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Potency of Swietenia Macrophylla King and Pachyrhizus Erosus (L.) Seed Powder and Extracts Against Tribolium Castaneum (Herbst)

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POTENCY OF *SWIETENIA MACROPHYLLA* KING AND *PACHYRHIZUS EROSUS* (L.) SEED POWDER AND EXTRACTS AGAINST *TRIBOLIUM CASTANEUM* (HERBST)

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BY

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Dedication

To my

Grandmother

and

Parent

DECLARATION

I hereby declare that the research reported in this thesis entitled "POTENCY OF *SWIETENIA MACROPHYLLA* KING AND *PACHYRHIZUS EROSUS* (L.) SEED POWDER AND EXTRACTS AGAINST *TRIBOLIUM CASTANEUM* (HERBST)" submitted to the Institute of Biological Sciences, University of Rajshahi, for the degree of DOCTOR OF PHILOSOPHY was carried out by me under the supervision of Dr Md Saiful Islam Faruki, Professor, Department of Zoology (Supervisor) and Dr KAM Shahadat Hossain Mondal, Professor, Institute of Biological Sciences, University of Rajshahi (Co-supervisor). The thesis has not been currently submitted elsewhere for any other degree.

30.06.13

Md. Abul Hossain Mondal

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CERTIFICATE

This is to certify that Md. Abul Hossain Mondal carried out his research works under our supervision as a University Grand Commission (UGC) Ph D Research Fellow. We are pleased to forward his thesis entitled, "POTENCY OF *SWIETENIA MACROPHYLLA* KING AND *PACHYRHIZUS EROSUS* (L.) SEED POWDER AND EXTRACTS AGAINST *TRIBOLIUM CASTANEUM* (HERBST)" submitted for the degree of DOCTOR OF PHILOSOPHY. He carried out his research at the IPM and Toxicology Laboratory of the Institute of Biological Sciences, University of Rajshahi, Bangladesh, under our supervision. He has fulfilled all necessary requirements for submission of the thesis for the award of Ph D degree.

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The Author

male, female and unsexed adults of *T. castaneum* after exposure at 3, 5 and 7 days. Whereas the toxicity of methanol extracts of mahogany and kesur seeds were also evaluated against larvae and adults of the same stages after exposure at 5, 7 and 14 days. Both the plant seed extracts were effective in controlling both larvae and adults of *T. castaneum.*

The larvae and adults of *T. castaneum* were exposed to *S. macrophylla* and *P. erosus* seed powders treated food for detecting repellent effect. The 16 day old larvae were repelled significantly ($P<0.01$) after exposure to food treated with mahogany seed powder at 1 and 24h than 9 and 12 day old larvae. Similar repellent effect was also recorded on kesur seed powder. The highest repellency (93.30%) was recorded for 9 day old larvae exposed to mahogany seed powder treated food and 16 day old larvae for kesur seed powder treated food at 2% dose after 24h exposure. Both the plant powder had produced significant repellent effect on adults.

The chloroform seed extracts of mahogany showed significant ($P<0.05$) repellent effects on 9 and 12 days old larvae of *T. castaneum* after 1h exposure to treated filter paper. The methanol seed extracts had no repellent effects at any exposure periods and in any larval stages. The *S. macrophylla* seed extracts of chloroform and methanol similarly had no repellent effects on adults. The chloroform and methanol seed extracts of kesur had no significant repellent effects on larvae and adults of *T. castaneum* at any exposure periods.

The mahogany and kesur seed powders and extracts either alone or in combination on reproductive potential of *T. castaneum* were evaluated. The treatments significantly ($P<0.001$) reduced the number of eggs laid by females developed from treated foods and the fertility of the laid eggs.

The deformities in adults were noted from larvae after exposure to treated food, and from pupae after exposure to treated filter paper and treated food. All the treatments of mahogany and kesur seed powders and extracts either alone or in combinations significantly ($P<0.001$) produced adult deformities in *T. castaneum.*

The formation of larval, pupal and F1 adult progenies of *T. castaneum* were observed from adults released on treated food with different doses of mahogany and kesur seed powder separately. All the treatments of both plant seed powders significantly ($P<0.001$) suppressed the population. Similarly, the larval, pupal and adult populations of *T. castaneum* significantly ($P<0.001$) reduced by the effects of chloroform and methanol extracts of mahogany and kesur seeds. In the development of population, powder and extracts of kesur seeds were more effective than that of mahogany.

CONTENTS

Chapter 1

G E N E R A L
INTRODUCTION

Botanical Insecticides

Prospect of the botanicals

Plants used in this study

The Insect used for this study

T. castaneum as a stored grain pest

Life cycle of *T. castaneum*

Damage done by *T. castaneum*

Control measure

Disadvantages of synthetic chemical insecticides

Alternative pest management strategies

Background of the study

Aims of the research

Objectives of the research

Chapter 1

GENERAL INTRODUCTION

Botanical Insecticides

Botanical insecticides are insect killing chemical substances obtained from plants. These chemicals include an array of glycosides, alkaloids, saponins, tannins, essential oils, cyanogens, phenolics, amino acid analogs, non protein amino acids, proteinase inhibitors, cardiac glycosides, and other organic compounds, whose metabolic functions are presently obscure (Youngken 1950).

Prospect of the botanicals

Plants are considered to be the most potent to human beings not only because of their support for food and shelter, but also because they provide all the requirements for the survival of the civilization during the past few decades. The world advanced rapidly with remarkable development in pesticide technology and medicine, but there are still some problems especially for undesirable changes in gene pool for the presence of some mutagenic agents. So a question has arisen for sustainability and the survivability of the living beings on the planet with non-hazard environment. Hence, a worldwide interest has created in the revolution and use of age- old traditional botanical agents (Heyde *et al.* 1984).

Several insecticides have been tried to control the insect pests. Control by chemical insecticides are very effective, but indiscriminate use of chemical pesticides has given rise to many serious problems, including resistance by pest species, environmental pollution, threat to wild life, motivation by weather, hazards from handling etc, as mentioned earlier These hazards have created awareness to people and developed a worldwide interest for the use of botanical pest control agents as botanicals are comparatively safer to mammalian and higher animals (Feinstein, 1952).

In the rural areas of Bangladesh, farmers traditionally mixed leaves, bark, seeds, roots or oils of certain plants with stored grains to keep them free from insect attacks. Such techniques have been inherited as part of traditional culture (Saxena *et al.* 1989). Recently a number of investigators isolated, identified and screened chemical compounds from plants and reported the effective use of these materials as insecticides against stored grain pests (Ahmed *et al.* 1980, Khanom *et al.* 1990a,b; Khalequzzaman and Islam 1992a,b; Talukder and Howse 1994).

The plants synthesize and accumulate a complex array of extractable bioactive organic chemicals with specific stereochemistry called secondary metabolites (Balandrin and Klocke 1988, Harborne 1988), providing the richest source of economically important organic chemicals on earth (Grainge and Ahmed 1988) For example, a good secondary metabolite having a high degree of structural complexity is Azadirachtin. These economically important metabolites are normally obtained from plant materials by stem distillation or by extraction with organic or aqueous solvents (Balandrin and Klocke 1988). Secondary metabolites produced by the plants are used against insects, mites, pathogens and even weeds (Grainge and Ahmed 1988). Biochemists often refer to them as natural products (Geissman and Crout 1969) to distinguish them from synthetic products that are produced in the laboratory (Simmonds *et al.* 1992).

Extracts of plants have been used by humans for control of insects since before the time of the ancient Romans (Talukdar and Howse 1995). The interest in botanical pesticides revealed during the recent years because of some of the serious drawbacks of the synthetic insecticides including lack of selectively, impact on the environment and the emergence and spread of pesticides resistance (Grainge and Ahmed 1988, Su and Mulla 1998).

Botanicals are environmentally non pollutive, renewable, inexhaustible, indigenously available, easily acceptable, largely non phytotoxic, systemic epimeral, thus readily biodegradable, relatively cost effective and hence most suitable in the strategy of integrated pest management (Upadhyay *et al.*1996).

Plants used in this study
Taxon: *Swietenia macrophylla* King

Taxonomic Hierarchy

Kingdom	Plantae	–Plants
Subkingdom	Tracheobionta	–Vascular plants
Super division	Spermatophyta	–Seed plants
Division	Magnoliophyta	–Flowering plants
Class	Magnoliopsida	–Dicotyledons
Subclass	Rosidae	
Order	Sapindales	
Family	Meliaceae	-Mahogany family
Genus	*Swietenia* King	–Mahogany
Species	*Swietenia macrophylla* King	

Common names

Honduras mahogany	–	English
Mahogany	–	English
aguano	–	Portuguese (Brazil)
caóba	–	Portuguese (Brazil)
mogno	–	Portuguese (Brazil)
caoba	–	Spanish

Local name

- Bara Mahogini (Rahman 2009).

Synonyms

- *Swietenia candolei* Pittier
- *Swietenia krukovii* Gleason
- *Swietenia belizensis* Lundell
- *Swietenia macrophylla* King var. *marabaensis* Ledoux et Lobato
- *Swietenia tessmanii* Harms

(NPGS-GRIN.Taxon; MMPND-Sorting *Swietenia* names; Agro Forestry Tree Database)

Related species of interest

The genus consists of two other species, *S. mahagony* and *S. humilis.* The three species are poorly defined biologically, in part because they hybridize freely.

Distribution and habitat

Humid zone species of the new world, widely distributed, natural as well as cultivated; native to Mexico (Yucatan), Central and northern South America (Amazon region). Extensively planted mainly in southern Asia and the Pacific; also introduced into West Africa. In Bangladesh, this species is planted throughout the country (Gullison *et al.* 1996, Rahman 2009).

Uses

Mahogany is one of the most valuable furniture timbers in the world due to the decorative and attractive timber with good technical characteristics. It is widely planted in the tropics in reforestation and aforestation programmes. In agro forestry systems it is used for shade and fuel wood (Cottle 1959, Lyhr 1992, Soerianegara *et al.*1 993).

Botanical description

Usually evergreen tree, 30-35m long. Bark grey and smooth when young, turning dark brown, ridged and flaky when old. Leaves up to 35-50 cm long, alternate, glabrous, paripinnate; 4-6 pairs of leaflets, each leaflet 9-18 cm long. Flowers small and white, 10-20cm long, branching panicles (Alvenga *et al.*1988).

Fruit and seed description

Fruit: Dehiscent, usually 5-lobed capsule, erect, 12-5(-22)cm long, grayish brown, smooth or minutely verrucose. Outer valves woody, 5-7 mm thick, inner valves much thinner. In the centre is a woody, 5 angled columella extending to the apex. The fruits split open from apex or base when they are ripe and dry. Seeds are hanging from the columella by their wing, leaving conspicuous scars after their release. Usually 35-45 seeds per fruit.

Seed: brown, oblong, compressed, crested and extended into a wing at the attachment end, 7.5-15 cm long incl. wing with extensive air spaces. The seeds are dispersed by wind. There are1800-2500 seeds per kg (Nataniela *et al.* 1997).

Flowering and fruiting habit

Flowers are unisexual and the tree monocious. The flowers are pollinated by insects. Hybridization is frequent, especially with *S. mahagoni* where the species grow together. Usually only one flower of the inflorescence develops into a fruit, the others are aborted. Development from flower to mature fruit takes 9-12 months.

Phenology data are summarized here:

	Flowering	Fruiting
Central and northern S. America	April-June	Jan-March
Southern S. America	Sept-Oct	July-Aug
British Virgin Is. and Puerto Rico	May-June	Sept-Oct
Costa Rica	March-April	Dec-Jan
Solomon Islands		June-Sept
Philippines	March-June	Dec-March

(Pennington *et al.* 1992).

The long development time for the fruit makes crop assessment possible several months before harvest. Flowering usually takes place when trees are leafless or just coming into new leaf shortly before the rainy season.

Harvest

The fruits are preferably collected from the trees just before they split open or from the ground immediately after seed fall. Seed production varies according to site and year. A crucial factor for seed production is pollination efficiency, which may be erratic especially outside the natural range of distribution. A mature tree of *S. macrophylla* can produce up to 200 mature fruits in a year or about 4.8 kg of seeds. However, usually the production is only 2.5-4 kg per tree for trees with fairly exposed crowns (Nataniela *et al.* 1997).

Processing and handling

Mature dry fruits or dry seeds collected from the forest floor can be stored for some days in sacks without significant deterioration. However, in order to reduce bulk it is often preferable to initiate processing in the field. The fruits will split open when dried for 1-4 days, depending on maturity, after which the seeds are easily released by gentle shaking of the fruits. Fruit parts (valves and columella) are removed by hand. Further reduction of bulk by manual dewinging may be desired (Nataniela *et al.* 1997).

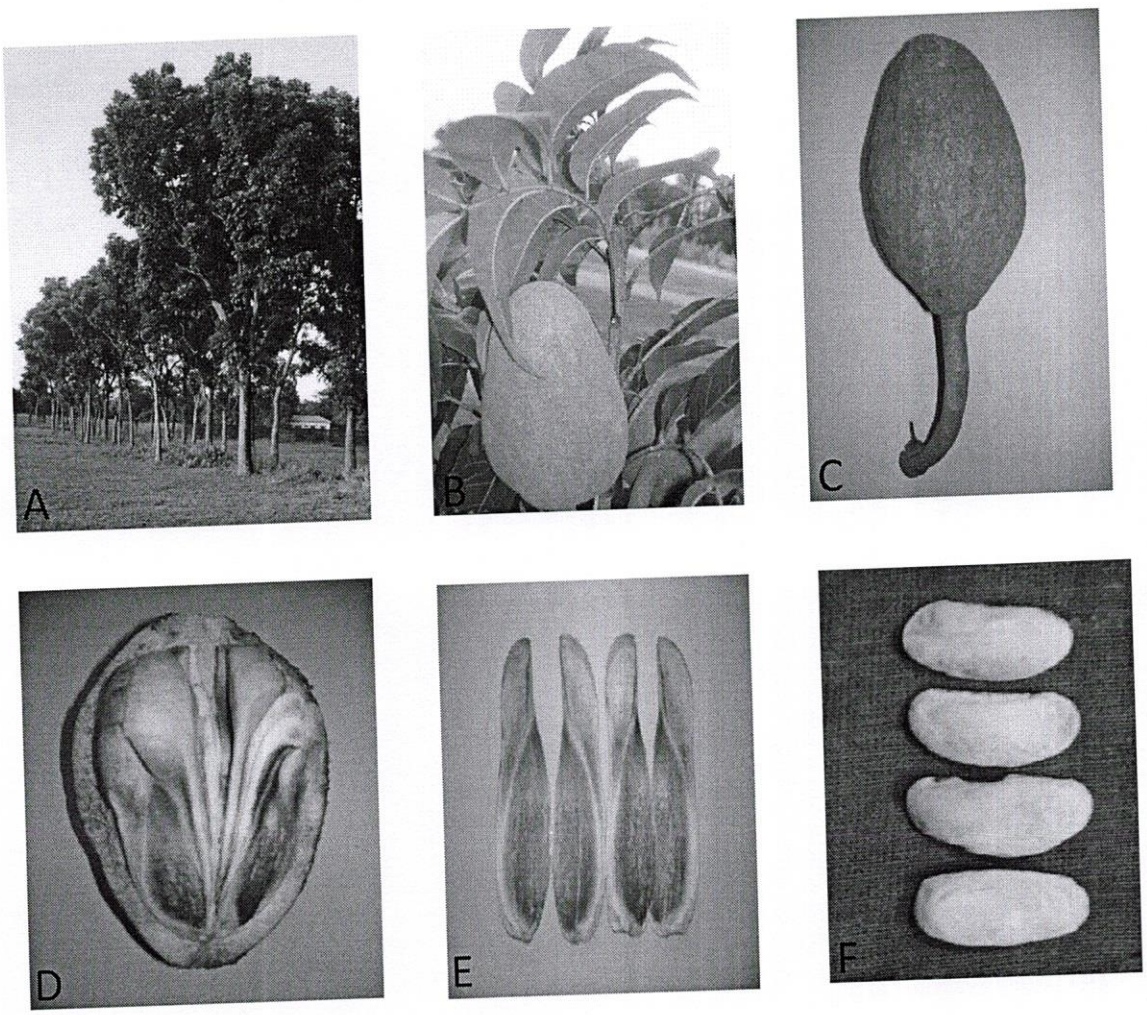


Plate 1. *S.macrophylla* tree with different parts; A-Mature trees, B-Branch with leaves and fruit, C-Fruit, D-Splited fruit, E-Winged seeds, F-seeds.

Storage and viability

Seed is orthodox and if stored at 3-7% moisture content at low temperatures (1-5°C), it will retain high viability for several years. If the seed is stored in paper bags at room temperature, 7-8 months storage can be expected without loss in viability. Initial moisture content in mature seeds is 9-12%. Germination percentage of fresh seeds is 60-90% (Nataniela *et al.* 1997).

Pretreatment

Pretreatment is generally not necessary but germination of seeds with low moisture content may be enhanced by soaking in water for 12 hours.

Sowing and germination

Under test conditions seeds are germinated in sand at fluctuating 35-30°C or constant 30°C and 12/12 for 8/16 hours light /dark. In the nursery, seeds are sown in a bed of light sand in 3-7 cm deep furrows or holes or directly in containers. Germinating seeds should be kept moist and under shade. Seeds will germinate in 10-21 days. The seedlings are kept under shade until out planting, which can take place when they are about 50-100 cm tall (Nataniela *et al.*1997).

Taxon: *Pachyrhizus erosus* (L.)

Taxonomic Hierarchy

Kingdom	Plantae	–Plants
Subkingdom	Tracheobionta	–Vascular plants
Super division	Spermatophyta	–Seed plants
Division	Magnoliophyta	–Flowering plants
Class	Magnoliopsida	–Dicotyledons
Subclass	Rosidae	
Order	Fabales	
Family	Fabaceae	–Pea family
Genus	*Pachyrhizus* Rich. ex. DC. *pachyrhizus*	
Species	*Pachyrhizus erosus* (L.). Yam bean	

Common names

Kesur	- Bengali
Yam bean	- English
patate cochon	- French
pois patate	- French
Yambohne	- German
mishrikand	- India
jícama	- Spanish

Local name

- Kesur, Shak-alu, Kesur-alu (Naderuzzaman 2009)

Synonyms

- *Cacara erosa* (L.)Kuntze
- *Cacara palmatiloba* (DC.)Kuntze
- *Dolichos erosus* L.(basionym)
- *Dolichos palmatilobus DC.*

- *Pachyrhizus angulatus* Rich. ex DC.
  Pachyrhizus bulbosus Kurz
- *Pachyrhizus erosus var. palmatilobus* (Moc. & Sessé ex DC.)R. T. Clausen
- *Pachyrhizus palmatilobus* (DC.) ined.
- *Pachyrhizus strigosus* R.T.Clausen

Botanical description

A twining, climbing or trailing herb, with a large tuber, root simple or lobed, turnip shaped with light brown skin and white flesh. Stem with tony hair .Leaves trifoliate, alternate leaflets ovate rhomboid, coarsely dentate or 5-lobed, stipules linear lanceolate 5-10mm long, stipels linear. Flowers an axillary racemes, 1-5 flowers born in dense clusters or short pedicels at each node of peduncle. Calyx 4 lobed, unequal. Corolla violet or white. Stamens diadelphous, anthers uniform. Ovary sub sessile. Styles ciliate, recurved, stigmas subglobose. Fruit a pot, flattened, finely strigose, constricted, 4-12 seeded. Seeds almost square shaped, flattened, yellow, brown or red.

Flowering and fruiting: October – January.

Chromosome number: 2n =22 (Fedorov 1969)

Habitat: Plain dry lands, also cultivated.

Distribution

Originated in Mexico and Central America, now cultivated in tropics. In Bangladesh, it was recorded from Chittagong and Dhaka districts (Naderuzzaman 2009)

Economic uses

The tubers are mostly consumed fresh in salads or lightly fried .Tubers is also eaten raw.

Ethno botanical information's

Immature pods are used locally in south East Asia as a vegetable. The ground seeds are used as an insecticide or as fish poison.

Propagation: By seeds (Naderuzzaman 2009)

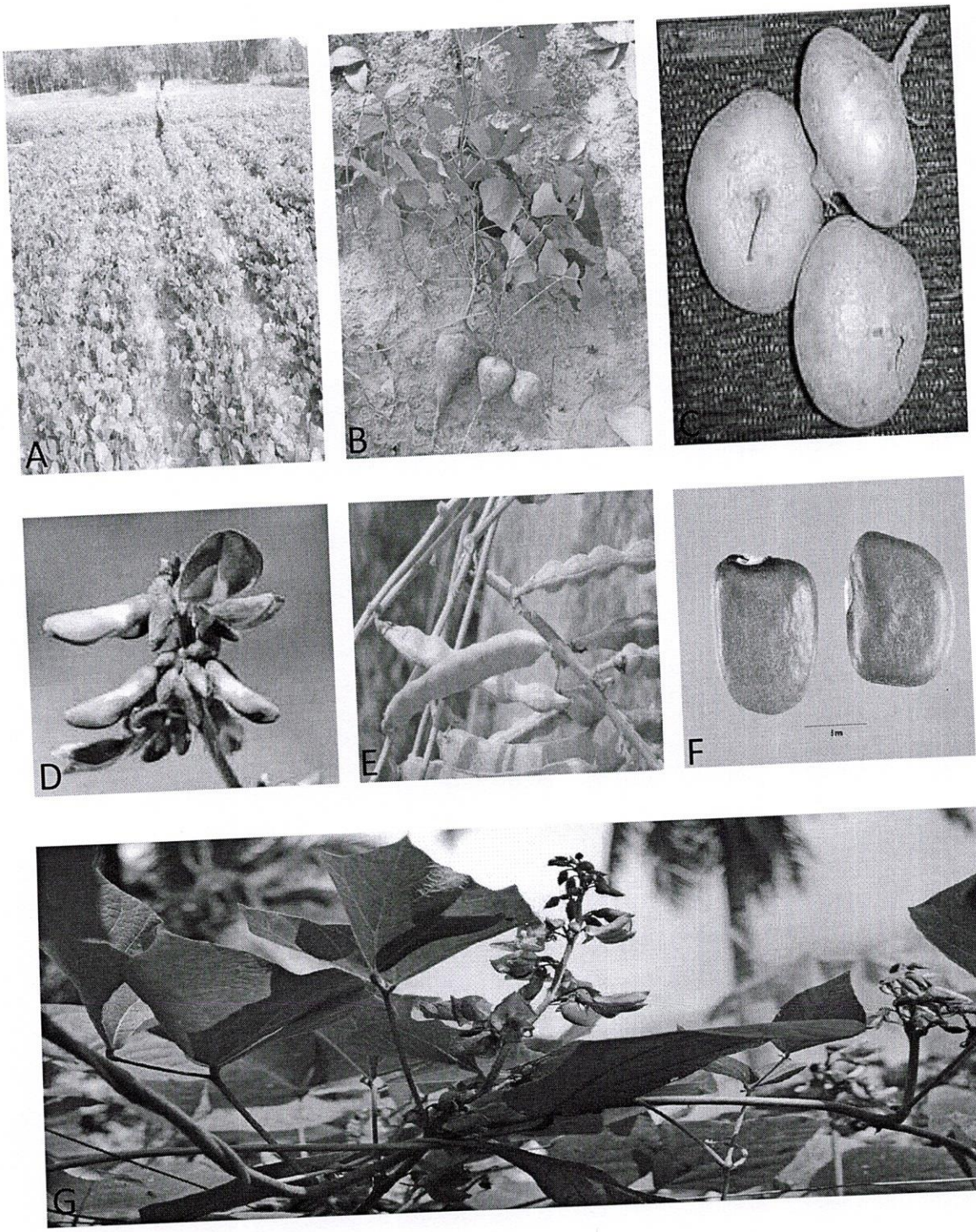


Plate 2.Cultivated field of *P. erosus* and its different parts; A-Cultivated field, B-Kesur-alu with stem, C-Kesur-alu, D-Flowers, E-Stem with bean, F-Seeds, G-Climbing stem with flowers.

The insect used for this study

Taxon: *Tribolium castaneum* (Herbst)

Taxonomic Hierarchy

Kingdom	Animalia (animals)
Eumetazoa	(metazoans)
Bilateria	(bilaterally symmetrical animals)
Protostomia	(protostomes)
Ecdysozoa	
Phylum	Arthropoda (crustaceans, insects,spiders and relatives)
Uniramia	
Subphylum	Hexapoda
Class	Insecta (insects)
Subclass	Pterygota (winged insects)
Superorder	Neoptera
Holometabola	
Order	Coleoptera (beetles)
Suborder	Polyphaga
Superfamily	Tenebrionoidea
Family	Tenebrionidae
Genus	*Tribolium*
Species	*Tribolium castaneum* Herbst

Synonyms

- *Colydium castaneum* Herbst
- *Dermestes navalis* Fabricius
- *Tenebrio castaneus* Schönhegr
- *Phaleria castanea* Gyllenhal
- *Uloma ferruginea* Dejann
- *Tribolium casteneum* MacLeay
- *Margus castaneus* Dejean
- *Stene ferruginea* Westwood
- *Tribolium ferrugineum* Wollaston

Common names

- Red flour beetle
- Rust red flour beetle
- Bran bugs

- Tribolium rouge de la farine, petit ver de la farine (France)
- Rotbraune reismehlkäfer (Germany)
- Tribolio castaneo, gorgojo castano de la harina (Spain)
- Chi Ni Gu Dao (China)

T. castaneum as a stored grain pest

Rust-red flour beetle, *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae) is a polyphagous and cosmopolitan pest. It is one of the most established insect pests of stored products. It is the most abundant and detrimental pest in flourmills, grain bulks, oilseeds and warehousing facilities (Zettler and Cuperus 1990, Zettler 1991). It feeds on those grains only, which have already been damaged by primary pests. Its presence in stored foods directly affects both the quantity and quality of the commodity (Mondal 1994). Insects may cause damage to the seed embryos, which results in decreased germination (Baier and Webster 1992).

A huge damage of food grains during storage due to various insect pests is a very serious problem. A large number of insects including many species of beetles and weevils are responsible for this damage. These insects have been reported to be associated with stored grains causing losses of the food intended for both human and animal consumption (Kabir *et al.* 1989). More than 2000 species of field and storage pests annually destroy approximately one third of world food production, valued about $100 billion among which highest losses (43 % of potential production) occur in developing Asian countries (Ahmed and Grainge 1986). In USA and Canada, 20-26 % of the stored wheat was infested by insect pests .In India losses caused by insects was 65 % of stored grains .More than 20 % losses may occur in tropical countries through insect attack after harvest (Alam 1971, Mondal 1994). In Bangladesh huge amount of food grains are damaged annually by insect pests (Alam 1971). Among these insect pests *T. castaneum* (Herbst) (Coleoptera: Tenebrionidae) is one of the most common and major pest occurring in situations where grain products are stored (Chittenden 1896). It is one of the annoying pests in retail grocery stores and warehouses and extremely serious in flour mills of the warmer parts of the world. *Tribolium* is a secondary serious pest and is worldwide in distribution due to the development of world trade (Good 1936, Pruthi and Singh 1950, Sokoloff 1974). It is not exactly known about the origin of their grain dwelling habit, but according to Wilber and Mills (1978) *Tribolium* beetles have been associated with stored grain at least since early Egyptian times. Specimens of *Tribolium* were found in Pharanoiac tomb of about 2500 B. C. when commerce was largely restricted to the Mediterranean region and Southern Asia (Andres 1931). *Tribolium* is thought to have originated in the wild state in wood in India. It was also found in North America and elsewhere but not at all commonly (Blair 1930). *Tribolium* originally

lived under the bark of trees and in rotting logs and later on, adopted the flour feeding habit (Good 1933, 1936).

T. castaneum is a colonizing species (Dawson 1977). Both larvae and adults exploit a wide variety of stored products, which contributed their status as major pests (Ziegler 1977). *T. castaneum* can survive on dry commodities particularly on milled cereals and animal feeds, but they do not multiply rapidly on dry cereal grains if these are undamaged and free of grain fragments (Cotton and Frankenfeld 1945). Later on, these beetles were originally herbivorous, feeding primarily on carbohydrates, fungi and other materials of plant origin (Good 1933, 1936). Like most other stored product beetles, *T. castaneum* cannot penetrate deeply into the stored commodity. Under natural conditions they can survive as scavengers or predators on social insects. There was a hypothesis that the cannibalistic habit of *Tribolium* originally were omnivorous, surviving in nature as scavengers or semi-predators (Muller and Sokoloff 1982). Cannibalism and predation play an important role in nutrition of *T. castaneum*. The eggs and pupae are often cannibalized by the adults, the males showing a preference for pupae and the females for eggs. *Tribolium* larvae and adults are highly efficient cannibals of eggs and pupae (Ryan and Park 1970, Mondal and Akhtar 1989).

The red flour beetle *T. castaneum* feeds on cereal and cereal products of all kinds and other food stuffs, including cracked grain, whole wheat flour, bran, rice flour, cornmeal, barley flour, oatmeal (Chittenden 1996, 1997). They also feed on beans, dried fruits, nuts, chocolate, peppers, peas, oilseeds, coffee, cocoa, semolina and specimen in insect collection (Good 1933). Some cereal products are more infested than others (Chapman 1918, Shepard 1940, Magis 1954). They are found in great numbers on infested material and caused serious loss and considerable damage to flour and grains that have previously been attacked by other pests, e.g. weevils. Much of the damage done by *T. castaneum* is directly to the kernels (germ and endoplasm). The entire life cycle of *Tribolium* is passed within its original environment (Park 1934a,b). The beetles are unable to feed on whole cereal grains because their mouthparts are not adapted for attacking large hard pieces of food. Hence, they are secondary pests of cereal grains, having a preference for the embryo (Chapman, 1931). Heavy infestations of the *Tribolium* beetles occur in dust consisting of flour, broken kernels and excreta (Khan and Mannan 1991). The germination of stored grain seeds is also impaired or destroyed by the activities of *Tribolium* beetles. Moreover, the infestation of stored wheat by *Tribolium* causes significant increases in fat acidity, which also decreases seed germination .The degree of damage to grains depends on many factors such as temperature, relative humidity, grain sample and insect's species (Adams 1977).

Life cycle of *T. castaneum*

Among stored product insects *Tribolium*'s life span is very long. Generally, it ranges from three months to a year and eight months, but it may be over three years (Good 1936). The long life span and long reproductive period enable *Tribolium* spp. to spend a considerable period searching for new food sources (Dawson 1977). *T. castaneum* possesses in its life-cycle egg, larvae, pupae and adult stage (Good 1936)

The egg is white and translucent, surface is sticky, so that particles of flour remain adhere to it. It is always covered with foreign matter. The incubation period of the eggs is 4 to 5 days (Brindley 1930).

The eggs hatch into small and white larvae. The general colour is yellowish-white which measure, 1.18 mm in length and 0.18 mm across the head capsule. The first instar larval weight is 0.028mg (Brindley 1930). For a short time before each moulting, the larva is inactive and body is large in proportion to the head. The skin splits dorsally over the head and thorax and the larva emerges. It is at first white like. But after 24 hours it takes a yellowish colour. Immediately after moulting, when the larva has expanded as a result of being freed from the old skin, it has often been observed to remain quiet for a time (Chapman 1918).

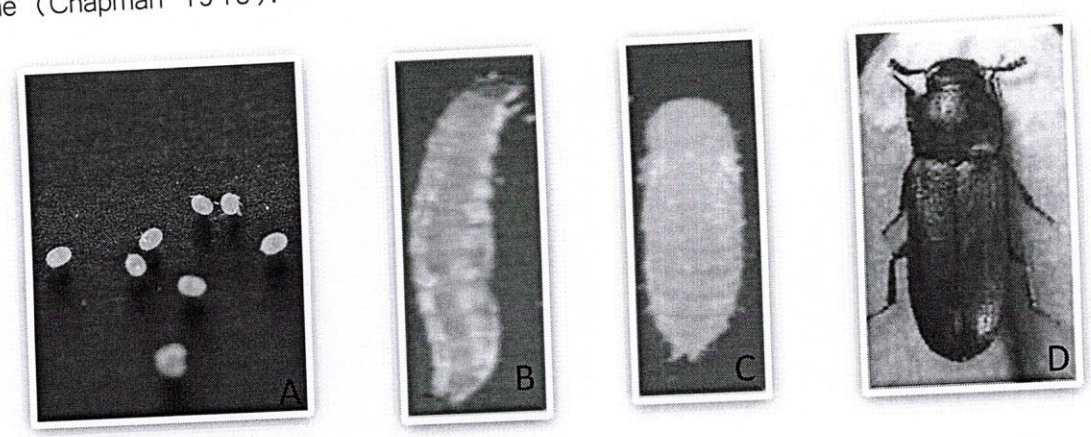


Plate 3. Different stages of life cycle of *T. castaneum*; A-eggs, B-larvae, C-pupae, and D-adult.

T. castaneum posses six larval instars in their development (Chapman 1918, Brindley 1930, and Mondal 1983). There is no fixed number of larval moult, but the number ranges from 6 to 11 or more. This variation is due to both external conditions, such as food, temperature and humidity and also to individual characteristics entirely apart from external influences (Mondal 1984a).

The larvae gradually increase in size with every moult. As the time for pupation advances the last instar larvae become more and more quiescent and contracted and finally pupate. The larval period is 16-18 days.

