7 mm wide. Males are brown to black with indistinct reddish brown markings on elytra. Females are slightly larger than males and lighter in color. The head is small and deflexed with a short 11-segmented antenna. The antennae have a club of three to five segments, which fit into a groove in the side of the head; the adults are covered with hairs.

2.1.4 Biology and Ecology

The optimum condition for development of khapra beetle do not correspond well with its geographical distribution, which indicates a preference for hot, dry areas, where condition are more humid, khapra beetle may not be able to compete with other beetle species typically have a higher reproductive potential and shorter life cycle (CABI, 2005). Ofuya and Lale (2001) stated that, the life cycle of dermestid beetles shows a typical holometabolous development. *T. granarium* may have from one to more than ten generations per year depending on food availability and quality, temperature and humidity.There are two genetic variations of larvae: those that are able to undergo facultative diapause and those that are unable to do so. Larvae of the first type are stimulated into diapause by adverse conditions such as low or high temperatures and/or lack of food (EPPO/CABI, 1997).

A complete life cycle may be as short as 26 days (temperature 32–35° C) or as long as 220 days or more in a suboptimal environment. In temperate climates larvae become inactive at temperatures below 5°C, so the pest is able to survive and breed only in protected environments (EPPO/CABI,1997).

Howe (1952) reported that, Under optimal conditions, khapra beetle can sustain a population increase of 12.5 times per month, for that reason population can build-up in a short time under hot, dry, conditions. It can survive in colder and heated situation such as warehouses, food plants and grain stores. Khapra beetle is primarily active at dusk. Adults are usually short lived, but have been known to survive several months or a year at temperatures below 16°C (USDA, 1982). Abdalla (1986) mentioned that, the shortest duration of development in Sudan was 38.5 days in Safra variety.

Development can occur at a relative humidity as low as 2%. In comparison, high relative humidity may be the limiting factor in the survival of khapra beetles in introductions (Howe and Lindgren, 1957). In humid climates, it does not compete well with other better adapted species (Anonymous, 1981).

Oviposition: After copulation, oviposition commences immediately at 40°C and lasts 3-4 days. At 25°C there is a preoviposition period of 2-3 days. Development is most rapid in hot, humid environments, taking about 18 days at 35°C and 73% R.H. under these conditions (CABI, 2004). Each female usually deposits about 50 eggs in its lifetime. At temperatures above 32°C this number may go up to 100 eggs per female. Abdulla and Al mallah (1990) demonstrated that, at 25 ± 1°C and 5% R.H the average number of eggs laid by khapra beetle on rice, sesame and chickpea was (27.2, 20.0 and 14.4 eggs), repectively. Temperature between 25-40°C has little or no effect on the average number of eggs laid, which is approximately 35 per female (Howe, 1952; CABI, 2004).

Eggs are deposited loosely and usually singly in host material and also in grooves or cracks formed by the removal of the fried shoots at the ends of the

grain. Hatching usually takes in 1-2 weeks (Hadaway, 1956). Harris (2006); and Szito (2007) stated that, females lay an average of 50 to 100 eggs, which are loosely scattered in host material.

Anonymous (1981) stated that, Eggs hatch in three to 14 days after the female lays an average of 50 to 90 eggs that are loosely scattered in the host material. Abdallah (1986) stated that, the egg hatched in about 5-6 days under an average temperature of 31.7°C and 27.1% RH.

Larvae: The larva is the most prominent stage in the population. Throughout population growth, low temperature and the accumulation of faecal pellets cause some larvae to enter diapause and hide either in crevices or on the walls. The larvae develop rapidly into the pupal stage, e.g. in 15 days at 35°C. If the temperature falls below 25°C for any period of time, the larvae are cold-hardy, surviving temperatures below -8°C. Diapause often occurs at constant temperature, below 30°C. In diapause, the larva can moult but is relatively inactive and rarely feeds. It tends to seek out crevices in the fabric of buildings. A larva can remain in this state for several years, but the provision of a new consignment of food, especially in warm conditions, may stimulate renewed development and pupation. Young larvae are unable to feed on whole grains and depend on damaged grains or grain products for food (they readily attack softer foods such as nuts). Such damaged grains are always present in practice in lots of stored grain. Older larvae can feed on whole grains. The amount and condition of the food present affects the speed of development, but larvae can survive long periods (at least 13 months) without food. Starvation of dormant larvae for 3 months, followed by a brief period of feeding, results in the production of 41% of the normal number of eggs. However, this percentage is ample for the survival of the pest. One to 3 months of starvation does not affect the pupation rate of dormant larvae (EPPO 2010).

Abdullah and Al mallah (1990) reported that, the average duration of each developmental period for the larval stage duration on rice, sesame and chickpea

was 3.6, 4.0 and 4.6 days, respectivaly and for the prepupal stage duration was 4.6 days. The average number of larval molts is four for males and five for females (CABI, 2004).

Rebolledo and Arroyo (1995) showed that, the 1st, 3rd and 5th larval instars of *T. granarium* when kept without food, only the 5th larval instar continued development until the adult stage.

Anonymous (1981) stated that, if the temperature falls below 25°C for a period of time or if larvae are very crowded, they may enter diapause. They can survive temperatures below -8°C. In diapause, the larvae can molt but are inactive and may remain in this condition for many years.

Pupation: The larvae leave diapause and pupate if subjected to a considerable temperature shock (i.e. a much lower temperature for at least one month followed by a return to warm condition). A similar but less effective stimulus is the introduction of fresh food. Hadway (1956) reported that, pupal stage lasted in 3-6 days for males and 3-8 days for females. The pupa usually remains inside the skin of the last larval instar. Pupal development is unaffected by humidity and varies in length from five days at 25°C to three days at 40°C. On adult emergence the pupal skin is pushed to the posterior end of the larval skin, the adult remains with the larval skin for a day or more (CABI, 2004).

Adult emergence: When the adult fully emerged, copulation can take place immediately (CABI, 2004). Sexual maturity is usually reached 2 days after emergence (USDA, 1982). Adult do not feed and can live for 11-15 days (Darling, 1951). Abdalla (1986) reported that, at 30°C and 28.5% R.H adult emerged in 47± 1.17 days in *Safra* variety of dura, 51.4±1.17 days in wheat and 54±1.12 days in millet. Anonymous (1981) stated that, Adult khapra beetles have wings, but apparently do not fly and feed very little. Mated females live from four to seven days, unmated females from 20 to 30 days, and males from seven to 12 days. Mating occurs about five days after emergence, and egg laying begins almost immediately at 40°C. Egg laying may begin at one to three days at

cooler temperatures, but no eggs are produced at 20°C. Complete development depends upon temperature. Optimum temperature for development is 35°C.

The adult male life span was 3.6, 4.0 and 5.2 day on rice, sesame and chickpea respectively (Abdullah and Al mallah 1990).

Abdalla (1986), stated that the duration of *T. granarium* and its development on the average was: 5.6 days for the egg stage and the whole duration from egg to adult emergence took 47±1.17, 51.4±1.17 and 54±1.12 on *Safra*, wheat and Millet grains, respectively (experimental conditions were 30.2°C and 28.5% R.H.). The shortest duration of development was 38.5 days obtained on *Safra* variety during August/ September 1983. Few insects entered diapause in the period October to March 1983/84. Their duration lasted on the average 134 days. Abd El Aziz, (1984) stated that, duration of immature stages of *T. granarium* averaged 31.5, 32.5, 33.1 and 33.4 days on *Dabar*, *Safra*, *Faterita* and *Mugud*, respectively, at mean temperature of 32.5°C, and mean relative humidity of 49.5 %. At 26.6°C, mean temperature, and 25.7 % mean relative humidity, eggs of Trogoderma failed to hatch.

Saliheen, (2005) Stated that, female deposited 47.9,37 and 38 eggs in Sorghum; millet and wheat in average respectively. The incupation period of the eggs ranged between 5-8 days with an average of 6.44±0.71 days. The beetle passed through 5 instars.the larval duration was 44±7.5 days for Sorghum. from pupal to the adult stage the duration was 6.17±0.4 days .the whole life cycle from egg to the adult varied according to the grain variety, in Sorghum it was 43-57 days with average 50±5.9 days, in Millets it was 40-56 days with avarege of 47.8±9.8 days and Wheat was 41-58 days with average 48.5±7.3 days. The adult female lived for 10.3±0.8 days while the adult male lived for 11.5 days. The percentage of loss of weights was 1.48% in sorghum,1.34% millet and 1.07% in wheat.The percentage of attacked seeds (damaged seeds) were 26.85%.22.73% and 20.89% for Wheat, Sorghum and Millet.

Musa and Dike (2009) stated that, the life cycle of the Khapra beetle, *T. granarium* (Coleoptera: Dermestidae) on stored groundnut was studied under fluctuating laboratory conditions of 25±5°C and 70±5% relative humidity.There were five larval instars and the total development time from egg to adult ranged from 37 to 40 days with an average of 37.95 days. The duration of each developmental stage was egg: 6.05 days; first instar: 3.8 days; second instar: 4.7 days; third instar: 5.6 days; fourth instar: 6.2 days; fifth instar: 6.8 days and pupa: 4.8 days. Females had an average fecundity of 80.2 eggs. Mean adult longevity was 12.4 days.

2.1.5 Economic Importance

Trogoderm granarium is a serious pest of stored products under hot dry conditions and of quarantine importance to several countries .This beetle is one of the most important stored product pests worldwide which maintains its presence in stores in very low numbers and it is able to survive long period of time in inactive state (Dwivedi and Shekhawat, 2004). Reproduction may be so rapid that larvae are found in large numbers in the surface layers of binned grain, suggesting that, in stored grain most damage takes place within the top 30 cm. The beetles have also been found along the walls and corners of the grain storage facilities.

Damage by this insect is mostly caused when the larvae feed; complete destruction of grain and pulses may take place in a short time. Ofuya and Lale (2001) reported that, the larvae being the destructive stage of the insect pest. The adults possess wings but are not capable fliers and do not feed. Its discovery in a non-infested area usually leads to an immediate quarantine of suspected goods and an expensive eradication and control effort. This beetle has never been observed to fly; therefore, its spread is probably dependent on movement of infested goods or in containers where it may be transported while in diapause.

Development rates and survival vary considerably depending upon temperature, light, moisture, season, and host species.

T. granarium has a high capacity for population growth. Infestation increases of 1.7 to 2.4 times per week have been reported, but under optimal conditions (33-37°C) populations of *T. granarium* can even increase by 12.5 times per month (Karnavar 1973; French and Venette 2005). According to Aldryhim and Adam (1992); and Stibick (2007), *T. granarium* usually has 4-5 generations per year, but this figure can reach 12 under optimal conditions.

Detection of the pest is based on visual inspection of the cast skins from the larvae, excessive dust on the grain (Harris,1984; Pasek, 1998), and by trapping methods. However, if beetles are not trapped, it does not mean that they are not present (Barak, 1995).

Pasek, (1998), reported that Khapra beetle is the most voracious pest of stored grain products under hot, dry conditions. It can destroy more than 30% of the products. Losses caused by *T. granarium* have been reported to range from 0.2 to 2.9% over a period of 1 to10.5 months (Irshad, *et. al*., 1988).

Arain, *et. al.,*(2006) stated that, the grain consumed by male was15.5 to 18 mg in 24 to 28 days while the female consumed was 18 to 24 mg in 27.5 to 31 days. The incurred loss can be direct such as loss in weight or indirect such as reduction in quality of stored product by changing the appearance, color, contamination by dead or live insects, cast skin, faeces in addition to losses in germination power. Other losses include damage to granary structure and cost of pest control operations. In addition, infestation is often followed by colonization by secondary insect pests, fungi and consequently leading to deterioration in grain characteristics. Feeding also results in an increase of moisture, crude fibre and total protein content (Mason, 2002).

Kapra beetle economic importance lies not only in the serious damage it can cause to stored dry commodities but also in the export restrictions faced by countries when they have established populations of this pest. Live populations

can stay in uncleaned containers, packaging material and cargo holds for extended periods of time, infesting non-host material. *T. granarium* may also increase the likelihood of contamination by *Aspergillus flavus* (Sinha and Sinha, 1990). Severe infestation by khapra beetle makes grain unpalatable and unmarketable due to depletion of specific nutrients. Jood and Kapoor (1994) reported substantial loss of vitamins, thiamine, riboflavin and niacin at 25% and above grain infestation by this insect pest.

Larval feeding in sorghum grains has been found to adversely affect quality of minerals (Jood *et al*., 1992), available carbohydrates (Jood *et al*., (1993a), protein and starch digestibility (Jood and Kapoor, 1992) and bioavailability of proteins (Jood *et al*., 1993b).

Sudesh *et al*., (1996) stated that, in qualitative losses the total soluble sugar, reducing sugar, non reducing sugar and starch contents of wheat, maize and sorghum grains were affected adversely at 25%, 50% and 75% insect infestation caused by *T. grainarium* and *R. dominica* separately or by mixed population. *R. dominica* significantly reduced available carbohydrates at 50% and 75% infestation.

2.1.6 CONTROL:

Physical control: Heat treatment has proved to be very effective. Ismail *et al*., (1988) reported that, heat treatment is very effective against diapause larvae of *T. granarium*. During their investigations, a 30 minutes exposure at 60°C gave 100% kill of all stages of the khapra beetle. Battu *et al.,* (1975) found that, LT95 values for diapausing and non-diapausing larvae at 50°C were 7.4 and 3.0 hours, respectively. They further reported that mortality of larvae began at 42.5°C; complete mortality however required 8 days exposure at that temperature.

However, it has been reported that some natural mortality of larvae during the diapausing occurred in stores due to warming caused by activities of the khapra

beetle itself. Diapausing larvae are more resistant to high temperature than non-diapousing larvae. In storage facilities trapping proved to be a useful surveillance tool using pheromone and larval traps.

A combination of trap, food attractant and pheromone will help to attract beetles, and allow for the necessary control measures to be adopted (ISSG, 2004)

Treatment with fast electrons, using a linear accelerator, could provide an efficient method of controlling khapra beetle in store grain (CERIS, 2004; ISSG, 2004).

(Kansu, 1962) found that, 6000r of gamma radiation or more reduced reproduction capacity when applied to the male pupae of *T. granarium* and 15000 r sterilized all the males in two of three tests while 7500r applied to female pupae had no effect on reproduction.

Natural Enemies: Several natural enemies for *T. granarium* have been reported. These include: *Amphibolus venators* (Klirg) Hemipteran (Battue, *et al*., 1975), Mites *Acarapis docta* (Berlesse) (Sochandhany and Mukherjee, 1971; Kapil and Bhanet, 1971), and *Pyemotes sp.;* the Protozoan *Adelina tribolli* (Bhatia); and the parasitic wasps *Anisopteromalus calandrae* (Howard), *Divarnus basilis* (Rondani) [=*D. laticeps* (Ashmed)], *Holeryris spp*., and *Synopeas spp*. (Haines, 1991). *Laeluis pedatus* is parasitoid of khapra beetle.

Al-Kirshi (1999) studied the efficacy of this parasitoid in controlling the beetle; the venom of *L. pedatus* caused 6% larval mortality.

Chemical Control: The stored insect pests are mainly controlled by synthetic chemicals, the authorized fumigants and pesticides include the following: Phosphine, Methyl bromide, Malathion, Permethrin, Cypermethrin and Bifenthrin.

The synthetic pesticides associated with a lot of hazards, due to their effect to humans, beneficial insects and other vertebrates, also the continued use of

pesticides result in insects out-breaks and development of the insect resistance against pesticides (EL Baroni, 1991). These pesticides are used for rapid control, but are expensive, not readily available and may be poisonous to humans and environment (Tsumura *et. al.,* 1994). Extensive usage of broad spectrum synthetic pesticides during the last century has created so many environmental problems worldwide, and particularly in Sudan (Abdel Bagi *et al*., 2006). Major demerits of chemicals, however, include ozone layer depletion, high costs of chemicals, resistance of pests to pesticides and harmful effects on human beings (Bell and Wilson, 1995; WMO, 1995; Gao *et al.,*2008). Collins *et al*., (2005) stated that methyl bromide which has been identified as an ozone depleter, and the growing adverse consumer reaction to the presence of residues from grain protectants. However, methyl bromide is deemed harmful for the ozone layer. (Pasek, 1998), and has been banned/restricted in some countries.

The problem of phosphine resistance in insects was first detected in the 1970s in a laboratory-based assessment of insects collected during a world-wide pesticide resistance survey. Hole *et al*., (1976), stated that khapra beetle appears relatively tolerant to insecticides and many fumigants especially at larval stage. Harris (1984) mentioned that, the Khapra beetle has showed some signs of resistance to some chemicals e.g. phosphine, and Malathion. In 1982, reports of field resistance to phosphine were verified in Bangladesh, and later in other countries including Pakistan and India, and also in Africa and in Southeast Asia (Taylor, 2002). In Pakistan, *T. granarium* has been observed to have gone resistant to phosphine due to substandard techniques of fumigation (Irshad and Iqbal, 1994). Sharma and Kalra, (1998) also reported resistance to phosphine in different developmental stages of *T.granarium*.

Moreover, Malathion and Cypermethrin have gone ineffective due to development of resistance in insect pests of stored grain, particularly in *T. granarium* (Saxena and Sinha, 1995). Alam *et al.,* (1999) and Chaudhry, (2000) reported that, at least 11species of stored-product insects including *T.granarium*,

S. granarius and *T. castaneum* etc. are now known to have developed resistance to phosphine. Pasek (1998) reported that, Khapra beetle shows signs of resistance to some common pesticides including phosphine (hydrogen phosphide, PH3); improper application may be a contributing factor to the development of this resistance. Phosphine resistance can be easily selected from field populations of most stored product insects and, unfortunately, this suggests that the frequency of resistant gene(s) might be quite high and that multiple genes may be involved in the selection for the strong resistance, (Chaudhry, 2000). Furthermore, once developed, phosphine resistant insects show little loss of fitness and the resistance is stable. Stibick (2007) reported that, Khapra beetle shows signs of resistance to some common pesticides including phosphine. Ahmedani *et al*., (2007) reported a phosphine resistant strain of *T. granarium* which exhibited resistance levels of 2.54 - 3.98 folds.

Furthermore, there is an increasing dichotomy between the demands of the first world for quality food uncontaminated by insecticidal residues, and desperate need of third world population to maintain level of food security (Donahaye *et al*., 2000).

2.2 Sorghum

Sorghum is the fifth most important cereal in the world and a major staple food in the diets of the people of semi-arid tropics in Asia and Africa (ICRISAT, 1992). As a human food it is ground into flour and made into porridge and chapatis (unleavened bread). Sorghum is a cereal of remarkable genetic variability.

Sudan is agricultural country where various crops are raised by irrigation and rain fed schemes. Sorghum is the most important staple food crops in the Sudan (Ahmed, *et al*., 2004). The main crops produced include sorghum (*sorghum bicolor* (L.)), wheat (*Triticum vulgare*(L.)) and millet (*Pennisetum typhpides* (L.) R.Br.) .Sorghum occupies about 40% of the country 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 the North and South Kordofan (Elkhidir, 1982).

2.2.1 Taxonomy:

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

Genus: *sorghum*

Species: *bicolor*

2.2.2 Description:

Sorghum is annuals, few are perennials. Cultivated and most weedy sorghum are non-rizomatus, clums nodes are either glabrous or shorty tomentose the inflorescence is contracted. The branches of the inflorescence alternate. *Sorghum bicolor* (L.) includes all cultivated Sorghums as well as a group of semi wild plants often regarded as weeds. Historical records and archaeological data have been able to clearly state the origin and domestication of *S. bicolor*. Previously species 271 cultivars were recognized, 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 and has both male and female parts, and the other flower is stalked and usually male (A-msalu and Endashaw, 1998).

Before consumption or export grains are usually stored for variable periods under different conditions, however during storage the grains are ravaged by

insects and other pests. Insects are the main pests which caused the greatest damage to stored grains all over the world Sorghum grains are attacked by a large number of insects in stores. *T. granarium* is among the most serious and of widest occurrence in stores in tropical and sub-tropical regions of Asia and Africa (Atwal, 1976; Sahmkhe. *et. al.,*1985; Viljoen, 1990).