The pupae of *Tribolium* are naked and with the occasional exception of a slight abdominal movement, they are inactive. They are whitish-yellow when first formed but turn yellowish with age, being brown at the time of emergence of adult (Brindley 1930).The pupae have a mean length of 3.46 mm, and a width of 1.12 mm. There is a tendency for the female pupae to be longer than the male. The pupal condition is the time of determining the sex of the beetles. The only reliable external sexual characteristic for any stage is found in the pupal stage. When the ventral posterior ends of the male and female pupae are examined under microscope this sexual distinction is observed. On the terminal segment the female has a pair of small appendages, which are reduced to indistinct elevations in the male (Halstead 1963).

Immediately after emergence the chitinous exoskeleton of the adult beetle is soft; the new adults are inactive and are light brown in colour. In one or two days, the beetles have assumed the typical redish-brown colour with the exoskeleton quite hard. The very old *Tribolium* adults are nearly black. There seems to be quite consistent tendency for the females to be larger than the males but there are enough exceptions to this fact to prevent the size of the adults from being used as a reliable criterion of sex (Yeasmin 2002).

Chapman (1918) pointed out that the last larval instar was more influenced by ecological changes, with respect to its duration, than any other developmental stages. The average length of time required for the completion of a *Tribolium* life cycle at optimum of temperature (30°), humidity (70%) and food is 30 days (Brindley 1930, Goody 1933). The cycle becomes longer as the temperature lowers. The larvae and pupae do not seem so able to withstand low temperatures, as do the adults. *Tribolium* adults die in a few weeks if subjected to a temperature as low as 7°C (Chapman 1931).

The freshly emerged males and females copulate on an average of 2 days after their emergence. A female *Tribolium* normally lays 400 to 500 eggs, and 90 percent of these eggs hatch (Good 1933).

The number of eggs laid per day is not large. In no case more than 13 viable eggs are laid in one day by a single female, and the average was only 2 or 3 per day under optimum condition (Good 1933). Brindley (1930) recorded 18 eggs in one day. Oviposition is affected by certain environmental factors such as flour, humidity (Holdaway 1932), temperature, conditioning of flour by beetles living in it (Park 1934a,b; Mondal 1983) as well as population density relationships (Mondal 1984).

Damage done by *T. castaneum*

The beetles contaminate more than they consume (Khan and Mannan 1991). A few beetles are enough to contaminate the flour medium. Their feeding and metabolic activities alter the colour of the flour into pinkish, giving a persistent and disagreeable odour. This also adversely affects the viscous and elastic properties of the flour creating a taint (Payne 1925, Mondal 1983, Engelhardt *et al.* 1965), making it unsuitable for human consumption (Mondal 1992). It may cause gastric disturbance if used as food (Payne 1925) and the flour is said to be conditioned (Park 1934b).

According to Khan and Mannan (1991) both adults and larvae contaminate more than they consume and the contamination involves a) the presence of living or dead insects or insect pests; b) cast exuviae, egg shells and pupal cases; faecal matter, and finally c) noxious and persistent odours and webbing of food (Ghent 1963, Mondal 1983 1985).

The most important factor to contaminate the flour medium is accumulation of quinones (Good 1936, Roth 1943, Mondal 1985, 1992) given off by adult *Tribolium.* The beetles possess a pair of well developed odoriferous glands located one pair in the prothorax and other in the abdomen of both sexes from which quinones are secreted (Sokoloff 1974). Many *Tribolium* species produce quinones but the amount varies depending on species (Mondal 1992, 1994). Quinone secretion in insects including *Tribolium* has been reviewed by Roth and Eisner 1962, Weatherston and Percy 1970, and Mondal 1992. In storage, flour is mainly conditioned by these quinones (Ghent 1963). Quinine secretions of *Tribolium* were analysed by many workers (Alexander and Barton 1943, Hackman *et al.* 1948, Loconti and Roth 1953, Engelhardt *et al.* 1965, Ladisch *et al.* 1967a, Tschinkel 1975, Markarian *et al.* 1978). The secretion comprises of mainly ethylquinone and methylquinone (Alexender and Barton1943). In addition to these compounds, methylhydroquinone also occur in quinine (Hackman *et al.* 1948). The quinone consists of 80-90 % ethylquinone; 10-20 % methylquinone and a trace of other components (Loconti and Roth 1953, Markarian *et al.* 1978). Suzuki *et al.* (1975) first identified seven unsaturated hydrocarbons from the quinones of flour beetles. These are 1-pentadecene; 1-heptadecene; 1,8-heptadecadiene, 1-tetradecene; 1,6-pentadecadiene heptadecatriene and 1-hexadecene. These hydrocarbons act as defensive compounds (Alexander and Barton 1943, Loconti and Roth 1953, Roth and Eisner 1962, Tschinkel 1969, 1975). A colourless oil, identified as 1-pentadecene was reported in different species of *Tribolium* (Loconti and Roth 1953, VonEndt and Wheeler 1971, Keville and Kannowski 1975, Tschinkel 1975). The odoriferous gland contains 12.4 to 76.0 microgram of quinones with an average of 39.5 microgram per

beetle (Sokoloff 1974). The quinones including other hydrocarbons are highly reactive and are both acutely toxic, allergenic and even carcinogenic to human beings (Ladisch *et al.* 1967b). Poisoning by hydroquinone - quinone systems in man also causes jaundice, anemia, haemoglobinuria and cachexia. Toxicity may also cause respiratory depression, skin blanching and cyanosis before death in mammals. Respiratory impairment may be due to inadequate blood oxygen .The quinone vapor from the heavily infested and contaminated medium is also irritating to man causing gastric disorders (Park 1934a). It smells like an aldehyde, irritating the mucous membrane of the nose. In high concentration it also irritates the eyes (Chapman 1926).

Tribolium adults are also well known for their pheromone secretion (Butler 1970). The male adults produce aggregation pheromone (Burkholder 1982, Mondal 1985) and females produce sex pheromone (O'Ceallachain and Ryan 1977). Kevill and Kannowski (1975) first reported the presence of pheromone in *Tribolium.* Seven unsaturated hydrocarbones in *T. castaneum* and *T. confusum* having repellent activities were reported by Suzuki *et al.* (1975) and they categorized as alarm pheromones. The aggregation pheromone has been identified as 4.8- dimethyldecanal in *T. castaneum* and *T. confusum* by Suzuki (1980, 1981a,b). This aggregation pheromone is called **Tribolure** (Suzuki *et al.* 1987). Ryan and Ceallachain (1976) reported presence of two types of pheromones in *T. confusum.* The first one produced by the male is attractive to both sexes (Shorey 1976) and the second one produced by the female is attractive only to males (Butler 1970). There are cross responses of *Tribolium* to their pheromones (Faustini *et al.* 1982, Suzuki *et al.* 1987, Mondal 1993). It is noticeable that *T. freemania* more closely related species to *T. castaneum* than *T. confusum* did not respond to pheromone secreted by *T. castaneum* but was attracted to that secreted by *T. confusum* (Suzuki *et al.* 1987). *Tribolium brevicornis* was highly attracted to *T. castaneum* and *T. confusum* but the latter two species did not respond to *T. brevicornis* (Faustini *et al.* 1982).

Control measure

Because of the great economic importance of *Tribolium* spp., many studies on these pests have been dealt with its control (Dyte and Rowlands 1967, 1970; Dyte 1970, Khan 1981, Ali *et al.*1983, Mondal and Port 1984, Mondal 1984a, 1985, 1986; Mukherjen and Ramachandran 1989, Saleem and Shakoori 1990, Rajendran 1990, Khalequzzaman and Islam 1992, Husain 1995a,b and Husain *et al.* 1995). Except chemical pesticides no other control method has been established in Bangladesh so far. Millions of tons of pesticides are being used annually (Ameen 1994). In Bangladesh, a total of 7.35 metric tons of pesticides was imported under 112 trade names that valued of Taka 10 crores

during 1992. Since then the use of pesticides has been increased and in 1993 nearly 10000 metric tons pesticides were sold to the farmers. In 1994 more than 100 categories of pesticides were registered and marketed by different companies (Yeasmin 2002).

In Bangladesh, *T. castaneum* and *T. confusum* are abundantly found associated with stored grain of different cereals (Alam 1971). It is available in almost every kind of stored grains and their products. Many workers in many countries widely used locally available plant materials to protect stored products against insect pests, including *Tribolium* species (Jotwani and Sircar 1965).

Disadvantages of synthetic chemical insecticides

The resistance to the insecticides in stored grains pests was first reported when flour beetle, *Tribolium castaneum* (Herbst) was found resistant to DDT and malathion (Bhatia *et al.* 1971). Later, lindane resistance in this insect was reported from Moharastro, Rajisthan, Uttar Prodesh and Panjab (Champ and Dye 1976).

In agricultural pests the resistance was first reported in Singara beetle (*Galerucella birmanica* Jacoby) in 1963, and since then many pests have already developed resistance. The most promising approach to contain this malady is integrated pest management (IPM), which includes the use of environment friendly chemical control measures. In order to ensure long-term effectiveness and to provide guidelines for judicious use of all classes of insecticides, sound resistance management strategies are needed (Forrester 1990). Regular monitoring of key insect pests for resistance to synthetic pyrethroids and other widely used pesticides must be undertaken. As a result of the development of resistance in insects, higher doses of pesticides are applied which ultimately leads to increase environmental pollution and effect on wild life, honey bees, soil properties, non target species and food chain (Upadhyay *et al.* 1996).

Synthetic chemical insecticides which have been widely used all over the world during the past few decades to control pests are chlorinated hydrocarbons, organophosphate compounds, carbamates, pyrethroids, etc (Busvine 1971, WHO 1984, Kumar 1986, Lim and Visvalingam 1990, Setakana and Tan 1991). The most commonly used insecticides are DDT, dieldrin, lindane, chlordane, heptachlor, malathion, dibrom, fenithion, parathion, dichlovos, ENP, and sevin (WHO 1984,1992,1995).

All insecticides are poisons, and the degree of toxicity varies greatly among them. Insecticide's mode of actions involves all the anatomical, physiological and biochemical response to the chemical. Moreover, the fat present in the organism also undergoes reaction with the treated chemicals. All insecticides block metabolic

processes in insects, but this is done in different ways by different compounds. According to their mode of action, the major groups of the most frequently used insecticides are (i) nerve poison, (ii) muscle poison (iii) physical toxicants or poisons (Pedigo 1996).

Control of insect pests by chemical pesticides has serious drawbacks including insects resistance to chemical pesticides, outbreak of secondary pests, adverse effects on the non-target organisms, pesticide residues, hazards to environment (Smith 1970), elimination of economically beneficial insects and several predators (Smith and Von de Bosch 1967), toxicity to human beings and wildlife and finally, higher cost of production or application (Khan and Mannan 1991).

Alternative pest management strategies

To alleviate pest problems in storage, synthetic pesticides are generally recommended. But the indiscriminate use of synthetic pesticides poses a serious threat to man, wild life and their environment as mentioned earlier. Hence, there is a worldwide interest in the development of alternative strategies including the use of new types of insecticides derived from a re-evaluation of age-old, traditional pest control agents. Such chemical substances may be toxic to insects in varying degrees and are therefore of potential selective advantages in deterring those enemies (Fraenkel and Stem 1951).

In order to minimize over dependence on pesticides in crop protection and to avoid harmful effects on man and ecosystem, different countries have adopted IPM program with emphasis on (i) regular pest surveillance for need based and timely application of selective and safer pesticide instead of calendar based prophylactic measures using broad spectrum pesticides, (ii) conservation and augmentation of beneficial species such as parasites, predators and pathogens, (iii) promotion of improved cultural practice, including use of tolerant/resistant varieties, (iv)use of non-chemical methods of pest control, (v)use of botanical and biopesticides, (vi)training and extension field functionaries and farmers and (viii) IPM demonstration at the farmers fields (Upadhyay *et al.* 1996).

Back ground of the study

Prior to the commencement of this study, a baseline survey was conducted among the farmers, seed sellers, websites and in the seminar library of the Institute of Biological Sciences, University of Rajshahi, Bangladesh to obtain information on plants used for the protection of stored grains against insect pest attack; especially *Tribolium castaneum*. Information gathered from these sources was augmented with that found in the literature and the following plants seed were found to be the commonest and most frequently used for protection against insect attacks; *S. macrophylla and P. erosus.*

To planning the research considered the following aspects –

Characteristics of botanical insecticides

- Plant-derived insecticides consists of a mixture of biologically active compounds
- Insects develop resistance slowly
- Can be broad-spectrum in activity
- Safe to use, unique in the mode of action and easy to process and apply
- Less or non-toxic to higher animals and the environment
- Easily can be produced by farmers
- More selective and biodegradable

Characteristics of conventional pesticides

- Developed genetic resistance to insect species,
- Toxic residues in the grains, handling hazards, health hazards to operatives
- Direct toxic to non-target organisms
- Concentrated in food chains.
- More expensive
- More toxic to higher animals and environment

At this context possible alternative strategies may be-

- Need effective, biodegradable pesticides with greater selectivity
- Pest management systems might be economic, eco-friendly and sustainable

Considering the above alternative pest management strategies the present research topic has been planned to find out the –

"Potency of *S. macrophylla* and *P. erosus* seeds against *T. castaneum* (Herbst)," if any.

Aims of the research

- To reduce the environmental pollution and health risks associated with use of conventional pesticides.
- Research objectives will be achieved in a sustainable manner by developing eco-friendly botanical pesticides.
- To develop cost effective and sustainable storage pest control strategies through botanical pesticides.
- To understand the modes of action of the active components of the following test plant seed powders and extracts which may improve grain storage practice upon stored product pest.

Objectives of the research

The overall aims of this research were to evaluate the potency of essential seed powder and extracts of *S. macrophylla and P. erosus* against *T. castaneum*; a pest of stored grains, while the specific objectives were-

- Toxicity of *S. macrophylla* and *P. erosus* seed powders and extracts against *T. castaneum*
- Behavioral response of *T. castaneum* to *S. macrophylla* and *P. erosus* seed powders and extracts
- Potency of *S. macrophylla* and *P. erosus* seed powders and extracts on fecundity of *T. castaneum*
- Potency of *S. macrophylla* and *P. erosus* seed powders and extracts on fertility of *T. castaneum*
- Potency of *S. macrophylla* and *P. erosus* seed powders and extracts on deformities of *T. castaneum*
- Potency of *S. macrophylla* and *P. erosus* seed powders and extracts on the development of *T. castaneum* population

Chapter 2

REVIEW OF LITERATURE

Global Food security and safe management

Insecticide resistance in stored product pests

Alternative strategies for stored products pest management

Traditional uses of potential plant products

Bio-potential plant products

Bio-potency of *S. macrophylla*

Bio-potency of *P.erosus*

Chapter 2

REVIEW OF LITERATURE

Global food security and safe management

Food security and safety are the vital issues, wanting focus to deal, adequately, with the global food requirements in future. Ample production, proper processing, safe packaging/storage, appropriate distribution, judicious supply and rational consumption are the main components of the food security programs. In the post-harvest system of the perishable and semi-perishable food, pest insects play a major role as destructive agents, deteriorating its quantity and excellence, whose efficient and safe management is compulsory to achieve the food security targets (Ashfaq *et al.* 2001)

Conservation of reserve food grain stocks is necessary to ensure a continuous supply at stable prices (Talukder 2005). Losses due to insect infestation are the most serious problem in grain storage, particularly in the developing countries, where poor sanitation and use of inappropriate storage facilities all encourage insect attack (Talukder *et al.* 2004, Talukder 2005). It was estimated that more than 20,000 species of field and storage pests destroy approximately one-third of the world's food production, valued annually at more than $100 billion, among which the highest losses (43% of potential production) occur in developing Asian and African countries (Jacobson 1982, Ahmed and Grainge 1986). In the USA and Canada, 20-26% of stored wheat was infested by stored-product pests (White *et al.* 1985). In India, losses caused by insects accounted for 6.5% of stored grains (Raju 1984). In tropical countries, grain harvested at high ambient temperatures and delivered into storage loses heat only slowly and hence provides ideal conditions for a rapid build-up of many grain insects (Wallbank and Greening 1976). The efficient control and removal of stored grain pests from food commodities has long been the goal of entomologists throughout the world. Synthetic pesticides are the major tools for crop protection in developed countries. However, considerable problems including genetic resistance of insect species, toxic residues in the grains, handling hazards, health hazards to operatives and pest resurgence (Schoonhoven 1982, Sharaby 1988, Chiu 1989, Rembold 1989, Shaaya *et al.* 1997)may arise from the continued application of these insecticides. These problems lead to rapidly rising application and marketing costs. Continuous and heavy usage of synthetic insecticides results in direct toxicity to non-target

organisms such as beneficial parasites, predators and others. Certain chemicals may also be concentrated in food chains. Therefore, it may be worthwhile to seek insecticide supplements of natural origin (Owusu 2001, Talukder and Miyata 2002).

The search for more selective and biodegradable insecticides is a promising field within stored-product pest management strategies. The azadirachtin isolated from the neem tree, *Azadirachta indica,* hold particular promise as insecticides of botanical origin. They have no known mammalian toxicity, act at low concentrations and are easily biodegradable (Freedman *et al.* 1979). Tissues of higher plants contain arrays of biochemicals that are thought to be defensive in function. They include alkaloids, steroids, phenolics, saponins, resins, essential oils, various organic acids and other compounds (Beck and Schoonhoven 1980, Jacobson 1990). Because of their metabolic roles in the plant were mainly obscure, they are generally known as "secondary plant chemicals" or "allelochemics" produced as metabolic by-products with possible defense functions. It is well known that secondary plant metabolites may act as kairomones, allomones, stimulants or deterrents of feeding and oviposition, and as antifeedants, insecticides and insect hormone mimics (Nawrot *et al.* 1986). During last three decades, many plant allelochemicals including nicotine, pyrethrins, azadirachtin and rotenoids have been isolated, characterized and developed as commercial insecticides (Berenbaum 1989). Some plant-derived insecticides consist of a mixture of biologically active compounds and hence insects are not exposed to the same selection pressure as with conventional insecticides and develop resistance slowly (Chiu 1989).

Insecticide resistance in stored product pests

The incidence of insecticide resistance is a growing problem in stored product protection. Resistance to one or more insecticides has been reported in at least 500 species of insects and mites (Georghiou 1990). Champ (1985) reported that resistance to pesticides used to protect grain and other stored foodstuffs is widespread and involves all groups of pesticides and most of the important pests. The development of cross- and multi-resistant strains in many important insect species is a serious concern all over the world (Dyte and Halliday 1985, Zettler and Cuperus 1990, Chaudhry 1997). Insecticide resistance problem in different stored-grain insects were reported from different countries including the Australia, United States, United Kingdom, Germany, India, Pakistan, Philippines, Taiwan, Morocco and others (Dyte and Halliday 1985, Prickett 1987, Rassman 1988, Irshad and Jilani 1989, Zettler and Cuperus 1990, Sayaboc *et al.* 1992, Yao and Lo 1995, Benhalima *et al.* 2004). Stored products insect pests were found to be resistant against different insecticides including the cyclodienes, bioresmethrin, carbamates, carbaryl, chlorpyrifos-methyl, cyanophos, cyfluthrin, cyhalothrin,

cypermethrin, DDT, deltamethrin, diazinon, dichlorvos, ethylenedibromide, fenitrothion, lindane, malathion, methylbromide, organophosphates, permethrin, phosphine, phoxim, pirimiphosmethyl, promecarb, propoxur, pyrethrins, temephos and tetrachlorvinphos (DARP 2003). The resistance of certain stored product pests to widely used food industry pesticides has reached the highest levels ever recorded in the USA (Fehrenbach 1991). In another example, malathion resistance in stored product insect pests was reported from all over the world and currently, there are 122 insect pest species, which are found as resistant to this insecticide (DARP 2003). Fumigation is still one of the most effective method for the prevention of stored product losses from insect-pests, but stored product insects were showing a slow upsurge in fumigation resistance (Donahaye 2000). Widespread resistance to phosphine has emerged in several species of stored-product insects in many countries, which in some instances may have caused control failures (Chaudhry 1997). Benhalima *et al.* (2004) investigated the phosphine resistance status of insect pests in Morocco and found that, with the exception of one population of *S. oryzae,* all samples tested contained phosphine-resistant individuals. The rapid spread of resistant strains through international trade is indicative of a problem likely to occur with other stored-product pests (Dyte 1970). As for example, White and Watters (1984) reported that malathion-resistant stored grain insects enter Canada primarily through international trade.

Alternative strategies for stored products pest management

The increasing serious problems of resistance to pesticides and of contamination of biosphere associated with the large scale use of broad spectrum synthetic pesticides have directed the need for effective, biodegradable pesticides with greater selectivity. This awareness has created a worldwide interest in the development of alternative strategies, including the discovery of new types of insecticides (Heyde *et al.* 1994). However, new insecticides will have to meet entirely different standards. They must be pest specific, non-toxic to mammals, biodegradable, less prone to pest resistance, and relatively less expensive (Hermawan *et al.* 1997). This has led to re-examination of the century-old practices of protecting stored products using plant derivatives, which have been known to resist insect attack (Talukder and Howse 1995, Ewete *et al.* 1996). Plant-derived materials are more readily biodegradable, less likely to contaminate the environment and less toxic to mammals. Therefore, today, researchers are seeking new classes of naturally occurring pesticides that might be compatible with newer pest control approaches (Talukder and Howse 1995, Shaaya *et al.* 1997, Talukder and Miyata 2002). Talukder *et al.* (2004) reported that potential use of bioactive plant materials in storage pest management systems might be economic and environmentally friendly. The manipulation of natural product chemicals, such as insect attractants, repellents,

stimulants, antifeedants and arrestants, which are normally encountered by insects, may fulfill the required criteria.

Traditional uses of potential plant products

Since the dawn of human history, they tried to protect their harvest produce against arthropod pests. The Egyptian farmers used to mix the stored grain with fire ashes (Abdel-Gawaad and Khatab 1985). The ancient Romans used false hellebore *(Veratrum album)* as a rodenticide, and the Chinese are credited with discovering the insecticidal properties of *Derris* species. Pyrethrum was used as an insecticide in Persia and Dalmatia, and tobacco plant preparations have been similarly used for nearly 2 centuries (Ahmed and Grainge 1986). In many areas of the world, locally available plants are currently in wide use to protect stored products against damage caused by insect infestation (Hassanali and Lwande 1989). Indo-Pakistani farmers use neem leaves for the control of stored grain pests; while various Nigerian tribes use roots, stems and leaves of plants (Giles 1964, Jotwani and Sircar 1965, Girish and Jain 1974, Ahmed and Koppel 1985, Ahmed and Grainge 1986). The farmers of Togo protect harvested cowpeas by adding a mixture of sand and plants or ashes and ground paprika (Zehrer 1984). In northern Cameroon, cowpeas are traditionally mixed with sieved ash after threshing and the mixture put into a mud granary or a clay jar (Wolfson *et al.* 1991). In Eastern Africa, the leaves of the wild shrub *Ocimum suave* and the cloves of *Eugenia aromatica* are traditionally used as effective stored grain protectants (Powel 1989). In Rwanda, farmers store edible beans in a traditional closed structure (imboho) and whole leaves of *Ocimum canum* are usually added to the stored foodstuff to prevent insect damage within these structures (Weaver *et al.* 1991). Owusu (2001) suggested the natural and cheaper methods for the control of stored-product pests of cereals, with traditionally useful Ghanaian plant materials. In some South Asian countries, food grains such as rice or wheat are traditionally stored mixed with 2% turmeric powder (Chatterjee *et al.* 1980, Saxena *et al.* 1988). The use of oils in stored-products pest control is also an ancient measure. Botanical insecticides such as pyrethrum, derris, nicotine, oil of citronella and other plant extracts have been used for centuries (Khalique *et al.* 1987). Pakistani villagers traditionally protect their stored pulses from insect attack simply by coating them with a thin film of edible oil (Khan 1982, Khalique *et al.* 1988). More than 150 species of forest and roadside trees in India produce oilseeds, which have been mainly used for illumination, medicinal purposes and as insecticides from ancient times to early 20th century (Mariappan *et al.* 1988).

Bio- potential plant products

Over the past 3 decades, there has been much work on the isolation and identification of a wide array of biologically active natural products that in some way affect the behaviour, development and/or reproduction of pests including insects. Secoy and Smith (1983) recorded 677 different species of plants in 131 families suitable for use in pest control. Grainge *et al.* (1986) produced a suitable list of 1,600 plant species and Ahmed *et al.* (1984) reported about 2,000 species. Yang and Tang (1988) reported that in China, different parts or extracts of 276 plant species are used as pesticides. Jacobson (1990) in a survey reported that almost 1,500 plant species from 175 plant families act as insect feeding deterrents. In controlling stored-product insects, Talukder (1995) listed 43 plant species as insect repellents, 21 plants as insect feeding deterrents, 47 plants as insect toxicants, 37 plants as grain protectants, 27 plants as insect reproduction inhibitors and 7 plants as insect growth and development inhibitors.

The increasing attempts to replace synthetic insecticides with less expensive and locally available pest control means have been undertaken especially in the tropics (Jermy 1990). Pesticidal plants are utilized in two main ways: first, the active compounds are isolated, identified, and chemically synthesized. If feasible, these compounds or their active analogues are synthesized and marketed by the chemical industry. The second approach is suitable for farmers in developing countries and for organic fanning. Plant tissues or crude products of the plant, such as aqueous or organic solvent extracts, are used directly. These practices are labour intensive, but are often economically and ecologically sound, and do not require sophisticated technology (Yang and Tang 1988).

Bio-potency of *S. macrophylla*

Swietenia macrophylla seeds contain tetranortriterpenoids, swietenine, swietenine acetate and swietenolide (a bitter principle), swietenolide tiglate, swietenolide diacetate, augustineolide, 8,30-epoxy swietenine acetate and 3b-6-dihydroxydihydrocarapin (Chan *et al.* 1976, Taylor and Taylor 1983, Kojima *et al.* 1998, Mootoo *et al.* 1999, Solomon *et al.* 2003).

3, 6-Di-*O*-acetylswietenolide 0.25-hydrate was isolated from the ethyl acetate extract of the seeds (Fowles *et al.*, 2007). Other tetranortriterpenoids isolated from the seeds were methyl 3b-tigloyloxy-2,6-dihydroxy-1-oxo-meliac-8(30)-enate, methyl 3b-tigloyloxy-2-hydroxy-1-oxo-meliac-8(30)-enate, methyl 3b-tigloyloxy-2-hydroxy-8a,30a-epoxy-1-oxo-meliacate, methyl 3b-acetoxy-2,6-dihydroxy-8a,30a-epoxy-1-oxo-meliacate and methyl 3b-isobutyryloxy-2,6-dihydroxy-8a,30a-epoxy-1-oxo-meliacate (Kojima *et al.* 1998) and 3b,14-dihydroxymexicanolide, 3-O-tigloylswitenolide, febrifugina, 3, 6-di-O,O-acetylswietenolide (Schefer *et al.* 2006).

The terminal shoots, and mature and senescent leaves of the *S. macrophylla* contained essential oils which largely consisted of sesquiterpenes. The compounds that have been identified were a-copaene, b-bourbonene, b-cubebene, b-elemene, b-caryophyllene, b-gurjunene, allo-aromadendrene, g-himachalene, germacrene D, germacrene A, b-ionone, bicyclogermacrene, a-bisabolene, b-bisabolene, g-bisabolene, 7-epi-a-selinene, cadina-1, 4-diene, hexadecanoic acid and ethyl hexadecanoate. Oils from the terminal shoots (212mg, 0.053% w/w), mature leaves (193mg, 0.048% w/w), and senescent (188mg, 0.047%) leaves contained 19, 16, and 13 components, respectively. All samples contained germacrene D as the major constituent (58.5–66.5%). The oils all contained g-himachalene, germacrene A, cadina-1,4-diene, hexadecanoic acid, and ethyl hexadecanoate, although in different proportions. The oils from mature and senescent leaves were mostly similar and contained 10 similar compounds (Soares *et al.* 2003).

Traditional Uses

A most valued tropical hardwood as its timber is easily worked, durable and has a rich red colour (Brown *et al.* 2003).

The seeds are chewed or pounded and swallowed by the natives and the common people of Malaysia to treat high blood pressure (Chan *et al.* 1976). The seeds are traditionally used by the local healers of East Midnapore, West-Bengal, India to cure diarrhoea (Maiti *et al.* 2007).

The Mosetene Indians of Andean Piedmont, Bolivia, drink a decoction of the crushed seeds to induce abortion. To heal wounds and skin problems including skin allergy in children, the crushed seeds are mixed with *Attalea phalerata* seed oil and applied onto the skin as a poultice. The Mosetenes also used the bark as a dying agent. Previous research showed a strong correlation between the dying properties of species and its antimalarial activity. It is also used to dye cotton thread, brown. A decoction of the seeds is used to treat malaria in Indonesia (Munõz *et al.* 2000) and in India, where it is also used to treat diabetes and hypertension (Solomon *et al.* 2003).

Antimicrobial activity

The antimicrobial activity of a methanol extract of *S. macrophylla* bark was examined against selected gram positive and gram negative bacteria (20 strains) and fungi (4 strains). The methanol extract of *S. macrophylla* bark showed high sensitivity against *Escherichia coli* strains while all Shigella strains showed resistance. The extract was effective against *Candida albicans* but least effective against *Penicillium* sp. (Dewanjee *et al.* 2007).

Antiprotozoan activity

A lectin isolated from the leaves of *S. macrophylla* (molecular weight=295 kDa) was cytotoxic against *Acanthamoeba* sp. (a corneal keratitis-causing amoeba) and *Tetrahymena pyriformis* (a ciliate) indicating its potential as an antiparasitic agent. *S. macrophylla* lectin showed cytotoxicity against *Acanthamoeba* sp. and *Tetrahymena pyriformis* at concentrations as low as 25 ppm and 10 ppm, respectively. The mechanism could involve interaction of the lectin with sugars present in the protozoans (Endriga *et al.* 2005).

Antimalarial activity

The bark extract of *S. macrophylla* showed good both *in vivo* (73% inhibition of the rodent malaria *Plasmodium vinckei petteri* at 250mg/kg) and *in vitro* activity (78% inhibition of chloroquine resistant *Plasmodium falciparum* strains (Indo) at 100 µg/mL against malarial. The standard antimalarial drugs for the *in vitro* assay were *Cinchona calisaya* stem bark extract (0.4µg/mL produced 100% inhibition) and chloroquine (100% inhibition at 148ng/mL). For the *in vivo* assay, *Cinchona calisaya* bark extract produced 91% inhibition at 250mg/kg/day while chloroquine (5mg/kg/day) inhibited 100% of the parasite growth (Munõz *et al.* 2000).

The water extract of *S. macrophylla* seeds strongly inhibited the growth of *Plasmodium falciparum* and *Babesia gibsoni* with inhibition rates of almost 100% and more than 85%, respectively. *Babesia gibsoni* is a canine intra-erythrocytic parasite that causes anemia. Its life cyle is similar to that *P. falciparum* and both produce similar disease symptoms (Murnigsih *et al.* 2005).

Anti-inflammatory, antimutagenic and antitumor-promoting activity

The crude ethanol extract of the seeds *S. macrophylla* (1mg/g body weight) showed anti-inflammatory activity as it reduced carrageenan-induced inflammation in mice by 79 %(Guevara *et al.* 1996).The solvent fractions of the ethanol extract, i.e. hexane, CCl_4 and methanol fractions showed less anti-inflammatory activity. The methanol fraction elicited the highest inhibition (60%) while the hexane fraction produced a low inhibition of 23%. The ethanol extract (0.02 mg/g body weight) showed antimutagenic effects by the micronucleus test as it reduced the number of micronucleated polychromatic erythrocytes induced by the mutagen mitomycin C, by almost 50%. The ethanol crude extract and its solvent fractions showed significant antitumor-promoting activity as they inhibited Epstein-Barr early-antigen (EBV-EA) activation using 12-O tetradecanoylphorbol-13-acetate (TPA) as the tumor promoter (Guevara *et al.* 1996).

Antidiarrhoeal activity

The petroleum ether extract of *S. macrophylla* seeds (25, 50 & 100mg/kg body weight, p.o.) showed antidiarrhoeal activity in castor oil-induced diarrhoea in rats,

indicating its potential for development as an antidiarrhoeal drug (Maiti *et al.* 2007).The extract of *S. macrophylla* produced a reduction in the rate of defecation and improved the consistency of faeces, effects that were comparable to those produced by the standard anti-diarrhoeal drug, diphenoxylate (50mg/kg). The maximum effects were seen with 100mg/kg body weight of *S. macrophylla* seed extract. The mechanism may involve increased reabsorption of water due to decreased intestinal motility as the petroleum ether seed extract elicited a profound decrease in intestinal transit and significantly inhibited castor oil-induced entero-pooling (intestinal fluid accumulation), effects which were comparable to those produced by atropine sulphate and a drug that produced gastrointestinal hypomotility. The extract was equally effective at preventing or curing diarrhoea (Maiti *et al.* 2007).

Antifeedant activity

The antifeedant property of the seed extracts of *S. macrophylla* were investigated using the fall armyworm (FAW), *Spodoptera frugiperda* and the striped cucumber beetle (SCB), *Acalymma vittatum* (F.).The seed extracts were highly deterrent (feeding ratios of 0.02 and 0.18 for the ethanol and hexane extracts, respectively) in the FAW bioassay.The feeding ratio was defined as the percentage of an extract-treated leaf disk consumed/percentage of control disk consumed. The feeding ratio of 1.0 indicated no deterrency as equal quantities of treated and control leaf disks were eaten. The extracts were non lethal since 20 % mortality was seen with the ethanol extract while no mortality occurred with the hexane extract. However, none of the insects pupated while the larvae were all small. The antifeedant activity was also exhibited against SCB although *S. macrophylla* seed extract was not as potent as the other plant extracts that were also screened (Mikolajczak and Reed 1987).