Abdalla (1986) stated that, on the basis of the percentage of damaged seeds, loss percentage in weight and population build up, the varieties *Safra* and *Mugud* were highly susceptible where as the varieties *Feterita* and *Deber* were intermediate in their susceptibility and wheat was the least susceptible. Grain hardness had a negative relation with the susceptibility, while grain size had a positive relation. The germination capacity decreased with the advancement of storage period. The highest feeding activity occurred in September, the lowest feeding occurred in the cooler months (December, January and February). Insignificant variation in the attraction of the tested varieties to *T. granarium* was observed, however, more larvae were attracted to *Safra* than *Mugud* followed by *Feterita* and *Deber*. In the comparative loss percentage in weight caused by *T. granarium* and *R. dominica* all the tested varieties were found susceptible to both insects. With respect to *T. granarium* the tested varieties could be classified into three categories: *Safra* and *Mugud* in the most susceptible, *Feterita* and *Deber* intermediate in susceptibility and wheat is the least susceptible.

2.3 Botanicals

Botanicals are materials or products of plants origin valued for their pesticidal, medicinal or therapeutic properties. Phyto-pesticide materials range from whole fresh plants to purely isolate bioactive phyto-chemicals or their formulations which are effective against pests and pathogens (Prakash and Rao, 1996).

The use of botanical pesticides to protect plants from pests is very promising because of several distinct advantages; Pesticidal plants are generally much safer than conventionally used synthetic pesticides; Pesticidal plants have been in nature as its component for millions of years without any ill or adverse effect on the ecosystem. In addition, plant-based pesticides are renewable in nature and cheaper. Also, some plants have more than one chemical; the chances of developing quick resistance to these different chemicals are highly unlikely (Saxena, 1989). Plant-derived pesticides can be transferred into practical applications in natural crop protection, which can help the small-scale farmers (Binggeli, 1999).

Okonkwo and Okoye (1996) stated that, local alternatives such as the natural products are cheaper, easily available way for controlling pests, which are safe for humans, and environment. Most pesticide plants also have medicinal values, and some are consumed by humans as spices. The use of insecticides of natural origin are therefore an important development in storage pest control as they have short residual action, low mammalian toxicity and reduced environmental pollution.

Present trends in the world directed to the use of plants that have insecticides properties. Some plant extracts are highly effective and safe for human beings and environment, convenience and inexpensive for protection of stored grains. Recent studies have shown the importance of natural chemicals as possible source of non-phytotoxic, systemic and easily biodegradable alternative

pesticides (Singh, 1994; Mason and Mathew, 1996; Qasem and Abou-blan, 1996).

According to Birch, *et al.,* (1993), plants produce a wide range of defensive compounds to protect themselves from pests and pathogens. These compounds may protect the plant against pathogens and insect pests by acting as repellent, anti-feeds, ovicides, antivirus vectoring activities and growth regulators. Ayvaz. *et al*., (2010) stated that, the interest in botanical insecticides has increased as a result of environmental concerns and insect resistance to conventional chemicals.

Sukumar *et al.,* (1991) reported 99 families, 267 genera and 346 species of plants to have insecticidal properties. During co-evolution between plant and insect, the former produced several metabolic by-products, which act as repellents, growth disruptors or regulators, larvicides, and antifeedant against invading insect (Patil *et al*., 2006). Their pesticidal or microbiocide property was attributed to their secondary metabolites which are triterpenoids and non-terpenoids (Finar, 1986; Hellpap and Dryer, 1995).

Duke, (1990); and Baser *et al*., (1998) reported that, natural products contain secondary plant compounds such as terpenes (monoterpenes, sesquiterpenes and triterpenes), steroid, alkaloids, phenol and cardiac glycosides. Plant insecticides are often alternatives effective as organophosphates or other neurotoxins for pest control due to multiple modes of action. It included toxicity, anti-feedant and anti-oviposition effects (Sutherland *et al.,* 2002).

Zhu *et al.,* (2001) stated that, plant products like essential oils, possess a broad spectrum of pest control properties and have been widely investigated for their larvicidal, toxic, repellent, ovicidal, antifeedant and anti-oviposition effects.

The effectiveness of many plant products for use against stored grain pests have been reviewed by Jacobson (1958, 1975, 1983, 1989). The effects of plant products so far reported include insecticidal, repellent and anti-feedant activities (Huang *et al.,* 1998).

Certain plants have already been reported to possess repellent action against stored grain pests (Nawrot *et al.,* 1982; Ahmed and Eapen, 1986; Behal, 1998). Many plant extracts are known to possess insecticidal activity against various stored product insects (Schmutterer 1990, 1995; Desmarchelier, 1994; Shaaya *et al*., 1997).

Dwivedi and Garg (2003) reported that, Plant products widely used as traditional stored grain protectants in powder form, crude mixtures or extracts due to their easy accessibility and biodegradable nature. Hasan *et al*., (2006) stated that, the toxicity of plant extracts had been checked against a number of stored product insects.

Shulka, *et al.,* (2000) screened some essential oil Limon grass against the *T. granarium, S. oryzae, Coreyra cepholonica* and *Ephestia cautella*. (Sardamma, *et al.,* 1977) mixed rice grains with powdered neem seed kernel and found that it effectively protected grains against *T. granarium*, attack during storage for various periods.

(Siddig, 1980) found in Sudan that, treating wheat with powdered neem seeds reduced the damage and the effect increased as the dosage increased. Abdalla, (2003) found that Garlic fumigation reduced the rate of increase in population of *T. granarium*, larvae over prolonged storage (15-60 days). El Nadi *et. al.,* (2001) studied the toxicity of aqueous, methanol and acetone extracts of three plants *Rhazya stricta*, *Azadirachta indica*, and *Heliotropium bacciferum* on Khapra beetle (*T. granarium*) larvae, all extracts showed remarkable toxicities.

Neem extracts are very effective against khapra beetle as well as many other insects. There is an indication that burning neem leaves will fumigate stored goods. However, these may be used as supplemental treatment. The use of deoiled neem (*Azadirachta indica*) seed powder mixed into wheat seemed to be an effective and cheap method to control the pest in stored wheat in India (Singh, *et. al.,*1978; Dabire, 1993; Arivudainambi and Singh 2003).

Rajapaske and Van Emlen (1997) reported that, Oil extracted from plants have been extensively used in tropical countries for crop protection.

The protection of stored products such as groundnut by the use of plant materials is a common practice among farmers in West Africa (Lale and Vidal 2001; Maina and Lale, 2004).

Many plants like *A. squamosa, L. camara, C. inermis, C.fistula, A. indica and C. procera* have been proved to be lethal for various stored grain pests and delayed the developmental stages by interfering with their apolytic and molting processes (Tewari & Singh, 1978; Dwivedi & Garg, 2003; Dwivedi & Karsawara, 2003; Deka & Singh, 2005). Leaves of *O. sanctum* (L.), *Vitex negundo* (L.), *Aegle marmelos* (L.) and *Lippia geminata* (L.) have been used for the protection of stored rice forms in rural India (Prakash & Rao, 2006).

Sudan is a large country covering all geographical zones from desert to ever -green forests, and for that it is one of the richest countries in natural flora. Plants of this country, both cultivated and wild are undoubtfully an unlimited reservoir for medicinal, pharmaceutical, agricultural and aromatic chemicals. In Sudan, a number of studies have been made for the control of stored grain pests through application of plant extracts (e.g., Ali, 1988; Ahmed, 1993; Fageer, 1999; Ibrahim, 2003; and Eldoush, 2009).

The tropical flora is a major source of plant-based insecticides (Aranason *et al*., 1989). Aromatic species, particularly those in the family Labiatae (or Lamiaceae) are among the most widely used plants in insect pest control (Morton, 1981; lambert *et al*., 1985; Lawrence, 1988; Shaaya *et al.,* 1997). Among the most common species of Ocimum (labiatae) in West Africa are *O. basilicum* .L. (sweet basil) and *O. canum* Sims (white basil) (Berhaut, 1975). Because of its popularity, it is often referred to as the "queen of the herbs" (Bhatnagar *et al.,* 1993). The leaves oil is reported to possess anti-bacterial properties and acts as an insecticide. It inhibits the in vitro growth of *Mycobacterium tuberculosis* and *Micrococcus pyogenes* var. *aureus*. It has

marked repellent action and insecticidal activity against mosquitoes (Nadkarni, 1976).

Banarjee and Nigam (1985) observed repellent effect in leaves of basil (*O.basilicum*) against stored grain pests. Jembere *et. al.*, (1995) tested the bioactivity of materials extracted from the leaves of *O. kilimandscharicum* Guerke against *S. zeamais, R. dominica* and *S. cerealella* in maize and sorghum grains in the laboratory. Exposing adults of each pest species to dried ground leaves and an essential oil extract of *O. kilimandscharicum* induced 100 % mortality after 48 hours. Fresh and dried whole leaves were not toxic to *S. zeamais* or *R.dominica.* Grains treated with dried ground leaves and an essential oil extract caused significant reductions in the number of progeny and survival rate of all three pest species tested. There was no adult survival or progeny production in grains treated separately with each of the two materials at concentrations of 25.0 g (dried ground leaves) and 0.3 g (essential oil) per 250 g of grain, respectively. Unlike *R. dominica* and *S. cerealella*, grains treated with fresh leaves enhanced the feeding activity of *S. zeamais*. Ground leaves and the essential oil, however, protected the grains against feeding by all three species, resulting in lower weight loss and number of damaged seeds compared with untreated grains. All the plant materials were repellent to *S. zeamais* with the essential oil extract applied at 0.3 g per 250 g of grain evoking the highest repellent action. There was, however, considerable variation in the repellency of the materials against *R. dominica* and *S. cerealella*.

Yogita *et. al*., (2001) evaluated the leaf extracts of some plants i.e. *O. basilicum* L.; Amaltas*, Cassia fistula* L.; Datura, *Datura metel* L. as grain protectants of sorghum seeds against *T. castaneum*. In all extracts, survival rate ranged from 23.33 to 48.33 percent. All the plant extracts at 1.0, 2.5, and 5.0 ml per 100 g seed treatment prolonged the developmental period of *T. castaneum* from 5 to 15 days. The weight loss in the seed treatment with the extracts at 1.0 ml per 100g seed ranged from 4.67 to 12.79 percent; at 2.5 ml per 100 g seed it ranged

from 2.65 to 8.25.0 percent; and at 5.0 ml per 100 g seed it ranged from 2.67 to 4.13 percent.

Swain and Baral (2004) evaluated the effect of different plant materials on rice weevil (*S. oryzae*) and pulse beetle (*Callosobruchus chinensis* L.). The plants used were akanda *[C. procera (*Ait.)], acacia (*Acacia* sp.), begunia (*Vitex negundo* L.), eucalyptus *(E. globulus*), karanja (*P. glabra* [*P. pinnata*]) and neem (*A. indica*). Leaves of all the plants were used in the form of dusts. In *C. chinensis* the begunia dusts showed good efficacy in controlling the insects than the other treatments. The rate of development of both insects was also affected by the different plant materials. The materials also caused significant reduction in progeny produced by the insects. Bekele *et al.*, (1996) evaluated the bioactivity of materials from the leaves and succulent stems of *O. suave* (Willd) against *S. zeamais*, *R. dominica* and *S. cerealella* in maize and sorghum. *O. suave* applied as dry or ground leaves was not toxic to *S. zeamais* but as essential oil extract was highly toxic to the weevil. Higher dosages of ground leaves and essential oil extract caused 100% mortality in *R. dominica*. *S. cerealella* was most susceptible to *O. suave,* since all the plant materials bioassayed caused high mortality. The materials also caused significant reduction in progeny produced by the insects. All the plant materials were highly repellent to *S. zeamais*, with ground leaves having the highest repellent action. There was, however, considerable variation in the repellency of the materials to *R. dominica* and *S. cerealella*. Ground leaves and essential oil extract provided the greatest protection of maize and sorghum against attack by the insects. The potential practical use of *O. suave* as grain protectants in farm-stored grains in rural communities in Africa was highlighted.

Lohra and Singhavi (1998) reported the repellency power of tulsi (*O. tenuiflorum* L) at the rate of 1.0, 2.5 and 5.0 ml per 100 g sorghum seeds against *T. confusum*. (Khajuria and Malik, 2003) evaluated dried leaves of neem, eucalyptus, tulsi [*O. tenuiflorum* L.], melia, Mint and Chrysanthemum, applied

at 1.0 and 2.0 g per 25 g of sterilized rice, against the rice weevil, *S. oryzae*, which is the main pest of rice under storage. Observations recorded at 24 hour intervals revealed that, all treatments were significantly superior to the untreated control. Mint was the most effective among the botanicals, as it recorded 100% mortality at both concentrations after one day, followed by neem, melia, tulsi, eucalyptus and chrysanthemum.

Singh and Punam Kumari (2005) conducted an experiment to assess the insecticidal property of tulsi (*O. sanctum* L. [*O. tenuiflorum*]). Tulsi leaf powder increased the mortality rate of *T. granarium*, with increasing doses and duration of exposure. However, absolute mortality was not observed. Tulsi did not affect the viability of grains.

Manzoor *et al*., (2011) results revealed that after eleven days of feeding, all extracts of *O. sanctum*, showed moderate toxic effect, however the maximum termite mortality (84.45 ± 27.21) was observed in the ethylacetate leaves extract and minimum mortality (43.89 ± 39.97) was observed in stem extract of water. In each extract, mortality was significantly different from control. Also the leaves extract caused more mortality, suggesting the availability of high contents of toxic materials in leaves. All extracts treated filter paper had a significantly repellent effect on *H. indicola*. It was also revealed that maximum repellency (29.1) was in methanol root extracts while water extracts showed minimum repellency (21.3).

Maria. *Et. al.,* (2008) reported that essential oils, distilled from seeds of *Coriander sativum* and *Carum carvii* and from leaves of five different varieties of *O. basilicum*, were fractionate by column chromatography and tested in the laboratory for volatile toxicity against three stored rice pests (*S. oryzae*, *R. dominica* and *Cryptolestes pusillus*). The active fractions were analyzed by GC-MS. Coriander contained linalool (1617 ppm of the oil) as the main product active against the three pests. Camphor-rich fractions (over 400 ppm) were very toxic to *R. dominica* and *C. pusillus*. The caraway profile included carvone and

limonene as expected but (E)-anethole, generally regarded as a minor product in the essential oil of this species, was also a major component, being present at 365 ppm. Carvone was the most effective (972 ppm) monoterpenoid against *S. oryzae*. In addition, (E)-anethole at 880 ppm was toxic to *R. dominica* while vapors of limonene (1416 ppm) and fenchone-rich (554 ppm) fractions killed adults of *C. pusillus* only.

Obeng-Ofori *et al.*, (2000) when testing species of Ocimum in the control of *S. zeamais* found that each substance, either topically applied or impregnated in the maize grains, was highly poisonous for the weevil. Jembere *et al*., (1995) proved the bioactivity of both, the extract and the essential oil of *O. kilimandscharicum* on *S. zeamais*, *S. cerealella* and *R. dominica*. Weaver *et. al*., (1991) evaluated the effectiveness of linalool, a component of *O. canum*, on stored products pests. Prates *et. al*., (2000) concluded that the ingestion test and the contact with the grain, impregnated with the substance, have proved to be more efficient than the contact test made with the filter paper.

Baptista *et al.,* (2002), when evaluating the insecticide activity of medicinal plants essential oil against pests, such as the fall armyworm (*Spodoptera frugiperda*), verified that the essential oils of *O. gratissimum* (basil), *O. basilicum* (sweet basil) and Rutagraveolens (rue) were poisonous for caterpillar, and the calculated LD50 were: *O.gratissimum* (0,518 μL/insect), *O.basilicum* (0,33 μL/insect) and *R.graveolens* (0,220 μL/insect).

For *Capsicum spp* a lot of work has been done to investigate the efficacy of powder of *C. frutescens* on the survival of insect pest including *S. zeamais* and *C. maculatus*. Adedire and Ajayi, (1996) recorded 100% mortality of *S. zeamais* treated with *C. frutescens* in 28 days after treatment on maize grains. Asawalam *et. al*., (2007) reported *C. frutescens* to have shown 75% mortality of *S .zeamais* 33 days after treatment. The results indicated that *C. frutescens* effectively protected maize grains against weevil attack. It exhibited fumigant mode of action since it has a characteristic pungent smell and pepperish in nature *C.*

frutescens and *N. tabacum* were also reported to affect adult emergence of *S. zeamais* on maize grains revealing 10.0% and 12.0% emergence respectively.

The efficacy of chilli pepper (*C. frutescens* L.) in the control of *C. maculates* appeared to be Conflicting. While (Ajayi *et al*., 1987) reported that ground chilli pepper at 10 g/kg cowpea afforded no significant effect on *C. maculates*. Ivbijaro and Agbaje (1986); and Ofuya (1986), contended that it caused moderate adult mortality and therefore afforded some degree of protection against post harvest losses caused by this pest.

Oni, (2011) reported that *C. annum* and *C. frutescens* fruit and seed powders were evaluated in the laboratory for the control of *C. maculates* (F.) in stored cowpea and *S. zeamais*, in stored maize. *C. frutescens* seed powder and *C. annum* seed powder dust were toxic to *C. maculates* and *S .zeamais* at the rate of 5.0g, 7.5g and 5.0g, per 50g cowpea and 50g maize within 48 hrs and 96 hrs respectively.

AL-Moajel (2004) demonstrated that powders prepared from parts of 11 different plant species were tested for effectiveness on *T. granarium* adults and larvae reared on wheat grains under laboratory conditions. *C. frutescens* caused highest (77-85%) and significant (F=54.40) mortality of *T. granarium* adults at all concentrations within 7 days, followed by *L. inermis* at all concentration (73-78%), (F=42.65). A significant mortality of *T. granarium* larvae was observed at all concentration (2,4 and 6%) for *L. inermis* and at 6% of *C. frutescense* thus *C. frutescense* and *L. inermis* had significant effect on mortality of adults and larvae and signicantly reduced F1 progency.

Adenike and Olubunmi (2011) reported that, in the laboratory, the aqueous extracts of *Lawsonia inermis* caused a significant reduction ($P< 0.05$) in nematode egg hatched. Egg hatch was 92.0% in the untreated control (0% extract) as compared to 11.7% in 25% crude extract of *L. inermis* (L) extract. Within two days of the experiment 98.4% mortality was observed in 100% crude concentration of *L. inermis* (L), as compared with 0% mortality in the

control. All concentrations of the extract caused significantly higher mortality than the control. In the screenhouse, 15% aqueous crude concentration significantly reduced nematode population in the root and in the soil. All treated plants were also less galled compared to the untreated control.

Mordue (2004) Stated that, a number of plant species like *A. indica A. Juss*, *Melia azedarach* L*., Lantana camara* L*., Cannabis sativa* L*., Nerium indicum Mill., Eucalyptus* sp., *Ricinus communis* L. as well as *Solanum nigrum* L. are known to possess insecticidal properties, although only a few of these have been exploited commercially. The compounds from these plants have a number of useful activities like toxicity, repellence, feeding and oviposition deterrence and insect growth regulate activity.

Maribet (2008), demonstrated that, a study was conducted to evaluate the insecticidal action of five locally available plants namely*: A. indica* (Neem), *Cymbopogon citratus* (Lemon Grass), *L. camara* (Lantana), *O. basilicum* (Basil) and *Tagetes erecta* (African marigold) against maize weevil, *S. zeamais* Motsch. Following the repellency, adult mortality and antioviposition and growth inhibition tests. Results revealed that all test materials exhibited repellency action against maize weevil. Powdered leaves of neem and lantana were noted to be highly repellant while powdered leaves of lemon grass, basil and African marigold were observed to be moderately repellant against maize weevil within 96 hours of exposure. Corn grains treated with powdered leaves of lemon grass and basil exhibited a low mortality of 5.33% and 0.66%, respectively, at 24 DAII. Other test plants revealed zero adult mortality. None among the test plants manifested antiovipositional and growth inhibitory action against maize weevil. All examined corn grains except for carbaryl - treated corn grains showed larval tunnel. The total development period of the maize weevils emerged from both treated and untreated corn grains was the same (39 days) and 100% insect survival was noted indicating zero percent of insects that reached larval or pupal stages only. The adult body weight was comparable among treatments.

Khalif and Al-Farhani (2008) studied the effects of leave's powders of *Nicotiana tabacum, Nerium oleander, Ziziphus spinachristi, Vitex agnus–castus, Lantana camara, Myrtus communis, Clerodendron inerum* and *Eucalyptus globules* on the mortality reduction in F1 progeny and repellents. The results on the red flour beetle showed that the leaves powders of *N. tabacum, C.inerum* and *Z. Christi* had the best effect on the mortality of adults after seven days (100%).

Ayoub and Kingston (1981); Ayoub and Svendse, (1981) stated that, *C. procera* with common name Usher, this plant has been widely used in Sudanese medicinal system. The bioactivity of the *C. procera* tested as insecticidal (Jacob and Sheila,1993;Khan and siddiqui,1994; Moursy,1997). Wat *et. al.,* (1962) reported that, plants of Usher contain insecticidal ingrediants and the leaf is used for destroying fowl lice in Senegal. In the Moshi district of Tanganyika, the plant is placed in the bed by Africans as an insecticide. Ahmed *et. al.,*(2006) stated that, shaker aqueous extract of leaf, flower and roots of *C. procera* proved most effective in the control of *Henosepilachna elaterii* showed strong repellent activity and thus deterred the insects from feeding. Five percent shaker extract of different plant part gave 100% protection of cucurbit leaf and no larva survived after exposure to 5% extract and 2.5% concentration of shaker extracts highly reduced the fecundity and longevity of the insect. The results show the potential of the aqueous shaker extrat in the control of vegetable pests.

In recent past, some indigenous plants have been reported to possess repellent property against khapra beetle. Abrol and Chopra (1963) had evaluated several indigenous plants for repellent action against *T.granarium*. Dwivedi and Bajaj, (2000) assessed Cassia leaf extract for its repellent activity on khapra beetle.

Preissel, *et. al.,* (2002) reported that, all parts of *Datura* plants contain dangerous levels of poison and may be fatal if ingested by humans or other animals, including livestock and pets.

Giannini (1997) stated that, the infective ingrediants are the Tropane alkaloids, atropine hyoscyamine and scopolamine which are classified as

deliriants, or anticholinergics. Due to the elevated risk of overdose in uninformed users, many hospitalizations, and some deaths, are reported from recreational use. Oduor-Owino (1992) reprted that, *D. metel* had significantly greater suppressive effects on gall formation than did *T.minuta* or *D. stramonium*, for control of *Meloidogyne javanica*. Tomato plants grown with the three nematicidal plants had significantly greater shoot growth and fruit yield than control plants. Later Dwivedi and Sharma (2002) investigated repellency of 5 plant extracts include Datura against khapra beetle.

Mahfuz (2007) demonstrated that,the efficacy of seven different plants extracts viz. Acorus *Calamus rhizome*, leaves of *D. fastuosa*, *D. stramonium* and seeds of *D. stramonium*, *Corchorus capsularis*, *Aphanamixis polystachea* and *Jatropha curcas* on *Tribolium confusum* adult was studied. Dose mortality experiments were conducted with three solvent (petroleum ether, acetone and methanol) extracts separately but *J. curcas* seed was tested with petroleum ether extract only. Among three solvents, petroleum ether extract exhibited piquant toxic effect against the beetle at all the intervals although *D. fastuosa* leaf produces no mortality at 24 hours of treatment. Acetone extract of *A. calamus* rhizome, *D. fastuosa* leaf*, D. stramonium* seed and *C. capsularis* seed produced mortality at all the intervals but *D. stramonium* leaf and *A. polystachea* seed did not show any toxic effect. Methanol extract of *C. capsularis* seed showed toxicity at all the duration.

Karzan *et. al.,* (2011) tested the effects of ethanol extracts of *Datura stramonium*, *Solanum nigrum*, *Quercus infectoria, Xanthium strumarium* and cypermethrin on the mortality, egg hatching, reduction in F1 progeny and repellents on the red flour beetle. The results showed that cypermethrin had the best effect on the mortality of adults (100%) on all concentrations, whereas the fruits of *D. stramonium* and *X. strumarium* had a mortality rate of 100% in 2% and 4% concentrations. Egg hatching was also delayed, and began after four days of treatment, in *Q. infectoria* and *X. strumarium*. Ethanol plant extracts of

D. stramonium caused 100% mortality of larvae at a concentration of 1% after eight days of treatment, followed by the alcohol extract of *S. nigrum* with 97.43% mortality in 1% concentration. Mix of ethanol plant extract with food reduced F1 progeny. Cypermethrin and *D. stramonium* were given the best effect that reaches 17.06% and 18.11% respectively. Repellents percentage showed that ethanol extracts of *D. stramonium* and *S. nigrum* showed repellents of 91.87% and 91.45% in 4% concentration after 24 hours of treatment.

Deshmukh and Borle (1975) also reported the toxic effect of petroleum ether extract of *D. alba (D. fastuosa*) seed on *Dactynotus carthami*. Khalequzzaman and Islam (1992) reported that, methanolic extract of *D. metel (D. alba, D. fastuosa*) leaf was more toxic than other extracts on *T. castaneum*.

The seed of *Jatropha curcas* are in general toxic to Humans and animal curcin, a toxic protein isolated from the seeds, was found to inhibit protein synthesis in invitro studies. The high concentration of phorbol esters present in Jatropha seed has been identified as the main toxic agent responsible for Jatropha toxicity (Adolf *et.al.,* 1984; Makkae *et al*., 1997).

All parts of Jatropha (seeds, leaves &bark) have been used in traditional medicine and for veterinary purposes for a long time (Dalziel,1955; Duke, 1988). The oil and aqueous extract from oil has potential as an insecticide. For instance it has been used in the control of pulse, potato & corn (Kaushik and Kumar, 2004). Methanol extracts of Jatropha seed (which contains biodegradable toxins) are being tested in Germany for control of bilharzia – carrying water snails.

Although several workers have demonstrated the possible application of powder or extracts from plant materials to *T.granarium*, limited information is available on the use of mixture of plant powders against insect pests. Many scientists have been conducting researches over the last three decades aimed at identifying botanicals that would replace synthetic organic chemicals but the

efficacies of the plant mixtures have been less investigated (Emeasor *et. al.,*2007).

Kitch *et. al.,*(1997) reported that, using herbal mixtures for crop protection is traditional with some farmers. Efficacy of mixed formulations of medicinal plant powders for stored grain protection has been subjected to empirical verification (Ogunwolu and Idowu,1994; Dawodu and ouya, 2000; Emeasor *et al.,*2007). Synergistic or additive effects would be desirable to enhance efficacy. Lale (2002) reported that mixing different essential oils from plants in some cases provided much better control than single use. Babarinde *et. al.,* (2011) investigated bioactivity of *Piper guineense* seeds and *Moringa oleifera* leaf powders applied singly or in a mixture against larvae and adult *T. granarium*. Adults were more susceptible to plant powders than larvae, and adult mortality recorded in *P. guineense* at 1.0 g, 0.5 g and *M. oleifera* at 1.0 g/20 g seeds were not significantly different from the mortality observed with the recommended dose of Pirimiphos methyl at five days after treatment (DAT). Larval mortality observed in a mixture of both plants (1:1; w/w) caused significantly higher mortality (77.5%) than other treatments at 5 DAT. All treatments (*P. guineense* and *M. oleifera* applied singly or in a mixture) were repellant to larvae *T. granarium* with 60% repellency recorded in the mixture of plants, 50% repellency in *P. guineense* and 30% repellency in *M. oleifera* slurry.

CHAPTER THREE
MATERIALS AND METHODS

MATERIALS AND METHODS

A laboratory experiment was carried out during 2011-2013, at Shambat, Department of Crop Protection, Faculty of Agricultural Studies - Shambat, Sudan University for Science and Technology, to evaluate the efficacy of different plant products against Khapra beetle (*T. granarium*).

3.1.1 Collection and mass rearing of insects

Mixed age cultures of *T. granarium* were collected from ARC (Agricultural Research Center) Khartoum- Sudan for rearing in the laboratory. Cultures were reared on healthy sorghum grains, variety faterita, free from insect infestation, purchased from local market (Plate1). The cultures of *T. granarium* were allowed to multiply in cylindrical glass jars, each covered with muslin cloth and fixed with a rubber band and kept in a room of low light intensity at room temperature (Plate2). The cultures were cleaned periodically. Adults of khapra beetle were allowed to lay their eggs; the third larval instars were collected from the cultures for the bioassay. (Plate 3).

3.1.2 Preparation of the plant materials

Sample plants: eight (8) botanical species were collected from different areas of Khartoum State to be used in the study. The different plants were labeled with their local and scientific names as follows:

Basil *Ocimum basilicum* L., (Plate 4).

Henna *Lawsonia inermis* L. (Plate 5).

Senna *Cassia senna* Mill., (Plate 6).

Lantana *Lantana camara* L., (Plate 7).

Datura *Datura alba* Nees, (Plate 8).

Usher *Calotropis procera* Ait. (Plate 9).

Chili *Capsicum frutescens* L. (Plate 10).

Jatropha *Jatropha curcas* L. (Plate 11).

3.1.3 Preparation of plant powders

Fresh leaves of the first six plants and ripe fruits of chili and Jatropha were collected from their plants, washed with tap water and allowed to dry under shade at room temperature conditions. Dried Leaves and fruits were grounded by an electric blender (Moulinex.Tybe:LM242). The obtained powders were passed through a sieve (25 mesh) and stored in darkness at room temperature in tightly closed glass jars until needed. (Plate 12).

3.1.4 Preparation of plant aqueous extracts

The aqueous solutions of Usher, Datura leaves and Jatropha fruits, were prepared by adding 10,15 and 20 gms of the powder to 90,85 and 80 ml of distilled water respectively, in conical flasks. The mixtures were thoroughly shaken by hand for ten minutes and kept in the laboratory for 24 hrs at room temperature, then the mixtures were filtered using filter papers .The solutions were kept in cleaned flascks and used for the repplancy experiments. (Plate 13).

3.1.5 Preparation of plant mixture powders

Powders of the two most effective plants, Usher leaves and Jatropha fruits were mixed (as powder) in the ratios of (Usher: Jatropha, 100:0, 80:20, 60:40, 40:60, 20:80, 0:100 and 0:0). The obtained powder was stored in darkness at room temperature in tightly closed jars until needed. (Plate 14).

3.2 Experiments

3.2.1 Experiment I: Effect of plant powders

A - Mortality effect: The method of (Saramma and Verna, 1971) was followed with minor modifications. Plant extracts were tested for their insecticidal activity. Fruits and leaves powders of each plant were mixed at different dose rates(10%,15% and 20%) with uniform and cleaned local sorghum variety (faterita) seeds (10 g) in each Petri-dish . The control Petri-dish contained untreated seeds. Groups of 10 larvae of *T. granarium* (3^{rd} instar) were inoculated into each Petri-dish. The experimental set-up was replicated four times. The

number of dead insects in each Petri dish was recorded after 1, 10, 20 and 30 days. (Plate15)

B - Antifeedant effect: To investigate the antifeedant effect of plant powders.10 larvae (3^{rd} instar) were placed in a Petri-dish containing known weight (10 g) of faterita seeds treated with the different dose rates (10%, 15% and 20%). Each treatment was replicated four times. Seeds were weighted again, at 10 days intervals from treatment, to compare the loss in seeds weights among different treatments. Food consumed was calculated and compared to the control, and the percentage of food consumed was recorded. (Plate15).

Percentage of antifeedant activity was computed by using the formula given by Luco *et al*,.(1994):

The percentage feeding index (PFI):

$$PFI = \frac{\text{Area fed in treated}}{(\text{Area fed in treated} + \text{Area fed in solvent control})} \times 100$$

3.2.2 Experiment II: Repellency test

Repellency test was conducted following the method of Talukdar and Howse (1993); and Amin *et al*,. (2000). The dried extracts were dissolved in distilled water to make solutions of different concentrations. For the experiment, three concentrations of three more promising plants: Datura, Usher and Jatropha, were prepared. Nine centimeter diameter filter papers (Whatman No. 40) were marked into two portions. One-milliliter solution of each extract was applied to one half of the filter paper (treated half) and on the other half one milliliter of distilled water was applied (controlled half). The treated filter papers then air-dried and placed in a Petri-dish. Twenty (20) insects were placed there, 10 on the control half and 10 on the treated half. Three replications were used in this experiment. Number of insects on each side was counted at 30 min intervals up

to the second hour after treatment. Percent repellency was calculated by using the following formula from Abbott (1925):

$$\text{Percent Repellency} = \frac{A - B}{A} \times 100$$

Here,

A = Average number of insects present on untreated portion.

B = Average Number of insects present on treated portion.

The percentages of repellency then categorized according to the following scale by the methods of Amin *et al.* (2000) and Roy *et al*. (2005).

Class	Repellency Rate (%)
0	>0.01- 0.10
I	0.10 to 20.00
II	20.10 to 40.00
III	40.10 to 60.00
IV	60.10 to 80.00
V	80.10 to 100.00

3.2.3 Experiment III: Weevil bioassay with plant materials

In this experiment, the method described by Fatope, *et al.,* (1995) was followed with some modifications. Four glass containers were filled with 50 g each of unperforated seeds. Portions (5 g, 10g and 15g) of dry pulverized plant materials corresponding to 10%, 20%, and 30% (w/w) respectively, were added to three of the glass containers. The untreated seeds in the fourth container served as control. Each glass container was infested by adding (30 larvae) of *T. granarium* (3^{rd} instar) .The glass containers were then closed with muslin cloth and left at room temperature.Tests at each dosage and the control were repeated 4 times for the three most promising plants, Usher, Datura and Jatropha. After 4 months, the seeds in each glass container were examined for perforations.

(Plate16). The number of seeds perforated in the treated and control containers was counted for the determination of the (weevil perforation index) (WPI) and calculated for each dosage for comparison of the grain protectant effects of the plant materials.

$$WPI = \frac{\%\text{ of treated seeds perforated}}{\%\text{ of control seeds perforated} + \%\text{ of treated seeds perforated}} \times 100$$

A WPI value > 50 indicates negative grain protectant effect or enhancement of infestation by the weevil.

3.2.4 Experiment IV: Effect of plant mixture powders

The most promising two plants (Usher & Jatropha) were used in this experiment. These plants were mixed as powder in the ratios of (Usher: Jatropha, 100:0, 80:20, 60:40, 40:60, 20:80, 0:100 and 0:0) The untreated combination (0:0) served as the control for the experiment. The combinations were admixed with 10 g of experimental sorghum seeds variety (faterita) at 10%, 15% and 20%, dose rates in Petri-dishes. 10 larvae (3^{rd} instar) of *T. granarium* were added to each Petri-dish. Each combination was replicated three times. Mortallity rate was collected at (1, 10, 20 and 30 days). (Plate17).

The experiment was assigned in a completely Randomized Design (CRD). The data were subjected to analysis of variance (ANOVA). The treatment means were separated using the Least Significant Difference (LSD) at 5% level of probability.

3.3 Statistical analysis

The experiments were assigned in a completely Randomized Design (CRD). The data were subjected to analysis of variance (ANOVA). The treatment means were separated using the Least Significant Difference (LSD) at 5% level of probability.

Plate 1 : Cleaned Sorghum seeds, variety faterita

Plate 2: Mass rearing of insects

Plate 3: 3rd instar larvae of *T. granarium*

Plate 4: Basil *Ocimum basilicum* L.

Plate 5: Henna *Lawsonia inermis* L.

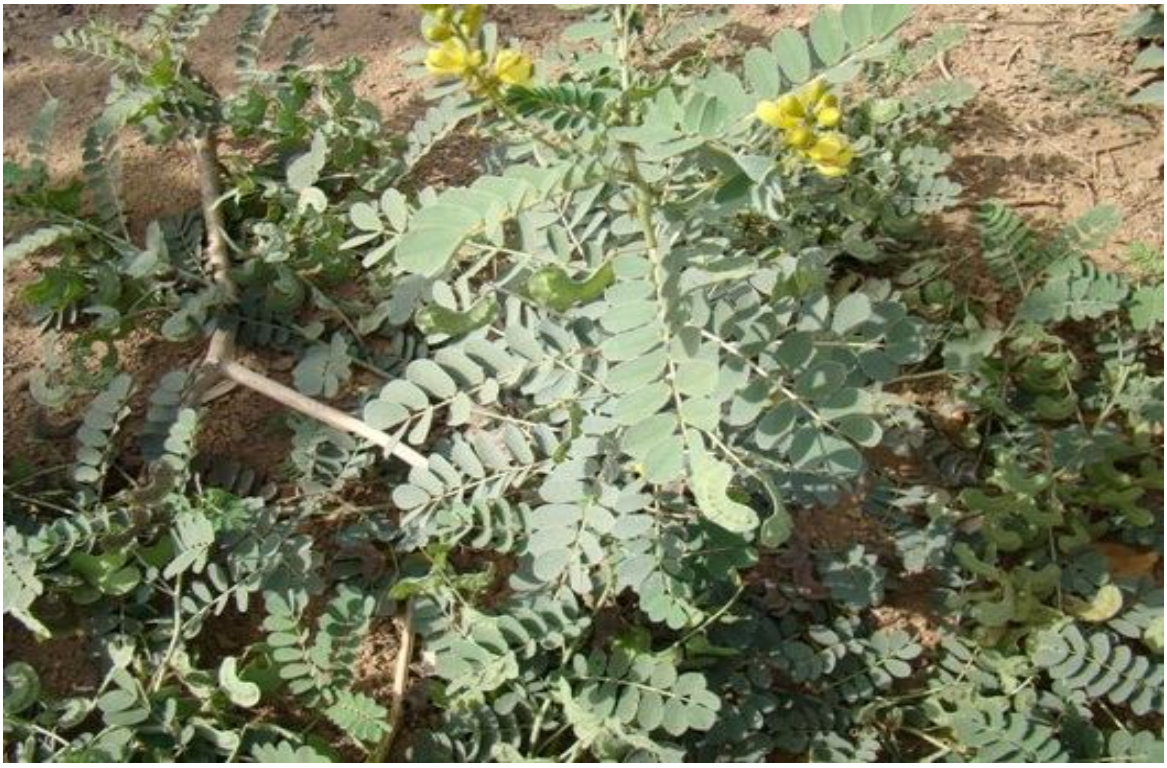


Plate 6: Senna *Cassia senna* Mill.

Plate 7: Lantana *Lantana camara* L.

Plate 8: Datura *Datura alba* Nees.

Plate 9: Usher *Calotropis procera* Ait.

Plate 10: Chili *Capsicum frutescens* L.

Plate 11: Jatropha *Jatropha curcas* L.

Plate 12: plants powder extracts

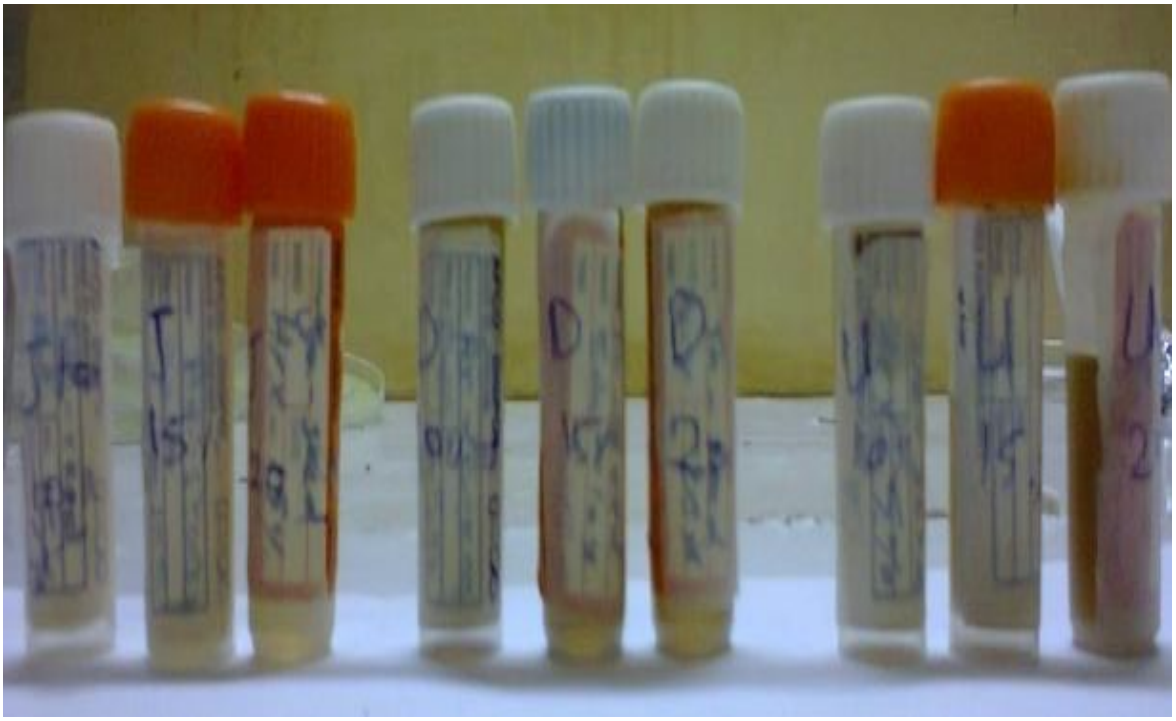


Plate 13: plants aqueous extrats

Plate 14: plants mixture powder extracts

Plate 15: Mortality treatments

Plate 16: WPI treatments

Plate 17: plant mixture treatments

CHAPTER FOUR

RESULTS

RESULTS

4.2 The Effect of Natural products on Khapra beetle infestation

4.2.1 The effect of Basil leaves powder extract (BLPE) on infestation of Khapra beetle larvae on Sorghum seeds.

The three tested concentrations (10%, 15% and 20%) of BLPE resulted in fewer numbers of larvae. The highest numbers of died larvae (2.57, 3.52, 3.85 and 3.77) were recorded from larvae treated with 20% of BLPE in 1st, 10th, 20th and 30th day respectively, while the lowest number of larvae were recorded from control (0.70, 1.32, 1.95 and 1.95) for the same intervals respectively. Also, mean number of died larvae increased with the increase of concentration and time. The highest number of died larvae was recorded from larvae treated with 20% of BLPE (3.85) in 20th day compared to the larvae treated with 10% (0.70) in 1st day. Generally there were significant differences found between the concentrations and control Table (1).