Brine shrimp lethality activity

In the 24 h brine shrimp (*Artemia salina* Leach) bioassay, the ethanol and hexane extracts of *S. macrophylla* seeds elicited 22 and 44% mortality, respectively while at 48 h, the mortality were 48 and 76%, respectively (Mikolajczak and Reed 1987).

The crude methanol extracts of the stem barks and leaves of *S. macrophylla* elicited LC_{50} values of >1000 and 704.83μg/mL, respectively, in the brine shrimp lethality bioassay. The positive control for this assay was the crude extract of the stem bark of *Annona squamosa* which showed an LC_{50} value of 6.5μg/mL (Pisutthanan *et al.* 2004).

Haemorrhagic activity

The seeds of *Swietenia* species and the bark of *S. mahagony* have been reported to induce uterine haemorrhage which can lead to death (Munõz *et al.* 2000).

Adverse Effects in Human

The allergic contact dermatitis, rhinitis and conjunctivitis in joiners who were exposed to Honduras mahogany dust (Estlander *et al.* 2001). The contact dermatitis due to *S. macrophylla* has also been described elsewhere 2, 6-Dimethoxy-p-benzoquinone, is a relatively good sensitizer in guinea pigs. It was isolated in small amounts from *S. macrophylla*. It is recommended that 2,6-dimethoxy-p-benzoquinone be used in patch tests in in cases of suspected contact dermatitis to *S. macrophylla* (Hausen 1978).

Bio-potency of *P. erosus*

Jicama (*P. erosus*) has an appearance similar to a turnip or a large radish. Its skin is thin and it can be gray, light brown or maroon. In addition, it has a short root and its flesh is white. Only the tubercle is edible. The best land for culturing this plant is a frank-sandy type. Sowing takes place during July and August and is normally monocultured. Harvesting takes place at the end of November. The jicama has a skin that can be easily peeled. This plant contains fructans, triterpenes, steroids, phytosterols and phenols in its leaves, stem and the roots. It contains vitamin C, found in roots about 2570mg/kg wet weight), and has significant amounts of iron (6mg/kg) and potassium (1750mg/kg) in leaves. Rotenone, a substance with insecticide properties that may be toxic to humans, is also found in leaves, stems, sheath, and seeds (Hung *et al.* 2007). It has been found that ethanol extracts of the seed decreased locomotor activity, produced muscle relaxation and showed anxiolitic and anti-aggressive activity (Abid *et al.* 2006).

The white flesh is for consumption, usually juicy, and having a moderately sweet to very sweet flavor. It is also commonly used as a juice drink and as a syrup rich in fructans. It is also eaten as a vegetable. Raw jicama has a taste similar to that of a pear or an apple. It does not lose its color when exposed to air. As a result of the aforementioned, raw jicama is used as an additional dish prepared with raw vegetables (Hunter 1999).

The leaves can be used in the elaboration of medicinal infusions, due to the phytochemical components present. The oleoresin in the jicama is known to have antifungal activity because it inhibits the growth of *Fusarium sp.* strains upto 80% of development of this fungus in corn. In addition, it has toxic properties for the control of the diamondback moth and bean worm (Juárez *et al.* 2004, Song *et al.* 2005). In addition, the large amounts of iron and potassium (2460mg/kg) in the leaves, together with protein content (75%), make this part of the plant an

important alternative for its industrial use in livestock nutrition (Cervantes 1986). Jicama is also used as a water binding ingredient to help to inhibit microbial (especially fungus) propagation in food compositions that have 15–50% moisture (Friedman *et al.* 1975).

Studies on the chemical constituents of the seeds of *Pachyrrhizus erosus* (Leguminosae) resulted in the isolation of nine known components: five rotenoids [dolineone(3),pachyrrhizone(5),12a-hydroxydolineone(7),12a-hydroxypachyrrhizone (9), and 12a-hydroxyrotenone (2)], two isoflavonoids [neotenon (4) and dehydroneotenone (8)], one phenylfuranocoumarin [pachyrrhizine (6)], and a monosaccharide (dulcitol). The full 1H- and 13C-NMR assignments for the isolated products except a sugar, including revision of previous assignments in the literature, are reported. Moderate anti herpes simplex virus (HSV) activity was observed in 12a-hydroxydolineone (7) and 12a-hydroxypachyrrhizone (9) among the isolated products. (Phrutivorapongkul *et al.* 2002)

Rotenone, a substance with insecticide properties that may be toxic to humans, is also found in leaves, stems, sheath, and seeds (Hung *et al.* 2007). It has been found that ethanol extracts of the seed decreased locomotor activity, produced muscle relaxation and showed anxiolitic and anti-aggressive activity (Abid *et al.* 2006.

Chapter 3

GENERAL METHODOLOGY

Introduction

Collection and preparation of test plant materials

Preparation of seed powder

Preparation of seed extracts

Test insect and maintenance

Precautions

Chapter 3

GENERAL METHODOLOGY

Introduction

Experiments on the potency of plant seed powders and extracts as contact toxicants, behavioral response, and effects on different biological aspects viz. fecundity, fertility, deformities and population study of *T.castaneum* were conducted. Test insect cultures were maintained in the incubator at a temperature of 30± 0.5°C, without any light and relative humidity control during the experiments in the laboratory.

Collection and preparation of test plant materials

Mahogany (*S. macrophylla*) seeds were collected from the mahogany tree of Carmichael College Campus, Rangpur. Fresh and mature fruits were collected from the tree between February to March and dried in shade. The fruits split open from the base when dried for 1- 4 days and depending on maturity, after which the seeds are easily released by gentle shaking of the fruits. Fruit parts (valves and columella) and seed covering were removed by hand. The seeds were further dried to amoisture content for storage and grinding. Seeds of Kesur (*P.erosus*) were purchased from the local market. Both of the seeds before grinding in an electric grinder were washed and well dried in an oven at 40°c for few hours.

Preparation of seed powder

Powder preparations of the seeds were made separately. Approximately 500g of dried mahogany seed and 500g of kesur seed were ground to powder in an electric grinder machine separately. The seeds of kesur powdered smoothly, while the mahogany seeds powder becomes sticky one. Resulting both of the powder was passed through 0.40mm mesh sieve to obtain a fine dust. Both dusts were preserved in sealed packets in a refrigerator at 5°C until used for preparation of extracts and insect bioassays.

Preparation of seed extracts

The solvent used in the extraction process were chloroform and methanol serially. For extraction, powdered seed of mahogany and kesur were extracted separately. Powder and extracts were prepared using the method of Talukder and Howse (1993) with slight modifications. Two hundred grams of ground seed dust of mahogany and kesur were separately mixed with 300ml of chloroform and stirred for 15 minutes and then left to stand for 72 hours. The mixer was then filtered through Whatman #1 paper and the solids were stirred again for 10 minutes with

250ml of chloroform and filtered and both of the filtrates were combined. The solvent from the pooled filtered solution was evaporated using an electric hot plate at 45°c until the solvent is completely evaporated. After complete evaporation of solvents, the final crude extracts were weighed. Chloroform extracts of mahogany and kesur were 4g and 3.5g respectively. Thus, the methanol extracts were prepared. Methanol extracts of mahogany and kesur were 2.5g and 2.3g respectively. All of the extracts were preserved in sealed bottles in a refrigerator at 5°C until used for insect bioassays.

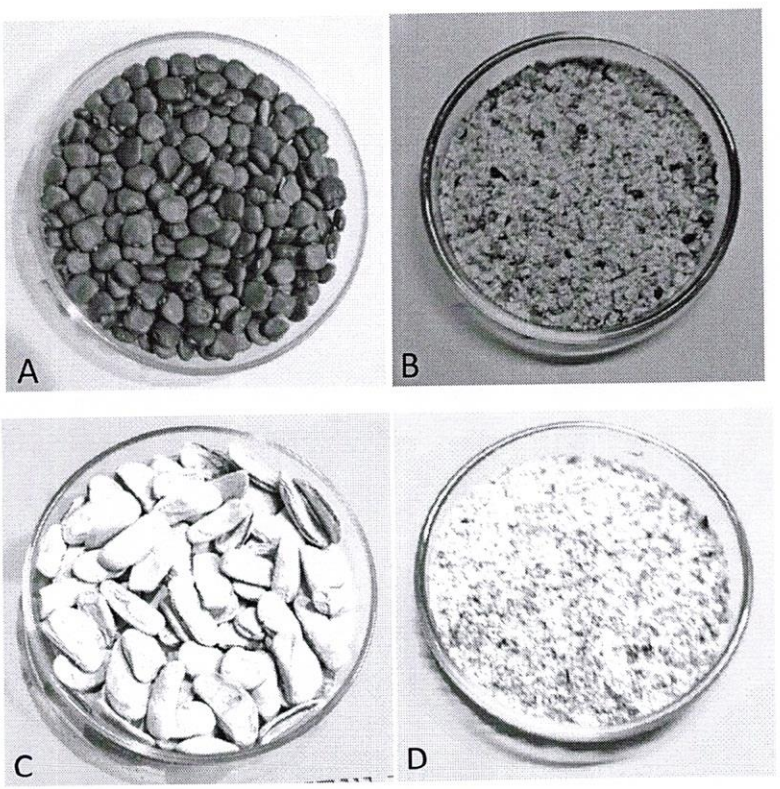


Plate 4. Collected seeds and powders; A-Kesur seeds, B-Kesur seed powder, C-Mahogany seeds, D- Mahogany seed powder.

Maintenance of test insect

Collection of test insects

The red flour beetle, *Tribolium castaneum* Herbst was used for the present experiments. A small population *of T. castaneum* beetles was obtained from the IPM (Integrated Pest Management) laboratory stock culture of the Institute of Biological Sciences, University of Rajshahi, Bangladesh. They were reared under laboratory conditions, on diet of the wheat flour, in an incubator at 29.5°C, without any light and humidity control.

Preparation of food medium

Whole meal flour was used as a standard food medium (Park and Frank 1948) throughout the experiments. The food used in the experiment was the homogenous mixture of flour and brewer's yeast at 19:1 ratio (Park and Frank 1948, Park 1962) considered as standard test food (STF). Both flour and yeast were previously passed through a 250 micrometer sieve. The food medium was sterilized at 120°C for six hours in an oven. The food was not used until at least 15 days after sterilization in order to have its moisture content being equilibrate with that of the environment (Khan 1981, Mondal 1984a).

Mass rearing of test insects

Mass rearing was maintained in glass beakers (500ml) in an incubator at 29.5°C without light and humidity control. About three hundred adult beetles were introduced in a beaker containing standard food medium. The cultures were checked at regular intervals and eggs and larvae were separated to grow properly. A piece of crumpled filter paper was placed inside the beaker for easy movement of the beetles. The beaker was covered with a piece of cloth at the top using a rubber band to prevent the possible contamination and escape of insects (Mondal and Perween 1997).The subsequent progenies of the beetles were used in the experiments.

Collection of eggs

About four hundred beetles of both sexes were placed in beaker containing food medium. The beaker was covered with a cloth and kept in an incubator at 29.5°C. The eggs were collected on the following day by sieving the medium through a 250-micrometer aperture sieve (Khan and Selman 1981). These eggs were transferred to a petridish (9cm in diameter) containing a filter paper at the bottom (Mondal and Perween 1997) and incubated at 29.5°C.

Transfer of newly hatched larvae

Larvae hatched in about 5-7 days at 29.5°C into the incubator. The newly hatched larvae were collected with a fine brush and transferred to the standard food medium in a petridish using the method described by Mondal and Parween (1997)

Determination of larval instars

About one hundred newly hatched larvae were transferred to a petridish (9cm diameter) containing approximately 25g food medium and were reared in an incubator at 29.5°C. Most of the larvae had six instars (Mondal 1984a). The second, third, fourth, fifth and sixth instar larvae were obtained from the larval culture on the 3rd, 6th, 9th, 12th and 16th day from hatching respectively (Mondal 1984c). The newly hatched larvae were considered as first instar. After every three days the food medium was changed by a fresh one to avoid conditioning by larvae themselves (Park 1935).

Determination of sex

Sex determination of the beetle was not possible in the larval or adult stage. Pupa was sexed by the microscopic examination of the exo-genital process of the pupa (Halstead, 1963). Female exo-genital papillae are much larger than that of male which are two fingers like structures just anterior to the urogomphi. On the contrary, the male papillae are smaller that look like just finger strips rather than fingers (Anon 2000).The pupae thus sexed were placed in separate petridishes and incubated at 30°C for emergence of adults.

Precautions

All glassware and sieves were dry sterilized at 180°C for two hours in an oven. The working table was swabbed with ethyl alcohol. All other used materials were cleaned regularly after every use. Culture was rotated regularly by setting up new culture and the old food media were discarded.

Chapter 4

TOXICITY OF *S. MACROPHYLLA* AND *P.EROSUS* SEED POWDERS AND EXTRACTS AGAINST *T. CASTANEUM*

Introduction

Materials and Methods

Methods of the bioassay

Preparation of doses

Application of doses

Direct contact toxicity test of powders

Treated food toxicity test of powders

Residual film toxicity tests of extracts

Treated food toxicity test of extracts

Statistical analysis

Results

Direct contact toxicity effects of powders

Treated food toxicity effects of powders

Residual film toxicity effects of mahogany seed extracts

Treated food toxicity effects of extracts

Discussion

Chapter 4

TOXICITY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS AGAINST *T.CASTANEUM*

Introduction

In Bangladesh *T. castaneum* is abundantly found in stored grains of different cereals. Control of these insects relies heavily on the use of synthetic insecticides and fumigants, which has led to the problems such as disturbances of the environment, increasing cost of application, pest resurgence, resistance to pesticides and lethal effects on non target organisms in addition to direct toxicity to users (Okonkwo *et al.* 1996).

The botanical pesticides tend to have a broad spectrum activity, are safe and relatively specific in their mode of action and easy to process and use in the traditional settings (Sinha 2010). Higher plants are rich source of novel natural substances that can be used to develop environmental safe methods for insect control (Arnason *et al.* 1989).

Today several plant based products are used to control a wide variety of pests, for example many oils and formulations from plant extracts are being marketed as pesticides around the world (Ngamo *et al.* 2007, Salunke *et al.* 2009). In many areas of the world locally available plant materials are widely used to protect stored product against damage by insect infestation (Golob and Webley 1980). Insecticidal compounds from seeds of *Pachyrhizus erosus* were studied to determine their insecticidal toxicity. There were seven insecticidal compounds altogether from the seeds, whose mode of action to the different tested insects were different. The main insecticidal ingredient was 12a-hydoxyrotenone (Li YouZhi *et al.* 2009).

The present experiments aims to provide information about the insecticidal potency of *S. macrophylla* and *P. erosus* seed powders and crude extracts against larvae and adults of *T. castaneum*.

Materials and methods

Common materials and methods were discussed in General Methodology (Chapter.3).

Methods of the Bioassay

In the present bioassay method seed powders and extracts of Mahogany and Kesur were investigated against *T. castaneum* larvae and adults by 'Direct Contact Method'(DCM), residual toxicity termed 'Residual Film Method'(RFM) (Busvine

1971) and dietary exposure termed 'Treated Food Method'(TFM) (Talukder and Howse 1994).

Preparation of doses

i). Powders: Required amount of refrigerated fine powder and respective standard test food (STF) were weighed individually in an electronic balance, using a small aluminium foil boat and mixed thoroughly for desired doses. Amount of mixed powder (in mg) was converted into percentages as (%)w/w (% weight/weight) according to the amount of corresponding STF.

ii). Extracts: Required amount of refrigerated crude extracts were weighed individually in an electronic balance, using a small aluminium foil boat and dissolved in the corresponding solvents according to the ratio of dry weight, considered as stock solution. The stock solution was then serially diluted with the respective solvent for making the desired doses.

Application of doses

A preliminary screening of different doses was performed on different larval ages and adults of male, female and unsexed to obtain expected mortalities following the above mentioned bioassay methods. A stock solution for each of the extract was prepared as 1mg/2ml solvent for RFM treatment and 100mg/1ml solvent for TFM treatment.

Direct contact toxicity test of powders

Doses of seed powder of mahogany and kesur seed powders were weighed and applied in each of the glass petridish (9cm dia.) at a certain amount and converted into µg/cm^2 dividing the amount with area of the petridish. Calculated doses were 70.77, 141.15, 283.08 µg/cm^2 against male, female and unsexed adults. Thirty adult beetles (10-16day old) were released into each petridish with three replications and covered with glass lid. A control batch was also maintained with the same number of insects without any treatment. All the petridishes with beetles were then kept in the dark in an incubator at 30°C temperature for maintaining stock culture. Mortality of the insects was recorded after 3, 7, 14 and 21days of exposure to treatment. The insects which could not walk and failed to respond even after probing with a soft brush were considered as dead.

Treated food toxicity test of powders

Four gram of wheat flour (STF) was taken in each of the glass petridish (9cm dia.) and treated separately with mahogany and kesur seed powders. Powders were applied at various doses viz. 0.5, 1 and 2(%w/w) against larvae and adults respectively. Thirty insects (9, 12 and 16 days old larvae/ 10-16 days old adults) were released into each petridish and covered with glass lid. A control

batch was also maintained with the same number of insects (larvae/adults) without any treatment. Each treatment was replicated three times. All the petridishes with insects were then kept in the dark in an incubator at 30°C. Mortality of the test insects was recorded at 3, 7, 14, and 21 days of post exposure. The death of insects was confirmed by following the above mentioned procedure.

Residual film toxicity test of extracts

Taking 1ml from stock solution for each sample (chloroform and methanol) of mahogany and kesur seed extracts was applied on each petridish (6cm dia.) in such a way that it made a uniform film over the petridish. The actual amount of extract (in µg) present in 1ml mixture was calculated and the dose µg/cm^2 was determined by dividing the amount present in 1ml with the area of the petridish. Calculated doses of chloroform and methanol extracts of mahogany and kesur seeds were used against larvae and adults of *T. castaneum*. The petridishes were then dried for 30 minutes for complete evaporation of the solvent. After drying, 20 insects (larvae of 9, 12 and 16 days old, and adults of 10-16 days old) were released into each petridish and covered with glass lid. Each treatment was replicated five times. A Control batch was also maintained with the same number of insects in petridish by applying the solvent only. The petridishes with insects were kept in the dark in an incubator at the same temperature as mentioned earlier. Mortality of the insects was assessed after 24 and 48h for larvae while 24, 48 and 72h for adult.

Treated food toxicity test of extracts

One ml of extracts from the prepared stock solution of each of the extracts (chloroform and methanol) of mahogany and kesur seeds was taken and mixed thoroughly with certain amount of STF by an electric blender, and make other successive doses by serial dilution. The treated flour was air dried for 30 minutes for complete evaporation of the solvent. The actual amount of extract (in µg) present in 1ml mixture was calculated and the dose/gm flour was determined by dividing the amount present in 1ml with the used amount of flour in each petridish. The dose was expressed in ppm. Two gram of treated flour was uniformly spread in each petridish (6cm dia.). Twenty larvae of 9, 12 and 16 day old and adults of 10-16 day old were released separately into each petridish with five replications. A control batch was also maintained with the same number of insects in the petridish by applying the solvent only. The petridishes with the treated food and insects were placed in an incubator at 30°C. Mortality of the larvae and adults was determined by counting the dead insects at 3, 5 and 7 days of post exposure for chloroform extracts and 5, 7 and 14 days of post exposure for methanol extracts of mahogany and kesur seeds respectively.

Statistical Analysis

The mortality percentage was corrected using Abbott's formula (Abbott 1925) and then subjected to Probit analysis according to Finney (1947) and Busvine (1971).

The median lethal dose (LD_{50}) and regression equation were also determined.

The data obtained from DCM and TFM toxicity test of powders were analyzed statistically using one way ANOVA and the means were compared using Tukey's multiple comparison test (1953). Calculations were done by SPSS software of 15 version.

Results

Direct contact toxicity effects of powders

The results of the experiments and statistical analysis are shown in the Tables 1 and 2 and Appendix Tables 1-6.

Insect mortality at 3,7,14 and 21 days of treatment due to direct contact toxicity of mahogany and kesur seed powders on *T. castaneum* adults (male, female and unsexed) were evaluated at three different doses viz. 70.77, 141.15, 283.08 $\mu g/cm^2$ (Tables 1 and 2 ; App.Tables 1-6). From the effects of mahogany seed powder, it was found that the lowest mortality for unsexed adults at 3days exposure was 3.33% and highest mortality for female adults at 21day exposure was 93.33%(Table 1). Also in Table 2(effects of kesur seed powders) lowest mortality for male adults at 3day exposure was 14.43% and highest mortality for unsexed adults at 21day exposure was 93.33%. From the results it was revealed that the order of toxicity of two powders were Kesur >Mahogany. It was found that mortality percentages were directly proportional to the toxicity of powder constituents and also with the time after treatment.

Treated food toxicity effects of powders

Mortality(%) of *T. castaneum* larvae and adults for 3, 7, 14 and 21 day after treatment due to treated food toxicity of powders of mahogany and kesur seeds were presented in Tables 3-6 and App. Tables 7-18.

Both mahogany and kesur seed powders were found to be toxic causing mortalities of *T. castaneum* larvae and adults. The effects of treating the food with seed powders of mahogany and kesur on *T. castaneum* larvae (9, 12 and 16 days) and freshly emerged adult (male, female and unsexed) were investigated by comparing using the doses 0.5, 1 and 2% w/w. At a concentration of 0.5% w/w lowest mortality (3.33%) counted in 9 days larvae for mahogany seed powder and the highest effects (95.58%) were found in 16 days larvae for

Kesur seed powder dosed at 2% w/w (Table 3). There were no significant differences in susceptibility among sexes (male, female and unsexed; Table 5 and 6). Mortality percentages were increased over time in both mahogany and kesur seed powders. In contrast, kesur was more effective than mahogany. Mortality effects of the powder treatments were both dose and time dependent.

Residual film toxicity (RFM) effects of seed extracts

The residual effects of the chloroform and methanol extracts of mahogany and kesur seeds are given in Tables 7 and 8; App. Tables 19-78. The effects of both seed extracts on different stages of *T. castaneum* were evaluated by probit analysis.

Experiment 1.

Table 7 and Fig.1a-1f and 2a-2f represented the RFM results of mahogany seed extracts. The exposure periods were 24 and 48 hours for larvae and 24, 48 and 72 hours for adults. LD_{50}, Regression equation and Chi-square values were calculated to evaluate the effects for Chloroform and methanol extracts against larvae (9, 12, 16 days) and adults (male, female, unsexed) respectively (Appendix Tables 19-48).

From the LD_{50} values of probit analysis it was found that the chloroform extracts was more effective than methanol extract of mahogany at 24, 48 and 72 hours of exposure. Chloroform extracts had the highest toxic effects on 16 days larvae at 48h exposure and the lowest LD_{50} were 1.51μg/cm^2 but in methanol extract on 16 days larvae at 48h exposure the lowest LD_{50} was 68.19μg/cm^2. From comparative study of the results it was found that adults were more tolerant than larvae to both of the extracts of chloroform and methanol. In most of the cases it was observed that mortality of the adults and larvae were dose and exposure period dependent. Overall, it was seen that in this experiment chloroform extract of mahogany were more potent than methanol extract against *T. castaneum* larvae and adults. Probit regression lines of the different doses were calculated; they showed a linear relationship between mortality percentages and extract concentration at 24, 48 and 72 hours after treatment.

Experiment 2.

Table 8; Figures 3a-3f and 4a-4f and Appendix Tables 49-78 represented RFM results of kesur seed extracts. Observation was conducted on larvae (9, 12 and 16 days) and adults (male, female and unsexed) after application following contact exposure. The exposure periods were 24 and 48 hours for larvae and 24, 48 and 72 hours for adults.

For 16 days larvae at 48h exposure the LD_{50} values of chloroform extracts was 3.596μg/cm^2 and for male adults at 24h exposure the LD_{50} values of chloroform extracts was 28.05μg/cm^2 but in case of methanol extracts for 9days larvae at 48h of exposure the LD_{50} value was 31.21μg/cm^2 and for adult male at 24h exposure the LD_{50} value was 897.65μg/cm^2. In this experiment, chloroform extract of kesur seed showed the highest toxic effects against different stages of flour beetle and the LD_{50} values were lower than those in the methanol extract. Adult male and female were more tolerant than adult unsexed against both chloroform and methanol extracts of kesur seed extracts. From result it is obvious that chloroform extract was many times toxic than methanol extract against all of the larval and adult stages of *T. castaneum.* It also found that mortality of the larvae and adults were dose and exposure time dependent. Comparing all of the regression lines at 24, 48 and 72 hours after treatment, the regression lines for chloroform extract showed positive and higher mortality in each case.

Treated food toxicity (TFM) effects of seed extracts

The results of the chloroform and methanol extracts of mahogany and kesur seeds are given in Tables 9 and 10. The effects of both seed extracts on different stages of *T. castaneum* were evaluated by probit analysis.

Experiment 1.

TFM results of the chloroform and methanol extracts of mahogany seeds were showed in the Table 9; Figures 5a-5f and 6a-6f and Appendix Tables 79-114.

Mortalities for chloroform extract on larvae(9, 12, 16 days) and adults(male, female, unsexed) were recorded at 3, 5 and 7 days of exposure and for methanol extract on larvae and adults were recorded at 5, 7 and 14 days of following exposure.

There was a significant difference between chloroform and methanol extracts. Chloroform extract was more toxic due to exposure time and dose. Result shows that in chloroform extract at 7days exposure on 9days larvae lowest LD_{50} was 7186.12ppm but in methanol extract at 14 days exposure on16 days larvae lowest LD_{50} was 14514.44ppm. The chloroform extract was found to be more toxic than methanol extract in the TFM experiments. In this experiment, dose and exposure periods for methanol extracts were higher than those of the chloroform extracts but most of the cases mortality not so high in methanol extract than chloroform extract. Adults were more tolerant than larvae against both of extracts. Results of this study demonstrated that toxicity of the extracts decreased with the increasing larval ages. This may clear that insect's age plays an important role in influencing susceptibility.

Experiment 2.

The results on the effects of chloroform and methanol extracts of kesur seeds on larvae and adults presented in Table 10; Figures 7a-7f and 8a-8f. The statistical analysis of the results are given in Appendix Tables 115-150.

The exposure periods were 3, 5 and 7days for larvae (9, 12 and 16 days) and 5, 7 and 14 days for adults (male, female and unsexed).

The lowest LD_{50} values of 7937ppm for chloroform extract and 7767ppm for methanol extract were recorded at 7 and 14 days post exposure respectively for 12 day old *T. castaneum* larvae. Similarly, the lowest LD_{50} values were 5786 and 6843ppm respectively for chloroform and methanol extracts were obtained for unsexed adult *T. castaneum* (Table 10). The regression lines plotted on dose mortality data obtained from chloroform and methanol extracts on larvae and adults showed positive liner regression *i.e.* the mortality of insects increased with increasing doses of the extracts (Figures 7a-7f and 8a-8f).

From the result it was observed a significant difference in susceptibility of chloroform and methanol extracts and also adults. Among larvae 12 day old and in case of adults unsexed adults were more susceptible to both chloroform and methanol extracts. On the other hand, among larvae and adults were comparatively less tolerant then larvae to both extracts. In the present experiment, it was also observed that both larvae and adults required more doses and higher exposure period for methanol extract to kill 50% population than chloroform extract which indicates that the chloroform extract was more toxic and potent than methanol extract.

Table 1. Effect of *S. macrophylla* seed powder on the mortality of *T. castaneum* adults by DCM (N=90)

Adult stage	Dose µg/cm²	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
Male	70.77	1.33±0.58ab	4.44	2.67±1.15b	8.91	4.67±1.53c	15.57	5.33±1.53b	17.76
	141.15	2.33±1.53ab	7.77	7.00±1.00a	23.34	16.33±1.53b	54.42	24.00±1.00a	80.01
	283.08	3.67±1.53a	12.24	8.67±1.53a	28.89	23.33±1.15a	77.76	27.33±2.52a	91.11
	O(Control)	0.00b	0.00	0.00b	0.00	0.00d	0.00	0.00c	0.00
Female	70.77	1.33±1.53a	4.44	2.67±1.15bbc	8.91	4.33±0.58bc	14.43	6.33±1.15b	21.09
	141.15	2.33±2.08a	7.77	4.67±2.08ab	15.57	9.67±1.53b	32.22	21.00±5.20a	69.99
	283.08	2.33±1.53a	7.77	7.00±1.00a	23.34	18.00±6.08a	60.00	28.00±2.00a	93.33
	O(Control)	0.00a	0.00	0.00c	0.00	0.00c	0.00	1.00b	3.33
Unsexed	70.77	1.00±1.00b	3.33	6.00±2.00ab	20.01	14.33±5.03a	47.76	14.33±2.08c	47.76
	141.15	4.00±1.73a	13.32	9.00±3.00a	30.00	15.00±3.00a	50.01	21.33±0.58b	71.10
	283.08	5.33±0.58a	17.76	10.00±4.58a	33.33	20.00±1.73a	66.66	27.67±3.21a	92.22
	O(Control)	0.00b	0.00	0.00b	0.00	0.00b	0.00	0.00d	0.00

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 2. Effects of *P. erosus* seed powder on the mortality of *T. castaneum* adults by DCM (N=90)

Adult stage	Dose µg/cm²	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
Male	70.77	4.33±1.53bc	14.43	9.00±3.00bc	30.00	11.67±1.53b	38.91	13.67±1.53b	45.57
	141.15	7.00±2.65ab	23.34	17.00±5.57ab	56.67	23.00±1.00a	76.68	26.33±2.31a	87.78
	283.08	10.33±1.53a	34.44	21.00±3.00a	69.69	26.00±1.73a	86.67	27.33±3.06a	91.11
	O(Control)	0.00c	0.00	0.00c	0.00	0.00c	0.00	1.00c	3.33
Female	70.77	5.00±2.00ab	16.68	7.33±1.15c	24.42	9.67±0.58c	32,22	13.00±1.00b	43.32
	141.15	8.33±2.52ab	27.78	14.00±1.73b	46.68	18.33±2.52b	61,11	22.00±4.58a	73.32
	283.08	9.33±5.51a	31.11	21.67±3.06a	72.24	25.67±3.21a	45.56	27.00±2.65a	90.00
	O(Control)	0.00b	0.00	0.00d	0.00	0.00d	0.00	1.00c	3,33
Unsexed	70.77	5.33±2.52b	17.76	10.67±2.08a	35.58	13.00±1.00c	43.32	16.33±1.53b	54.42
	141.15	14.33±0.58a	47.76	15.33±0.58a	51.09	19.00±1.73b	63.33	26.67±3.51a	88.89
	283.08	15.33±0.58a	51.09	17.67±4.93a	58.89	24.00±3.00a	80.01	28.00±2.65a	93.33
	O(Control)	0.00c	0.00	0.00b	0.00	0.00d	0.00	3.00c	9.99

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 3. Effect of *S.macrophylla* seed powder on the mortality of *T.castaneum* larvae of different ages by TFM (N=90)

Larval ages(days)	Dose (%) w/w	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
9	0.5	1.00±0.05ab	3.33	2.33±1.53b	7.77	4.33±2.08c	14.43	5.00±2.00b	16.68
	1	2.33±1.53ab	7.77	6.67±1.15a	22.23	16.00±2.00b	53.34	24.00±1.00a	80.01
	2	3.33±1.45a	11.1	8.33±1.53a	27.78	23.33±1.15a	77.76	27.00±3.00a	90.00
	O(Control)	0.00b	0.00	0.00b	0.00	0.00d	0.00	3.00b	9.99
12	0.5	1.33±1.15a	4.44	2.33±1.53ab	7.77	8.00±5.29a	26.67	6.00±1.00c	20.01
	1	2.00±1.00a	6.66	5.00±1.00a	16.68	24.67±14.22a	82.23	22.00±2.00b	73.32
	2	2.67±2.08a	8.91	5.33±1.53a	17.76	33.33±23.18a	111.09	27.00±2.65a	90.00
	O(Control)	0.00a	0.00	0.00b	0.00	0.00a	0.00	0.00d	0.00
16	0.5	1.67±0.58a	5.58	2.67±0.58ab	8.91	4.33±1.53bc	14.43	6.00±1.73b	20.01
	1	2.33±2.52a	7.77	4.00±2.65ab	13.32	10.00±3.00ab	33.33	21.33±6.43a	71.1
	2	2.33±1.53a	7.77	6.67±1.53a	22.23	17.33±6.81a	57.78	28.67±1.53a	95.58
	O(Control)	0.00a	0.00	0.00b	0.00	0.00c	0.00	2.00b	6.66

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 4. Effect of *S.macrophylla* seed powder on the mortality of *T.castaneum* adults by TFM (N=90)

Adult stage	Dose (%) w/w	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
Male	0.5	1.00±1.73bc	3.33	6.00±3.00ab	20.01	13.00±4.58a	43.32	16.00±3.61b	53.34
	1	4.00±1.73ab	13.32	9.00±3.00a	30.00	15.00±3.00a	50.01	21.33±0.58ab	71.10
	2	5.33±0.58a	17.76	10.00±4.58a	33.33	20.00±1.73a	66.66	27.67±3.21a	92.22
	O(Control)	0.00c	0.00	00.00b	00.00	00.00b	00.00	00.00c	00.00
Female	0.5	1.00±1.73ab	3.33	6.00±3.00b	20.01	13.00±1.73a	43.32	17.00±1.73b	56.67
	1	4.00±1.73a	13.32	8.67±2.52b	28.89	15.00±3.00a	50.01	23.00±4.58ab	76.68
	2	1.00±1.73ab	3.33	10.33±1.53b	34.44	17.33±2.08a	57.78	27.00±3.00a	90.00
	O(Control)	0.00b	0.00	00.00b	00.00	00.00b	00.00	00.00c	00.00
Unsexed	0.5	0.00±0.00a	0.00	6.00±2.00a	20.01	11.00±1.00a	36.66	16.67±1.53b	55.56
	1	2.00±3.46a	6.66	7.00±1.73a	23.34	13.00±1.73a	43.32	23.00±4.58ab	76.68
	2	1.00±1.73a	3.33	7.33±2.89a	24.42	14.33±3.21a	47.76	27.00±3.00a	90.00
	O(Control)	0.00a	0.00	00.00b	00.00	00.00b	00.00	00.00c	00.00

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 5. Effect of *P.erosus* seed powder on the mortality of *T.castaneum larvae* of different ages by TFM (N=90)

Larval ages(days)	Dose (%) w/w	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
9	0.5	2.00±1.00ab	6.66	2.67±1.15b	8.91	5.33±2.08b	17.76	12.00±7.00b	39.99
	1	3.67±2.08ab	12.24	9.00±1.00a	30.00	19.33±1.15a	64.44	26.33±2.52a	87.78
	2	5.00±2.65a	16.68	9.33±3.06a	31.11	21.67±3.06a	72.24	28.67±1.15a	95.58
	O(Control)	0.00b	0.00	0.00b	0.00	0.00c	0.00	2.00c	6.66
12	0.5	1.00±0.94bc	3.33	2.67±0.58bc	8.91	4.67±0.58bc	15.57	5.33±1.53b	17.76
	1	3.00±1.00ab	9.99	7.33±4.16ab	24.42	14.00±5.29ab	46.68	22.33±5.69a	74.43
	2	5.33±1.15a	17.76	10.33±2.52a	34.44	24.00±6.93a	80.01	28.67±1.53a	95.58
	O(Control)	0.00c	0.00	0.00c	0.00	0.00c	0.00	3.00b	9.99
16	0.5	1.33±1.53a	4.44	2.33±1.53b	7.77	5.00±2.00ab	16.68	8.67±2.08c	28.89
	1	1.67±1.53a	5.58	4.00±1.00ab	13.32	4.00±1.00ab	13.32	21.00±3.61b	69.99
	2	2.33±1.53a	7.77	8.33±3.51a	27.78	8.33±3.51a	27.78	29.67±0.58a	98.91
	O(Control)	0.00a	0.00	0.00b	0.00	0.00b	0.00	1.00d	3.33

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 6. Effect of *P.erosus* seed powder on the mortality of *T.castaneum* adults by TFM (N=90)

Adult stage	Dose (%) w/w	Mortality at							
		3DAT		7DAT		14DAT		21DAT	
		Mean ± SD	%	Mean ± SD	%	Mean ± SD	%	Mean ± SD	%
Male	0.5	5.00±1.73ab	16.68	9.67±3.21bc	32.22	13.00±1.73b	43.32	13.67±1.53b	45.57
	1	8.00±3.46a	26.67	19.00±6.25ab	63.33	22.67±1.53a	75.57	27.00±3.00a	90.00
	2	9.00±3.00a	30.00	22.00±3.46a	73.32	26.00±1.73a	86.67	28.00±3.46a	93.33
	O(Control)	0.00b	0.00	0.00c	0.00	0.00c	0.00	0.00c	0.00
Female	0.5	5.00±1.73ab	16.68	8.00±1.73ab	26.67	9.67±0.58c	32.22	13.00±1.00b	43.32
	1	8.67±3.06ab	28.89	14.00±1.73a	46.68	18.00±3.00b	60.00	22.00±4.58a	73.32
	2	10.00±6.25a	33.33	18.00±7.94a	60.00	26.00±4.58a	86.67	27.00±3.00a	90.00
	O(Control)	0.00b	0.00	0.00b	0.00	0.00d	0.00	0.00c	0.00
Unsexed	0.5	6.00±3.00b	20.01	10.67±1.53a	35.58	14.00±1.00c	46.68	16.00±1.00b	53.34
	1	10.67±1.15a	35.58	16.00±1.73a	53.34	19.00±1.73b	63.33	26.67±3.51a	88.89
	2	11.67±1.15a	38.91	16.00±4.36a	53.34	24.00±3.00a	80.01	28.33±2.89a	94.44
	O(Control)	0.00c	0.00	0.00b	0.00	0.00d	0.00	0.00c	0.00

DAT-Days after treatment

Means followed by the same letter in each column of each stage are not significantly different (P>0.05) by Tukey's multiple comparison test

Table 7. Potency of *S. macrophylla* seed extracts of Chloroform and Methanol against different stages of *T. castaneum* by RFM

Seed Extracts	Life Stages	Exposure Period (h)	LD_{50} µg/cm^2	Y - values	X^2 (3df)
S. macrophylla (Chloroform)	9days larvae	24	5.218	2.915+1.213X	2.645
		48	2.026	2.390 + 1.996X.	2.250
	12days larvae	24	4.158	2.876+1.311X	0.087
		48	2.094	2.307 + 2.038X	1.515
	16days larvae	24	3.965	2.913+1.305X	3.893
		48	1.516	3.086+1.620X	5.986
	Adult male	24	9.294	3.333+.846X	1.614
		48	4.466	3.415+1.030X	1.872E-02
		72	12.24	3.084+1.760 X	4.249
	Adult female	24	60.62	3.241+.986X	2.259
		48	29.05	3.480+1.038X	2.669
		72	6.897	3.620+1.645 X	3.799
	Adult unsexed	24	39.81	3.195+1.1279X	2.120
		48	21.57	3.034+1.473X	14.033
		72	11.61	2.988 +1.888 X	13.970
S. macrophylla (Methanol)	9days larvae	24	1885	2.599+.733X	1.387
		48	62.79	1.611+1.884X	1.185
	12days larvae	24	819.51	2.549+0.841X	0.489
		48	80.78	1.340+1.918X	3.378
	16days larvae	24	1233	2.354+0.855X	0.238
		48	68.19	1.305+2.0146X	1.357
	Adult male	24	2552	1.029+1.165X	1.465
		48	667.05	1.223+1.337X	1.493
		72	127.41	0.999+1.900 X	3.497
	Adult female	24	7103	1.884+0.808X	0.919
		48	473.9	2.033+1.108X	1.599
		72	105.3	0.517+2.215X	0.711
	Adult unsexed	24	11931.1	1.745+0.798X	0.775
		48	755.8	1.713+1.141X	0.955
		72	123.4	0.625+2.091X	0.759

Table 8. Potency of *P. erosus* seed extracts of Chloroform and Methanol against different stages of *T.castaneum* by RFM

Seed Extracts	Life Stages	Exposure Period (h)	LD_{50} µg/c^2	Y - values	X^2 (3df)
P. erosus (Chloroform)	9days larvae	24	6.561	2.255 + 1.510X	2.083
		48	3.914	2.291 + 1.700X	13.581
	12days larvae	24	5.732	2.242 + 1.568X	0.865
		48	3.828	1.751 + 2.052X	5.448
	16days larvae	24	9.819	2.786 + 1.111X	4.794
		48	3.596	2.400 + 1.670X	10.07
	Adult male	24	28.05	3.599 + 0.967X	2.404
		48	12.70	3.787 + 1.098X	1.389
		72	5.586	3.853 + 1.534X	2.180
	Adult female	24	18.27	3.579 + 1.125 X	0.149
		48	9.294	3.691 + 1.351 X	3.747
		72	5.068	3.870 + 1.601 X	10.39
	Adult unsexed	24	16.69	3.385 + 1.320 X	2.843
		48	9.293	3.327 + 1.727 X	10.21
		72	3.969	3.832 + 1.950 X	0.953
P. erosus (Methanol)	9days larvae	24	341.74	2.407 + 1.023 X	2.585
		48	31.205	2.077 + 1.956 X	1.066
	12days larvae	24	317.60	2.555 + 0.976X	0.192
		48	31.328	1.845 + 2.108 X	2.068
	16days larvae	24	413.19	2.302 + 1.031 X	1.161
		48	35.299	2.169 + 1.828 X	2.976
	Adult male	24	897.65	2.145 + .966 X	2.394
		48	406.34	2.135 + 1.097 X	1.383
		72	178.56	1.547 + 1.533 X	2.161
	Adult female	24	317.60	2.555 + 0.976X	0.192
		48	297.19	1.659 + 1.350 X	3.742
		72	161.99	1.462 + 1.601 X	10.36
	Adult unsexed	24	534.02	1.399 + 1.319 X	2.838
		48	297.13	0.730 + 1.726 X	10.19
		72	126.84	0.900 + 1.948 X	0.946

Table 9. Potency of *S. macrophylla* seed extracts of Chloroform and Methanol against different stages of *T. castaneum* by TFM

Seed Extracts	Life Stages	Exposure period (days)	LD_{50} ppm	Y - values	X^2 (3df)
S. macrophylla (Chloroform)	9days larvae	3	842391.6	1.505 +0.589X	1.092
		5	203127.3	1.543 +0.651X	8.495
		7	7186.128	-1.081 + 1.576X	9.658
	12days larvae	3	1191326	1.513 +0.573X	2.104
		5	122972.3	1.037 +0.778X	0.545
		7	7777.573	-1.134 +1.576X	4.505
	16days larvae	3	1840313	1.310 + 0.588X	0.194
		5	151075.1	0.773 + 0.815X	0.759
		7	10843.02	-3.077 + 2.00X	2.846
	Adult male	3	273728.8	0.123 + 0.896X	1.1567
		5	75083.34	0.158 + 0.992X	2.105
		7	18203.93	-2.442 + 1.747X	0.535
	Adult female	3	142946.9	0.265 +0.918X	2.895
		5	37667.05	-0.177 + 1.131X	2.644
		7	13776.73	-2.274 + 1.757X	2.457
	Adult unsexed	3	329612.2	0.423 + 0.829X	1.079
		5	68010.71	-0.233 + 1.083X	0.267
		7	20367.13	-2.127 + 1.654 X	0.204
S. macrophylla (Methanol)	9days larvae	5	1738018	0.848 + 0.665X	0.552
		7	331638.6	0.969 + 0.730X	0.702
		14	15681.36	-3.851 + 2.111X	1.561
	12days larvae	5	1059280	0.777 + 0.700X	2.313E-02
		7	201850.9	-0.396 + 1.017X	1.477
		14	17108.07	-2.708 + 1.820X	1.269E-02
	16days larvae	5	721788.2	0.949 + 0.691X	1.625
		7	257105.7	1.155 + .710 X	0.110
		14	14514.44	-3.399 + 2.018X	1.103
	Adult male	5	907779.6	0.903 +0.687X	0.390
		7	134222	0.715 + 0.835X	0.183
		14	14148.92	-2.001 + 1.686X	2.959
	Adult female	5	576764.5	0.961 + 0.701X	0.787
		7	98836.11	-0.074 + 1.015X	0.704
		14	14162..24	-2.542 + 1.816 X	2.127
	Adult unsexed	5	258659.7	0.346 +0.859X	1.615
		7	118204.5	0.934 + 0.801X	1.708
		14	17511.07	-2.445 + 1.754X	0.444

Table 10. Potency of *P. erosus* seed extracts of Chloroform and Methanol against different stages of *T. castaneum* by TFM

Seed Extracts	Life Stages	Exposure period (days)	LD_{50} ppm	Y - values	X^2 (3df)
P. erosus (Chloroform)	9days larvae	3	100701	0.391+ 0.921X	0.503
		5	35028	0.433 + 1.004X	3.036
		7	9285	-1.837+ 1.723X	1.478
	12days larvae	3	170650	0.928 + 0.778X	0.270
		5	49582	0.642 + 0.928X	1.876
		7	7937	-2.827 + 2.007X	1.250
	16days larvae	3	138608	0.526 + 0.869X	0.872
		5	41528	0.181 + 1.043X	1.008
		7	8355	-2.354 + 1.875X	3.231
	Adult male	3	78824	0.414 + 0.936X	0.379
		5	15247	-0.570 + 1.331X	1.689
		7	7845	-1.549 + 1.681 X	1.092
	Adult female	3	57126	-3.10E-02 + 1.05X	0.596
		5	12625	-0.655 + 1.378X	2.262
		7	6401	-1.508 + 1.709X	4.382
	Adult unsexed	3	112592	0.596 + 0.871X	2.053
		5	19478	-0.534 + 1.290X	2.733
		7	5786	-1.200 + 1.648X	6.842
P. erosus (Methanol)	9days larvae	5	187709	0.303 + 0.890X	0.405
		7	101754	0.648 + 0.868X	4.558E-02
		14	8087	-2.891 + 2.019X	3.195
	12days larvae	5	262368	0.735 + 0.786X	1.078
		7	110887	0.837 + 0.825X	0.243
		14	7767	-2.203+ 1.851X	0.289
	16days larvae	5	210356	0.466+ 0.851X	0.120
		7	86033	6.45E-02 +1.00X	0.610
		14	9191	-3.080 + 2.038X	1.595
	Adult male	5	108727	0.972 + 0.799X	0.900
		7	39082	1.019 + 0.866X	3.209E-02
		14	8352	-2.532 + 1.920X	1.363
	Adult female	5	80917	0.372 + 0.942X	1.008
		7	46938	0.257 + 1.015X	0.295
		14	7717	-3.473+ 2.179X	2.021
	Adult unsexed	5	102758	0.245 + 0.948X	0.247
		7	36796	-0.273 + 1.154X	0.246
		14	6843	-2.606 + 1.983X	0.905

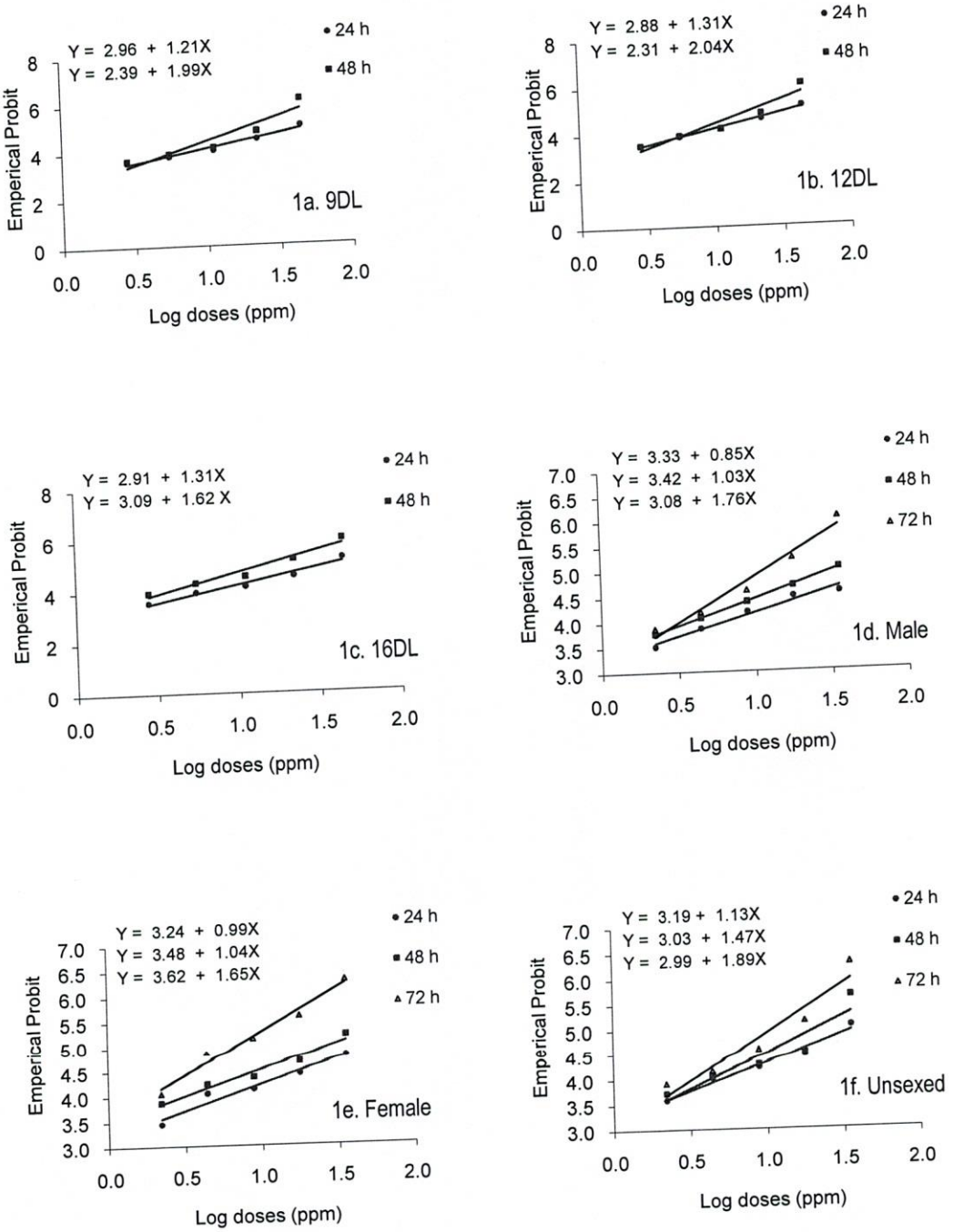


Fig. 1a-1f. Regression lines of the dose mortality potency with *S. macrophylla* seed extract in chloroform on *T.castaneum* larvae and adults by RFM (DL-days larvae, h-exposure hours)

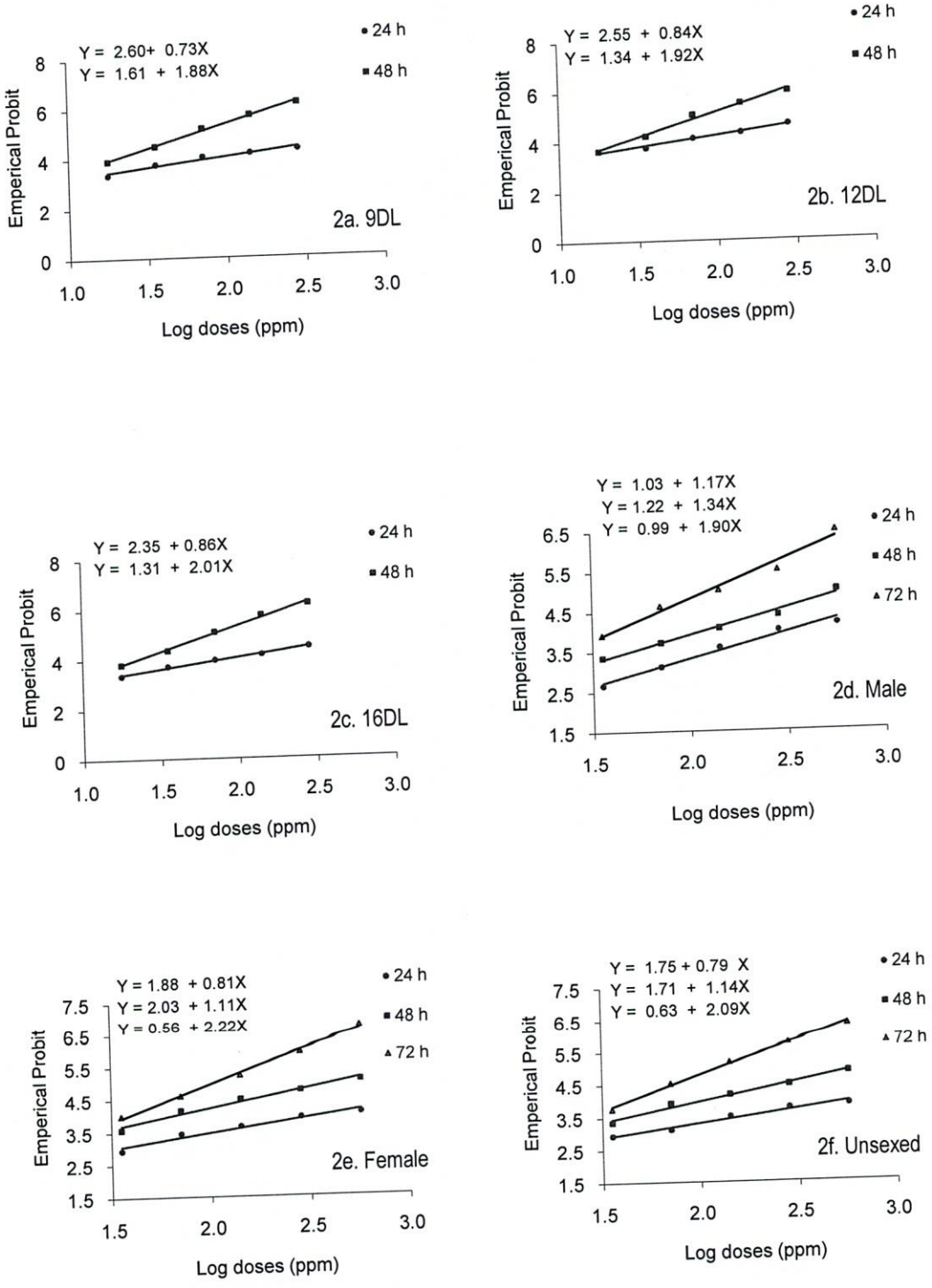
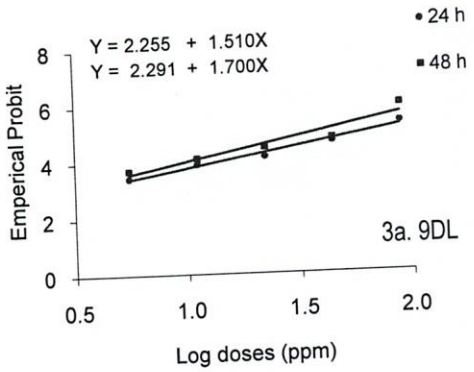
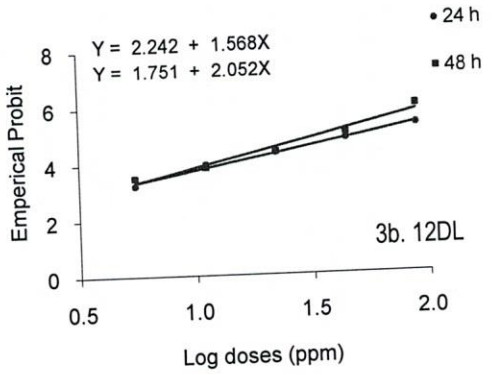
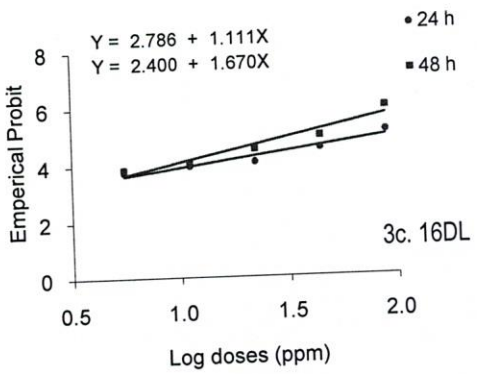
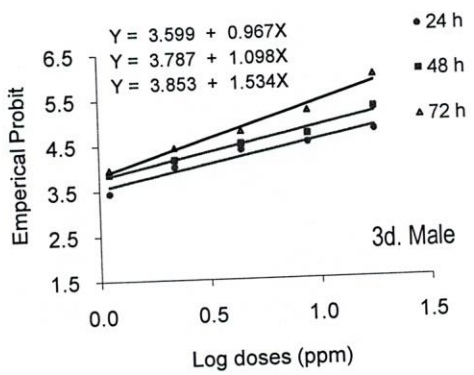


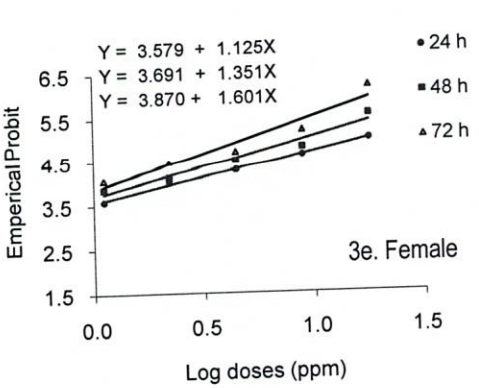
Fig. 2a-2f. Regression lines of the dose mortality potency with *S. macrophylla* seed extract in methanol on *T.castaneum* larvae and adults by RFM (DL-days larvae, h-exposure hours)











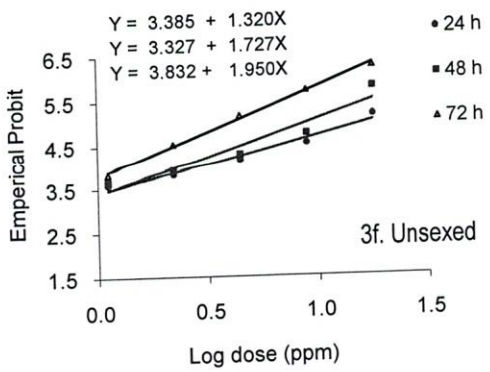
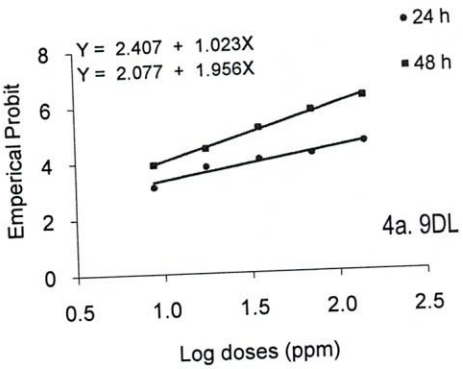
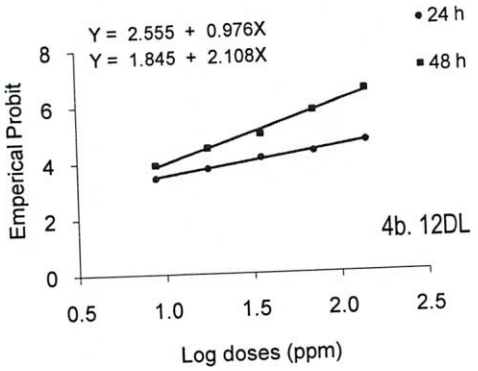
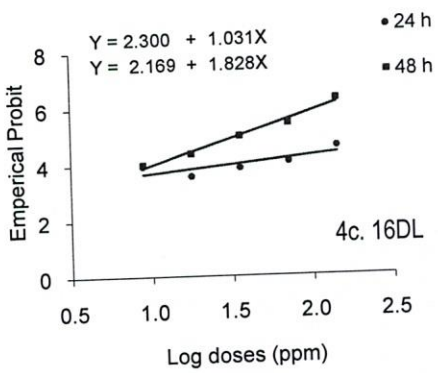
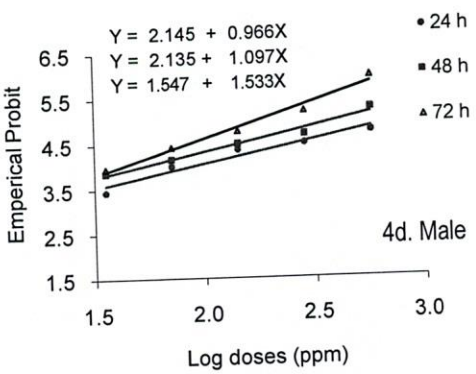


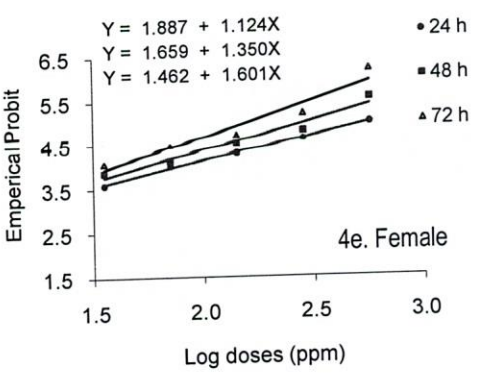
Fig. 3a-3f. Regression lines of the dose mortality potency with *P. erosus* seed extract in chloroform on *T.castaneum* larvae and adults by RFM (DL-days larvae, h-exposure hours)











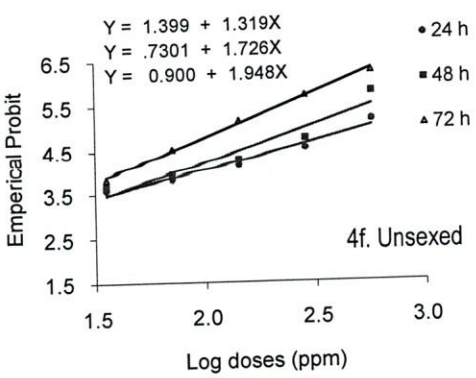


Fig. 4a-4f. Regression lines of the dose mortality potency with *P. erosus* seed extract in methanol on *T. castaneum* larvae and adults by RFM (DL-days larvae, h-exposure hours)

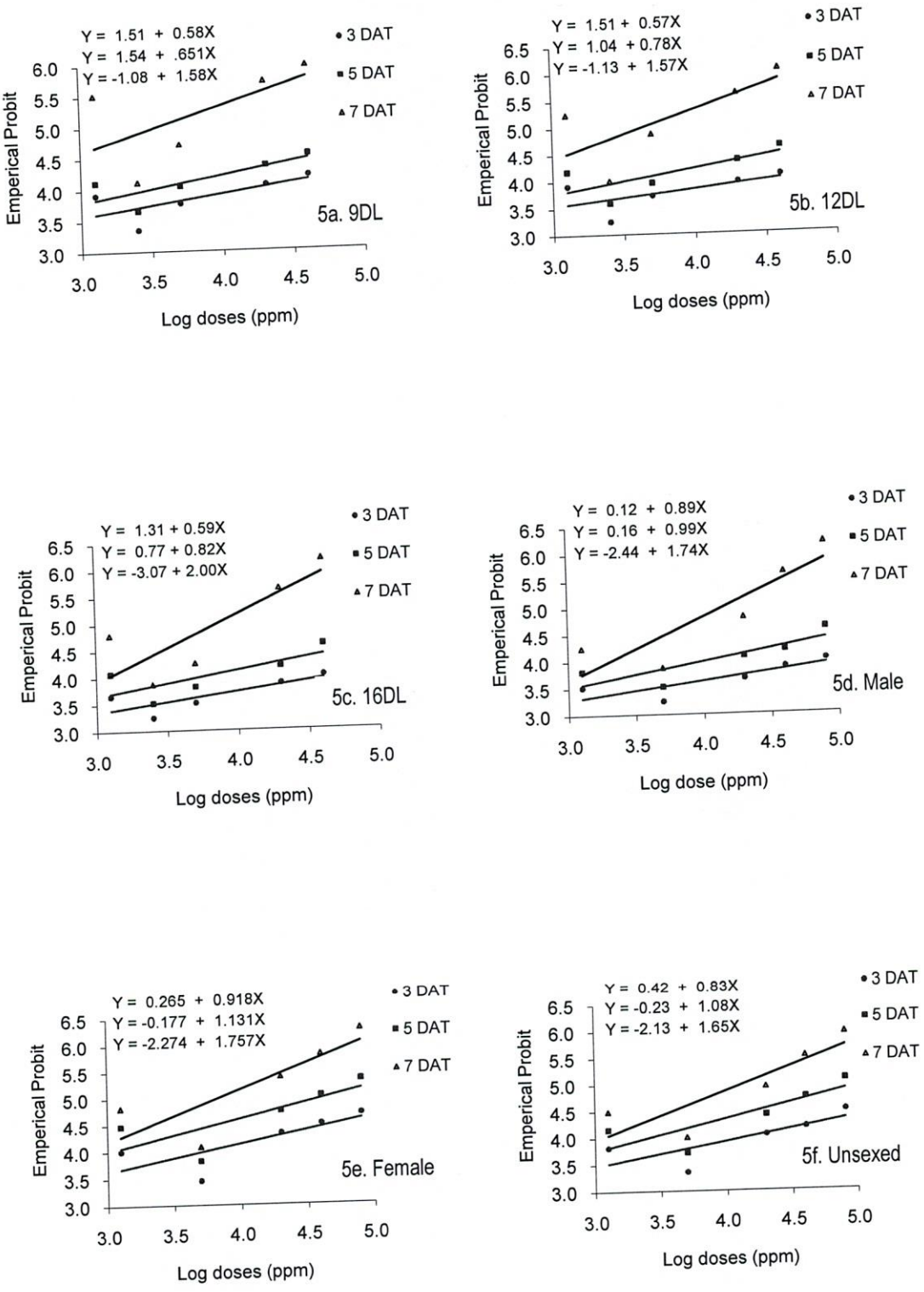


Fig. 5a-5f. Regression lines of the dose mortality potency with *S. macrophylla* seed extract in chloroform on *T.castaneum* larvae and adults by TFM (DL- days larvae, DAT- days after treatment)