4.1.2 The effect of Henna leaves powder extract (HLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Generally there was no significant difference in the mortality number of larvae between concentrations, but in the 30th day there was significant difference between concentrations. There were significant differences found between the concentrations compared to control.

Larvae mortality increased with the increasing of concentration, and also with the increase of the period. The highest number of died larvae was recorded from larvae treated with 20% of HLPE (5.00) in 30th day compared to the larvae treated with 10% (1.32) in 1st day Table (2).

Table 1: The effect of Basil leaves powder extract (BLPE) on infestation of Khapra beetle larvae on Sorghum seeds.

Concentrations	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0 (0.70) b	0.75(2.57) ab	0.75(2.57) ab	1.0(3.20) ab
15 %	0.5(1.95)ab	1.0 (2.90)ab	1.25(3.52) ab	1.5(3.77) a
20 %	0.75(2.57)a	1.25(3.52)a	1.5(3.85) a	1.5(3.77)a
Control	0 (0.70)b	0.25(1.32) b	0.5(1.95) b	0.5(1.95)b
SE ±	0.9	1.2	1.0	1.0
CV%	64.45	47.74	36.17	34.24

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

Table 2: The effect of Henna leaves powder extract (HLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.3(1.32) a	0.75(2.57) a	1.0(2.90) ab	1.25(3.52) b
15 %	0.5(1.95) a	1.0(3.20) a	1.0(2.90) ab	2.5(5.00) a
20 %	0.5(1.95) a	1.25(3.52) a	2.0(4.32) a	2.5(5.00) a
Control	0 (0.70) a	0.3(0.70) b	0.5(1.95) b	0.5(1.95) c
SE ±	1.1	0.7	1.5	0.8
CV %	80.79	28.17	50.85	23.01

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

4.1.3 The effect of Senna leaves powder extract (SLPE) on infestation of Khapra beetle larvae on Sorghum seeds

The number of died larvae increased with the increase of the concentration. Mortality also was increased with increase of time. Although there were numbers of dead insects obtained in all concentrations but there was no significant difference in the mortality number of the pest between concentrations. Mortality caused by all concentration was significantly different from the control. The highest numbers of died larvae were (2.57, 3.52, 4.67 and 4.92) recorded from larvae treated with 20% of SLPE in 1st, 10th, 20th and 30th day respectively, while the lowest number of larvae were recorded from control (0.70, 1.32, 1.95 and 1.95) for the same intervals respectively Table (3).

4.1.4 The effect of Lantanna leaves powder extract (LLPE) on infestation of Khapra beetle larvae on Sorghum seeds

There was number of insects died but generally there was no significant difference in the larvae mortality numbers between concentrations. There was no significant difference in concentrations compared to control in the 1st and 30th day. Mortality was increased with the increasing of the concentration also mortality increased with the increasing of time. The highest number of died larvae was recorded from larvae treated with 20% of LLPE (4.17) in 20th day compared to the larvae treated with 10% (1.32) in 1st day Table (4).

Table 3: The effect of Senna leaves powder extract (SLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.0(1.32) ab	0.75(2.57)ab	1.5(3.47) ab	1.5(3.47) ab
15 %	0.5(1.95)ab	1.0(2.90) ab	2.0(4.35) a	2.25(4.75) a
20 %	0.75(2.57) a	1.25(3.52)a	2.25(4.67) a	2.5(4.92) a
Control	0.0(0.70) b	0.25(1.32) b	0.5(1.95) b	0.5(1.95)b
SE ±	1.1	1.2	1.5	1.4
CV %	69.68	47.74	42.31	37.38

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

Table 4: The effect of Lantanna leaves powder extract (LLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.25(1.32) a	0.5(1.95) ab	1.25(3.52) ab	1.25(3.22) a
15 %	0.25(1.32) a	1.5(3.47)ab	1.25(3.22)ab	1.5(3.47) a
20 %	0.5(1.95) a	1.75(4.10)a	1.75(4.17) a	2.0(3.85) a
Control	0 (0.70) a	0.25(1.32) b	0.5(1.95) b	0.5(1.95) a
SE ±	1.1	1.5	1.2	1.5
CV%	86.11	55.91	38.48	51.01

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

4.1.5 The effect of Datura leaves powder extract (DLPE) on infestation of Khapra beetle larvae on Sorghum seeds

High numbers of dead insects were obtained with all concentrations but there was no significant difference in the mortality number of the pest between concentrations as genral. However between concentrations and control there was significant differences. Insect mortality was increased with the increasing of the concentrations. Also mortality increased with the increasing of time. The highest number of died larvae was recorded from larvae treated with 20% of DLPE (4.50) in 30th day compared to the larvae treated with 10% (2.57) in 1st day Table (5).

4.1.6 The effect of Usher leaves powder extract (ULPE) on infestation of Khapra beetle larvae on Sorghum seeds

The three tested concentrations (10%, 15% and 20%) of ULPE resulted in decrease numbers of larvae. Generally mortality caused by all concentrations was significantly different from the control. Although there were high numbers of dead insects obtained in all concentrations but as genral there was no significant difference in the mortality number of the pest between concentrations. The highest numbers of died larvae were (3.47, 4.10, 4.42 and 5.87) recorded from larvae treated with 20% of ULPE in 1st, 10th, 20th and 30th day respectively, while the lowest number of larvae were recorded from control (0.70, 1.32, 1.95 and 1.95) for the same intervals respectively. The number of died larvae increased with the increase of the concentration. Mortality also was increased with the increase of time Table (6).

Table 5: The effect of Datura leaves powder extract (DLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.75(2.57) a	1.0(2.90) ab	1.0(2.90) ab	1.0(2.60) ab
15 %	1.0(2.90) a	1.25(4.17)a	1.5(4.35) a	1.75(4.17) a
20 %	1.25(3.52) a	1.75(4.00) a	1.75(4.10) a	2.0(4.50) a
Control	0 (0.70) b	0.25(1.32) b	0.5(1.95) b	0.5(1.95) b
SE ±	1.0	1.3	1.3	1.4
CV%	43.79	42.89	41.51	42.73

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

Table 6: **The effect of Usher leaves powder extract (ULPE) on infestation of Khapra beetle larvae on Sorghum seeds**

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.75(2.57)ab	1.5(3.47) a	1.75(3.72)ab	1.75(4.10)ab
15 %	1.5(3.47) a	1.5(3.85) a	1.75(4.10)ab	2.0(4.10)ab
20 %	1.5(3.47) a	1.75(4.10)a	2.0(4.42) a	3.5(5.87) a
Control	0 (0.70) b	0.25(1.32) b	0.5(1.95) b	0.5(1.95) b
SE ±	1.5	1.3	1.5	1.5
CV%	62.41	43.47	43.32	39.21

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

4.1.7 The effect of Chili leaves powder extract (CLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Insect mortality was increased with the increasing of the concentration, high number of insect died was obtained in the highest concentrations. Mortality also increased with the increasing of time. As general there was significant difference in the mortality number of the pest between concentrations. The highest number of died larvae was recorded from larvae treated with 20% of DLPE (5.07) in 20th day compared to the larvae treated with 10% (1.32) in 1st day. There were no significant differences in concentrations compared to control in the 20th day Table (7).

4.1.8 The effect of Jatropha leaves powder extract (JLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Generally there were no significant differences in the mortality number of larvae between concentrations. A significant difference was found in concentrations compared to control. Insect mortality was increased with increasing of concentration, high number of insect died was obtained in the concentration 20%. Mortality also increased with increasing of time. The highest numbers of died larvae were (2.90, 4.10, 4.67 and 5.00) recorded from larvae treated with 20% of JLPE in 1st, 10th, 20th and 30th day respectively, while the lowest number of larvae were recorded from control (0.70, 1.32, 1.95 and 1.95) for the same intervals respectively Table (8).

Table (7): The effect of Chili leaves powder extract (CLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.25(1.32)bc	0.75(2.57)ab	0.75(2.27) a	1.25(3.52)ab
15 %	1.0(2.90)ab	1.25(3.52) a	2.3(3.87) a	2.5(3.52) ab
20 %	1.25(3.52) a	1.5(3.85) a	2.8(5.07) a	2.5(4.90) a
Control	0 (0.70) c	0.25(1.32)b	0.5(1.95) a	0.5(1.95) b
SE ±	1.0	1.0	2.1	1.0
CV%	50.27	35.96	65.94	31.57

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

Table 8: The effect of Jatropha leaves powder extract (JLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Concentrations %	Mean No. of died larvae / 1st day	Mean No. of died larvae / 10th day	Mean No. of died larvae / 20th day	Mean No. of died larvae / 30th day
10 %	0.5(1.95)ab	1.0(2.90) ab	1.0(2.90) ab	1.25(3.52) a
15 %	0.75(2.57)ab	1.5(3.47) ab	2.0(4.42) a	2.0(4.42) a
20 %	1.0(2.90) a	1.75(4.10) a	2.25(4.67) a	2.5(5.00) a
Control	0 (0.70) b	0.25(1.32) b	0.5(1.95) b	0.5(1.95) b
SE ±	1.2	1.5	1.2	0.9
CV%	61.15	52.63	37.07	25.91

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

4.2 Comparative between natural products:

Table (9) showed the toxicity bioassay of botanicals on the larvae of Khapra beetle. The highest numbers of died larvae were scored at 30th day with concentration 20% of Usher (5.87), where the lowest numbers of died larvae were scored at 1st day with concentration 10% of Senna (1.32).

At 1st day the highest mortality was found in the treatment with the consentration 20% Datura followed by the 20% Chili, 20% Usher, 15% Usher and 15% Datura with means (3.52, 3.52, 3.47, 3.47, and 2.90) respectively.

In the 10th day the highest mortality numbers were observed in the treatment with the consentration 15% Datura followed by the 20% Usher, 20% Jatropha, 20%Lantanna and 20% Datura with means (4.17, 4.10, 4.10, 4.10, and 4.00) respectively.

In the 20th day the highest mortality numbers were scored in the treatment with the consentration 20% Chili, 20% Jatropha, 20% Senna, 20% Usher and 15% Jatropha with means (5.07, 4.67, 4.67, 4.42 and 4.42) respectively.

In the 30th day the highest mortality numbers were found in the treatment with 20% Usher , 20% Jatropha, 20% Henna, 15% Henna, and 20% Senna with means (5.87, 5.00, 5.00 and 4.92) respectively.

Table 9: Comparative between natural products

Days / Treatment	1st	10th	20th	30th
20% Usher	3.47 a	4.10 a	4.42 ab	5.87 a
20% Jatropha	2.90ab	4.10 a	4.67 a	5.00 ab
20% Datura	3.52 a	4.00 a	4.10abc	4.50abc
20% Chili	3.52 a	3.85a	5.07 a	4.90abc
20% Henna	1.95abc	3.52ab	4.32abc	5.00 ab
20%Lantanna	1.95abc	4.10 a	4.17 abc	3.85bcd
20% Senna	2.57ab	3.52ab	4.67 a	4.92 abc
15% Usher	3.47 a	3.85a	4.10abc	4.05bcd
15% Jatropha	2.57ab	3.47ab	4.42 a	4.42abc
15% Datura	2.90ab	4.17 a	4.3abc	4.17abcd
15% Henna	1.95abc	3.20ab	2.90bcd	5.00 ab
10% Usher	2.57ab	3.47ab	3.72abcd	4.10abcd
10% Jatropha	1.95abc	3.47abc	2.90bcd	3.52bcde
10% Datura	2.57ab	2.90abc	2.90bcd	2.60de
10% Senna	1.32bc	2.57abc	3.47 abcd	3.47bcde
control	0.70c	1.32cd	1.95d	1.95e
SE ±	1.1	1.2	1.5	1.2
CV%	63.15	45.39	45.37	35.98

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05) according to Duncan's Multiple Range Test (DMRT).
* Figures in parentheses indicates transformed value (√x+0.5).

4.3 Plants extract Antifeedant results

Table (10) presents the effects of plant extracts on grain damage. The anti-feedant has been assessed on the basis of percentage feeding index (PFI) as a parameter of grains weight loss, the values show the effects of different plants material at different concentrations that acted as anti-feedant substances. The results showed that the infestation on the treated seeds was decreased.

A similar trend of plant effects was observed among the plants used. *D. alba* and *J. curcas* gave the lowest value of (0%) grain damaged (high antifeedant activity) at the dose 15% on 10^{th} day, followed by *L. inermis*.L, *C. senna*, *L. camara*, *D. alba*, *C. procera* and *J.curcas*,(0%) grain damage at the dose 20% on the first interval (10^{th} day). While in the third interval (30^{th} day) all plants extracts showed (0%) value of grain damaged at all doses. On the other side *C. frutescens* extracts showed high value of (41.9%, 35.7% and 35.7%) grain damaged(less antifedant activity) at the dose(10%,15% and 20%) respectively, followed by *L. inermis.L, D. alba* and *J. curcas* at value of (35.7%) at the dose(10%), on second interval (20^{th} day).

From the results, it is becoming evident that *D. alba* and *J. curcas* displayed some potential as anti-feedants to *T. granarium* larvae, but larvae still consume small amounts of treated grains.

Table 10: Plants extract antifeedant results

	O.basilicum		*L. inermis.*		*C. senna*		*L. camara*		*D. alba*		*C. procera*		*C.frutescens*	
	W.L mean (mg)	PFI	W.L mean (mg)	PFI	W.L mean (mg)	PFI	W.L mean (mg)	PFI	W.L mean (mg)	PFI	W.L mean (mg)	PFI	W.L mean (mg)	PFI
ntrol	0.15	50	0.15	50	0.15	50	0.15	50	0.15	50	0.15	50	0.15	50
%	0.03	16.7	0.05	25	0.03	16.7	0.03	16.7	0.03	16.7	0.03	16.7	0.08	34.8
%	0.03	16.7	0.03	16.7	0.03	16.7	0.03	16.7	0	0	0.03	16.7	0.05	25
%	0.03	16.7	0	0	0	0	0	0	0	0	0	0	0.05	25
ntrol	0.18	50	0.18	50	0.18	50	0.18	50	0.18	50	0.18	50	0.18	50
%	0.08	30.8	0.1	35.7	0.08	30.8	0.05	21.7	0.1	35.7	0.1	35.7	0.13	41.9
%	0.05	21.7	0.05	21.7	0.08	30.8	0.05	21.7	0.05	21.7	0.08	30.7	0.1	35.7
%	0.05	21.7	0.05	21.7	0.08	30.8	0.05	21.7	0.05	21.7	0.08	30.7	0.1	35.7
ntrol	0.1	50	0.1	50	0.1	50	0.1	50	0.1	50	0.1	50	0.1	50
%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
%	0	0	0	0	0	0	0	0	0	0	0	0	0	0

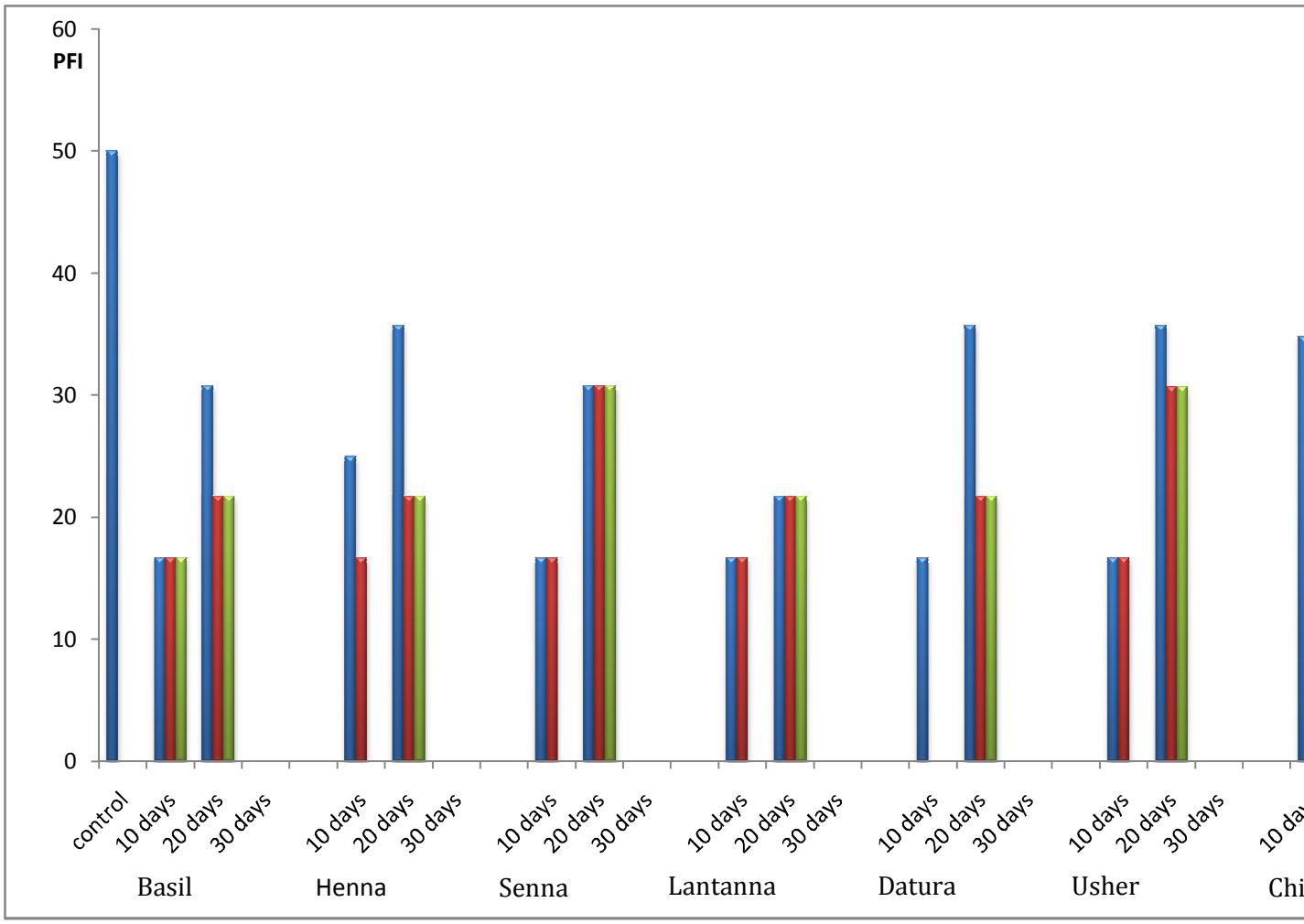


Figure 1: Plants extract antifeedant results

4.4 Plants extract Repellency results

In the current study, the three more effective plants extract were used, these plants showed repellency effects against *T.granarium.*

Leaves extract at 10% in *C.procera* showed the lowest repellency percentage 29.17%. On the other hand the higher repellency effects were obvious at higher concentration 20% in *J.curcus*(77.15%)

The repellent action increased with increase in concentrations of the extracts applied. The biological activity of plant extracts might be revealed that the various compounds present in the extracts have toxic and repellent effect. These compounds might be independently or jointly contribute to cause toxic and repellent actions against *T.granarium.*

The percentage of repellency of *T.granarium* in case of *C.procera* extract at concentrations 10% and 15% were laid in repellent class II, they were consider slightly repellent. While concentration 20% was laid in repellent class III, it was considered moderate repellent (Table11) (figure 2). Also in case of *D.alba* the percentage of repellency was in repellent class III at concentrations 10% and 15%, while it was class IV at concentration 20% which consider high repellent (Table12) (figure 3).