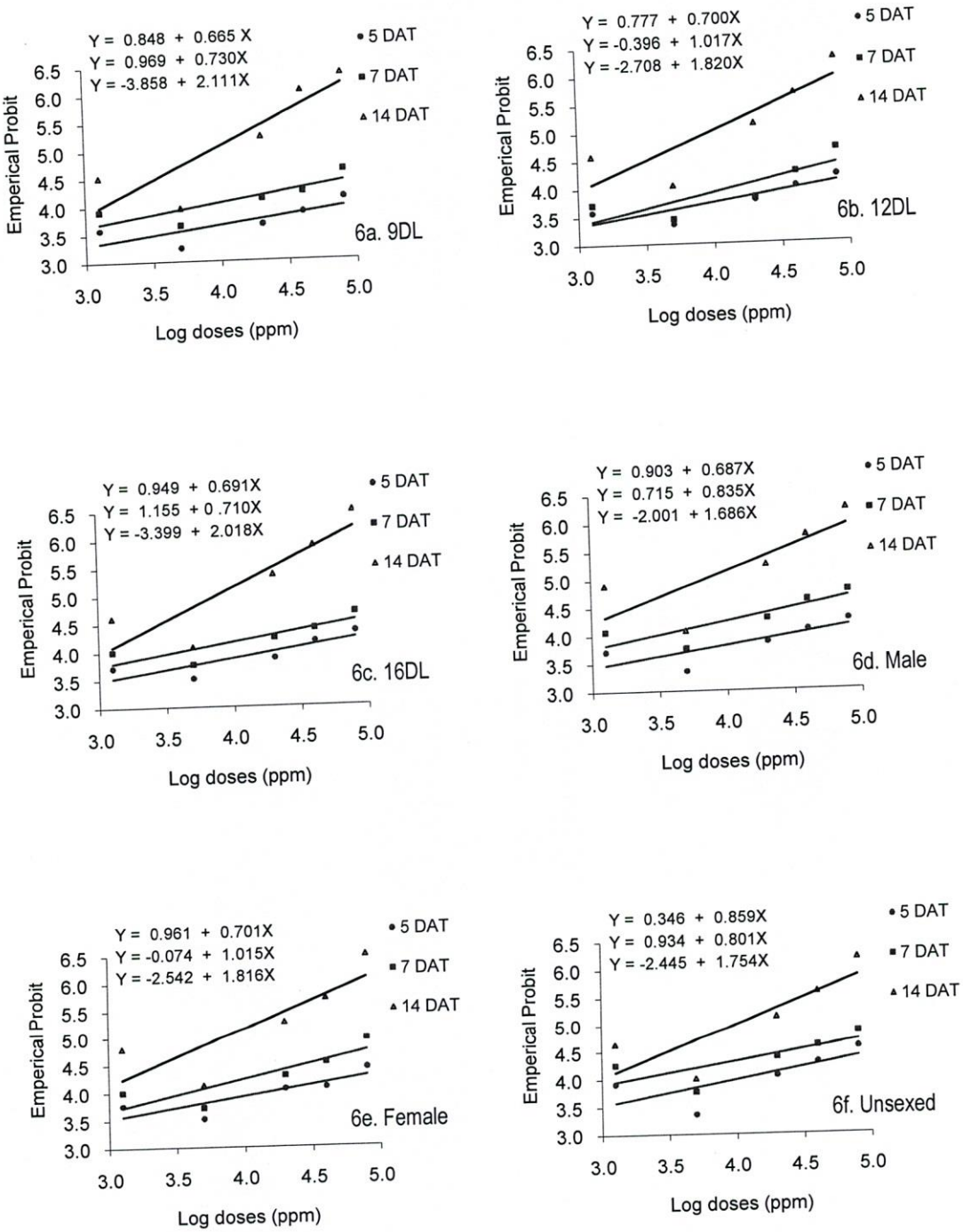


Fig. 6a-6f. Regression lines of the dose mortality potency with *S. macrophylla* seed extract in methanol on *T.castaneum* larvae and adults by TFM (DL- days larvae, DAT- days after treatment)

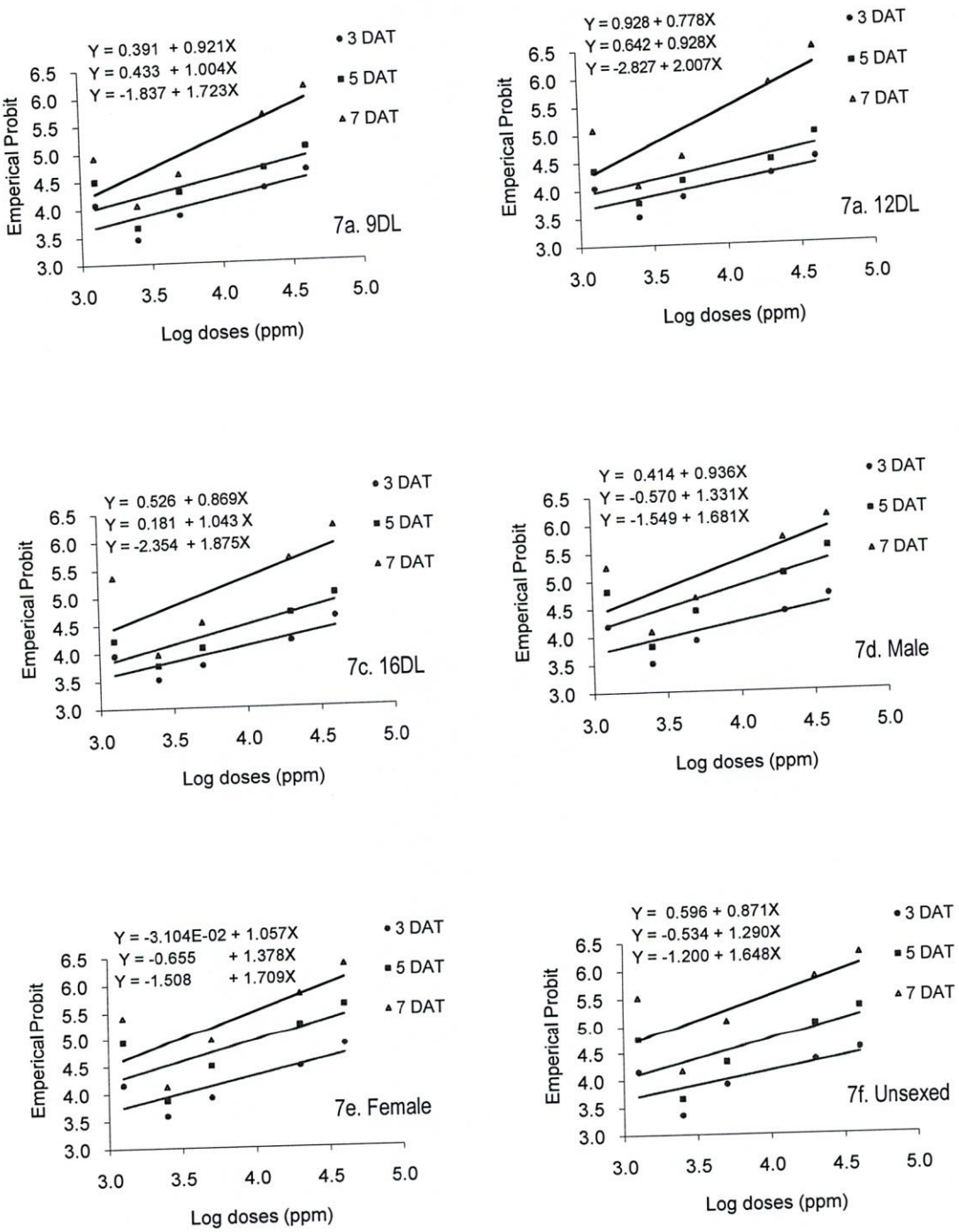
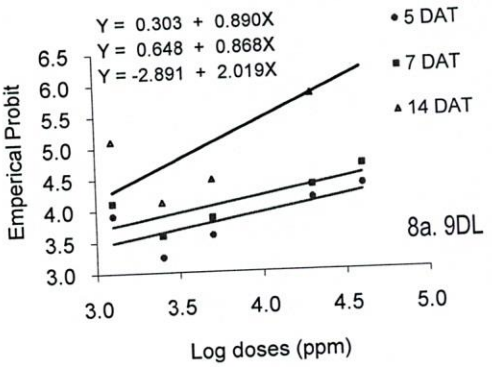
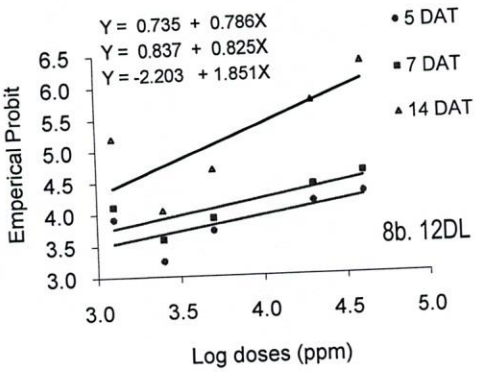
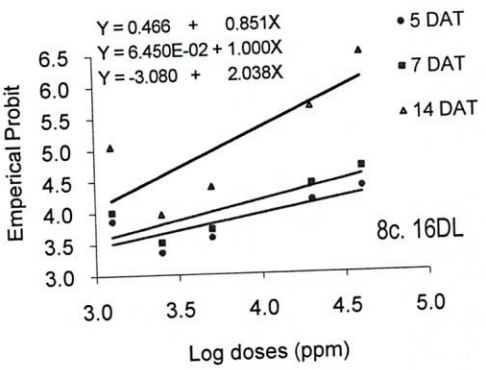
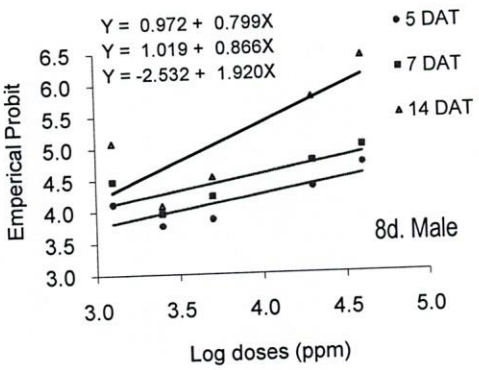


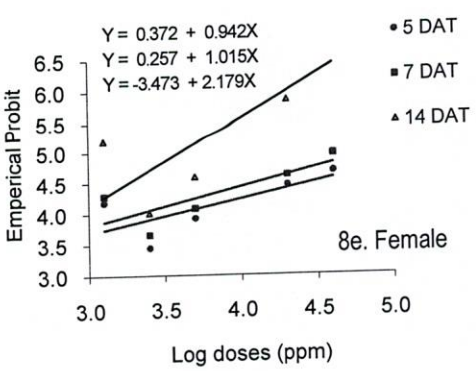
Fig. 7a-7f. Regression lines of the dose mortality potency with *P.erosus* seed extract in chloroform on *T. castaneum* larvae and adults by TFM (DL-days larvae, DAT-days after treatment)











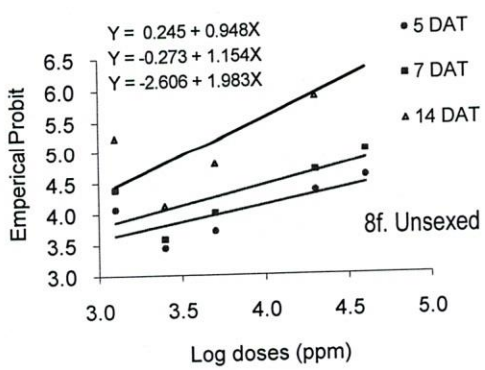


Fig. 8a-8f. Regression lines of the dose mortality potency with *P.erosus* seed extract in methanol on *T.castaneum* larvae and adults by TFM (DL-days larvae, DAT-days after treatment)

Discussion

The results of the present studies revealed that the powders and extracts from *S. macrophylla* and *P. erosus* were toxic ranking as seed powder of kesur > seed powder of mahogany (through DCM and TFM); and chloroform extract of kesur seed (through RFM and TFM)> chloroform extract of mahogany seed, methanol extract of kesur seed (through RFM and TFM)> methanol extract of mahogany seed. They were potent for use as a botanical pesticide against *T. castaneum.*

These powders and extracts were able to control the pests through both contact and oral intake. Meanwhile it is obvious that Kesur seed powder and extracts were the most potent since they were effective in controlling the pest due to contact and oral toxicity. On the other hand, mahogany seed powder and extracts were moderately or comparatively less potent due to contact and oral toxicity. The results of present studies were similar to Islam and Talukdar (2005) who reported that gradual decrease in LD_{50} values was with the time against *T. castaneum.*

Anwar *et al.* (2005) conducted experiment with bagging material and determined the efficacy of *Azadirachtin indica* against some insect pest of stored grains. They reported that 5% concentration caused 75% mortality after 30 days. The mortality caused by the citrus peel powder could be attributed to several mechanisms (Odeneyi *et al.* 2000). The use of the botanical powder have resulted to death in the tendency of the powder to block the spiracles of insects thus impairing respiration leading to the death of insects (Owoade 2008).The results of this study is in agreement with many other works on the use of plant products against stored products insects. Furthermore, the work of Bekele *et al.* (2001) showed that ground leaves of *Ocimum suave* was a source of repellents and toxicants against the maize weevil *S. zeamais,* the lesser grain borer *Rhyzopertha dominica* and the angoumois grain moth *Sitotroga cerealella.*

Mukherjea and Govindo (1958) reported that when ether and petroleum insoluble resin obtained from *Annona squamosa* were tested against *T. castaneum*, the average mortality of adult beetles were 94.66% by ether extract and 99.33% by petroleum insoluble resin extract at a concentration of 1.00 and 0.125% (w/w). An extract from the leaves of *Adhatoda vasca* was toxic to *T. castaneum* (Srivastava and Awasthi 1958). Visweswariah *et al.* (1971) reported that 22% mortality could be obtained at 10mg per petri dish against *T. castaneum by a solvent extract oil of A. squamosa* seed powder. The larvae of some stored product beetles exhibited higher tolerance to the contact insecticides than adults (Parkin 1954, Lloyed and Hewlett 1958, Tyler and Binns 1977). Visweswariah *et al.* (1971) also reported that potent insecticidal compound was present in the form of an oily material, which could be quantitatively extracted using petroleum

ether, hexane, acetone benzene, alcohol and chloroform. Ethyl acetate extracts of *A. squamosa* seeds showed larvicidal activity at 125-140 µg/2g diet for *Drosophila melanogaster* M. (Kawazu *et al.*1989).

In the 24h brine shrimp (*Artemia salina* Leach) bioassay, the ethanol and hexane extracts of *S. macrophylla* seeds elicited 22 and 44% mortality respectively, while at 48h the mortality were 48 and 76% respectively (Mikolajczak and Reed, 1987).The antifeedant activity was also exhibited against striped cucumber beetle, *Acalymma vittatum* although *S. macrophylla* seed extract was not as potent as other plant extracts that were also screened (Mikolajczak and Reed 1987).

Insecticidal efficacy from seeds of yam bean (*P. erosus*) were reported against the 4th instar larvae of *Aedes albopictus, Aphis gossypii*, and the 3rd instar larvae of both *Herse convolvuli (Agrius convolvuli)* and *Plutella xylostella* (Li YouZhi *et al.* 2009).

Many plant products such as essential oils and solvent extracts have been screened for their repellent, toxic and growth inhibitory activities against stored grain insect pests (Matthews 1993). Results of this study demonstrated that toxicity of the plant extracts decreased with the increasing larval ages. This may clearly support the previous reports that insect's age plays an important role in influencing susceptibility (Muwangi and Mukiama 1988). The present results are more or less similar to the findings of Mondal (1994) and Talukder (1995) who reported that the insecticidal properties of neem oil, Pithraj (*Aphanamixis polystachya*) seed extracts against *Tribolium* beetles and also similar to the findings of Upadhyay (2007)who revealed the insecticidal properties of Piper nigrum against *T. castaneum.*

Moreover, many other essential oils and their constituents also have huge potential as alternatives to currently used synthetic chemical pesticides for the management of *T. castaneum* populations (Shaaya *et al.* 1991, 1997; Lee *et al.* 2004, Sahaf *et al.* 2008, Ogendo *et al.* 2008, Nerio *et al.* 2009). The observed bioactivity against *T. castaneum* adults demonstrates that *A. officinarum* rhizome extract can be conveniently prepared by non polar and polar solvents, and may potentially prove to be effective for integrated pest management of *T. castaneum* populations. The activity of *A. officinarum* rhizome extract and its pure constituent level along with structure activity relationships against different life stages of the *T. castaneum* and other major stored grain insect pests may warrant further investigation. Moreover, provided with a proper formulation and scientific application strategy *A. officinarum* rhizome extract may be exploited for use to control insect infestation in small-scale farmer's level in developing countries (Isman 2006, 2008).

Chapter 5

BEHAVIOURAL RESPONSE OF *T.CASTANEUM* TO *S.MACROPHYLLA* AND *P.EROSUS* SEED POWDERS AND EXTRACTS

Introduction

Materials and Methods

Repellency test with powders

Repellency test with extracts

Statistical analysis

Results

Repellent effect of powders

Repellent effect of extracts

Discussion

Chapter 5

BEHAVIOURAL RESPONSE OF *T. CASTANEUM* TO S. *MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS

Introduction

Repellents from plant origins are considered safe in pest control operations as they minimize pesticide residues; ensure safety to the people, food, environment and wildlife (Khan 1982, Talukder and Howse 1995, Talukder *et al.* 2004). The plant extracts, powders and essential oils from different bioactive plants were reported as repellent against different stored product insects (Xie *et al.* 1995, Tripathi *et al.* 2000, Owusu 2001, Khan and Gumbs 2003, Boeke *et al.* 2004, Talukder *et al.* 2004). The essential oil of *Artemisia annua* was found as repellent against *T. castaneum* and *C. maculatus* (Tripathi *et al.* 2000, Talukder and Howse 1994,1995). Talukder (1995) listed 43 plant species as insect repellents.

The bitter gourd *(Momordica charantia* L.), dracaena tree *(Dracaena arborea*), *T. vogei, Blumea aurita* and horse wood *(Dausena anisata*) exhibited repellency against the weevil (Ofuya 1990, Boeke *et al.* 2004).

The literature on the biological properties of crude extracts and isolated secondary substances of plants against different insects and other organisms is abundant Jilani and Su (1983), Jilani *et al.* (1988) conducted insect repellency test using extracts of different plants on stored product pests. Boeke *et al.* (2004) evaluated the efficiency of 23 plant extracts on *C. maculatus* and found repellency of volatile oils. Novo *et al.* (1997, 1998) observed the repellent activity of several crude extracts of four native plants against *T. castaneum,* and antifeedant effect of *Anticarsia gemmatalis.*

The aim of this work was to evaluate the repellent properties of powder and crude extracts of *S. macrophylla and P. erosus* against *T. castaneum.*

Materials and Methods

Repellency test with powders

Repellency test with powders against *T.castaneum* was evaluated using the area preference method. One half of the petridish (9cm dia.) was spread with 1g of flour treated with *S.macrophylla and P.erosus* seed powders and the other half spread with 1g untreated flour as control. Doses were 0.5, 1 and 2% w/w for both of the powders. Ten insects (larvae/Adult) were introduced at the center in between two different food media of the petridish. The petridishes were kept in an incubator at 30°C without any light and humidity control. The treatments including controls were replicated 3 times. The numbers of insects present on the control and treated areas of the food media were recorded after 30min., 1 and 24h.

Repellency test with extracts

Repellent effects of *S. macrophylla and P. erosus* seed extracts against *T.castaneum* were evaluated using the disc method (McDonald *et al.* 1970).Test areas consisted of 9cm Whatman No # 1 filter paper cut in half. Test solutions were prepared by diluting 0.031, 0.063, and 0.125mg of each crude extracts in 2ml solvents. Each solution was uniformly applied to a half-filter paper disc using a micropipette corresponding to the doses of 0.98, 1.97 and 3.93 µg/cm^2.The other half of the filter paper were treated with solvent alone and used as control. Treated and control half disc were air dried for 30 min. to evaporate the solvent completely. Full disc was subsequently remade by attaching treated halves to untreated halves with clear adhesive tape. Each remade filter paper disc was placed into a 9cm (diam.) petridish .Ten insects (larvae/adult) were released separately at the center of the filter paper disc and the petridishes were covered with lids. The petridishes were then kept in an incubator at 30°c without any light and humidity control. The experiments were replicated 3 times and the numbers of insects present onto the untreated control and treated areas of the disc were recorded after 30min., 1 and 24h.

In both tests, larvae were 9, 12 and 16 day old and adults were 10 day old of male, female and unsexed.

Statistical analysis

The data obtained during area preference method and disc method repellency tests were analyzed statistically using one-way ANOVA and the means were compared using Tukey's multiple comparison tests.

Results

Repellent effect of powders

Both of the seed powders of *S.macrophylla* and *P.erosus* were significantly ($P>0.05$) effective with regards to orientation and repellency (Fig. 9, 10 and App. Tables 151-164) on different stages of *T. castaneum*. It was estimated that percent repellency increased at most of the doses with the increase of exposure period to treatments. Overall results showed that mahogany seed powder is more potent than kesur in terms of repellency. No significant difference was found between different stages viz. larvae and adults. Observed data indicates that mahogany seed powder has the highest average repellency of 99.99% and 93.30% after for adult male and 9 day old larvae respectively, and in kesur seed powder the highest average repellency rates were 93.30% and 90.00% for 16 day old larvae and adult males respectively after 24h exposure.

Repellent effect of extracts

Figures 11-14 and App. Tables 165-192 represent the repellent results of mahogany and kesur seed extracts of chloroform and methanol respectively. Highest repellent effect at 24h treatment (99.99%) was found in chloroform extract of mahogany on adult males. All the chloroform extracts were more effective than methanol extracts in both mahogany and kesure seeds. There were no significant variations due to Tukey's multiple comparison tests in the repellent effect on larvae and adults, but both of the extracts of mahogany and kesure were effective as repellent on different stages of *T. castaneum.* Comparison of repellency of different application rates revealed that repellency of plants most of the cases were dose and time dependant. At 0.98 $\mu g/cm^2$ repellency was 53.31, 60.00 and 69.99% where as at 1.97$\mu g/cm^2$ repellency was 56.7, 66.69 and 80.01% (Fig.3) which were significantly higher than the application rates of 0.98$\mu g/cm^2$. Statistically application rates of 0.98 and 1.97 µg/cm2 were non-significant.

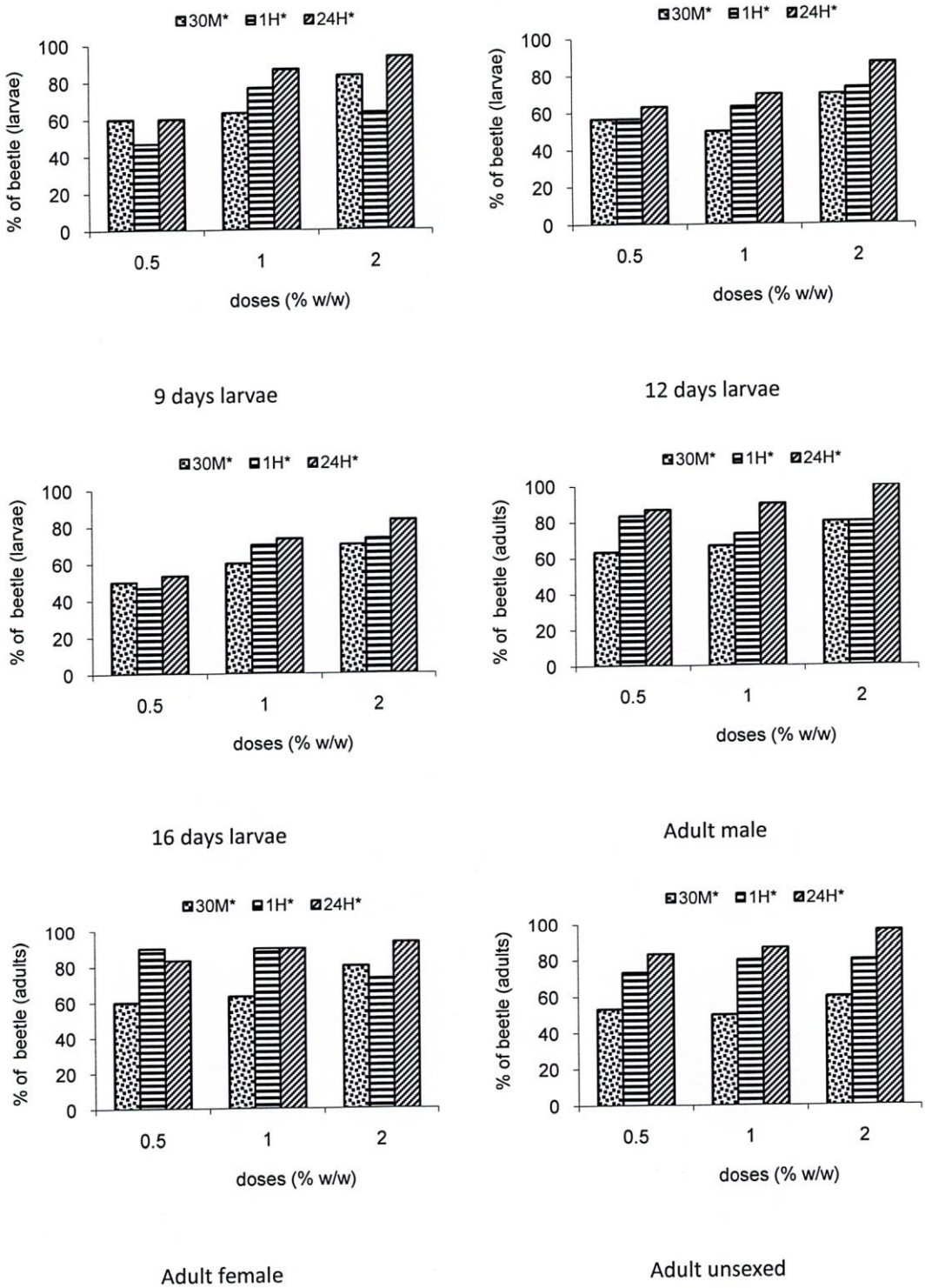


Fig.9.The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with mahogany seed powder at different doses

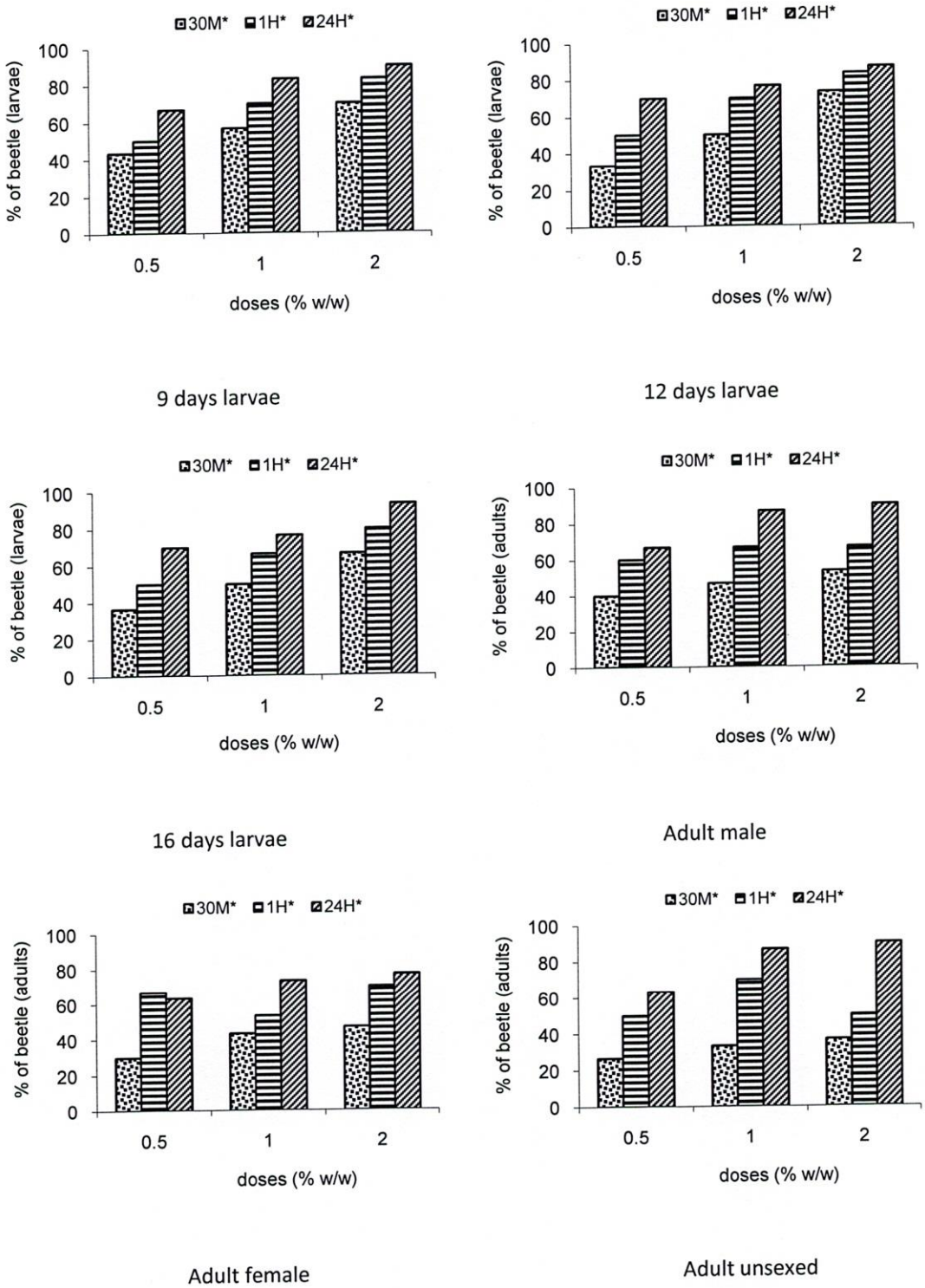


Fig. 10. The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with kesur seed powder at different doses

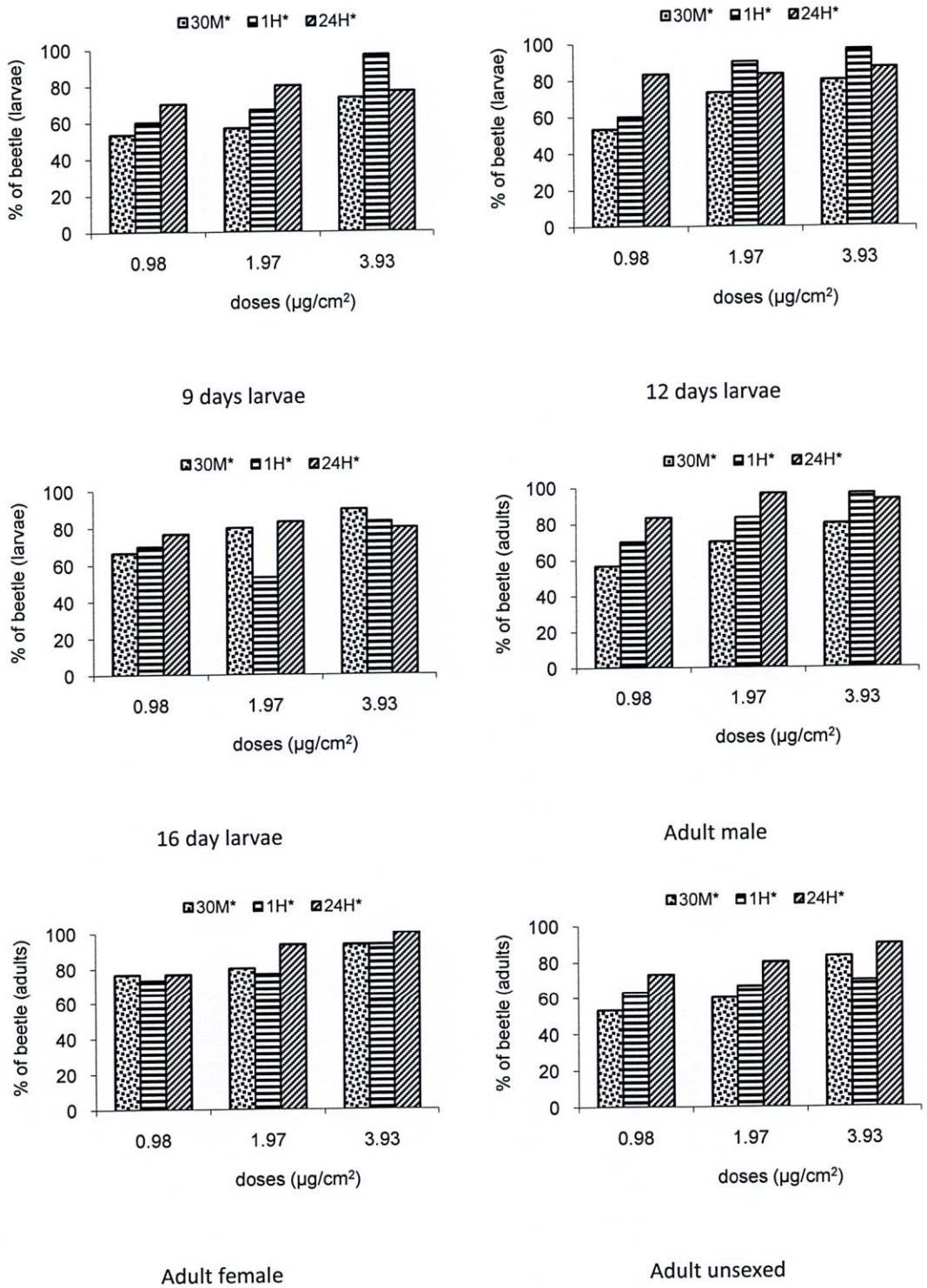


Fig. 11. The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with chloroform extract of mahogany seed at different doses

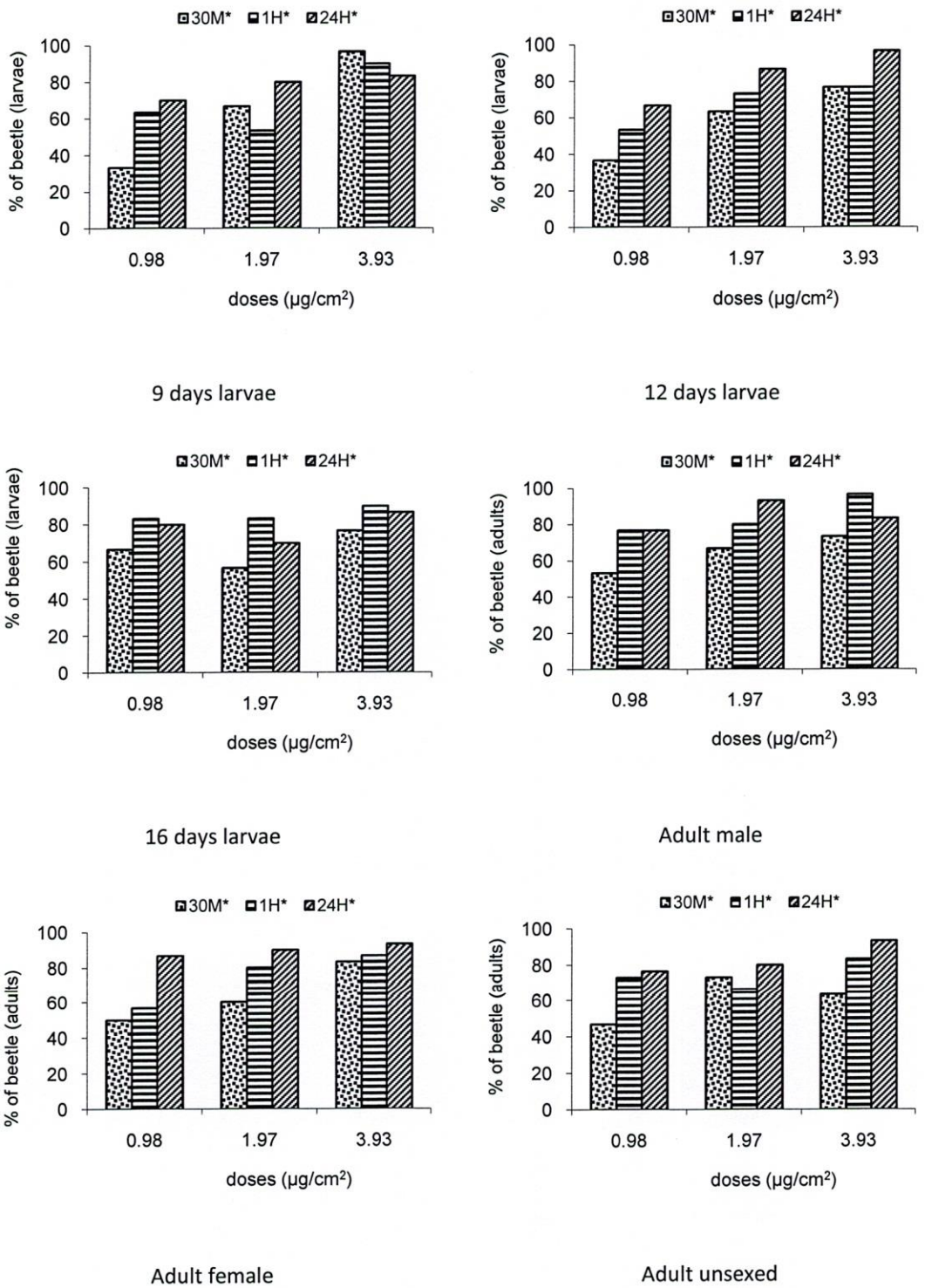


Fig. 12. The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with methanol extract of mahogany seed at different doses

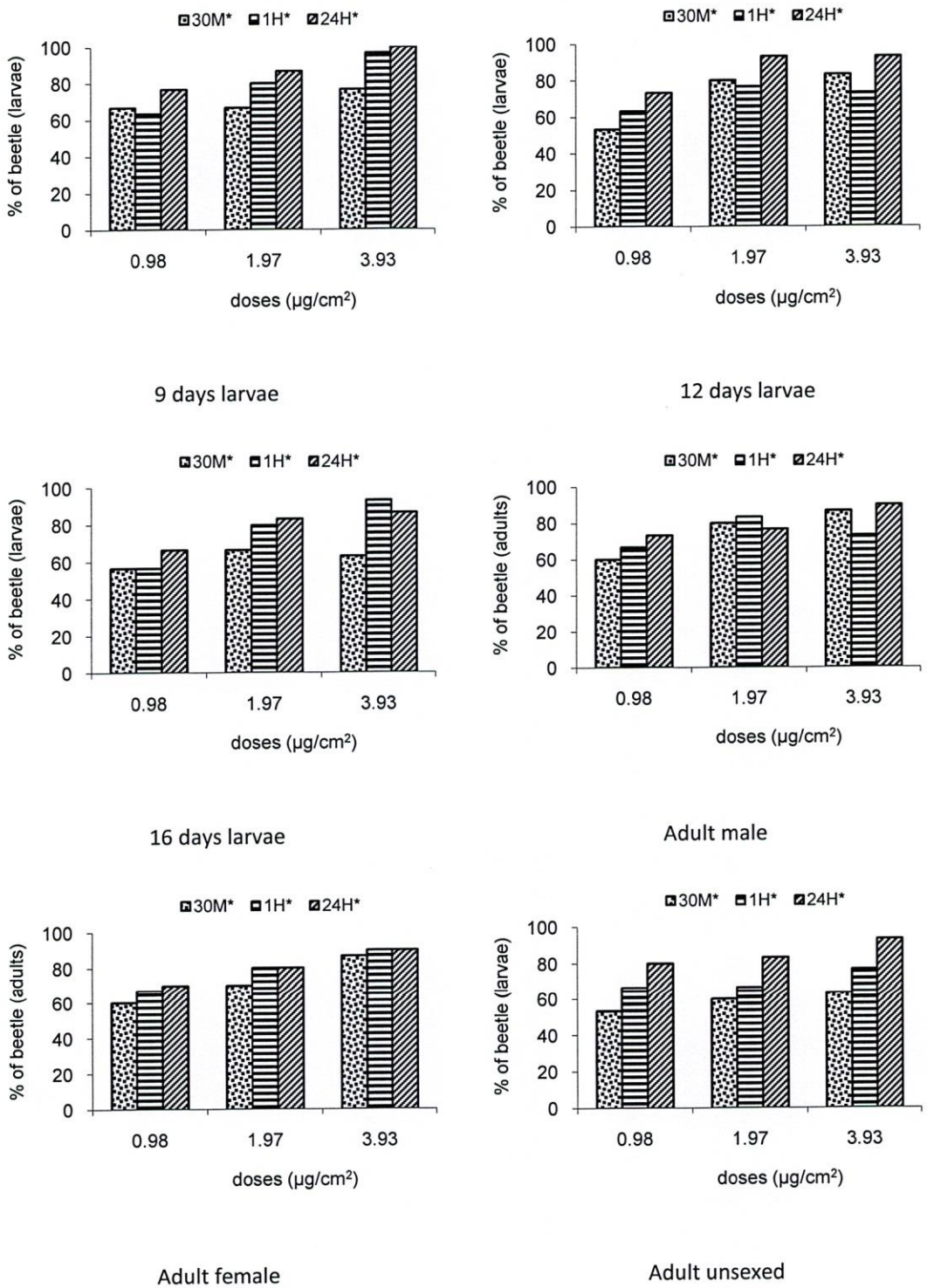


Fig. 13. The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with chloroform extract of kesur seed at different doses

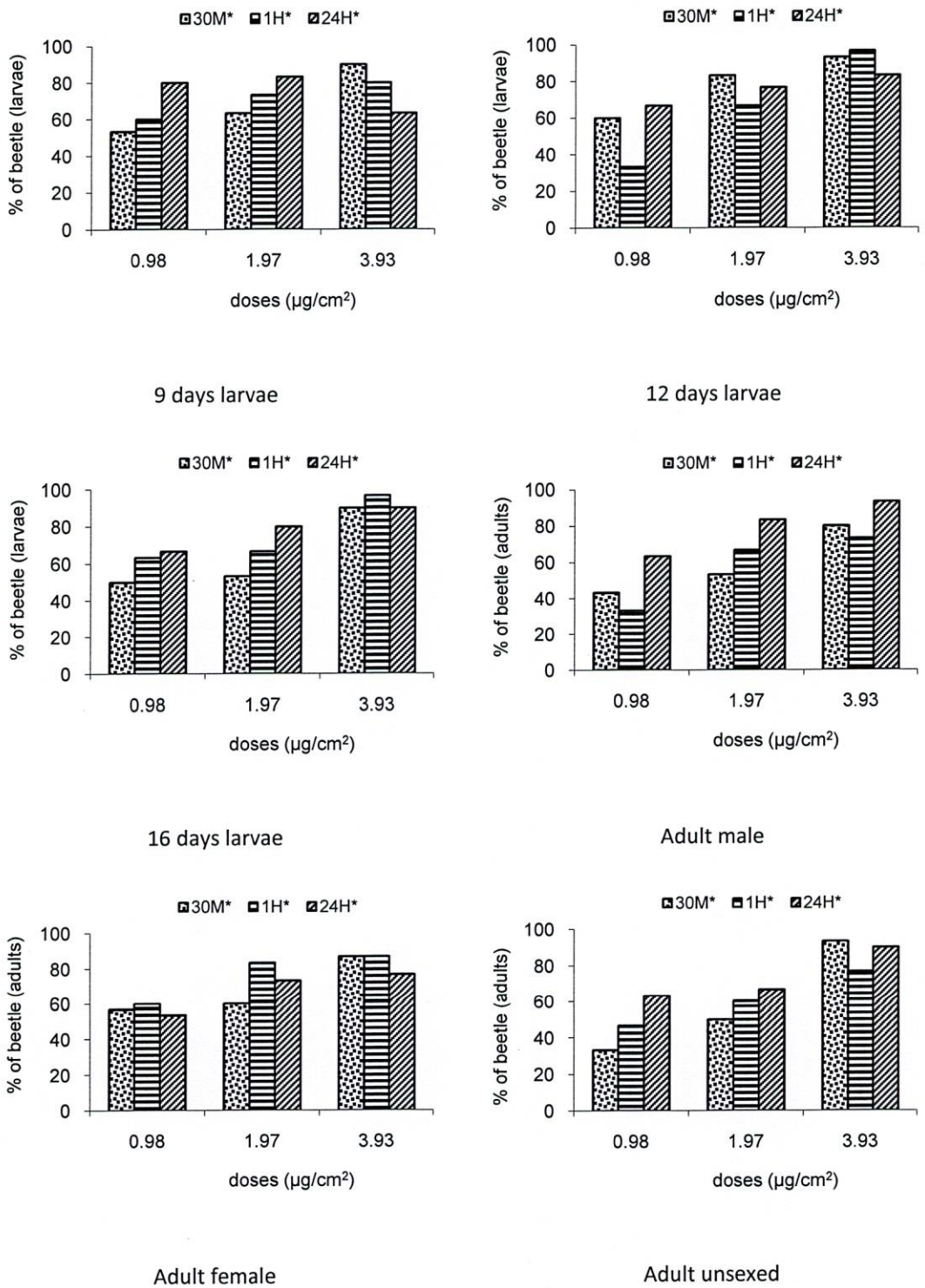


Fig. 14. The percentage of *T. castaneum* beetles in the half of the petridish containing flour medium treated with methanol extract of kesur seed at different doses.

Discussion

In the present experiments it was observed that mahogany and kesur seed powder and extracts were repellent on different stages of larvae and adults of *T.castaneum.* Repellency was more potent due to contact action and aromatic odor rather than ingestion of treated food. It was revealed that mahogany seed powder and extracts more effective as repellent than kesur due to aromatic odor.

Comparison of repellency in different times (30m. 1h and 24h) revealed that average mean repellency of plant extracts during 24h being the highest and significantly different from rest of the times (30m. and 1h). Average repellency during second intervals (1h) was significantly less than first (30m.) and last intervals (24h).

Khan and Marwat (2004) evaluated the leaves, bark and seeds of bakain (*Melia azadirach*) and *Calotropis procera* powder against lesser grain borer (*Ryzopertha dominica*). They tested that insect (*R. dominica*) was repelled from bakain's bark powder with 98.25% repellency followed by powder of *C. procera.*

The result is agreement with Mondal and Begum (1991) and Rahman and Mondal (1994) who reported the repellent effect of tobacco and neem leaf powder on *T. confusum* adults. Parveen and Mondal (1992) reported the repellent effect of turmeric (*Curcuma longa*) powder on both larvae and adults of *T. castaneum.* It was reported that caffeine and castor oil (Mondal and Akhtar 1993), sesame oil, mustard oil, linseed oil and neem oil (Akhtar 1997), biskatali (Hussain 1995a, Hussain *et al.* 1995), atta (Hussain *et al.* 1995), katabegun (Hussain 1995a), turmeric oil, neem oil, sweetflag oil, Margoson "O" (Jilani *et al.* 1988) were repellent to larvae and adults of *T. castaneum.*

The antifeedant property of the seed extracts of *S. macrophylla* were investigated using the fall armyworm (FAW), *Spodoptera frugiperda* and the striped cucumber beetle, *Acalymma vittatum.* The seed extracts were highly deterrent (feeding ratios of 0.02 and 0.18 for the ethanol and hexane extracts, respectively) in the FAW bioassay (Mikolajczak and Reed 1987). *Astagalus anisacanthus, Curcuma zedoaria, Ephedra intermedia, Ferula assafoetida, Foeniculum graecium, Nerium indicum, Salsola kali, Sophora griffuhii,* have been screened against *T. castaneum* and maximum average repellency of 57.6 have been recorded in *Astagalus anisacanthus* (Jilani *et al.* 1991). *T. castaneum* repellency in n-hexane extracted neem was 57, 65, 70% at 200, 400, 800 µg/cm2 respectively (Jilani *et al.* 1993). Thus, this study confirms the previous findings that mahogany and kesur seed powder and extracts are better repellent.

Chapter 6

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON FECUNDITY OF *T. CASTANEUM*

Introduction

Materials and Methods

Statistical analysis

Results

Discussion

Chapter 6

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON FECUNDITY OF *T.CASTANEUM*

Introduction

T. castaneum female generally lays eggs continuously for a long perid (Dick 1937, Imura 1989). Fecundity of *T. castaneum* are being affected by certain environmental factors including temperature, moisture (Park and Frank 1948), relative humidity (Holdawa 1932), flour medium (Nandi *et al.* 1990, Khalequzzaman *et al.* 1994) and conditioning of the medium by the beetles living in it (Crombie 1943, Prus 1961, Sonleitner 1961, Mondal 1984a, Mondal and Port 1985, Rahman 1992).

The average number of eggs laid per female varies from 3.24 to 19.66 depending on temperature between 27-34°C (Mondal 1984a, Mondal and Port 1985, Banu 2004, Khanom 2004).

Oviposition rate is also reduced in *Tribolium* by botanicals (Rahman 1992, Banu 2004, Khanom 2004, Rehana 2010). A number of IGR compounds have been reported to reduce the fecundity in stored product insect pests including *Tribolium* (Carter 1975, El-Sayed *et al.* 1984-85, Eisa *et al.* 1986, Nawrot *et al.* 1987, Elek and Longstaff 1994, Mazid 2000, Parween *et al.* 2001, Hasnat 2003, Khanom 2004).

The present study was performed to evaluate the potency of mahogany and kesur seed powders and extracts on the fecundity of *T. castaneum.*

Materials and Methods

Newly hatched larvae of *T. castaneum* were reared on fresh flour medium in a glass jar which was kept in an incubator at 30°C without any light and humidity control. After pupation pupae were sexed by microscopic examination. The sexed pupae were kept in petridish until adult emergence.

Ten days old adults of known sex were paired. Fifteen pairs were used for oviposition. Each pair was kept in a glass vial (50×20mm) containing 1g of food either treated or untreated (Control). The tops of the vials were plugged with cotton. The vials were kept in an incubator at 30°C. Eggs were collected after

every three days by sieving the food media over a period of 45 days (Khan and Selman 1981, Mondal 1984a).The food media were changed after every five days to avoid conditioning by the beetle themselves (Mondal 1984a).The food media were treated with mahogany seed powder (0.12% w/w), kesur seed powder (0.03% w/w), chloroform extracts of mahogany seed (2000ppm) and chloroform extracts of kesur seed (250ppm) individually and combindly.

Statistical analysis

The data obtained during experiments were analyzed statistically using One-way ANOVA and the means were compared by Duncan's Multiple Range Test (DMRT) (Duncan 1951). The results of the experiments were shown in the graph with error bar diagrams.

Results

The results of the experiment and statistical analysis are presented in Figure 15 and App. Tables 193-195.

The effects of the mahogany and kesur seed powders and extracts on fecundity of *T. castaneum* were evaluated by comparing the mean number of eggs laid in the treated and untreated Control media. Mahogany and kesur seed powder and extracts either alone or in combinations had significant ($P>0.001$) effects to reducing the fecundity of *T. castaneum*. The lowest mean number of eggs (5.35) was recorded in case of combined treatment with chloroform extracts of mahogany and kesur seed at a concentration of 2000ppm and 250ppm respectively (Fig. 15, column 8). Almost similar reducing trends were found in the column 6, 5 and 3 [Chloroform extract of kesur seed (KCE) at 250ppm, Kesur seed powder (KSP) 0.03% + mahogany seed powder (MSP) 0.12% and Kesur seed powder (KSP) 0.03% w/w respectively] (Fig.15). The highest oviposition rates were recorded in food treated with mahogany seed powder at a concentration of 0.12%. The females fed on the treated media laid fewer eggs than the females fed on Control media. In the treated media per day per female the minimum and maximum numbers of eggs were 2.40 and 9.15 but in control media minimum and maximum number of eggs were 6.08 and 10.65. The ANOVA and DMRT results showed that Kesur seed powder and extracts had more significant effects than mahogany in reducing the fecundity of *T. castaneum*.

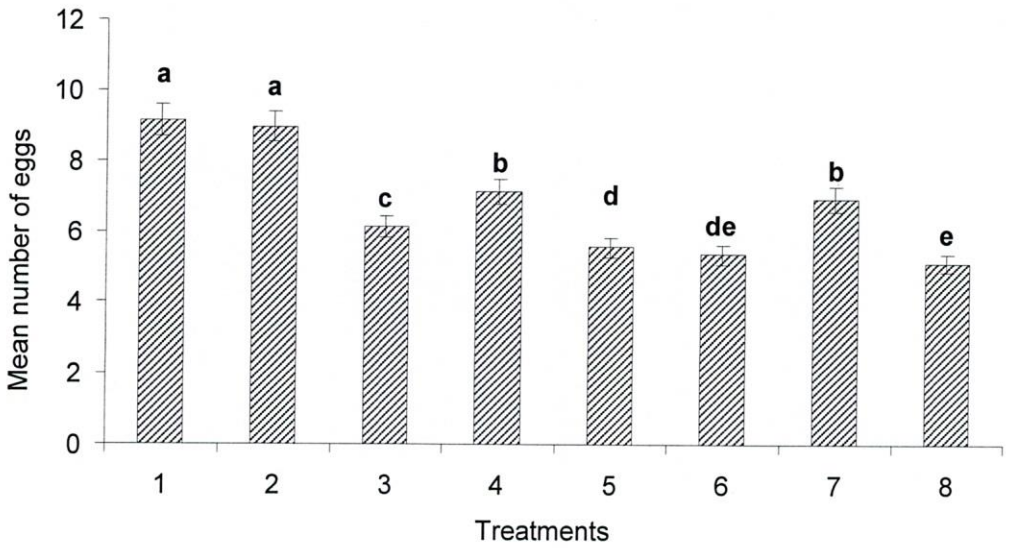


Fig.15. The mean number of eggs laid by a single female of *T. castaneum* reared on fresh medium (Control) and medium treated with different combinations of mahogany and kesur seed powder and extracts (Treatments: 1-Control (untreated), 2-Control (treated with chloroform), 3-KSP (0.03%), 4-MSP (0.12%), 5-KSP 0.03% + MSP 0.12%, 6-KCE 250ppm, 7-MCE 2000ppm , 8-KCE 250ppm+ MCE 2000ppm)

The bars followed by the same letter in the different column are not significantly different P>0.05 (DMRT)

Discussion

The mahogany and kesur seed powder and extracts were significantly effective over control with regards to oviposition rate. Varying activity by the following powder and extracts indicate that the pest controlling activities are not uniformly present in every aromatic plant. The seed powder and extracts of mahogany showed poor effects against ovoposition whereas that of kesur showed strog activity. The findings of the present investigation are in accordance with those of other workers who have previously reported that plant powders reduce life span and oviposition of bruchids, which include neem kernel powder (Sowunmi and Akinnsi 1983, Maredia *et al.* 1992), *Tridax procumbens* (Bhaduri *et al.* 1985), *Lantana camara* (Koona and Nijoya 2004) and seed powder of custard apple (Ali *et al.* 1983).

Bannu (2004) reported reduced fecundity in azadirachtin treatments in both *T. castaneum* and *T.confusum.* The present result is also similar to those of some researchers who reported that the reduction in oviposition of *Tribolium* due to botanicals (Saxena *et al.* 1980, Khanam and Talukder 1993, Mannan *et al.*

1993, Akhtar and Mondal 1994, Joseph *et al.* 1994, Khanam 2003, Khanom 2004, Rehana 2010). Jilani and Malik (1973) reported that neem seed extracts effectively reduce the reproduction of *T. castaneum*. Leaf of *A. indica* and *Vitex negundo* reduced the fecundity of *T. castaneum* (Amin 2000). Akhtar (1997) reported that neem oil was highly effective to reduce the fecundity of *T. castaneum* and *T.confusum.* The present result is similar to the findings of Cobbinah and Appoloh (1989), who reported reduced fecundity in different stored product insect pests due to neem oil. Cassia oil completely inhibited the reproduction of *Sitophilus zeamais, Ryzopertha dominica* and *T. castaneum* when mixed with wheat and wheat flour at the doses of 0.1%-0.2% in weight. Rahman and Talukder (2006) found that the powdered leaves and extracts of neem and bankalmi at 3% mixture provided good protection for black gram seeds by reducing the oviposition of *C. maculates*. Bhuiyan and Quiniones (1990) reported that nishinda leaf powder effectively prevented oviposition by the corn weevil. Talukder and Howse (1994) showed that the admixture of food with pithraj leaf, bark and seed powder reduced the oviposition rates of the pulse beetle. Srivastastava *et al.* (1988) reported that eucalyptus oil effectively prevented the oviposition of insects. Olaifa and Erhun (1988) and Fasakin and Aberejo (2002) observed that *p. guineense* spice powder prevented oviposition on *Callosobruchus maculatus* and *Dermestes maculatus* respectively and therefore reducing the longevity of the insect.

In the experiment, it was observed that in both powder and extract treatments as well as in Control, females laid fewer eggs at the beginning of oviposition and the number increased with the time. But the rate of oviposition started to decline after 30 days both in Control and treatments. This finding is some extent similar with the results of Mondal (1984a). Mondal and Port (1985) reported that due to longer larval feeding period in treated media, the physiology of the adult beetles affected that ultimately reduce the fecundity. These results are in general agreement with these present findings.

Chapter 7

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON FERTILITY OF *T. CASTANEUM*

Introduction

Materials and Methods

Statistical analysis

Results

Discussion

Chapter 7

POTENCY OF *S. MACROPHYLLA* AND *P.EROSUS* SEED POWDERS AND EXTRACTS ON FERTILITY OF *T. CASTANEUM*

Introduction

Environmental factors *i.e.,* light, temperature and humidity influence the fertility of *Tribolium* eggs (Quyam 1968, Haque and Islam 1978). Fertility of eggs in *Tribolium* depends on both the age of females (Howe 1962) and mating (Khalifa and Badaway 1955). Food (Khan and Bhuiyan 1983, Khan and Mazid 1985, Nandi *et al.* 1990, Khalequzzaman *et al.*1994) and conditioning of food (Mondal 1984a) influence the fertility of eggs in *Tribolium.* Azadirachtin of neem plants has significant effects on fertility of stored product insect pests (Rehena 2010) and other insects (Karnava 1987, Makanjuola 1989, Ho *et al.* 1994, Xie *et al.* 1995, 1996; Akhtar 1997, Rahim 1998, Manal and Sehnal 2000, Malek 2001, Khanam 2003, Banu 2004).

Egg mortality is one of the major factors of the insect's population control (Long *et al.* 1978, Mian and Mulla 1982a, Eisa *et al.* 1986). In some insect eggs need direct contact with the oils to have lethal effect on the embryo as observed in *C. maculates.* But the eggs of *T. castaneum* need not to be in direct contact with the oil. Rather food medium treated with oils enough to produce ovicidal effect in *T .castaneum* (Malek and Wilkins, 1994). It has been reported that *Azadirachtin* and different plant materials are toxic to eggs of stored product insect pests and other insects (Huang *et al.* 1997, Su and Mulla 1998, Hasan1999).The egg viability depends on both the age of eggs (Mondal *et al.* 1999) and the age of the egg laying females, which play important role in penetration of chemical through the egg shell (Ratnakaran *et al.*1985).

The present study was undertaken to evaluate the effect of *S. macrophylla* and *P. erosus* seed powders and extracts on fertility of *T. castaneum.*

Materials and Methods

In the present experiment eggs were collected from the previous experiment (Chapter-6). The 15 pairs of *T. castaneum* adults from each treatment were selected for the source of eggs and the number of eggs laid by each pair was recorded. Eggs were collected from 3rd to 45th days with equal interval of 3 days

from introduction of each pair into the experimental glass vials. The collected eggs were placed in separate petridishes for each treatment and incubated at 30°C without any light and humidity control until hatching. Eggs were observed daily with a binocular microscope and the number of hatched larvae were carefully noted and discarded. The percentage fertility was calculated on the basis of total number of the first instar larvae that hatched from the used number of eggs. Similar experiments were done for control with untreated adult beetles to observe the fertility.

Statistical analysis

The data obtained during experiments were analyzed statistically using One-way ANOVA and the means were compared by Duncan's Multiple Range Test (DMRT) (Duncan 1951). The results of the experiments are shown in the graph with error bar diagrams.

Results

Figure 16 and App. Table 196-197 showed the effectiveness of seed powder and extracts on fertility of *T. castaneum.* Results of the statistical analysis revealed that mahogany and kesur seed powders and extracts significantly ($P>0.001$) reduce the fertility of *T. castaneum* females compared to Control. The hatching percentage of eggs has been recorded as 62.06, 79.80, 54.40, 55.80, 77.11 and 42.32% for *T. castaneum* in the different treated media. The following food media were treated with different combinations of mahogany and kesur seed powder and extracts as kesur seed powder 0.03%, mahogany seed powder (MSP) 0.12%, kesur seed powder (KSP) 0.03% + mahogany seed powder 0.12% w/w, chloroform extract of kesur seed (KCE) 250ppm, chloroform extract of mahogany seed (MCE) 2000ppm and chloroform extract of kesur seed 250ppm + chloroform extract of mahogany seed 2000ppm respectively. But in the control media highest fertility rate was 97.58%. The results showed that kesur seed powder and extracts had the highest significant effects reducing the percentage of hatching over mahogany. The lowest percent of hatching was found in chloroform extract of kesur seed 250ppm + chloroform extract of mahogany seed 2000ppm. There were significant difference between the doses of powder and extracts of mahogany and kesur.

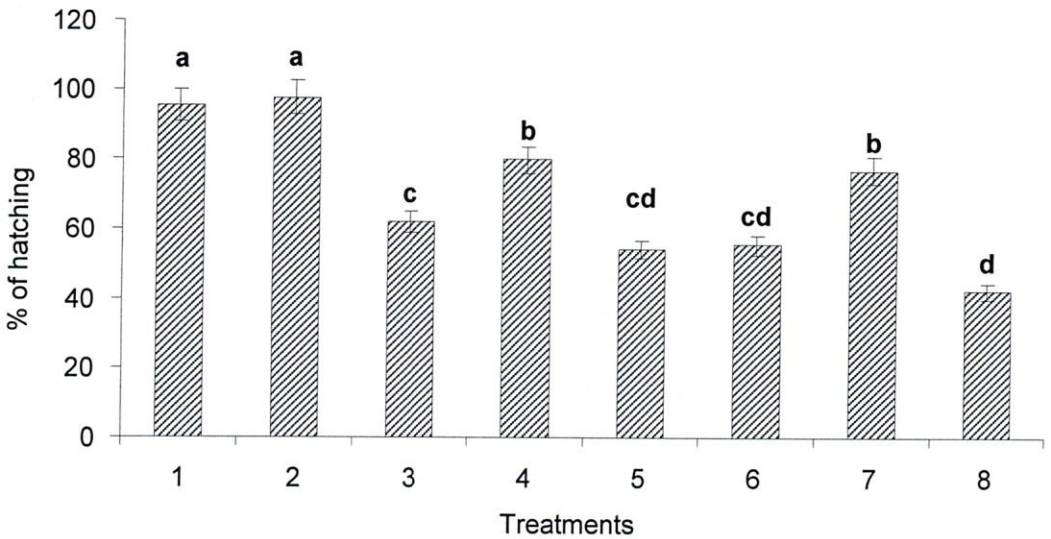


Fig.16. Egg hatching (%) in *T. castaneum* reared on fresh medium (control) and medium treated with different combinations of mahogany and kesur seed powder and extracts (Treatments: 1-Control (untreated), 2-Control(chloroform), 3-KSP 0.03%, 4-MSP 0.12%, 5-KSP 0.03% + MSP 0.12%, 6-KCE 250ppm, 7-MCE 2000ppm, 8-KCE 250ppm + MCE 2000ppm

The bars followed by the same letter in the same column are not significantly different according to ANOVA and DMRT, (P>0.05)

Discussion

The present work revealed that plant powder and extracts have significant effects on fertility of *T. castaneum*. Highest percent of egg hatching was recorded in control while lowest was noted for the chloroform extracts of kesur and mahogany. In contrast according to the results of ANOVA and DMRT nearest effects were found in Colum 3, 5 and 6 (Fig.16) due to the presence of kesur seed powder and extracts. But the Colum 4 and 7 representatives of merely mahogany seed powder and extract that showed less effect on fertility. The keur seed powder and extracts were highly significant than mahogany.

Fertility constitutes one of the prime factors for the survival of an insect population (Nandi *et al.* 1990). Malek (2001) reported the ovicidal activity of *Annona squamosa* seed oil and two new compounds on *T. castaneum*. Khanam and Talukder

(1993) reported the effects of methanolic extracts of *Polygonum hydropiper* leaf and *Aphanamixis polystachea* seed coat on the fecundity and fertility of *T. confusum*. Amin (2000) reported antiovipositional and antifertility effect of *A. indica* and *V. negundo* in *T. castaneum*. Khanam and Talukder (1993) reported the reduced fertility in *T. castaneum and T. confusum* due to bishkatali, neem, nishinda and royna. Caffeine and castor oil were also effective in reducing the fertility of eggs laid by *T. castaneum* as reported by Aktar and Mondal (1994).

In the present study, highest fertility of *T. castaneum* was recorded as 95.48% in Control. This result is almost similar to the previous studies on fertility of *T. castaneum* was reported as 94.18% (Hasnat 2003), 93.06% Mondal (1984a,1987a), 92.69% Aktar and Mondal (1994), 92.56% (Khanom 2004),92% (Rahman 1992),90% (Park 1933,Good1936), 89.03% (Yeasmin 2002),89% (Howe 1962), 88.63% (Banu 2004), 80.12% (Khan 1981, Quyam 1968) and 77.48% (Nandi *et al.* 1990). The lower percentage of fertility may be due to conditioning of the flour medium by the beetles themselves (Mondal 1984a).

Jacob and Sheila (1993) reported that intensive oviposition was depended on intensive feeding rate on the beetle. A number of plant materials have been reported to reduce the fertility in stored product insects (Jacob and Sheila 1993, Chaiyaboot 1988, Rahman 1992, Amin 2000).

Chapter 8

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON DEFORMITIES OF *T. CASTANEUM*

Introduction

Materials and Methods

Deformities in larvae after exposure to treated food

Deformities in pupae after exposure to treated filter paper

Deformities in pupae after exposure to treated food

Statistical analysis

Results

Discussion

Chapter 8

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON DEFORMITIES OF *T. CASTANEUM*

Introduction

Sometimes normal metamorphosis is interrupted due to the presence of exogenous materials in food and may produce different types of deformed individuals at any stage of insect life. Chemicals may have both physiological and biochemical effects on insects resulting in abnormalities, swelling in integument, elongated body surface, cuticle lesion and stiffness (Awad and Mulla 1984, Price and Stubbs 1984). Insect surviving insecticidal treatment may produce physiological effects other than death, impaired ability to develop or stop lay eggs (Loschiavo 1960). Insecticides and quinoid secretions produce deformities in the developmental stages of *Tribolium* (Roth and Howland 1941). It affects the development of larvae or pupae resulting abnormalities in the subsequent adults (SoKoloff 1972, Mondal 1984a). The abnormalities in larvae with wing pads which fail to become adults, pupae which produce monstrous imagoes with legs reduced in size or altogether wanting, adults with greatly reduced head, missing legs, antennae, mouthparts or elytral deformity (Roth and Howland 1941, SoKoloff 1972, Mondal 1984a). Elytral and pupal-adult intermediate deformities due to insecticidal treatments have been reported in *T. castaneum* (Khan 1981, Nakakita and Winks 1981, Mondal 1984a, Hasnat 2003, Hussain and Mondal 2005, Kamaruzzaman *et al.* 2006). Banu (2004) and Rehena (2010) reported the deformities in *T. castaneum* and *T. confusum* due to the effects of sub-lethal doses of azadirachtin on larval feeding. Feeding on plant materials treated food produces different kinds of deformities in insects (Nawrot *et al.* 1987.) Plant oils produce deformed characters in insects (Jilant *et al.* 1988, Subrahmanyan and Rao 1993). Similarly, leaf powders also produce abnormalities in *Tribolium* (Rahman 1992). Azadirachtin treatment interfered with the normal development of the larvae of Japanese beetle (Ladd *et al.* 1984). Juvenile hormone activity mimicking compounds were isolated from sweet basil oil (Bowers and Nishida 1980) and marigold oil (Saxena and Srivastava 1973), which produced deformities in bug species.