In case of the extracts of *J.curcus* the percentage of repellency was in repellent class II at concentrations 10% which consider slightly repellent, while it was class IV at concentrations 15%, 20% and it consider high repellent (Table13) (figure 4).

Table 11: The Repellency effect of Usher aqueous extract against Khapra beetle *T. granarium* on sorghum seeds

concentration	Time/minets	Mean		Repellency %	Overall mean repellency %	Class
		C	T			
10 %	30	10.67	9.33	12.56	29.17	II
	60	11.67	8.33	28.62		
	90	12	8	33.33		
	120	12.67	7.33	42.15		
15 %	30	11	9	18.18	29.17	II
	60	11.33	8.67	23.48		
	90	11.67	8.33	28.62		
	120	13.67	7.33	46.38		
20 %	30	11	9	18.18	44.95	III
	60	12.33	7.67	37.79		
	90	14	6	57.14		
	120	15	5	66.67		

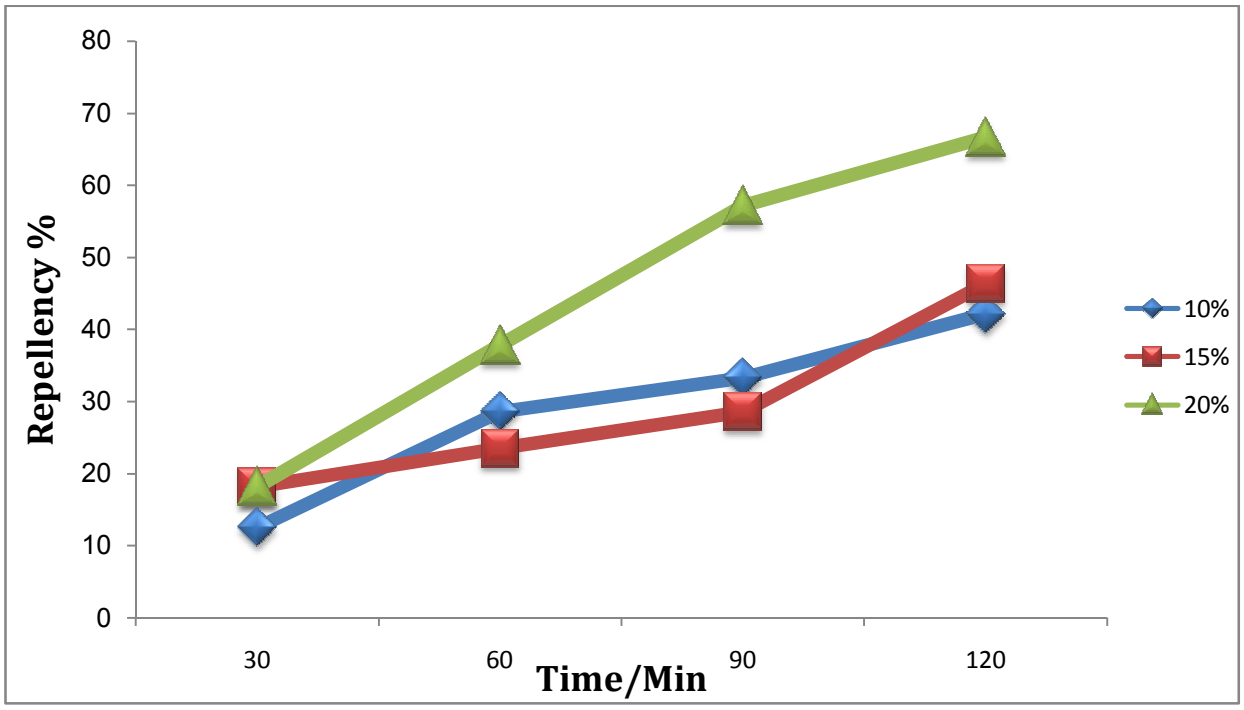


Figure 2: The Repellency effect of Usher aqueous extract against Khapra beetle *T. granarium* on sorghum seeds.

Table 12: The Repellency effect of Datura aqueous extract against Khapra beetle *T. granarium* on sorghum seeds

concentration	Time/minets	Mean		Repellency %	Overall mean repellency %	Class
		C	T			
10 %	30	13.33	6.67	49.96	56.99	III
	60	14.00	6.00	57.14		
	90	14.33	5.67	60.43		
	120	14.33	5.67	60.43		
15 %	30	12.67	7.33	42.15	58.95	III
	60	14.67	5.33	63.67		
	90	14.33	5.67	60.43		
	120	15.33	4.67	69.54		
20 %	30	14	6	57.14	67.59	IV
	60	14.67	5.33	63.67		
	90	15.33	4.67	69.54		
	120	16.67	3.33	80.02		

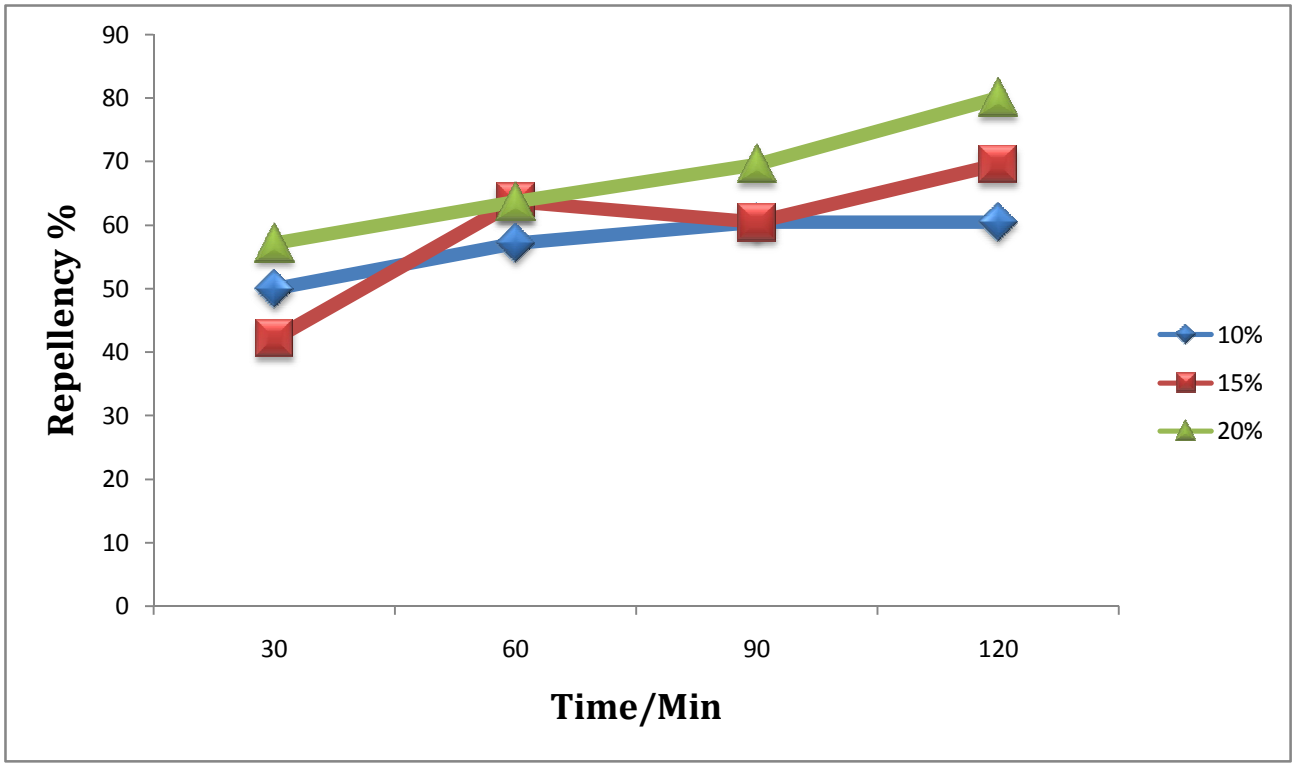


Figure 3: The Repellency effect of Datura aqueous extract against Khapra beetle *T. granarium* on sorghum seeds.

Table (13): The Repellency effect of Jatropha aqueous extract against Khapra beetle *T. granarium*. on sorghum seeds

Concentration	Time/minets	Mean		Repellency %	Overall mean repellency %	Class
		C	T			
10 %	30	12	8	33.33	35.56	II
	60	12	8	33.33		
	90	12.33	7.67	37.79		
	120	12.33	7.67	37.79		
15 %	30	15.67	4.33	72.37	75.47	IV
	60	16.67	3.33	80.02		
	90	16.67	3.33	80.02		
	120	15.33	4.67	69.45		
20 %	30	15	5	66.67	77.15	IV
	60	16	4	75		
	90	17.33	2.67	84.59		
	120	17	3	82.35		

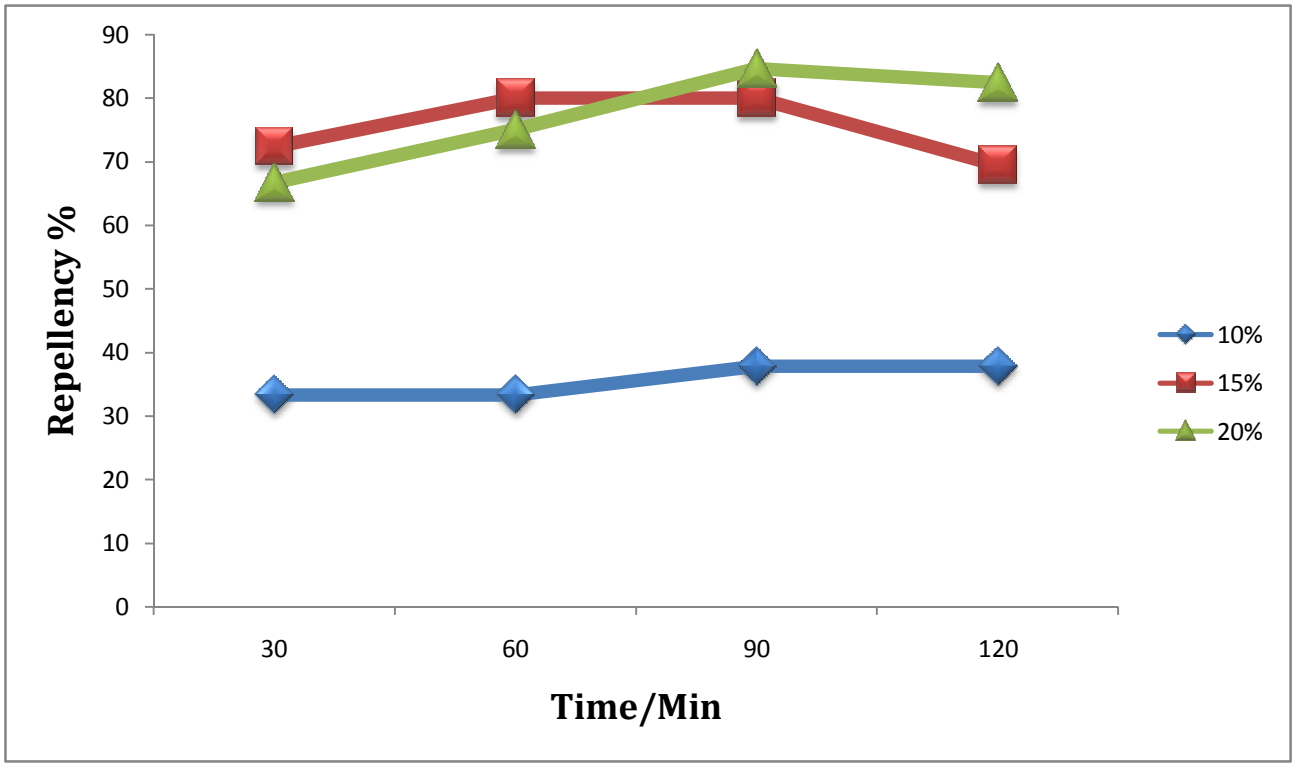


Figure 4: The Repellency effect of Jatropha aqueous extract against Khapra beetle *T. granarium*. on sorghum seeds

4.5 Weevil bioassay with plant materials:

This bioassay procedure thus allows plant materials with strong, weak or negative grain protectant effects to be detected, irrespective of their mode of action. The weevil perforation index (WPI) compares the activities of different species of plant extracts used.

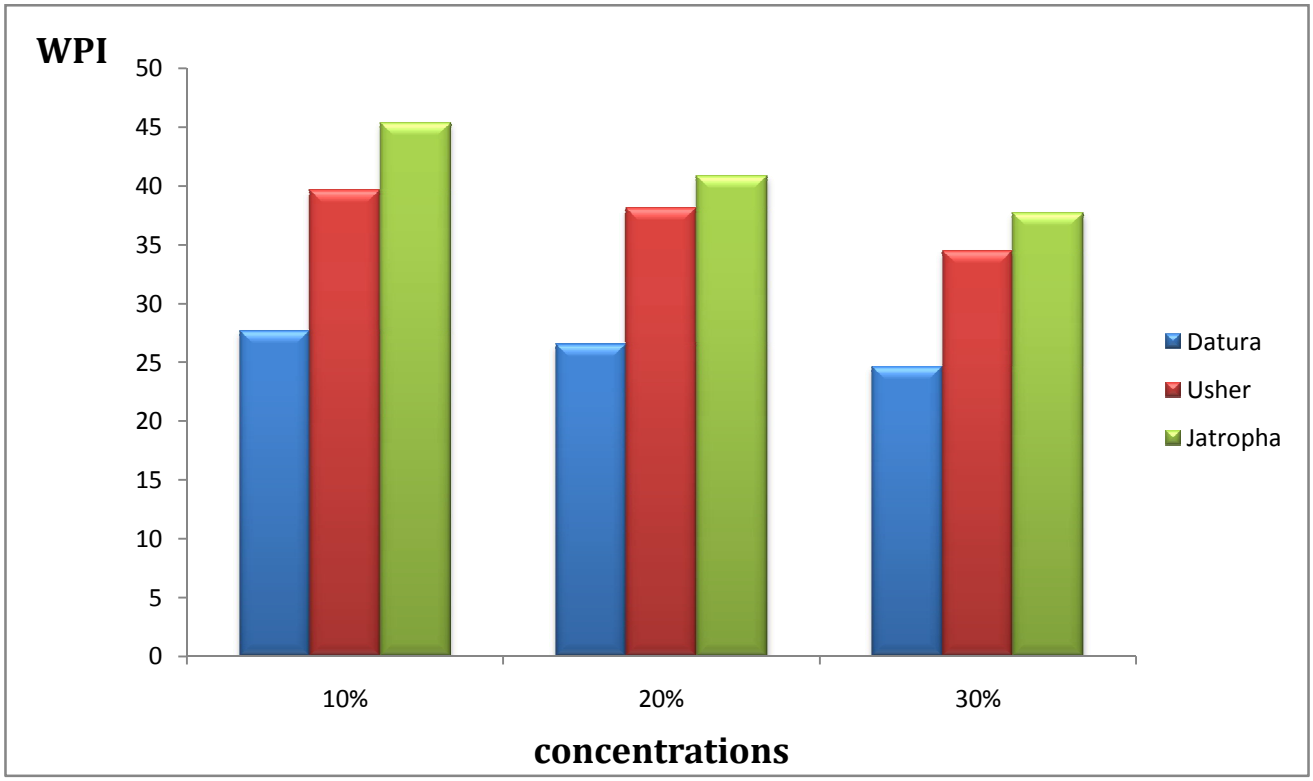
From this study, it is becoming evident that, Of the 3 plants screened, *D. alba* showed the best grain protectant effects, a WPI value was (24.63) at dose of 30% (w/w) and it is considered to be a strong effect. While *J. curcas* showed the lowest effect, a WPI value was (45.36) at dose of 10% (w/w).

However powder extracts of *D. alba, C. procera* and *J. curcas* as general prevented infestation and damage of the treated Sorghum seeds, at different levels, the Weevil Perforation Index (WPI) of *D. alba* was (27.66, 26.52 and 24.63) at (10%, 20% and 30% w/w) concentrations respectively. For *C. procera* the (WPI) was (39.67, 38.10 and 34.46) at concentrations (10%, 20% and 30% w/w) respectively and for *J. curcas*, (WPI) was (45.36, 40.82 and 37.69) at (10%, 20% and 30% w/w) concentrations respectively. Table (14), Figure(5)

Table 14: Weevil bioassay results

	Dose	Mean NO: of Perforated(damaged) seeds	Mean NO: of unperforated seeds	Total	% percent of Perforated seeds	WPI
Control		154.5	1352.75	1507.25	10.25	50
Datura	10 %	57	1396.25	1453.25	3.92	27.66
	20 %	55.25	1436	1491.25	3.70	26.52
	30 %	49.5	1427.75	1477.25	3.35	24.63
Usher	10 %	99	1390	1491.5	6.74	39.67
	20 %	91.25	1355	1446.25	6.31	38.10
	30 %	87.75	1393	1480.75	5.93	34.46
Jatropha	10 %	126.75	1362	1488.75	8.51	45.36
	20 %	104	1367.5	1471.5	7.07	40.82
	30 %	90.25	1366.25	1456.5	6.20	37.69

- A WPI value > 50 indicates negative grain protectant effect or enhancement of infestation by the weevil.



- WPI= Weevil perforation Index.

Figure 5: Weevil bioassay results

4.6 The effect of plant mixtures powders of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds

The insecticidal effects (mortality) of the plant mixtures on the insects at the 1st and 10th day showed no significant difference ($p>0.05$) at all concentrations. However, there was significant difference ($p<0.05$) in the mortality of the insects as the time of exposure increased at 20th and 30th day.

For the plant mixtures (U: J), Comb A (0:100) and Comb B (20:80), caused high larvae mortality (6.86%) at 30th day for the dose 20% . The result showed that mixed proportions of Usher & Jatropha especially combination A (0U: 100J) was most effective with mortality percentage (4.83, 6.23 and 6.86) at doses 10%, 15% and 20% respectively at the 30th day, while the combination F (100: 0) mortality percentage was (4.4, 5.46 and 5.46) at doses 10%, 15% and 20% respectively at the same interval.

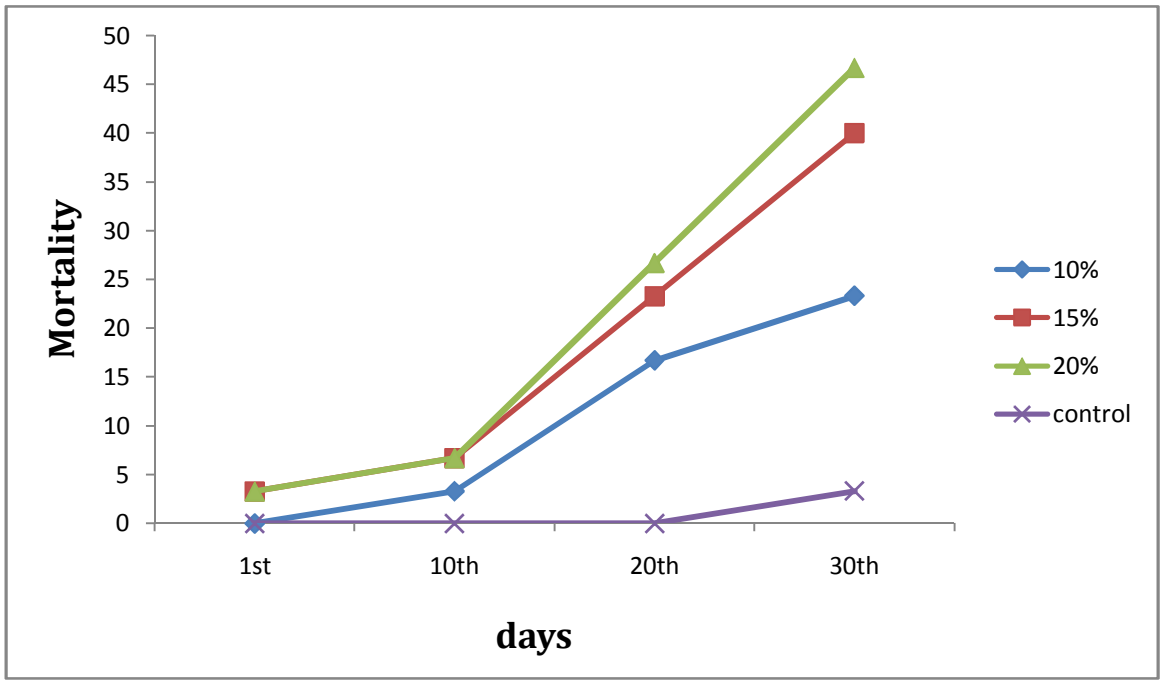
There was a significant difference as the concentration of plant materials increased. However, genarely at 20th and 30th day there was significant difference in the mortality of the insects between concentrations and between concentrations and control.Table (15) figures (6- 11).

Table (15) The effect plant mixtures powders of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.

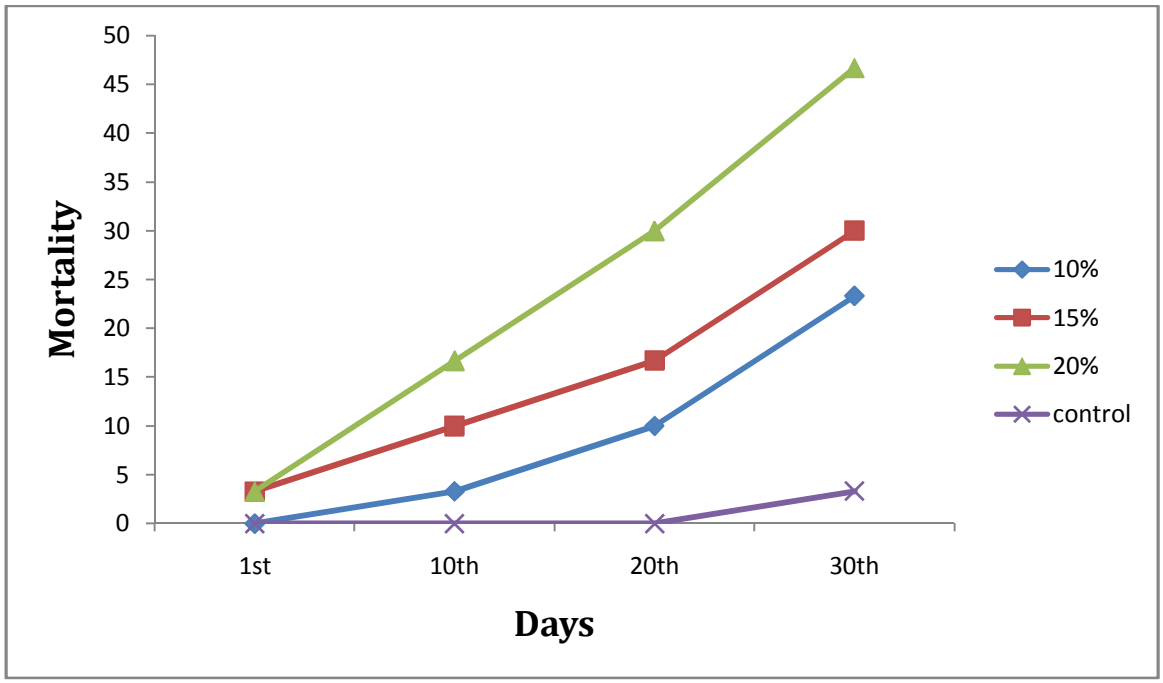
Combinations (U:J)	Cons %	1st	10th	20th	30th
Comb A (0: 100)	10 %	0(0.7) a	3.3(1.53) a	16.7(4.06) a	23.3(4.83) a
	15 %	3.3(1.53) a	6.7(2.36) a	23.3(4.83) a	40.0(6.23) a
	20 %	3.3(1.53) a	6.7(2.36) a	26.7(5.16) a	46.7(6.86) a
Comb B (20:80)	10 %	0(0.7) a	3.3(1.53) a	10.0(2.8) b	23.3(4.83) a
	15 %	3.3(1.53) a	10.0(2.8) a	16.7(3.96) a	30(5.46) a
	20 %	3.3(1.53) a	16.7(4.06) a	30.0(5.5) a	46.7(6.86) a
Comb C (40:60)	10 %	0(0.7) a	6.7(2.36) a	13.3(3.63) a	20.0(4.5) a
	15 %	0(0.7) a	6.7(1.96) a	16.6(4.06) a	23.3(4.83) a
	20 %	0(0.7) a	10(2.8) a	26.7(4.5) a	40.0(6.23) a
Comb D (60:40)	10 %	0(0.7) a	10(3.2) a	13.3(3.63) a	23.3(4.7) a
	15 %	0(0.7) a	10(2.8) a	20.0(4.4) a	33.3(5.76) a
	20 %	0(0.7) a	10(3.2) a	20.0(4.4) a	36.7(6.1) a
Comb E (80:20)	10 %	0(0.7) a	6.7(2.36) a	13.3(3.63) a	23.3(4.83) a
	15 %	0(0.7) a	6.7(2.36) a	13.3(3.63) a	26.7(5.16) a
	20 %	0(0.7) a	6.7(2.36) a	16.7(4.06) a	33.3(5.76) a
Comb F (100: 0)	10 %	0(0.7) a	3.3(1.53) a	10(3.2) a	20.0(4.4) b
	15 %	0(0.7) a	6.7(2.36) a	16.7(4.06) a	30.0(5.46) a
	20 %	0(0.7) a	6.7(2.36) a	16.7(4.06) a	30.0(5.46) a
Control		0(0.7) a	0(0.7) a	0(0.7) c	3.3(1.53) c
SE±		0.6	1.4	1.1	0.9
LSD(0.05)		0.91	1.98	1.57	1.37

* Means followed by the same letter(s) in the same Colum are not significantly different at (p=0.05).

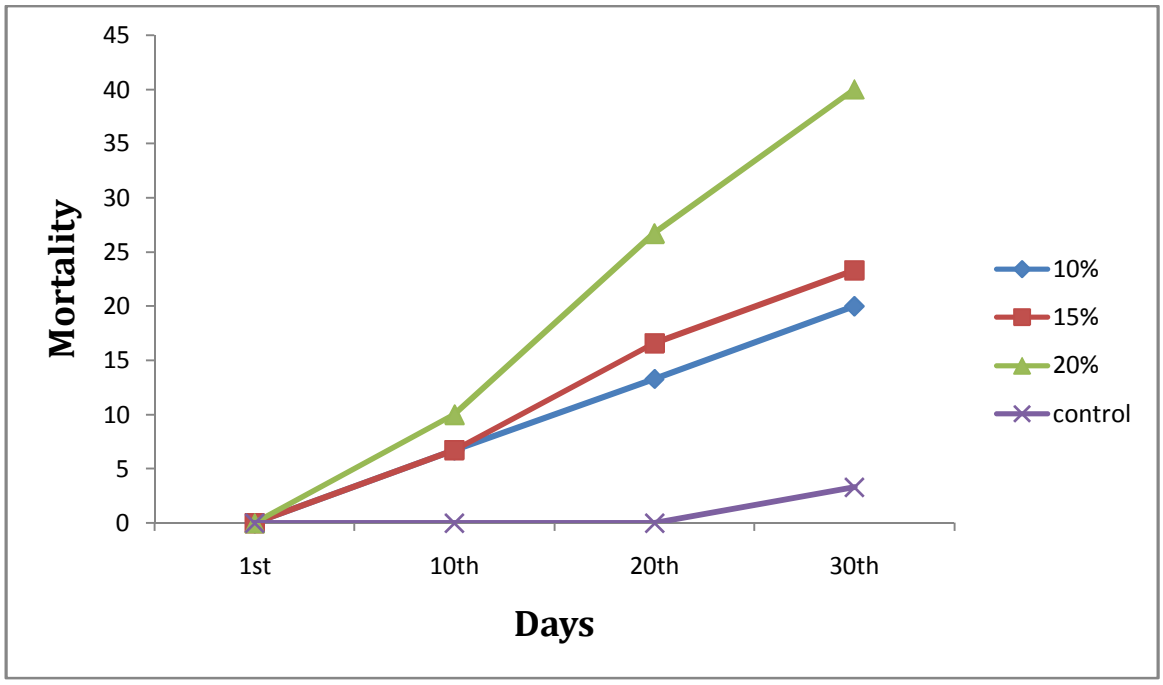
* Figures in parentheses indicates transformed value (√x+0.5).



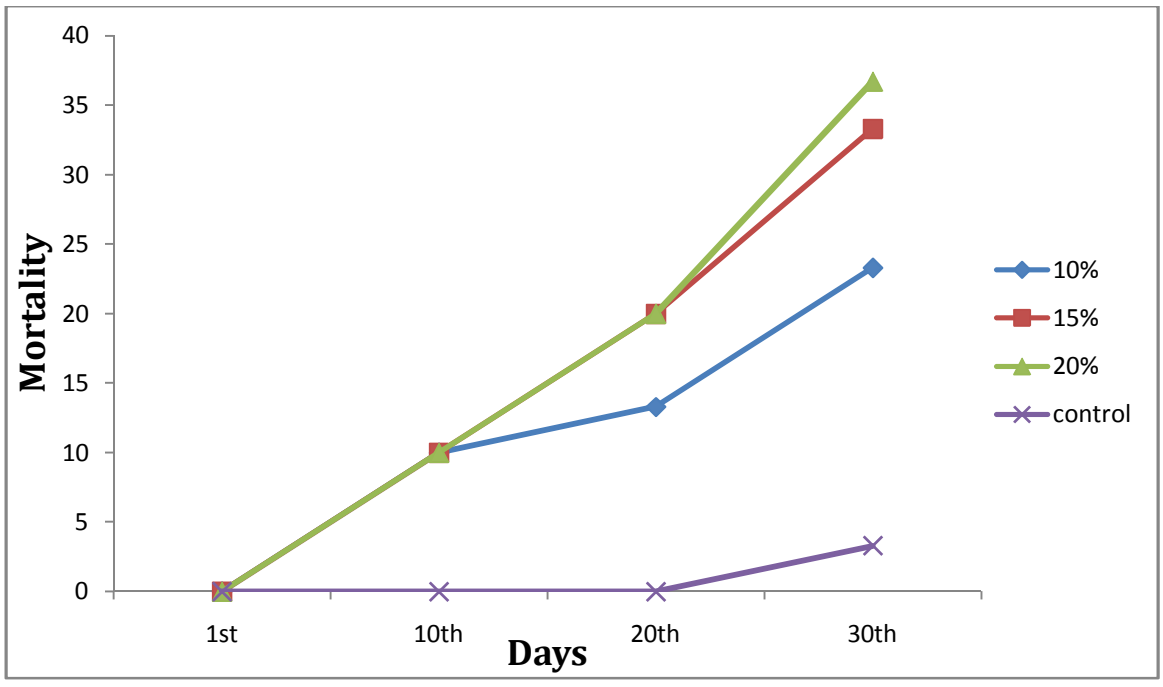
Figer (6) The effect combination (A) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.



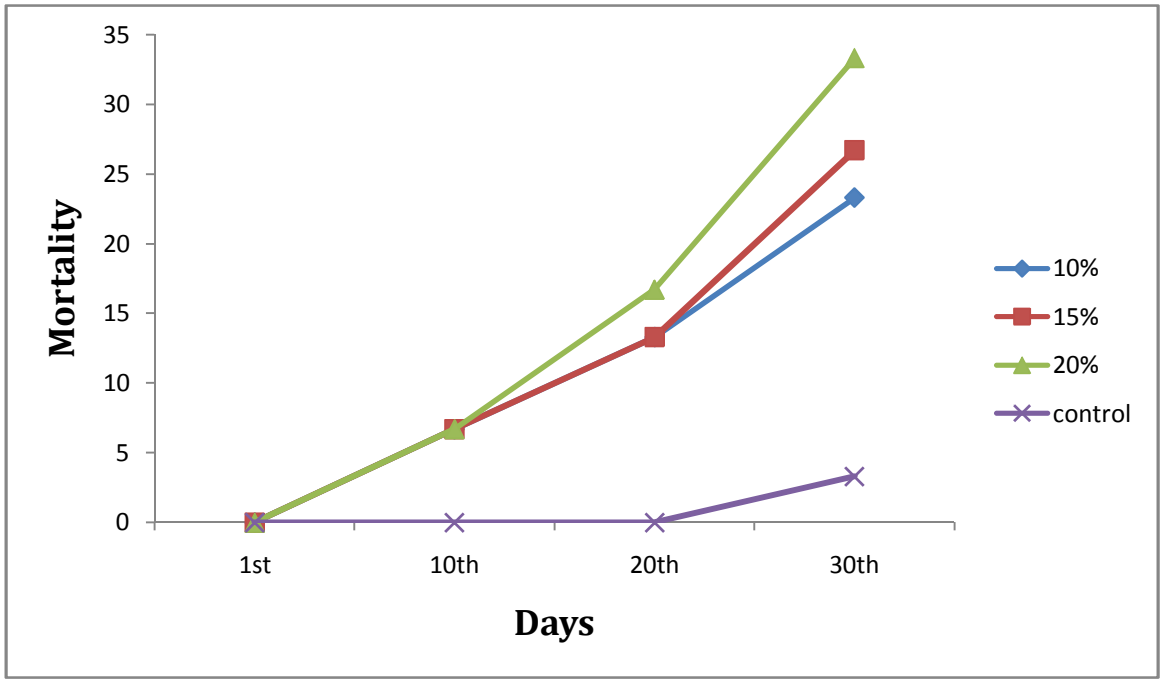
Figer (7) The effect combination (B) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.



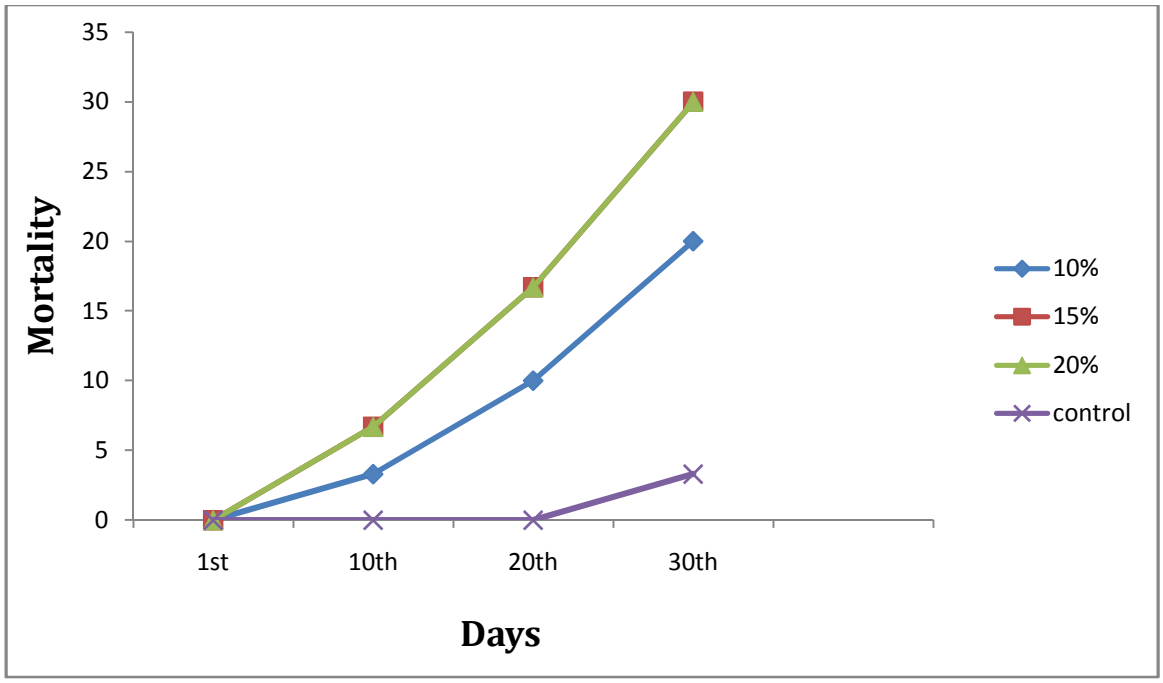
Figer (8) The effect combination (C) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.



Figer (9) The effect combination (D) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.



Figer (10) The effect combination (E) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.



Figer (11) The effect combination (F) mixture powder of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds.

CHAPTER FIVE

DISCUSSION

DISCUSSION

The conventional use of synthetic pesticides and their success during the past three decades led to their wide acceptance for use against different groups of agricultural pests. However, the extensive use of these synthetic insecticides associated with certain drawbacks and hazards; including high persistence, toxicity to mammals and non-target organisms, genetic resistance, environmental pollution, ozone depletion, and poor knowledge of application.

In a reaction to these problems, researchers all over the world have resorted to using more available and environmentally friendly botanicals; they focused on the use of plant products, such as plant powder, extracts and oils, which are cheaper, safe, of low mammalian toxicity, relatively short environmental persistence and enhance selectivity to target pests. Many plant products show a broad spectrum of activity against pest insects, ranging from insecticidal, antifeedant, repellent, oviposition deterrent, growth regulatory and antivector activities , Especially remarkable are tropical plants from which hundreds of secondary metabolites with insecticidal properties have been extracted (Hiiesaar *et. al*. 2001).

However, to control the Khapra beetle a considerable research effort has been done, the most promising are those derived from plants. Many investigations have identified and screened a variety of promising chemical compounds from leaves and seeds of many botanical families as insect feeding deterrent and growth inhibitors (e.g., Siddig, 1991; Mbata *et al.,* 1995; Fageer 1999; El Nadi *et. al*., 2001; Lale and Yusuf, 2001; Stoll 2001; Boeke *et. al.* 2004; Odeyemi and Ashamo 2005; Asawalam *et. al*. 2007). Plant powder formulation is cheap since organic solvents are not used.

The present study was carried out to investigate the insecticidal effect of eight plants naturally grown in Sudan namely Basil *Ocimum basilicum*, Henna *Lawsonia inermis*,, Senna *Cassia senna*, Lantana *Lantana camara* , Datura

Datura alba, Usher *Calotropis procera* ,Chili *Capsicum frutescens* and Jatropha *Jatropha curcas*., on the 3rd larval instar of khapra beetle *Trogoderma granarium*.

The results showed that all the plant materials had varying degree of insecticidal activities. The ability of the plant powders to cause mortality, of *T. granarium* 3rd instar larvae on Sorghum grains can be attributed to contact toxicity and other effects of the powders on the insect. The toxic effect was found to be dose and exposure-time dependent. Although their efficacy varied and the toxic action was relatively weak or slow for some plants used, *C.procera*, *J. curcas* and *D. alba* were found the most effective plants. The results showed that these three Botanicals have a considerable grain protecting activity against the tested insect at diferrent levels.

Usher *C. procera*

The treatments with Usher (*C. procera*) leaves powder showed promising insecticidal activity and had the highest percentage mortality on *T. granarium* larvae 3rd instar. In Table (6), the three concentrations of Usher leaves powder, revealed that larval mortality was affected by the increase in concentration. These finding agreed with Ahmed (1993) who studied insecticidal potentialities of the Ushar plant *C. procera* on *T. granarium* and reported that the damage was least in the ground leaves treatments. All treatments retarded the larval development of the tested insect compared to the control. The results also agreed with Sagheer *et. al.,* (2011) who stated that, mortality of *T. castaneum* increased with both an increase in concentration of 4 plant extracts as well as exposure time of treatments

In the present study, the antifeeding effect of usher becomes a well documented fact (Table 10), and it could be assumed that, treating insect food material with Usher powder can disrupt insect feeding by making the treated material unattractive or unpalatable and consequently, insect growth, survival

and reproduction are adversely affected. This result agreed with Sir El Khatim (2005), who stated that, 5%, 10% and 20% (W/V) water and ethanol extracts of flowers, roots and leaves powders all showed a good antifeedant effect. larval development was retarded with the three treatments, antifeedant effect increased with increasing dosages. Results also is in agreement with Ahmed (1993) who showed that, the extracts of Usher leaves, flowers and roots caused an antifeedant effects and retarded development in the larvae of *T. granarium*.

The repellency action of the test plant is shown in Table (11), *C. procera* bioassay result in class (III) repellency effect at high concenteration this result agreed with Ahmed *et al.,*(2006) who stated that, shaker aqueous extract of leaf, flower and roots of *C. procera* proved most effective in the control of *Henosepilachna elaterii*

The weevil perforation index (WPI) bioassay compared the activities of the extracts of the three plants used. WPI values of 50 shows that equal amounts of treated and untreated Sorghum seeds were perforated. From the results of Table (14), it was evident that, *C.procera* showed consedierable grain protectant effects and displayed some potential as antifeedants, stomach poisons, contact poisons and repellents. This resulted in reduction in weight loss and seed damage by *T. granarium* on treated sorghum seeds.