The present investigation was undertaken to observe any abnormalities produced in the red-flour beetle, *T. castaneum* due to treatments / feeding on food mixed with seed powders and extracts of mahogany and kesur.

Materials and Methods

Exp. 1. Adult deformities from larvae after exposure to treated food

Newly hatched (3 days) fifty larvae reared in fresh medium were used for each treatment. The petridishes (6cm) containing flour medium (2g) treated with mahogany and kesur seed powder and extracts either alone or in combinations. Powder dosed at the rate 0.12% and 0.03% in 20g STF and extract dosed at 2000ppm and 250ppm for mahogany and kesur respectively. Then petridishes with food and larvae were kept in an incubator at 30°C without any light and humidity control. The larvae and pupae were observed for any deformities and separated carefully. After emergence, adults were also observed for any deformities and recorded. The experiment was conducted with three replications, each with 50 larvae (N=150). A batch of untreated and chloroform treated controls also maintained with the same number of insects.

Exp. 2. Adult deformities from pupae after exposure to treated filter paper

Freshly formed pupae were collected from the culture medium and were sexed and used for this experiment. A filter paper was placed in the petridishes (9cm) and treated separately with mahogany and kesur seed powders and extracts either alone or in combinations. Calculated doses for mahogany and kesur seed powders were 31.45 and 125.81 µg/cm^2 and for extracts were 15.73 and 31.45µg/cm^2 respectively. In case of chloroform extract treated filter papers were dried over night for evaporation of the solvent. Thirty pupae were then introduced in each petridish and covered with lid. The treated petridishes with pupae were kept in an incubator at 30°C without any light and humidity control. The experiment was replicated three times. Similarly, an untreated and chloroform treated batches were maintained simultaneously as Controls. Adults emerged from the pupae were carefully observed to find out the deformities, if any.

Exp. 3. Adult deformities from pupae after exposure to treated food

Pupae formed by the larvae reared in fresh medium were placed in the petridishes (6cm) containing standard food either control or treated with mahogany and kesur seed powder and extracts either alone or in combinations. Powder dosed at the rate of 0.12% and 0.03% in 20g STF and extract dosed at 2000ppm and 250ppm for mahogany and kesur respectively. The petridishes with pupae were covered by glass lid and kept in an incubator at 30°C without light and humidity control. Emerged adults were observed daily for deformities, if any. Three replicates were used for each of the treatment and each replicate consisting of 30 pupae (N=90). Experiments were conducted for both male and female pupae.

Statistical analysis

The data obtained during experiments were analyzed statistically using One-way ANOVA and the means were compared using Duncan's Multiple Range Test (DMRT) (Duncan 1951).

Results

The potency of mahogany and kesur seed powders and extracts on deformities of *T. castaneum* were presented in Tables 11-13; Figures 17-19; Plate 5 and App. Tables 198-203.

Statistical analysis revealed that seed powder and extracts alone or in combination significantly produced deformities in *T. castaneum*. Kesur seed powder and extract were more effective than those of mahogany. Both larval and pupal treatments produced deformities in adults. The percent of adult deformities was higher in Experiment 2, where pupae were exposed to direct contact with treated filter paper. The lowest percent of adult deformities was found in Experiment 3, where pupae were exposed to the treated flour medium. The treated larval food in the Experiment 1, produced effects which alter the growth of the larvae ultimately produced deformities in larvae, pupae and mostly in adults. Chloroform extract of kesur was more effective (25.10% for female, in treated filter paper) than other powders and extracts and the lowest effect was found in chloroform extract of mahogany seed (1.15% for female, Table 13) when pupae exposed in the treated food. Combined action of powders and extracts were also very effective (35.32% for female, in Expt. 2, Table 12). Overall results reflect that percent of deformities were found more significant in adult females ($F=14.46$, $P<0.001$, Table 11; $F=47.27$, $P<0.001$, Table 12; $F=17.94$, $P<0.001$, Table 13) than males ($F=7.91$, $P<0.001$, Table 11; $F=16.14$, $P<0.001$, Table 12; $F=9.02$, $P<0.001$, Table 13).

The following morphological abnormal characteristics were found in the adults of *T. castaneum* developed from treatments on larval and pupal stages during experiments (Plate 5).

Adult deformities

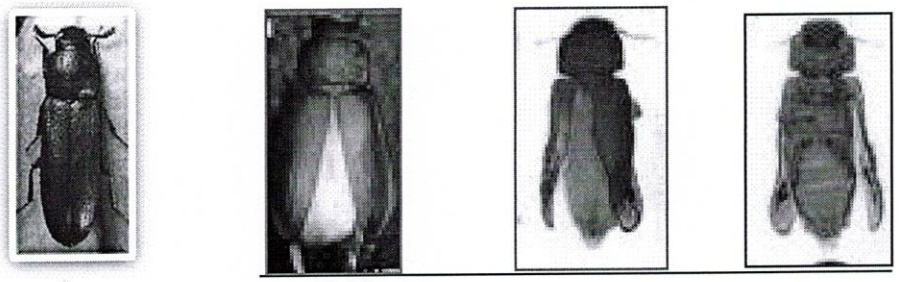
Size-adults emerged from treated food were smaller than those emerged from untreated ones

Abdomen-some of the adults were depressed and some were with humped backs

Symmetry-proper bilateral symmetry was lost to some extent in the adults of treated media. These adults failed to remain at normal position and were less motile.

Wing-most of the treated adults were with elytral deformities like broken elytra, elytra failed to pairing with each other, in some adults the membranous wings remained stretched and unfolded, often curled.

Ovipositor-in a number of treated adults, the ovipositor was protruded out of the genitalia.



A B

Plate 5. Deformities of adult *T. castaneum*. A-Normal adult, B-Deformed adults

Table11. Adult deformity (%) in *T. castaneum* developed after exposure of larvae to mahogany and kesur seed powders and extracts treated food

Product used	Doses	Adult emerged			% deformities		
		Total	Male	Female	Male	Female	Combined
	O(Control) (untreated)	146	72	74	0/00	0.00	0.00
	Control (chloroform)	142	67	75	0/00	0.00	0.00
Powders	MSP 0.12%	135	63	72	3.10	7.09	5.10
	KSP 0.03%	115	59	56	13.56	16.07	14.82
	MSP 0.12% +KSP .03%	110	51	59	17.92	15.45	16.69
Extracts	MCE 2000 ppm	134	69	65	5.87	6.21	6.04
	KCE 250ppm	95	45	50	13.94	21.92	17.93
	MCE 2000ppm+ KCE 250ppm	88	40	46	17.90	26.75	22.33

MSP-mahogany seed powder, KSP-kesur seed powder, MCE-chloroform extract of mahogany, KCE-chloroform extract of kesur

Table12. Adult deformity (%) in *T. castaneum* developed after exposure of pupae to mahogany and kesur seed powders and extracts treated filter paper

Product used	Doses	Adult emerged			% deformities		
		Total	Male	Female	Male	Female	Combined
	O(Control) (untreated)	180	90	90	0/00	0.00	0.00
	Control (chloroform)	179	90	89	0/00	0.00	0.00
Powders	MSP .12%	176	88	88	2.33	6.52	4.43
	KSP .03%	153	79	74	11.56	20.44	16.00
	MSP .12% +KSP .03%	147	76	71	11.88	12.68	12.28
Extracts	MCE 2000 ppm	170	84	86	1.15	7.11	4.13
	KCE 250ppm	134	70	64	13.07	25.10	19.09
	MCE 2000ppm+ KCE 250ppm	125	60	65	30.04	35.32	32.68

MSP-mahogany seed powder, KSP-kesur seed powder, MCE-chloroform extract of mahogany, KCE-chloroform extract of kesur

Table13. Adult deformity (%) in *T. castaneum* developed after exposure of pupae to mahogany and kesur seed powders and extracts treated food

Product used	Doses	Adult emerged			% deformities		
		Total	Male	Female	Male	Female	Combined
	O(Control) (untreated)	180	90	90	0/00	0.00	0.00
	Control (chloroform)	180	90	90	0/00	0.00	0.00
Powder	MSP .12%	174	85	89	2.38	1.15	1.77
	KSP .03%	164	84	80	8.38	7.42	7.90
	MSP .12% +KSP .03%	160	79	81	6.33	9.99	8.16
Extract	MCE 2000 ppm	174	87	87	1.23	3.45	2.34
	KCE 250ppm	158	76	82	6.44	9.83	8.14
	MCE 2000ppm+ KCE 250ppm	148	74	74	13.50	13.57	13.54

MSP-mahogany seed powder, KSP-kesur seed powder, MCE-chloroform extract of mahogany, KCE-chloroform extract of kesur

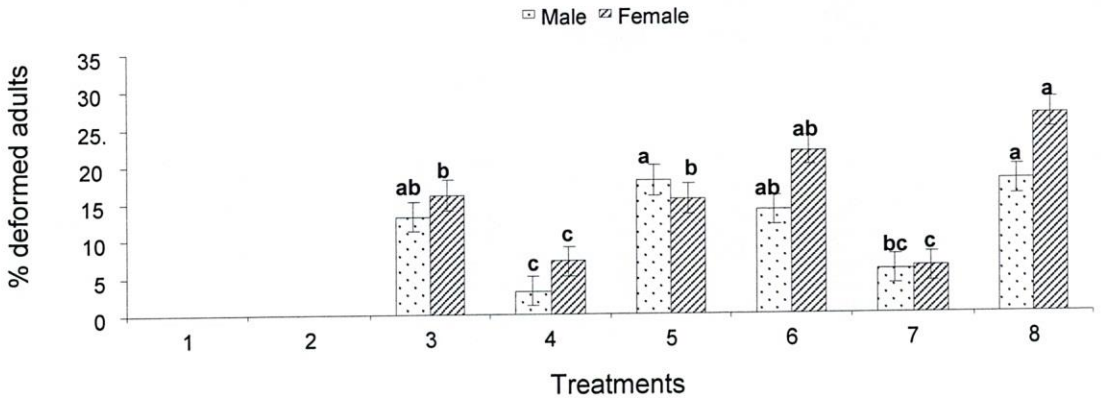


Fig.17. Percentage of deformed adults emerged from *T.castaneum* larvae reared on flour medium treated with mahogany and kesur seed powder and extracts alone or in combinations (Treatments: 1-Control (untreated), 2-Control (chloroform treated), 3-KSP(0.03%), 4-MSP(0.12%), 5-KSP 0.03% + MSP 0.12%, 6-KCE 250ppm, 7-MCE 2000ppm, 8- KCE 250ppm + MCE 2000ppm

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

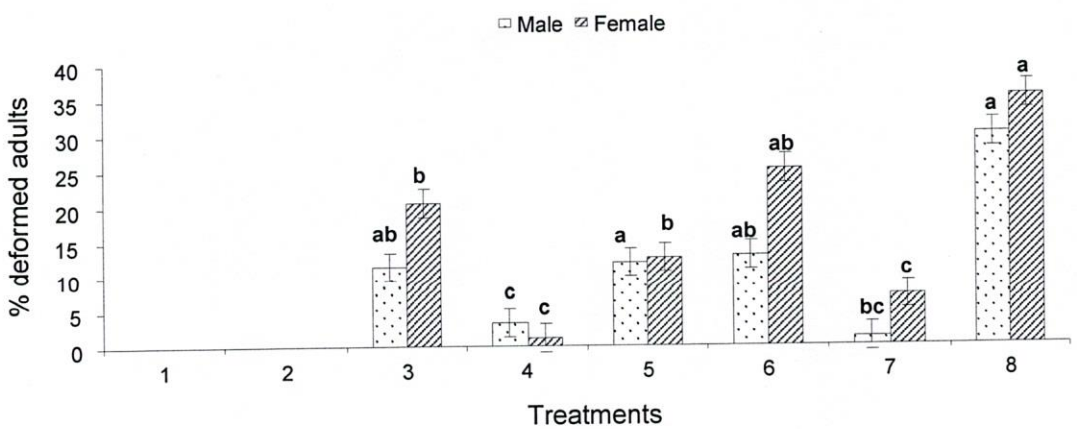


Fig.18. Percentage of deformed adults emerged from *T.castaneum* pupae exposed to the filter paper treated with mahogany and kesur seed powder and extracts alone or in combinations (Treatments 1-Control (untreated), 2-Control (chloroform treated), 3-KSP 31.45 μg/cm^2,4-MSP 125.81 μg/cm^2, 5-KSP 31.45 μg/cm^2+ MSP 125.81 μg/cm^2, 6-KCE 15.73 μg/cm^2, 7-MCE 31.45 μg/cm^2, 8-KCE 15.73 μg/cm^2+ MCE 31.45 μg/cm^2

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

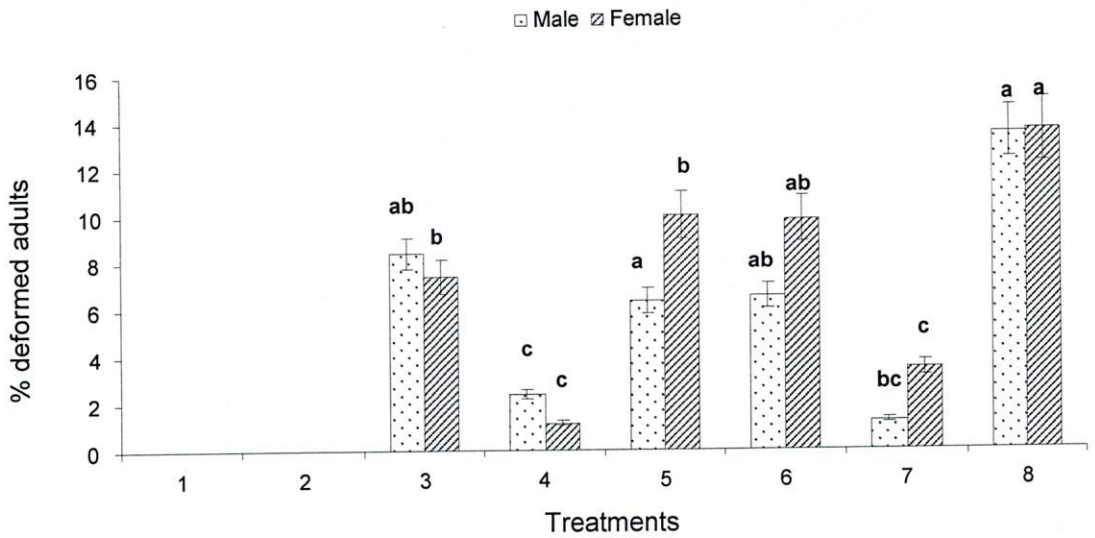


Fig.19. Percentage of deformed adults emerged from *T.castaneum* pupae exposed to the food medium treated with mahogany and kesur seed powder and extracts alone or in combinations (Treatments 1-Control (untreated), 2-Control (chloroform treated), 3-KSP 0.03%, 4-MSP 0.12%, 5-KSP 0.03% + MSP 0.12%, 6-KCE 250ppm, 7-MCE 2000ppm, 8-KCE 250ppm+ MCE 2000ppm

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

Discussion

In the present study the most pronounced effect was found on the adults and all the deformed characters might be resulted due to less sclerotization of the adult body. Presence of exogenous materials in food; contact with mahogany and kesur seed powders and extracts at any stage generally interrupt normal metamorphosis in *T. castaneum* produced various types of deformed individuals at any stage of their life. Formation of the deformed characters usually depends on the mode of action of the plants (Nawrot *et al.* 1987). Elytral deformities were also found in *T. castaneum* feeding on flour treated with leaf dust of Dhutura and Neem (Rahman 1992). The deformities due to botanicals in the present experiment is similar to the findings of Banu (2004) who reported deformities in adults of both *T. castaneum* and *T. confusum* due to azadirachtin treated larval food. Rehena (2010) reported deformities due to nimbicidine in larvae, pupae and adult stages. Akhtar (1997) found deformities in adults of *T. castaneum* and *T. confusum* emerged from the larvae reared in flour media treated with sesame oil, linseed oil, mustard oil and neem oil. Mahal *et al.* (2006) also reported deformities in *Ryzopertha dominica* due to some plant materials like *Murryea*

paniculata, Jatropha carcus, D. metel, Eucalyptus camadulensis, V. negundo, and *Nigella sativa.* In present experiment, deformed adults exhibited very short, less sclerotized elytra that failed to cover all the dorsal tergites, which agreed with the findings of Parween (2000a). The deformed larvae and pupae were failed to metamorphose into adults. The undersized and underweight adults with deformed wings and protruded ovipositor were found, unable to mate properly, and also failed to survive longer time.

Chapter 9

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON THE DEVELOPMENT OF *T. CASTANEUM* POPULATION

Introduction

Materials and Methods

Statistical analysis

Results

Discussion

Chapter 9

POTENCY OF *S. MACROPHYLLA* AND *P. EROSUS* SEED POWDERS AND EXTRACTS ON THE DEVELOPMENT OF *T. CASTANEUM* POPULATION

Introduction

Tribolium's life span is very long among stored product insects. Generally it ranges from three months to a year and eight months, but it may be over three years (Good 1936). *Tribolium* spp. have long life span and long reproductive period (Dawson 1977). It can reproduce rapidly under natural condition. Number of the population is greatly influenced by the temperature and humidity (Michael 1984, Bry and Davis 1985). A standard food medium with 29°C temperature and 70% humidity is optimum for the population of *T. castaneum* and *T. confusum* (Michael 1984). 30°C is regarded as the optimum temperature for the optimum development of *Tribolium* spp. Growth of the *Tribolium* population is affected by many factors including conditioning of the flour medium (Mondal 1984a) and cannibalism (Sonleithner 1961, Sokoloff *et al.* 1965, Mondal and Aktar 1989).

Researchers reported that plant parts, oil or extracts mixed with grain reduced insect oviposition, egg hatchability, post-embryonic development and progeny production (Ivbijaro 1983, Saxena *et al.* 1986, Saxena and Yadav 1984, Schmidt *et al.* 1991). A list of 43 plant species as reproduction inhibitors against stored-product insects was published by Talukder (1995). Plant extracts showed deleterious effects on the growth and development of insects and reduced larval pupal and adult weight significantly, lengthened the larval and pupal periods and reduced pupal recovery and adult eclosion (Khanam *et al.* 1990). The crude extract of plants also retarded development and caused mortality of larvae, cuticle melanization and high mortality in adults (Jamil *et al.* 1984). It was reported that grains coated with plant extracts completely inhibited the development of *S. oryzae* (Rajasekaran and Kumaraswami 1985). Plant derivatives also reduce the survival rates of larvae and pupae, and adult emergence (Tripathi *et al.* 2000). Development of eggs and immature stages inside grain kernels were also inhibited by plant derivatives (Obeng-Ofori and Reichmuth 1997).

The population of malathion resistant and susceptible strains of *T. castaneum* was significantly suppressed by the neem seed and leaf extracts (Khanom 2004). Similar results were also reported by Das *et al.* (2006) when eggs of *T.*

castaneum larvae treated with different doses of nimbicidine. Jbilou *et al.* (2006) reported some plant materials inhibited the F_1 progeny production of *T. castaneum.* Rehena (2010) reported that the population of *T. castaneum* reduced due to nimbicidine both alone and in combination with insecticide.

In the present study an attempt was made to find out the effect of different doses of mahogany and kesur seed powders and extracts on the development of *T. castaneum* population.

Materials and Methods

Pupae were collected by sieving the fresh medium and were sexed. The sexed pupae were kept in separate petridishes at 30°C in the incubator for emergence of adults. Fifteen day old 40 adults (male1: female1) were introduced in a plastic container containing 20g standard flour medium either untreated (Control) or treated with mahogany and kesur seed powders and extracts at different (sub lethal) doses. The following doses were 0.03, 0.06, 0.12% w/w for mahogany seed powder, 0.015, 0.03, 0.06% w/w for kesur seed powder and 500, 1000, 2000ppm for both chloroform and methanol extracts of mahogany seed and 125, 250, 500ppm for both chloroform and methanol extracts of kesur seed respectively. All treatments including controls were replicated three times. The plastic container was covered with a piece of thin cloth and tied with a rubber band. The container was then kept in an incubator at 30°C without light and humidity control. After every 15 days 10g of similar food was added to avoid the conditioning due to overcrowding and shortage of food (Mondal and Port 1995). The total number of progeny (adults, pupae, and larvae) was assessed after 4 months by sieving the medium. The percent reduction of population (PRC) over Control was determined using the following formula (Mondal and Port 1995).

$$\text{Percent reduction} = \frac{\text{Difference between no. of insects in control and treated media}}{\text{No. of insects in control}} \times 100$$

Statistical analysis

The data obtained during experiments were analyzed statistically using One-way ANOVA and the means were compared using Duncan's Multiple Range Test (DMRT) (Duncan 1951).

Results

Figures 20-31 and App. Tables 204-218 showed the effectiveness of mahogany and kesur seed powders and extracts on the development of *T. castaneum* population. Results of the statistical analysis revealed that seed powder and extracts significantly reduce the population of *T. castaneum* compared with that of

the Control. Kesur seed powder and extracts had the highest significant effects in reducing the total population over mahogany and in most of the cases total number of population decreased with the increase of doses. Highest PRC values of the total population were 35.52 and 54.43 for mahogany and kesur seed powder respectively. There was a significant difference between the effects of the powders due to ANOVA and DMRT. The highest PRC values for Chloroform and methanol extracts of mahogany were 40.69 and 41.29 and in case of kesur extracts were 58.51 and 56.72 respectively. Statistically it was found that there was no significant difference among the extracts of the same species but in different species it was significant (P>0.05). Chloroform extracts were more effective than methanol extracts in both cases of mahogany and kesur. The pupal population was significantly reduced in all the experiments.

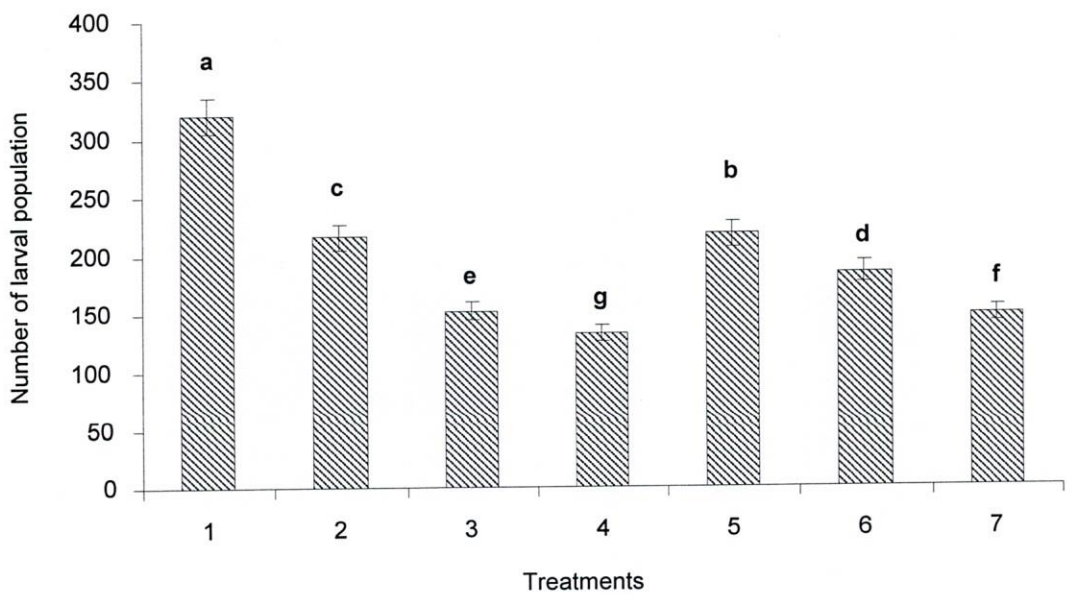


Fig. 20. Average larval population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* and *P.erosus* seed powder resulted from 20 pair adults (male1: female1) [Treatments; 1-Control; 2, 3, 4-mahogany seed powder (MSP); 5, 6, 7-kesur seed powder (KSP)]

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

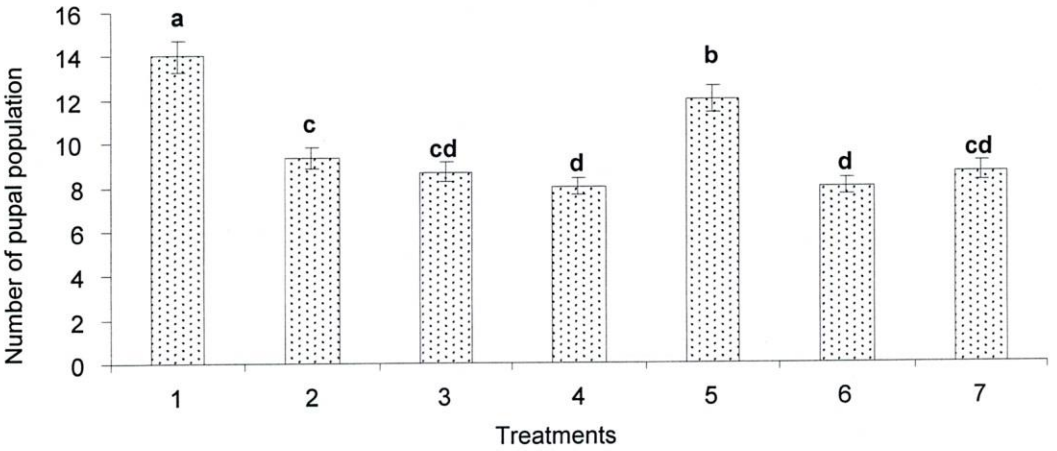


Fig. 21. Average pupal population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* and *P.erosus* seed powder resulted from 20 pair adults (male1: female1) (Treatments; 1-Control; 2, 3, 4-MSP; 5, 6, 7-KSP)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

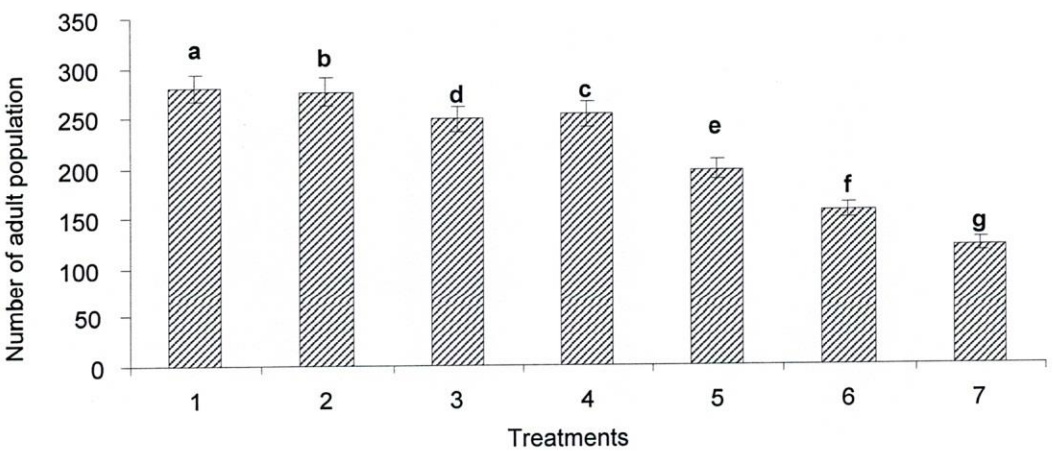


Fig. 22. Average adult population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* and *P.erosus* seed powder resulted from 20 pair adults (male1: female1) (Treatments; 1-Control; 2, 3, 4-MSP; 5, 6, 7-KSP)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

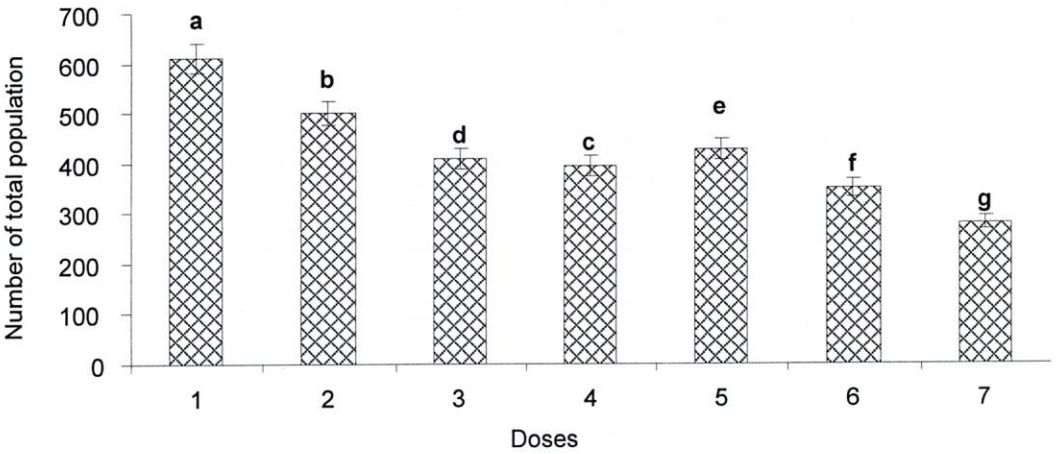


Fig. 23. Average total population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* and *P.erosus* seed powder resulted from 20 pair adults (male1: female1) (Treatments; 1-Control; 2, 3, 4-MSP; 5, 6, 7- KSP)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

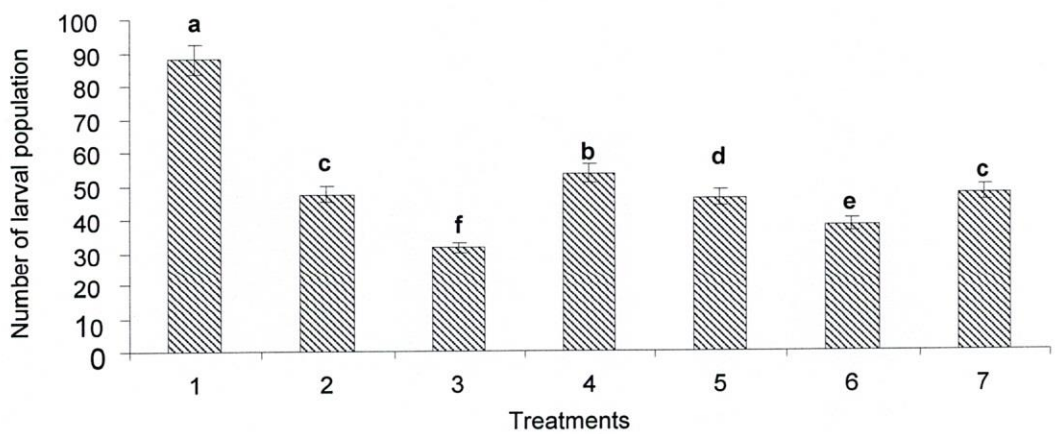


Fig. 24. Average larval population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extracts; 5, 6, 7-CH_3OH extracts)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

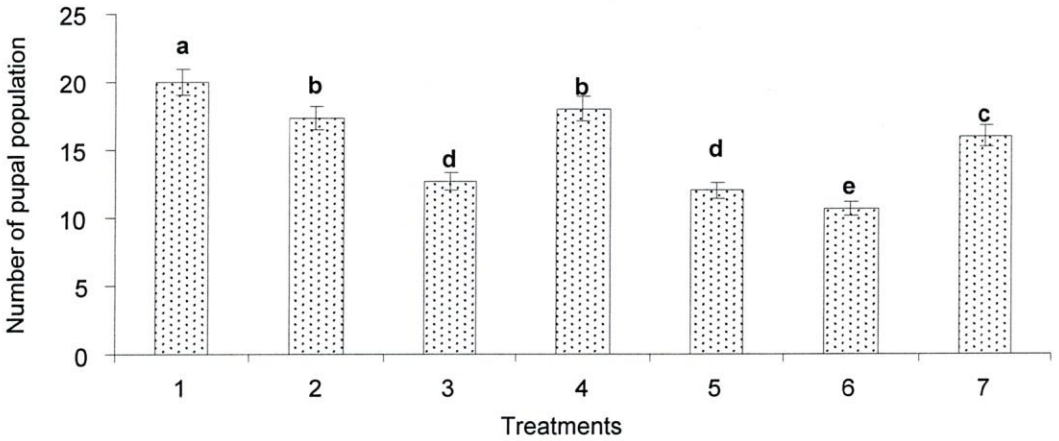


Fig. 25. Average pupal population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extracts; 5, 6, 7-CH_3OH extracts)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

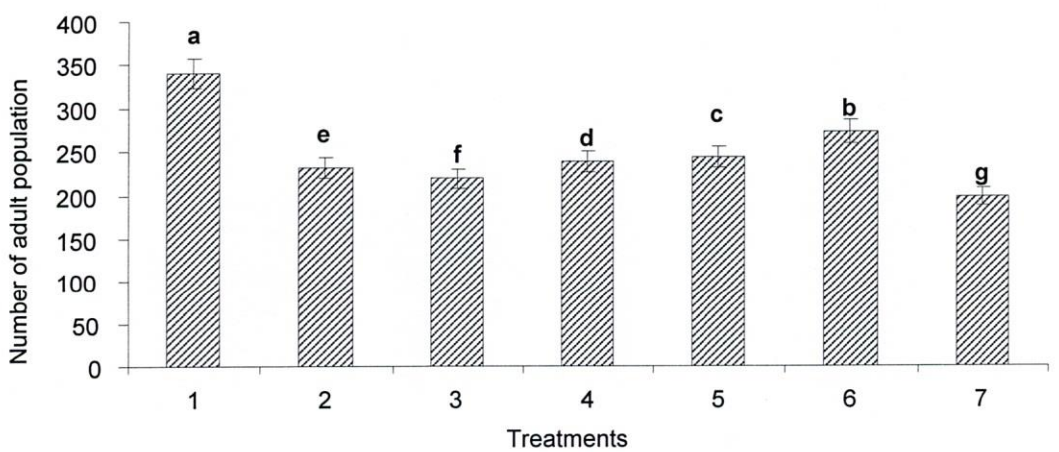


Fig. 26. Average adult population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extracts; 5, 6, 7-CH_3OH extracts)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