Insecticidal property of any plant material would depend on the active constituents of the plant material. Usher (*C. procera*) Insecticidal properties against stored products and other pests have been investigated by many researchers. Al-Robai *e.t al;* (1993); Hussein *et. al.,* (1994); and Mohammed (1999) reported the presence of alkaloids, flavonoids, cardiac glycosides as well as sterols and usharin in the entire parts of usher plant (*C. procera*). Concerning the effect of those compounds, other studies by Blades and Mitchell, (1986); and Ongilagha *et. al.,* (2004) showed that, the alkaloids and flavonoids of many plants have a repellent and antifeedant effects against many insect pests.

Jatropha *J. curcas*

The insecticidal activity of Jatropha was shown in Table (8).The treatments with Jatropha leaves powder showed promising toxicity effect and resulted in higher mortality percentage on *T. granarium* 3rd instar larvae. All concentrations of leaves powder, revealed that larval mortality was affected by the increase in concentration. and exposure period. Similer results were found by Ogunleye (2010) who test the insecticidal properties of seed oil of three botanicals namely *Jatropha curcas*, *Heliathus annus* (sunflower) and *Cocos nucifera* (coconut) on the maize weevil, *S. zeamais* Mots. The application doses were 0.1ml, 0.2ml, 0.3ml and 0.4ml per insect. His result indicated that the least rate of application of Jatropha produced 70% mortality after 24hours, while the dosage of 0.3ml and 0.4ml produced 80% mortality after 24hours. The control experiment remained at 0% level throughout the period of the experiments.

From the results of the present study (Table 10), it was clear that *J. curcas* displayed some potential as anti-feedants to *T. granarium* larvae. Antifedant activity of Jatropha was well documented by meny researchers (e.g., Meshram *et. al.,* 1996; and Rani *et.al.,* 2012). However there was no brevious studies on the antifeedant effect of Jatropha seed powder against *T. granarium*. However similer finds was reported by Bashir *et. al.,* (2013) who stated that the concentration of 5% Jatropha seed oil caused a significant, 50% more, antifeedant effect on the treated nymphs as compared to the untreated control group.

Concerning the repellency action of *J. curcas* seeds, the results indicated that the higher repellency effects were obvious at high concentrations. 15% and 20%. which laid in repellent class (IV). The use of *J. curcas* seeds powder as repllent against *T.granarium* have not studied. However similer findings was observed by Sabbour *et.al.,* (2013) when they studied the repellent Effects of *J. curcas*, and three other plants against *C. maculates*(F.) and *C. chinensis* (L.). Results,

showed that Jatropha oil acted not only as oviposition deterrents but also adversely influence fecundity.

At the end of four months storage period, the weevil perforation index (WPI) ranges between 45.36 and 37.69 in the treatments compared to the control. Table (15), Figer (5). The results determined the possibility of using seed powder extract in pest management. Application of the seed extract resulted in reduction of infestation and reduced seed perforation. This result in agreement with Shaaya *et. al.,*(1991& 1997) who reported that edible oils are potential control agents against *C. maculates*and can play an important role in stored-grain protection.

Datura *D. alba*

The treatments with Datura (*D. alba*) leaves powder showed conseidrable promising insecticidal effect. High numbers of dead insects were obtained with all concentrations but there was no significant difference in the mortality of the pest between concentrations (Table 5).The three concentrations of the plant leaves powder, revealed that the mortality of the larvae was affected by the increase in concentration and time. This is in agreement with Abid *et.al,* (2012), who assessed the contact toxicity and the trans-generational effect of *D. alba* leaf extract (DLE) against two important stored insect pests on rice, *T. granarium* and *S. oryzae*, under laboratory conditions. The highest DLE concentration (2.5 %) induced significantly high mortality with 33.5 and 45 % in *T. granarium* and S. *oryzae* after 7 days of exposure, respectively.

The result also agreed with Kuganathan (2010) who investigated the acute toxicity of *D. metel* at varying concentrations on grasshoppers and red ants. The results indicated that extract of *D. metel* leaves at higher concentrations was more toxic and it can be used as an insecticide against grasshoppers and red ants.

Antifeedants are of paramount importance in insect pest management since they are pest specific and retard feeding activities of pests. However, these are dependent upon the chemicals present in the plant parts. Antifeedant effect of Datura is well documented in this bioassy, it seems that powder extract of Datura leaves displayed some potential as anti-feedants to *T. granarium* larvae (Table10), therefore it could be assumed that, treating insect food material with *D. alba* powder can disrupt insect feeding by making the treated material unattractive or unpalatable and reduce the damage of seed by the pest.

The repellency action of the test plant shown in (Table 12) demonstrate that, *D. alba* bioassay result in class (IV) repellency effect at high concenteration, indicating that *D. alba* showed strong repellent activity and thus deterred the insects from feeding. Similar findings were reported by Karzan *et. al.,* (2011), who investigated the Effects of ethanol extracts of *D. stramonium* and others on the mortality, egg hatching, reduction in F1 progeny and repellents on the red flour beetle. He stated that, the ethanol extracts of *D. stramonium* and *Solanum nigrum* caused repellency percentages of 91.87% and 91.45% in 4% concentration after 24 hours.

The weevil perforation index (WPI) bioassay compared the activities of the extracts of the three plants used. Weevil Perforation Index (WPI) bioassay indicated that, Datura leaves powder used have a potential effect as grain protectants. Protectant ability of Datura powder shown in this test are in agreement with the observation of Kuganathan *et. al.,*(2007) who showed that, the extract of *D. alba* leaves at higher concentrations was more toxic and can be used as insecticide against aphids and black ants.

These toxic effects have been attributed by various authors to the presence of some chemical compounds. Chakravarty (1976) Stated that, *D. stramonium* contains alkaloid compounds such as atropine, scopolamine in the leaves, stems and fruits in addition to essential oils, which may be the direct reason of killing the insects.

Plant mixture bioassay

In the present study, the results of the plant mixcture experiment showed that, the larval mortality was significant as the concentration of the mixture of the plant extracts increased. Also, the results indicated that, the plant mixture became more effective over time, at all concentrations (Table 15). Comparison between the different combinations of the two plant extracts (i.e., combinations A- F) indicated that, the more the concentration of Jatropha extract, the more effective will be the combination. The toxicity of the plant extracts in their different proportions could be a result of their active ingredients, acting as stomach poisons, or repellents on *T. granarium* larvae. Accordingly, these results might indicate that, the active ingredient of Jatropha plant extract is more toxic to the larvae than that of Usher.

There were no previous studies on the effects of mixtures of Usher and Jatropha plant extracts on the mortality of *T. granarium*. However, similar findings of Larval mortality of *T. granarium* were obtained by Babarindea *et, al.*, (2009) using a mixture of two plants, *Piper guineense* seeds and *Moringa oleifera* leaf powders. The results showed significantly higher mortality (77.5%) of the larvae, and higher repellency (60%), were obtained when using the mixture of the two plant extracts than using any other extract singly. Another study was conducted by Dawudo and Ofuya (2000), using a mixture of fruit powders of *P. guineense* and *Dennettia tripetala* in equal proportion (50:50) against *C. maculatus*. Their results significantly caused mortality and reduced oviposition and adult emergence of *C. maculates*infesting cowpea seeds.

Conclusion

It was evident from this study that all the plant-part powders tested have the potential of being used as Biopesticides.

The results therefore strongly suggest the possibility of using the extracts of the three most effective plants Usher, Jatropha and Datura as toxicants, repellents and food poisoning agents against *T. granarium*.

Botanical protection of stored products against *T. granarium* when using plant mixtures could be more effective than one plant. The selection of other plant mixture will therefore accelerate the control of khapra beetle on stored Sorghum seeds.

However, there is need for more investigation to identify other local plant material mixtures that would be best used in storage of Sorghum against the disturbing infestation of *T. granarium.*

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APPENDICES

Appendix(1):

The Effect of Natural products on Khapra beetle infestation

Table (1): The effect of Basil leaves powder extract (BLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table (1): I

	Rep / conc	R1	R2	R3	R4	mean
Basil 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	0 0.7	0 0.7	0 0.7	0 0.7	0
	15%	0 0.7	10 3.2	0 0.7	10 3.2	5.0
	20%	0 0.7	10 3.2	10 3.2	10 3.2	7.5

The ANOVA Procedure

Source 1stb	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	10.54687500	3.51562500	3.86	3.49
Error	12	10.93750000	0.91145833		
Corrected Total	15	21.48437500			

Table (1): II

	Rep / conc	R1	R2	R3	R4	mean
Basil 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	10 3.2	10 3.2	0 0.7	10 3.2	0.75
	15%	0 0.7	10 3.2	20 4.5	10 3.2	1
	20%	20 4.5	10 3.2	10 3.2	10 3.2	1.25

The ANOVA Procedure

Source10th b	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	10.28187500	3.42729167	2.26	3.49
Error	12	18.22250000	1.51854167		
Corrected Total	15	28.50437500			

Table (1): III

	Rep / conc	R1	R2	R3	R4	mean
Basil 20th day	control	10 3.2	0 0.7	10 3.2	0 0.7	0.5
	10%	0 0.7	10 3.2	10 3.2	10 3.2	0.75
	15%	10 3.2	20 4.5	10 3.2	10 3.2	1.25
	20%	20 4.5	10 3.2	10 3.2	20 4.5	1.5

The ANOVA Procedure

Source20 b	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	9.11500000	3.03833333	2.62	3.49
Error	12	13.89500000	1.15791667		
Corrected Total	15	23.01000000			

Table (1): IV

	Rep / conc	R1	R2	R3	R4	mean
Basil 30th Day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	10 3.2	10 3.2	10 3.2	10 3.2	1
	15%	30 5.5	10 3.2	10 3.2	10 3.2	1.5
	20%	10 3.2	30 5.5	10 3.2	10 3.2	1.5

The ANOVA Procedure

Source30b	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	8.88500000	2.96166667	2.51	3.49
Error	12	14.18500000	1.18208333		
Corrected Total	15	23.07000000			

Table (2) The effect of Henna leaves powder extract (HLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table (2): **I**

	Rep / conc	R1	R2	R3	R4	Mean
Henna 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	0 0.7	0 0.7	10 3.2	0 0.7	0.3
	15%	10 3.2	10 3.2	0 0.7	0 0.7	0.5
	20%	10 3.2	10 3.2	0 0.7	0 0.7	0.5

The ANOVA Procedure

Source 1h	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	4.29687500	1.43229167	1.00	3.49
Error	12	17.18750000	1.43229167		
Corrected Total	15	21.48437500			

Table (2): **II**

	Rep / conc	R1	R2	R3	R4	Mean
Henna 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.3
	10%	10 3.2	10 3.2	0 0.7	10 3.2	0.75
	15%	10 3.2	10 3.2	10 3.2	10 3.2	1
	20%	10 3.2	20 4.5	10 3.2	10 3.2	1.25

The ANOVA Procedure

Source10h	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	19.14500000	6.38166667	12.86	3.49
Error	12	5.95500000	0.49625000		
Corrected Total	15	25.10000000			

Table (2): **III**

	Rep / conc	R1	R2	R3	R4	Mean
Henna 20th Day	control	10 3.2	0 0.7	10 3.2	0 0.7	0.5
	10%	0 0.7	10 3.2	20 4.5	10 3.2	1
	15%	10 3.2	20 4.5	10 3.2	0 0.7	1
	20%	40 6.4	10 3.2	10 3.2	20 4.5	2

The ANOVA Procedure

Source20h	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	11.50687500	3.83562500	1.63	3.49
Error	12	28.27750000	2.35645833		
Corrected Total	15	39.78437500			

Table (2): **IV**

	Rep / conc	R1	R2	R3	R4	mean
Henna 30th Day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	20 4.5	10 3.2	10 3.2	10 3.2	1.25
	15%	30 5.5	20 4.5	20 4.5	30 5.5	2.5
	20%	30 5.5	30 5.5	20 4.5	20 4.5	2.5

The ANOVA Procedure

Source30h	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	25.43687500	8.47895833	10.69	3.49
Error	12	9.51750000	0.79312500		
Corrected Total	15	34.95437500			

Table(3) The effect of Senna leaves powder extract (SLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table(3): **I**

	Rep / conc	R1	R2	R3	R4	mean
Senna 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	0 0.7	0 0.7	0 0.7	0 0.7	0
	15%	10 3.2	10 3.2	0 0.7	0 0.7	0.5
	20%	0 0.7	10 3.2	10 3.2	10 3.2	0.75

The ANOVA Procedure

Source 1s	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	7.81250000	2.60416667	2.00	3.49
Error	12	15.62500000	1.30208333		
Corrected Total	15	23.43750000			

Table(3): **II**

	Rep / conc	R1	R2	R3	R4	mean
Senna 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	10 3.2	10 3.2	10 3.2	0 0.7	0.75
	15%	10 3.2	20 4.5	0 0.7	10 3.2	1
	20%	20 4.5	10 3.2	10 3.2	10 3.2	1.25

The ANOVA Procedure

Source10s	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	10.28187500	3.42729167	2.26	3.49
Error	12	18.22250000	1.51854167		
Corrected Total	15	28.50437500			

Table(3): **III**

	Rep / conc	R1	R2	R3	R4	mean
Senna 20th day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	10 3.2	30 5.5	20 4.5	0 0.7	1.5
	15%	30 5.5	30 5.5	10 3.2	10 3.2	2
	20%	30 5.5	20 4.5	10 3.2	30 5.5	2.25

The ANOVA Procedure

Source20s	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	17.82250000	5.94083333	2.54	3.49
Error	12	28.03500000	2.33625000		
Corrected Total	15	45.85750000			

Table(3): **IV**

	Rep / conc	R1	R2	R3	R4	mean
Senna 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	20 4.5	10 3.2	0 3.2	30 5.5	1.5
	15%	20 4.5	30 5.5	20 4.5	20 4.5	2.25
	20%	30 5.5	10 3.2	30 5.5	30 5.5	2.5

The ANOVA Procedure

Source30s	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	22.77500000	7.59166667	3.81	3.49
Error	12	23.89500000	1.99125000		
Corrected Total	15	46.67000000			

Table (4)The effect of Lantanna leaves powder extract (LLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table (4): **I**

	Rep / conc	R1	R2	R3	R4	mean
Lantana 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	15%	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	20%	10 3.2	10 3.2	0 0.7	0 0.7	0.5

The ANOVA Procedure

Source1L	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	3.12500000	1.04166667	0.80	3.49
Error	12	15.62500000	1.30208333		
Corrected Total	15	18.75000000			

Table (4): **II**

	Rep / conc	R1	R2	R3	R4	mean
Lantana 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	15%	10 3.2	20 4.5	0 0.7	30 5.5	1.5
	20%	10 3.2	10 3.2	20 4.5	30 5.5	1.75

The ANOVA Procedure

Source10L	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	20.05250000	6.68416667	2.91	3.49
Error	12	27.60500000	2.30041667		
Corrected Total	15	47.65750000			

Table (4): **III**

The ANOVA Procedure

	Rep / conc	R1	R2	R3	R4	mean
Lantana 20^{th} day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	10 3.2	20 4.5	10 3.2	10 3.2	1.25
	15%	0 0.7	20 4.5	20 4.5	10 3.2	1.25
	20%	10 3.2	20 4.5	20 4.5	20 4.5	1.75

The ANOVA Procedure

Source20L	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	10.47187500	3.49062500	2.27	3.49
Error	12	18.41250000	1.53437500		
Corrected Total	15	28.88437500			

Table (4): **IV**

	Rep / conc	R1	R2	R3	R4	mean
Lantana 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	20 4.5	10 3.2	0 0.7	20 4.5	1.25
	15%	30 5.5	10 3.2	20 4.5	0 0.7	1.5
	20%	20 4.5	20 4.5	10 3.2	30 5.5	2

The ANOVA Procedure

Source30L	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	8.15500000	2.71833333	1.07	3.49
Error	12	30.49500000	2.54125000		
Corrected Total	15	38.65000000			

Table (5) The effect of Datura leaves powder extract (DLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table (5): **I**

	Rep / Conc	R1	R2	R3	R4	mean
Datuora 1st day	Control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	10 3.2	0 0.7	10 3.2	10 3.2	0.75
	15%	20 4.5	10 3.2	0 0.7	10 3.2	1
	20%	20 4.5	10 3.2	10 3.2	10 3.2	1.25

The ANOVA Procedure

Source1D	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	17.73500000	5.91166667	5.24	3.49
Error	12	13.53500000	1.12791667		
Corrected Total	15	31.27000000			

Table (5): **II**

	Rep / conc	R1	R2	R3	R4	mean
Datuora 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	10 3.2	20 4.5	10 3.2	0 0.7	1
	15%	10 3.2	10 3.2	10 3.2	20 3.2	1.25
	20%	10 3.2	40 6.4	10 3.2	10 3.2	1.75

The ANOVA Procedure

Source10D	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	20.62500000	6.87500000	3.89	3.49
Error	12	21.21500000	1.76791667		
Corrected Total	15	41.84000000			

Table (5): **III**

	Rep / conc	R1	R2	R3	R4	mean
Datuora 20th day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	20 4.5	10 3.2	10 3.2	0 0.7	1
	15%	30 5.5	10 3.2	0 0.7	20 4.5	1.5
	20%	20 4.5	10 3.2	10 3.2	30 5.5	1.75

The ANOVA Procedure

Source20D	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	14.89000000	4.96333333	2.61	3.49
Error	12	22.86000000	1.90500000		
Corrected Total	15	37.75000000			

Table (5): **IV**

	Rep / conc	R1	R2	R3	R4	mean
Datuora 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	20 4.5	20 4.5	0 0.7	0 0.7	1
	15%	20 4.5	10 3.2	20 4.5	20 4.5	1.75
	20%	10 3.2	20 4.5	30 5.5	20 4.5	2

The ANOVA Procedure

Source30D	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	18.07187500	6.02395833	3.02	3.49
Error	12	23.95750000	1.99645833		
Corrected Total	15	42.02937500			

Table(6) The effect of Usher leaves powder extract (ULPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table(6): I

	Rep / cons	R1	R2	R3	R4	mean
Usher 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	0 0.7	10 3.2	10 3.2	10 3.2	0.75
	15%	0 0.7	20 4.5	10 3.2	30 5.5	1.5
	20%	10 3.2	20 4.5	30 5.5	0 0.7	1.5

The ANOVA Procedure

Source10U	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	20.53687500	6.84562500	2.69	0.0933
Error	12	30.54250000	2.54520833		
Corrected Total	15	51.07937500			

Table(6): II

	Rep / conc	R1	R2	R3	R4	mean
Usher 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	30 5.5	10 3.2	0 0.7	20 4.5	1.5
	15%	10 3.2	20 4.5	10 3.2	20 4.5	1.5
	20%	20 4.5	30 5.5	10 3.2	10 3.2	1.75

The ANOVA Procedure

Source10U	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	19.29250000	6.43083333	3.35	3.49
Error	12	23.04500000	1.92041667		
Corrected Total	15	42.33750000			

Table(6): III

	Rep / conc	R1	R2	R3	R4	mean
Ushar 20th day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	0 0.7	30 5.5	10 3.2	30 5.5	1.75
	15%	20 4.5	10 3.2	10 3.2	30 5.5	1.75
	20%	20 4.5	20 4.5	30 5.5	10 3.2	2

The ANOVA Procedure

Source20U	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	14.63500000	4.87833333	2.06	3.49
Error	12	28.38500000	2.36541667		
Corrected Total	15	43.02000000			

Table(6): IV

	Rep / conc	R1	R2	R3	R4	mean
Usher 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	30 5.5	10 3.2	10 3.2	20 4.5	1.75
	15%	30 5.5	20 4.5	30 5.5	0 0.7	2
	20%	40 6.4	20 4.5	30 5.5	50 7.1	3.5

The ANOVA Procedure

Source30U	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	30.92187500	10.30729167	4.20	3.49
Error	12	29.42750000	2.45229167		
Corrected Total	15	60.34937500			

Table(7)The effect of Chili leaves powder extract (CLPE) on infestation of Khapra beetle larvae on Sorghum seeds

Table(7): **I**

	Rep / conc	R1	R2	R3	R4	mean
Chili 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	0 0.7	0 0.7	0 0.7	10 3.2	0.25
	15%	20 4.5	10 3.2	10 3.2	0 0.7	1
	20%	20 4.5	10 3.2	10 3.2	10 3.2	1.25

The ANOVA Procedure

Source1C	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	20.92250000	6.97416667	6.18	3.49
Error	12	13.53500000	1.12791667		
Corrected Total	15	34.45750000			

Table(7): **II**

	Rep / conc	R1	R2	R3	R4	mean
Chili 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	0 0.7	10 3.2	10 3.2	10 3.2	0.75
	15%	10 3.2	20 4.5	10 3.2	10 3.2	1.25
	20%	10 3.2	20 4.5	20 4.5	10 3.2	1.5

The ANOVA Procedure

Source10C	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	15.41187500	5.13729167	5.00	3.49
Error	12	12.33250000	1.02770833		
Corrected Total	15	27.74437500			

Table(7): **III**

	Rep / conc	R1	R2	R3	R4	mean
Chili 20th day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	10 3.2	0 0.7	0 0.7	20 4.5	0.75
	15%	10 3.2	70 8.4	0 0.7	10 3.2	2.3
	20%	10 3.2	20 4.5	30 5.5	50 5.5	2.8

The ANOVA Procedure

Source20C	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	25.41687500	8.47229167	1.80	3.49
Error	12	56.61250000	4.71770833		
Corrected Total	15	82.02937500			

Table(7): **IV**

	Rep / conc	R1	R2	R3	R4	mean
Chili 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	10 3.2	10 3.2	20 4.5	10 3.2	1.25
	15%	10 3.2	10 3.2	60	20 4.5	2.5
	20%	30 5.5	40 6.4	10 3.2	20 4.5	2.5

The ANOVA Procedure

Source30C	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	17.44500000	5.81500000	4.83	3.49
Error	12	14.44500000	1.20375000		
Corrected Total	15	31.89000000			

Table (8) The effect of Jatropha leaves powder extract (JLPE) on infestation of Khapra beetle larvae on Sorghum seeds seeds

Table (8): I

	Rep / conc	R1	R2	R3	R4	mean
Jatropha 1st day	control	0 0.7	0 0.7	0 0.7	0 0.7	0
	10%	10 3.2	10 3.2	0 0.7	0 0.7	0.5
	15%	0 0.7	10 3.2	10 3.2	10 3.2	0.75
	20%	20 4.5	10 3.2	10 3.2	0 0.7	1

The ANOVA Procedure

Source1J	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	11.31687500	3.77229167	2.44	3.49
Error	12	18.51750000	1.54312500		
Corrected Total	15	29.83437500			

Table (8): II

	Rep / conc	R1	R2	R3	R4	mean
Jatropha 10^{th} day	control	10 3.2	0 0.7	0 0.7	0 0.7	0.25
	10%	10 3.2	0 0.7	10 3.2	20 4.5	1
	15%	30 5.5	20 4.5	10 3.2	0 0.7	1.5
	20%	10 3.2	10 3.2	20 4.5	30 5.5	1.75

The ANOVA Procedure

Source10J	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	16.96500000	5.65500000	2.35	3.49
Error	12	28.93500000	2.41125000		
Corrected Total	15	45.90000000			

Table (8): III

	Rep / conc	R1	R2	R3	R4	mean
Jatropha 20th day	control	10 3.2	0 0.7	10 0.7	0 0.7	0.5
	10%	10 3.2	10 3.2	0 0.7	20 4.5	1
	15%	20 4.5	20 4.5	10 3.2	30 5.5	2
	20%	30 5.5	20 4.5	30 5.5	10 3.2	2.25

The ANOVA Procedure

Source20J	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	19.9925000	6.66416667	3.99	3.49
Error	12	20.06500000	1.67208333		
Corrected Total	15	40.05750000			

Table (8): IV

	Rep / conc	R1	R2	R3	R4	mean
Jatropha 30th day	control	0 0.7	10 3.2	10 3.2	0 0.7	0.5
	10%	10 3.2	10 3.2	20 4.5	10 3.2	1.25
	15%	20 4.5	30 5.5	10 3.2	20 4.5	2
	20%	20 4.5	30 5.5	30 5.5	20 4.5	2.5

The ANOVA Procedure

Source30J	DF	Sum of Squares	Mean Square	F Value	F table (5%)
Model	3	21.22500000	7.07500000	7.59	3.49
Error	12	11.18500000	0.93208333		
Corrected Total	15	32.41000000			

Appendix (2): Comparative between natural products:

The ANOVA Procedure table (1)

	Source	DF	Sum of Squares	Mean Square	F Value	F table (5%)
1st day	Model	31	120.5500000	3.8887097	2.75	1.59
	Error	96	135.5050000	1.4115104		
	Corrected Total	127	256.0550000			

The ANOVA Procedure table (2)

	Source	DF	Sum of Squares	Mean Square	F Value	F table (5%)
10th Day	Model	31	139.3555469	4.4953402	2.77	1.59
	Error	96	155.5325000	1.6201302		
	Corrected Total	127	294.8880469			

The ANOVA Procedure table (3)

	Source	DF	Sum of Squares	Mean Square	F Value	F table (5%)
20th Day	Model	31	130.0342969	4.1946547	1.86	1.59
	Error	96	216.5425000	2.2556510		
	Corrected Total	127	346.5767969			

The ANOVA Procedure table (4)

	Source	DF	Sum of Squares	Mean Square	F Value	F table (5%)
30th Day	Model	31	165.1686719	5.3280217	3.26	1.59
	Error	96	157.1075000	1.6365365		
	Corrected Total	127	322.2761719			

Appendix(3): Plants extract Antifeedant results data

Table(1) : BASIL antifeedant results

Table(1): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
BASIL 10th day	control	0.2	0.2	0.1	0.2	0.18	
	10%	0	0.1	0.1	0.1	0.08	30.8
	15%	0.1	0	0	0.1	0.05	21.7
	20%	0	0.1	0	0.1	0.05	21.7

Table(1): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
BASIL 20th day	control	0.1	0.1	0.2	0	0.1	
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(1): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
BASIL 30th day	control	0.2	0.1	0	0.3	0.15	
	10%	0.1	0	0	0	0.03	16.7
	15%	0	0	0.1	0	0.03	16.7
	20%	0	0	0	0.1	0.03	16.7

Table(2) HENNA antifeedant results

Table(2): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
HENNA 10th day	control	0.2	0.1	0	0.3	0.15	50
	10%	0.2	0.1	0.1	0	0.1	40
	15%	0	0	0.1	0	0.03	16.7
	20%	0	0	0	0	0	0

Table(2): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
HENNA 20th day	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0	0.2	0.1	0.1	0.1	35.7
	15%	0	0.1	0	0.1	0.05	21.7
	20%	0	0.1	0.1	0	0.05	21.7

Table(2): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
HENNA 30th day	control	0.1	0.1	0.2	0	0.1	
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(3) SENNA antifeedant results

Table(3): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
SENNA 10th day	control	0.2	0.1	0	0.3	0.15	50
	10%	0.1	0	0	0	0.03	16.7
	15%	0	0	0	0.1	0.03	16.7
	20%	0	0	0	0	0	0

Table(3): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
SENNA 20th day	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0.1	0.1	0	0.1	0.08	30.8
	15%	0	0.1	0.1	0.1	0.08	30.8
	20%	0.1	0	0.1	0.1	0.08	30.8

Table(3): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
SENNA 30 days	control	0.1	0.1	0.2	0	0.1	
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(4) LANTANA antifeedant results

Table(4): **I**

	Rep / conc	R1	R2	R3	R4	mean	PFI
LANTANA 10 days	control	0.2	0.1	0	0.3	0.15	50
	10%	0.1	0	0	0	0.03	16.7
	15%	0	0	0.1	0	0.03	16.7
	20%	0	0	0	0	0	0

Table(4): **II**

	Rep / conc	R1	R2	R3	R4	mean	PFI
LANTANA 20 days	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0	0	0.1	0.1	0.05	21.7
	15%	0.1	0	0	0.1	0.05	21.7
	20%	0	0.1	0.1	0	0.05	21.7

Table(4): **III**

	Rep / conc	R1	R2	R3	R4	mean	PFI
LANTANA 30 days	control	0.1	0.1	0.2	0	0.1	
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(5) DATURA antifeedant results

Table(5): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
DATURA 10 days	control	0.2	0.1	0	0.3	0.15	50
	10%	0	0.1	0	0	0.03	16.7
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(5): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
DATURA 20 days	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0.2	0	0.1	0.1	0.1	35.7
	15%	0	0.1	0	0.1	0.05	21.7
	20%	0.1	0	0.1	0	0.05	21.7

Table(5): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
DATURA 30 days	control	0.1	0.1	0.2	0	0.1	
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(6) USHER antifeedant results

Table(6): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
:USHER 10 days	control	0.2	0.1	0	0.3	0.15	50
	10%	0.1	0	0	0	0.03	16.7
	15%	0	0	0.1	0	0.03	16.7
	20%	0	0	0	0	0	0

Table(6): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
:USHER 20 days	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0.1	0.1	0.1	0.1	0.1	35.7
	15%	0.1	0.1	0.1	0	0.08	30.7
	20%	0.1	0	0.1	0.1	0.08	30.7

Table(6): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
:USHER 30 days	control	0.1	0.1	0.2	0	0.1	50
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(7) CHILI antifeedant results

Table(7): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
CHILI 10 days	control	0.2	0.1	0	0.3	0.15	50
	10%	0.1	0	0.1	0.1	0.08	34.8
	15%	0	0.1	0	0.1	0.05	25
	20%	0	0	0.1	0.1	0.05	25

Table(7): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
CHILI 20 days	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0.2	0.1	0.1	0.1	0.13	41.9
	15%	0	0.1	0.2	0.1	0.1	35.7
	20%	0	0	0	0	0	0

Table(7): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
CHILI 30 days	control	0.1	0.1	0.2	0	0.1	50
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(8) JATROPHA antifeedant results

Table(8): I

	Rep / conc	R1	R2	R3	R4	mean	PFI
JATROPHA 10 days	control	0.2	0.1	0	0.3	0.15	50
	10%	0.1	0	0	0	0.03	16.7
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Table(8): II

	Rep / conc	R1	R2	R3	R4	mean	PFI
JATROPHA 20 days	control	0.2	0.2	0.1	0.2	0.18	50
	10%	0.1	0	0.2	0.1	0.1	35.7
	15%	0.1	0.1	0	0	0.05	21.7
	20%	0	0.1	0	0.1	0.05	21.7

Table(8): III

	Rep / conc	R1	R2	R3	R4	mean	PFI
JATROPHA 30 days	control	0.1	0.1	0.2	0	0.1	50
	10%	0	0	0	0	0	0
	15%	0	0	0	0	0	0
	20%	0	0	0	0	0	0

Appendix(4) Weevil bioassay with plant materials

Table (1): Control results

CONTROL			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	176	1310	1486
R 2	122	1429	1551
R 3	125	1346	1471
R 4	195	1326	1521
Mean	154.5	1352.75	1507.25
% percent	10.25		

Table (2): Usher results

Table (2):I

Usher 10%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	72	1449	1521
R 2	107	1374	1481
R 3	106	1364	1480
R 4	111	1373	1484
Mean	99	1390	1491.5
% percent	6.74		

Table (2):II

Usher 20%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	136	1326	1462
R 2	95	1275	1370
R 3	43	1442	1485
R 4	91	1377	1468
Mean	91.25	1355	1446.25
% percent	6.31		

Table (2):III

Usher 30%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	85	1395	1480
R 2	108	1358	1466
R 3	61	1425	1486
R 4	97	1394	1491
Mean	87.75	1393	1480.75
% percent	5.93		

Table (3): Datura results

Table (3):I

Datura 10%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	57	1404	1461
R 2	43	1450	1493
R 3	72	1308	1380
R 4	56	1423	1479
Mean	57	1396.25	1453.25
% percent	3.92		

Table (3):II

Datura 20%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	71	1437	1508
R 2	40	1415	1455
R 3	53	1452	1505
R 4	57	1440	1497
Mean	55.25	1436	1491.25
% percent	3.70		

Table (3):III

Datura 30%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	50	1421	1471
R 2	46	1429	1475
R 3	57	1434	1491
R 4	45	1427	1472
Mean	49.5	1427.75	1477.25
% percent	3.35		

Table (4): Jatropha results

Table (4): I

Jatropha 10%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	141	1329	1470
R 2	146	1349	1495
R 3	130	1349	1479
R 4	90	1421	1511
Mean	126.75	1362	1488.75
% percent	8.51		

Table (4): II

Jatropha 20%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	107	1349	1456
R 2	79	1405	1484
R 3	118	1360	1478
R 4	112	1356	1468
Mean	104	1367.5	1471.5
% percent	7.07		

Table (4): III

Jatropha 30%			
	NO: of Perforated seeds	NO: of unperforated seeds	Total
R1	104	1374	1478
R 2	128	1349	1477
R 3	69	1335	1404
R 4	60	1407	1467
Mean	90.25	1366.25	1456.5
% percent	6.20		

Appendix(5):The effect plant mixtures powders of Usher & Jatropha on infestation of Khapra beetle larvae on Sorghum seeds

Table (1): The effect of comb A

Table (1):I

1st day----				
	R 1	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	0 (0.7)	0 (0.7)	10 (3.2)	3.3
20%	0 (0.7)	0 (0.7)	10 (3.2)	3.3

Table (1):II

----10 days-				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	10 (3.2)	3.3
15 %	0 (0.7)	10 (3.2)	10 (3.2)	6.7
20%	0 (0.7)	10 (3.2)	10 (3.2)	6.7

Table (1):III

---------- 20 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	20 (4.5)	10 (3.2)	20 (4.5)	16.7
15 %	20 (4.5)	30 (5.5)	20 (4.5)	23.3
20%	20 (4.5)	30 (5.5)	30 (5.5)	26.7

Table (1):IV

----------30 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	20 (4.5)	20 (4.5)	30 (5.5)	23.3
15 %	20 (4.5)	60 (7.8)	40 (6.4)	40.0
20%	40 (6.4)	40 (6.4)	60 (7.8)	46.7

Table (2): The effect of comb B

Table (2):I

1st day----				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	10 (3.2)	0 (0.7)	0 (0.7)	3.3
20%	0 (0.7)	0 (0.7)	10 (3.2)	3.3

Table (2):II

----10 days-				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	10 (3.2)	3.3
15 %	20 (4.5)	10 (3.2)	0 (0.7)	10.0
20%	20 (4.5)	10 (3.2)	20 (4.5)	16.7

Table (2):III

---------- 20 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	10 (3.2)	20 (4.5)	10.0
15 %	30 (5.5)	10 (3.2)	10 (3.2)	16.7
20%	30 (5.5)	30 (5.5)	30 (5.5)	30.0

Table (2):IV

----------30 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	20 (4.5)	20 (4.5)	30 (5.5)	23.3
15 %	40 (6.4)	20 (4.5)	30 (5.5)	30
20%	40 (6.4)	50 (7.1)	50 (7.1)	46.7

Table (3): The effect of comb C

Table (3): I

1st day----				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	0 (0.7)	0 (0.7)	0 (0.7)	0
20%	0 (0.7)	0 (0.7)	0 (0.7)	0

Table (3): II

----10 days-				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	10 (3.2)	10 (3.2)	6.7
15 %	20 (4.5)	0 (0.7)	0 (0.7)	6.7
20%	0 (0.7)	10 (3.2)	20 (4.5)	10

Table (3): III

---------- 20 days				
Cons / rep	R 1	R 2	R 3	Mean
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	10 (3.2)	20 (4.5)	13.3
15 %	20 (4.5)	20 (4.5)	10 (3.2)	16.6
20%	0 (0.7)	40 (6.4)	40 (6.4)	26.7

Table (3): IV

----------30 days				
Cons / rep	R 1	R 2	R 3	Mean
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	20 (4.5)	20 (4.5)	20 (4.5)	20.0
15 %	30 (5.5)	20 (4.5)	20 (4.5)	23.3
20%	20 (4.5)	50 (7.1)	50 (7.1)	40.0

Table (4): The effect of comb D

Table (4):I

1st day----				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	0 (0.7)	0 (0.7)	0 (0.7)	0
20%	0 (0.7)	0 (0.7)	0 (0.7)	0

Table (4):II

----10 days-				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	10 (3.2)	10 (3.2)	10
15 %	20 (4.5)	10 (3.2)	0 (0.7)	10
20%	10 (3.2)	10 (3.2)	10 (3.2)	10

Table (4):III

---------- 20 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	20 (4.5)	10 (3.2)	13.3
15 %	30 (5.5)	20 (4.5)	10 (3.2)	20.0
20%	30 (5.5)	10 (3.2)	20 (4.5)	20.0

Table (4):IV

----------30 days				
Cons / rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	10 (3.2)	20 (4.5)	40 (6.4)	23.3
15 %	40 (6.4)	40 (6.4)	20 (4.5)	33.3
20%	40 (6.4)	30 (5.5)	40 (6.4)	36.7

Table (5): The effect of comb E

Table (5):I

1st day----				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	0 (0.7)	0 (0.7)	0 (0.7)	0
20%	0 (0.7)	0 (0.7)	0 (0.7)	0

Table (5):II

----10 days-				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	0 (0.7)	10 (3.2)	6.7
15 %	10 (3.2)	10 (3.2)	0 (0.7)	6.7
20%	0 (0.7)	10 (3.2)	10 (3.2)	6.7

Table (5):III

---------- 20 days				
Cons / rep	R 1	R 2	R 3	Mean
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	10 (3.2)	20 (4.5)	13.3
15 %	10 (3.2)	20 (4.5)	10 (3.2)	13.3
20%	20 (4.5)	10 (3.2)	20 (4.5)	16.7

Table (5):IV

----------30 days				
Cons / rep	R 1	R 2	R 3	Mean
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	20 (4.5)	20 (4.5)	30 (5.5)	23.3
15 %	30 (5.5)	20 (4.5)	30 (5.5)	26.7
20%	40 (6.4)	20 (4.5)	40 (6.4)	33.3

Table (6): The effect of comb F

Table (6):I

1st day----				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	0 (0.7)	0 (0.7)	0 (0.7)	0
15 %	0 (0.7)	0 (0.7)	0 (0.7)	0
20%	0 (0.7)	0 (0.7)	0 (0.7)	0

Table (6):II

----10 days-				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	0 (0.7)	0 (0.7)	3.3
15 %	0 (0.7)	10 (3.2)	10 (3.2)	6.7
20%	10 (3.2)	0 (0.7)	10 (3.2)	6.7

Table (6):III

---------- 20 days				
	R 1	**R 2**	**R 3**	**Mean**
Control	0 (0.7)	0 (0.7)	0 (0.7)	0
10%	10 (3.2)	10 (3.2)	10 (3.2)	10
15 %	20 (4.5)	10 (3.2)	20 (4.5)	16.7
20%	20 (4.5)	10 (3.2)	20 (4.5)	16.7

Table (6):IV

----------30 days				
Cons rep	**R 1**	**R 2**	**R 3**	**Mean**
Control	10 (3.2)	0 (0.7)	0 (0.7)	3.3
10%	20 (4.5)	10 (3.2)	30 (5.5)	20.0
15 %	30 (5.5)	20 (4.5)	40 (6.4)	30.0
20%	30 (5.5)	20 (4.5)	40 (6.4)	30.0

Appendix(6):The effect plant mixtures powders of Usher & Jatropha

Table (1): The ANOVA Procedure(1st day)

	Source 1stb	DF	Sum of Squares	Mean Square	F Value
1st day	treatments	18	6.578947	0.365497	0.833333
	Error	38	16.66667	0.438596	
	Corrected Total	56	23.24561		

	Source 1stb	DF	Sum of Squares	Mean Square	F Value
10th day	treatments	18	29.58842	1.643801	0.791023
	Error	38	78.96667	2.07807	
	Corrected Total	56	108.5551		

Table (2): The ANOVA Procedure(10th day)

Table (3): The ANOVA Procedure(20th day)

	Source 1stb	DF	Sum of Squares	Mean Square	F Value
20th day	treatments	18	54.7814	3.043411	2.339192
	Error	38	49.44	1.301053	
	Corrected Total	56	104.2214		

Table (4): The ANOVA Procedure(30th day)

	Source 1stb	DF	Sum of Squares	Mean Square	F Value
30th day	treatments	18	73.98035	4.110019	4.138334
	Error	38	37.74	0.993158	
	Corrected Total	56	111.7204		