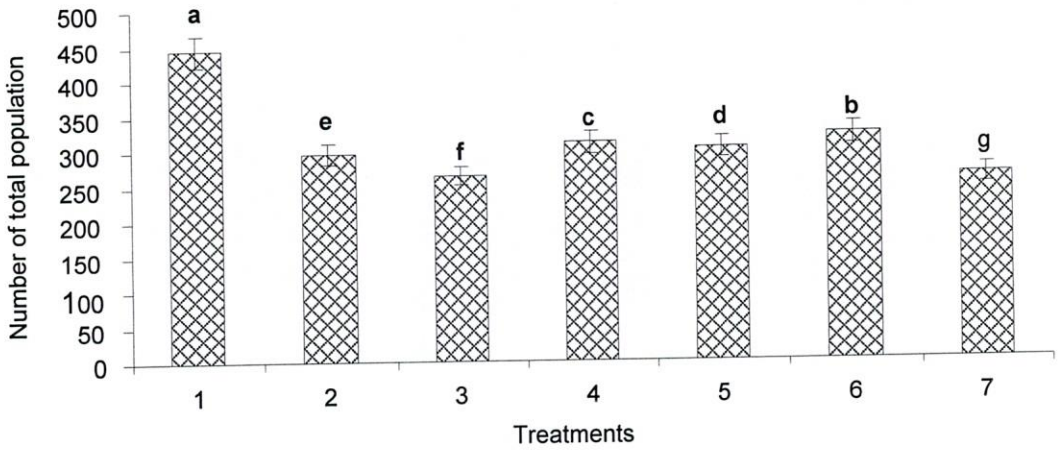


Fig. 27. Average total population of *T. castaneum* after 4 months in different treatments of *S. macrophylla* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extracts; 5, 6, 7-CH_3OH extracts)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

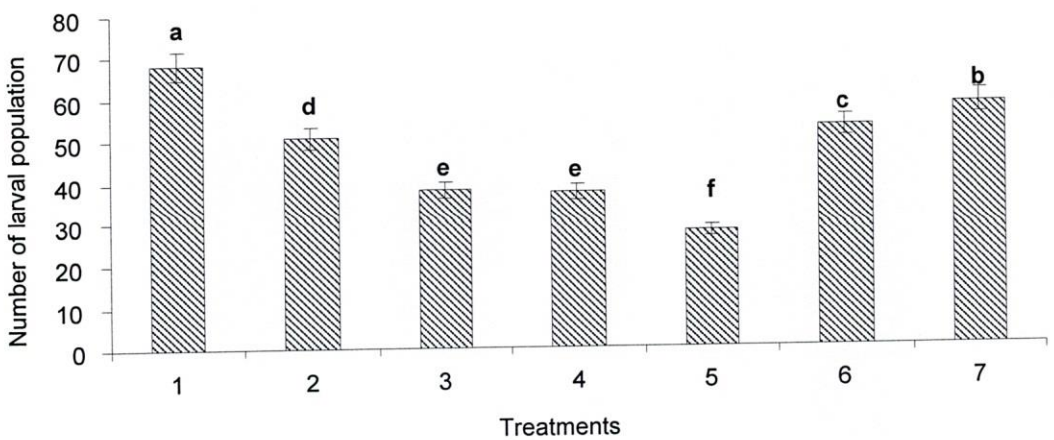


Fig. 28. Average larval population of *T. castaneum* after 4 months in different treatments of *P.erosus* seed extracts resulted from 20 pair adults (male1: female1). (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extract; 5, 6, 7-CH_3OH extract)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

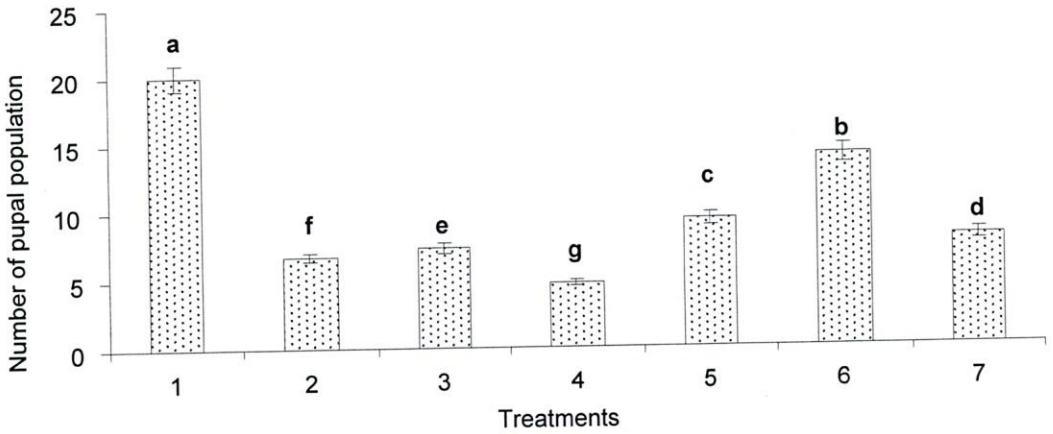


Fig. 29. Average pupal population of *T. castaneum* after 4 months in different treatments of *P.erosus* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extract; 5, 6, 7-CH_3OH extract)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

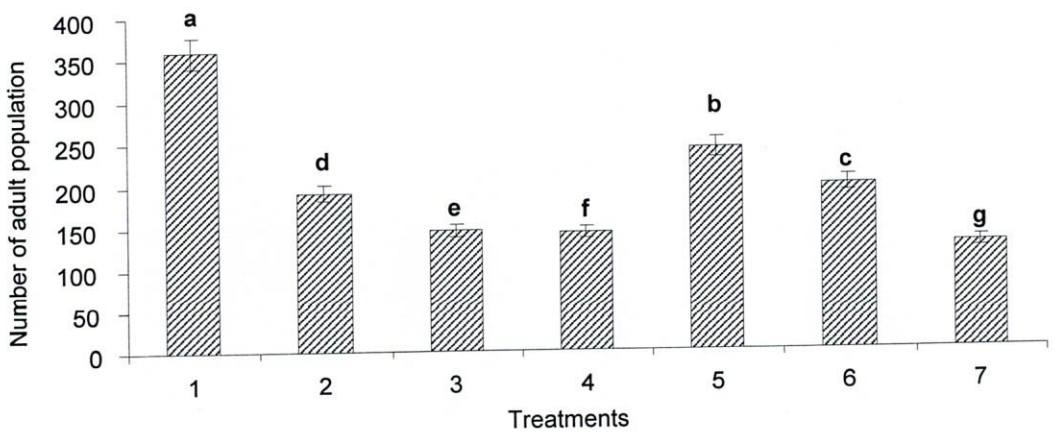


Fig. 30. Average adult population of *T. castaneum* after 4 months in different treatments of *P.erosus* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extract; 5, 6, 7-CH_3OH extract)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

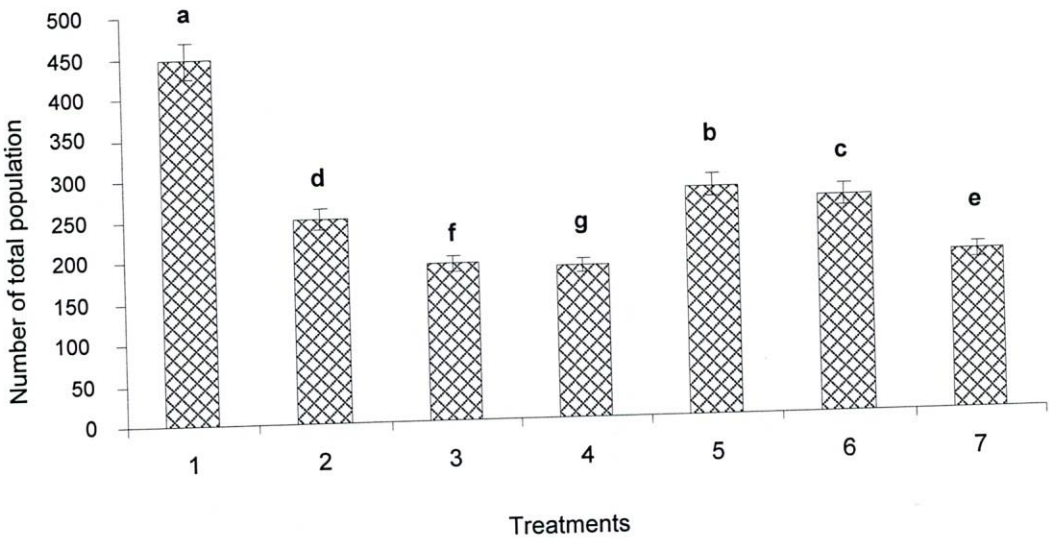


Fig. 31. Average total population of *T. castaneum* after 4 months in different treatments of *P.erosus* seed extracts resulted from 20 pair adults (male1: female1) (Treatments: 1-Control; 2, 3, 4-$CHCL_3$ extract; 5, 6, 7-CH_3OH extract)

The bars followed by the same letter in the different column are not significantly different, P>0.05 (DMRT)

Discussion

Mahogany and Kesur seed powders and extracts were effectively inhibited the progeny production of *T. castaneum*, when 15 days old adults were reared on either treated and untreated media for 4 months. All the treatments were very effective in reducing the population in comparison with control.

Banu (2004) found the reduced population of *T. castaneum* and *T.confusum* in Azadirachtin treated flour medium. Similar results were observed by Khanom (2004) that neem leaf and seed extracts inhibited the population of *T. castaneum.* Xiaoqing *et al.* (1998) reported the effective reduction of *T. castaneum* population due to several botanical extracts. Huang *et al.* (1997) reported that F_1 progeny production of *T. castaneum* was totally suppressed by nutmeg oil. Amin *et al.* (2000) found the inhibition activity of Akanda, Bishkatali, Neem extracts against the lesser grain borer. The present results also supports

the findings of Talukder & Howse (1995) who stated that the ground leaves, bark and seeds of *A. polystrachya* provided protection of wheat flour by reducing F1 progeny of *T. castaneum*. Zhang Xing *et al.* (1992) reported that the botanicals inhibited the population formation of *T. castaneurn*. Okonkwo and Okoye (1996) noted that both the powder and extract of *p. guineense* and *D. tripetela* inhibited adult emergence of *C. Maculatus* and *S. zeamaize* completely.

However, the present results revealed that mahogany and kesur seed powder and extracts in both chloroform and methanol have remarkable residual effects on *T. castaneum* by reducing the production of F1 progeny and/or by increasing the population mortality.

Chapter 10

GENERAL DISCUSSION

SUMMARY

GENERAL DISCUSSION

GENERAL DISCUSSION

The use of botanical pesticides in controlling insect pests is considered to be the most viable and environmentally safe approach to reduce the increasing danger caused by synthetic pesticides (Saxena 1982). Various plant powders and their extracts have been reported to possess insecticidal, oviposition deterrent and ovicidal activity against bruchids and some other insects (Siskos 2008 and Nyamador 2010). Insect growth regulators, botanical insecticides and microbial pesticides are highly effective, safe and ecologically acceptable (Weinzierl and Henn 1991, Nathan *et al.* 2005a,b; Nathan and Kalaivani 2005, Sadeghian and Mortazaienezhad 2007, Suman *et al.* 2010). Oil and powder obtained from neem (*Azadirachta indica* A. Juss) seed have been reported to provide sustained protection of stored grains (Ketoh *et al.* 2002, Ogunwolu and Idowu 1994, Lale and Ajayi 1996, Ogunwolu and Odunlami 1996).

The research described in this thesis investigated the effectiveness of plant seed powders and extracts as potential natural pesticides to be used as possible alternatives for synthetic pesticides that might intensively be used for the management of stored product pests especially *T. castaneum*. The investigations started with a base line study of the toxicological tests; subsequently laboratory experiments were performed to assess the potencies of the seed powders and extracts of mahogany and kesur plants when used as botanical pesticides, also comparing their potential during experiments.

Overall, the results obtained confirm the hypothesis that botanical pesticides have the potency to be used to control pests of stored grains, providing a promising alternative for synthetic pesticide use, especially because they pose lower risks for public health and environment.

Humans have used plant parts, products, and metabolites in pest control since early historical times. Plants are the chemical factories of nature, producing many chemicals, some of which have medicinal and pesticide properties. By using plant parts in early historical times and plant extracts and concentrated components in more recent times, man has been able to control certain pests with these remedies quite successfully. The current use and future potential of plants for pest control on farms and homes are detailed in an FAO document (FAO 1999). Casida and Quistad 1998 listed some important phytochemical products such as pyrethrum, derris, quassia, nicotine, hellebore, anabasine, azadirachtin, dlimonene, camphor and terpenes and all of which have been used as insecticides. There are

major groups of insecticides of plant origin that were used in developed countries before the advent of synthetic organic insecticides.

Chemical control is an effective strategy used extensively in daily life (Pavela 2009a). However, the widespread use of synthetic insecticides has led to many negative consequences (Pavela 2008), resulting in increasing attention to natural products (Pirali-Kheirabadi and Da Silva 2010). Among biopesticides, botanical ones are experiencing a revival due to their eco-toxicological properties (Cosimi *et al.* 2009). Plants play pivotal roles in ecological systems (Garcia *et al.* 2007). They may provide potential alternatives to currently used insect-control agents because they constitute a rich source of bioactive chemicals (Qin *et al.* 2010). These compounds act as fumigants (Choi *et al.* 2006), contact insecticides (Tang *et al.* 2007), repellents (Islam *et al.* 2009) and antifeedants (Gonzalez-Coloma *et al.* 2006) and may affect some biological parameters such as growth rate (Nathan *et al.* 2008), life span and reproduction (Isikber *et al.* 2006).

Risks and problems associated with the use of chemicals lead to increasingly stringent environmental regulation of pesticides (Pavela *et al.* 2010). There is therefore an urgent need to develop safer, more environmentally friendly and efficient alternatives that have the potential to replace synthetic pesticides and are convenient to use (Tapondjou *et al.* 2005). In this context, screening of natural products has received the attention of researchers around the world (Kebede *et al.* 2010). Many secondary plant metabolites are known for their insecticidal properties (Lopez *et al.* 2008), and in many cases plants have a history of use as home remedies to kill or repel insects (Kim *et al.* 2010). In recent decades, research on the interactions between plants and insects has revealed the potential use of plant metabolites for this purpose (Kamaraj *et al.* 2010). It is known that some chemical constituents of essential oils have insecticidal properties (Pavela 2009b). In some studies, essential oils obtained from commercial sources were used (Amer and Mehlhorn 2006a, b, c). Specific compounds isolated from plant extracts or essential oils were tested for fumigation purposes (Maciel *et al.* 2010).

In the search for alternatives to conventional pesticides, essential oils extracted from aromatic plants (Meliaceae; *Swietenia* spp.) have been widely investigated. Their toxicities on pests were of special interest during the last decade. With the objective of contributing to these studies, a literature search on the use of natural products (essential oils) which have already been evaluated particularly for insecticidal activity, has been carried out.

Botanicals against stored product insect pests

Sitophilus and *Tribolium* species cause considerable economic losses of stored wheat grain (Arabi *et al.* 2008 and Chu *et al.* 2010). Heavy infestations of these pests may cause weight losses of as much as 30–40% (Tatsadjieu *et al.* 2010). Pest's actions are able to cause up to 90% loss of cereal stocks after 5 months of storage (Nguemtchouin *et al.* 2010). Control of these insects relies heavily on the use of synthetic insecticides and fumigants, which has resulted in several problems (Zoubiri and Baliouamer 2010). Therefore, there is an urgent need to develop safe, convenient, environmental and low-cost alternatives. Considerable efforts have been focused on plant derived materials for potentially useful products as bioinsecticides (Jbilou *et al.* 2008). In integrated stored-product protection, phytochemicals may be used for (1) pest prevention, repelling pests from goods, (2) early pest detection, attracting pests to lures or (3) pest control by using toxic compounds (Lopez *et al.* 2008). Plant extracts and essential oils have potential to be used in crop protection. They contain compounds that show toxic effects in a wide range of insects (Ukeh *et al.* 2009).

Recommendations

This study is an attempt to find new potential botanicals against stored product insects. The promising powder and crude extract can be cost-effective and easy to use, less toxic to non-targeted organism, environmentally safe and biodegradable, compared with synthetic organic insecticides. Recommendations may be-

1. The results of this study would provide basic data to guide further identification of active ingredients. Ingredients can be developed into effective formulations that may also prevent the development of resistance.

2. Although reduced health risks are to be expected for the people and the environment when synthetic pesticides are being replaced by botanicals this still has to be studied further.

3. The crude plant materials should be examined with a variety of solvents to find appropriate solvent for purifying the active ingredient.

4. This investigation suggests that the active ingredient of the plant seed powder and extract responsible for causing mortality of beetles and larvae should be identified, for use and approval as if not to cause toxic effects to non-target organisms. If possible, it can be prepared as a commercial product or formulation to be used as a nature derived control agent.

Conclusion

Plant powders or crude extracts/essential oils are complex mixtures of various molecules. Their biological effects might be either the result of a synergism of all molecules or could reflect only those of the main molecules. In that sense, for biological purposes, it could be more informative to study the entire oil rather than some of its components because the concept of synergism seems to be important.

Keeping in mind the work of different scientists and researchers as discussed in the thesis about *S. macrophylla* and *P. erosus*, it may be suggested that the use of powders and crude extracts is safe and sound as compared to synthetic and commercial pesticides. So, it may be given preference over commercial pesticides for the use in stored product pests.

SUMMARY

SUMMARY

In the search for alternatives to conventional insecticides, seed powders and essential extracts extracted from *S. macrophylla* and *P. erosus* plant seeds have been investigated. Their toxicities toward insects were of special interest during the research. The purpose of this research is to provide an overview of the data about seed powder and essential extracts that have been reported to possess insecticidal activity and practical methods and recent techniques for screening these compounds. The review refers plants, their geographical distribution and the organism tested. Some aspects of recent insecticidal activity directed research on natural products were discussed.

Experiments on the potency of *S. macrophylla* and *P. erosus* seed powders and extracts as contact toxicants, behavioral response, and effects on different biological aspects viz. fecundity, fertility, deformities and population study of *T. castaneum* were conducted in the Laboratory.

The present experiments (Chapter 4) aims to provide information about the insecticidal potency of *S. macrophylla* and *P. erosus* seed powders and crude extracts against *T. castaneum*. Insect mortality at 3,7,14 and 21 days after treatment due to direct contact toxicity of powders of mahogany and kesur seeds on *T. castaneum* adults (male, female and unsexed) was evaluated at three different doses (70.77, 141.15, 283.08 $\mu g/cm^2$). From this findings it was revealed that the order of toxicity of two powders were Kesur > mahogany. Mortality percentages were directly proportional to the toxicity of powder constituents and also with the time after treatment.

The effects of treating food with the seed powders of mahogany and kesur on *T, castaneum* larvae 9, 12 and 16 days and freshly emerged adult male, female and unsexed were investigated by comparing using the doses 0.5, 1 and 2% w/w. At a concentration of 0.5% w/w lowest mortality (3.33%) encountered in 9 days larvae for mahogany seed powder and the highest effects (95.58%) were found in 16 days larvae for Kesur seed powder dosed at 2% w/w. There were no significant differences in susceptibility among sexes (male, female and unsexed). Mortality percentages were increased over time in both mahogany and kesur seed powders.

The residual toxicity effects of Chloroform and methanol extracts of mahogany and kesur seeds were determined in the laboratory by RFM. From probit analysis it was found that the chloroform extracts was more effective than methanol extract of mahogany at 24, 48 and 72 hours exposure. Chloroform extract had the highest toxic effect on 16 days larvae at 48H exposure and the lowest LD_{50} were 1.51µg/cm^2 but in methanol extract on 16 days larvae at 48H exposure the lowest LD_{50} were 68.19µg/cm^2.

In TFM chloroform extract were more toxic due to exposure time and dose. Result shows that in chloroform extract at 7DAT exposure on 9days larvae lowest LD_{50} was 7186.12ppm but in methanol extract at 14DAT exposure on 16 days larvae LD_{50} was 14514.44ppm. It is revealed that chloroform extract many times toxic than methanol extract through TFM experiments.

In RFM for kesur extracts exposure periods were 24 and 48 hours for larvae and 24, 48 and 72 hours for adults. For larvae the LD_{50} values of Chloroform extracts were 6.561, 3.914; 5.732, 3.828; 9.819 and 3.596µg/cm^2 at 24 and 48h exposure, and for adults the LD_{50} values for Chloroform extracts were 28.05, 12.70, 5.586; 18.27, 9.294, 5.068; 16.69, 9.293 and 3.969 µg/cm^2 at 24, 48 and 72h respectively. In this experiment, chloroform extract of kesur seed showed the highest toxic effects against different stages of flour beetle and LD_{50} values were too lowest than methanol extract.

The exposure periods were 3, 5 and 7days for larvae (9, 12 and 16 days) and 5, 7 and 14 days for adults (male, female and unsexed) (TFM results of kesur seed extracts). Due to exposure periods and different doses the lowest LD_{50} values for chloroform extracts were 5786, 6401, 7845ppm for adults and for methanol extracts LD_{50} values were 6843, 7717, 8352ppm for adults. In case of adults, the exposure periods were higher than those of larvae indicating that adults were more tolerant than larvae. From these findings it is found that toxicity of methanol extract was significantly less than chloroform extracts.

Seed powders of mahogany and kesur were significantly effective with regards to orientation and repellency in TFM (chapter 5) on different stages of *T.castaneum*. Overall results showed that mahogany seed powder is more potent than kesur in terms of repellency. Accumulated data indicated that mahogany had the highest average repellency of 99.99% and 93.30% after 24 hours interval on adult male and 9 days larvae respectively but in kesur highest average repellency rates were 93.30% and 90.00% on 16 days larvae and adult males respectively.

Highest repellent effects at 24h treatment (99.99%) were found in chloroform extracts of mahogany on adult males (in RFM). All the chloroform extracts were more effective than methanol extracts in both mahogany and Kesure seeds. There were no significant variations due to Tukey's multiple comparison tests in the repellent effect on larvae and adults, but both of the extracts of mahogany and kesure were effective as repellent on different stages of *T.castaneum.* Repellency of different application rates were most of the cases dose and time dependant.

The lowest number of eggs laid in the food treated with chloroform extracts of kesur and mahogany seed at a concentration of 250ppm and 2000ppm respectively (chapter 6). The highest oviposition rates were recorded in food treated with mahogany seed powder and extracts at a concentration of 0.12% and 2000ppm respectively. The females of all the treated media laid fewer eggs than the control media. In the treated media per day per female minimum and maximum number of eggs were 2.40 and 9.15 but in control media minimum and maximum number of eggs were 6.08 and 10.65. Kesur seed powder and extracts had more significant effects than mahogany in reducing the fecundity of *T. castaneum.*

Chapter 7 showed the effectiveness of seed powder and extracts on fertility of *T. castaneum.* Results of the statistical analysis revealed that mahogany and kesur seed powder and extracts significantly reduce the fertility of *T. castaneum* females compared to the control. The hatching percentage of eggs has been recorded as 62.06, 79.80, 54.40, 55.80, 77.11 and 42.32% for *T. castaneum* in kesur and mahogany seed powder alone or in combinations. The results showed that kesur seed powder and extracts had the highest significant effects reducing the percentage of hatching over mahogany. The lowest percent of hatching was found in chloroform extract of kesur seed 250ppm + chloroform extract of mahogany seed 2000ppm.

Seed powder and extracts alone or in combination significantly produced deformities in *T. castaneum* (Chapter 8). Kesur seed powder and extract were more effective than mahogany. Chloroform extract of kesur was most effective (25.10% for female, in treated filter paper) than other powders and extracts and the lowest effect was found in chloroform extract of mahogany seed (1.15% for male) when pupae exposed in the treated filter paper. Combined action of powders and extracts were also very effective (35.32% for female, in the treated filter paper with chloroform extracts of mahogany and kesur). Overall results reflect that percent of deformities were found more in adult female than male. The following morphological abnormal characteristics were found in the developmental

and growth stages as in the body size and shape, body color, outgrowth, wings, cephalic characters, ovipositor, symmetry etc.

Chapter 9 showed the effectiveness of mahogany and kesur seed powder and extracts on population of *T. castaneum.* Seed powder and extracts significantly reduce the population of *T. castaneum* compared to the control. Kesur seed powder and extracts had the highest significant effects in reducing the total population. Highest PRC values of the total population were 35.52 and 54.43 for mahogany and kesur seed powder respectively. The highest PRC values for chloroform and methanol extracts of mahogany were 40.69 and 41.29 and in case of kesur extracts were 58.51 and 56.72 respectively. Chloroform extracts were more effective over methanol extracts in both cases of mahogany and kesur. The pupal population was significantly reduced in all the treatments.

Chapter 11

References

Appendices

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APPENDICES

APPENDICES

Appendix Table 1. Analysis of variance on the mortality of male *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by DCM

Exposure periods(EP)	Source variation (SV)	Sum of Squares (SS)	Degrees of freedom (df)	Mean Squares(MS)	F values
3	Between doses	21.667	3	7.222	5.778(P<0.05)
	Error	10.000	8	1.250	
	Total	31.667	11		
7	Between doses	141.583	3	47.194	40.452(P<0.001)
	Error	9.333	8	1.167	
	Total	150.917	11		
14	Between doses	1024.917	3	341.639	227.759(P<0.001)
	Error	12.000	8	1.500	
	Total	1036.917	11		
21	Between doses	1646.333	3	548.778	227.080(P<0.001)
	Error	19.333	8	2.417	
	Total	1665.667	11		

App. Table 2. Analysis of variance on the mortality of female *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by DCM

Exposure periods	SV	SS	df	MS	F vales
3	Between doses	11.000	3	3.667	1.630(P>0.05)
	Error	18.000	8	2.250	
	Total	29.000	11		
7	Between doses	79.583	3	26.528	15.917(P<0.001)
	Error	13.333	8	1.667	
	Total	92.917	11		
14	Between doses	540.667	3	180.222	18.174(P<0.001)
	Error	79.333	8	9.917	
	Total	620.000	11		
21	Between doses	1418.250	3	472.750	58.485(P<0.001)
	Error	64.667	8	8.083	
	Total	1482.917	11		

App. Table 3. Analysis of variance on the mortality of unsexed *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by DCM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	56.250	3	18.750	17.308(P<0.001)
	Error	8.667	8	1.083	
	Total	64.917	11		
7	Between doses	182.250	3	60.750	7.147(P<0.05)
	Error	68.000	8	8.500	
	Total	250.250	11		
14	Between doses	666.000	3	222.000	23.786(P<0.001)
	Error	74.667	8	9.333	
	Total	740.667	11		
21	Between doses	1269.667	3	423.222	112.859(P<0.001)
	Error	30.000	8	3.750	
	Total	1299.667	11		

App. Table 4. Analysis of variance on the mortality of male *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by DCM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	171.583	3	57.194	19.610 (P<0.001)
	Error	23.333	8	2.917	
	Total	194.917	11		
7	Between doses	776.250	3	258.750	21.122 (P<0.001)
	Error	98.000	8	12.250	
	Total	874.250	11		
14	Between doses	1263.000	3	421.000	265.895 (P<0.001)
	Error	12.667	8	1.583	
	Total	1275.667	11		
21	Between doses	1382.917	3	460.972	108.464(P<0.001)
	Error	34.000	8	4.250	
	Total	1416.917	11		

App. Table 5. Analysis of variance on the mortality of female *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by DCM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	159.333	3	53.111	5.224(P<0.05)
	Error	81.333	8	10.167	
	Total	240.667	11		
7	Between doses	770.917	3	256.972	75.211(P<0.001)
	Error	27.333	8	3.417	
	Total	798.250	11		
14	Between doses	1104.917	3	368.306	86.660(P<0.001)
	Error	34.000	8	4.250	
	Total	1138.917	11		
21	Between doses	1172.250	3	390.750	53.897(P<0.001)
	Error	58.000	8	7.250	
	Total	1230.250	11		

App. Table 6. Analysis of variance on the mortality of unsexed *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by DCM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	488.250	3	162.750	93.00 (P<0.001)
	Error	14.000	8	1.750	
	Total	502.250	11		
7	Between doses	552.917	3	184.306	25.42(P<0.001)
	Error	58.000	8	7.250	
	Total	610.917	11		
14	Between doses	966.000	3	322.000	99.07 (P<0.001)
	Error	26.000	8	3.250	
	Total	992.000	11		
21	Between doses	1205.667	3	401.889	74.19(P<0.001)
	Error	43.333	8	5.417	
	Total	1249.000	11		

App. Table 7. Analysis of variance on the mortality of 9 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	19.333	3	6.444	4.54(P<0.05)
	Error	11.333	8	1.417	
	Total	30.667	11		
7	Between doses	132.667	3	44.222	29.48 (P<0.001)
	Error	12.000	8	1.500	
	Total	144.667	11		
14	Between doses	1027.583	3	342.528	141.73 (P<0.001)
	Error	19.333	8	2.417	
	Total	1046.917	11		
21	Between doses	1406.250	3	468.750	133.92(P<0.001)
	Error	28.000	8	3.500	
	Total	1434.250	11		

App. Table 8. Analysis of variance on the mortality of 12 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	11.667	3	3.889	2.33 (P>0.05)
	Error	13.333	8	1.667	
	Total	25.000	11		
7	Between doses	56.333	3	18.778	13.25(P<0.01)
	Error	11.333	8	1.417	
	Total	67.667	11		
14	Between doses	2083.667	3	694.556	3.61 (P>0.05)
	Error	1535.333	8	191.917	
	Total	3619.000	11		
21	Between doses	1478.250	3	492.750	164.25(P<0.001)
	Error	24.000	8	3.000	
	Total	1502.250	11		

App. Table 9. Analysis of variance on the mortality of 16 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	10.917	3	3.639	1.617(P>0.05)
	Error	18.000	8	2.250	
	Total	28.917	11		
7	Between doses	69.333	3	23.111	9.563 (P<0.01)
	Error	19.333	8	2.417	
	Total	88.667	11		
14	Between doses	505.583	3	168.528	11.690 (P<0.01)
	Error	115.333	8	14.417	
	Total	620.917	11		
21	Between doses	1427.667	3	475.889	40.790(P<0.001)
	Error	93.333	8	11.667	
	Total	1521.000	11		

App. Table 10. Analysis of variance on the mortality of male *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	56.250	3	18.750	11.842(P<0.01)
	Error	12.667	8	1.583	
	Total	68.917	11		
7	Between doses	182.250	3	60.750	6.231 (P<0.05)
	Error	78.000	8	9.750	
	Total	260.250	11		
14	Between doses	654.000	3	218.000	26.424(P<0.001)
	Error	66.000	8	8.250	
	Total	720.000	11		
21	Between doses	1260.917	3	420.306	71.038(P<0.001)
	Error	47.333	8	5.917	
	Total	1308.250	11		

App. Table 11. Analysis of variance on the mortality of female *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	27.000	3	9.000	4.000 (P>0.05)
	Error	18.000	8	2.250	
	Total	45.000	11		
7	Between doses	184.917	3	61.639	13.956(P<0.01)
	Error	35.333	8	4.417	
	Total	220.250	11		
14	Between doses	542.000	3	180.667	44.245(P<0.001)
	Error	32.667	8	4.083	
	Total	574.667	11		
21	Between doses	1274.250	3	424.750	51.485(P<0.001)
	Error	66.000	8	8.250	
	Total	1340.250	11		

App. Table 12. Analysis of variance on the mortality of unsexed *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *S. macrophylla* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	8.250	3	2.750	0.733(P>0.05)
	Error	30.000	8	3.750	
	Total	38.250	11		
7	Between doses	106.250	3	35.417	9.239(P<0.05)
	Error	30.667	8	3.833	
	Total	136.917	11		
14	Between doses	384.250	3	128.083	35.744(P<0.001)
	Error	28.667	8	3.583	
	Total	412.917	11		
21	Between doses	1274.000	3	424.667	52.536 (P<0.001)
	Error	64.667	8	8.083	
	Total	1338.667	11		

App. Table 13. Analysis of variance on the mortality of 9 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	42.000	3	14.000	4.54(P<0.05)
	Error	24.667	8	3.083	
	Total	66.667	11		
7	Between doses	194.917	3	64.972	22.27(P<0.001)
	Error	23.333	8	2.917	
	Total	218.250	11		
14	Between doses	1004.917	3	334.972	89.32(P<0.001)
	Error	30.000	8	3.750	
	Total	1034.917	11		
21	Between doses	1418.917	3	472.972	33.38(P<0.001)
	Error	113.333	8	14.167	
	Total	1532.250	11		

App. Table 14. Analysis of variance on the mortality of 12 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	50.000	3	16.667	20.00(P<0.001)
	Error	6.667	8	.833	
	Total	56.667	11		
7	Between doses	192.917	3	64.306	10.71(P<0.01)
	Error	48.000	8	6.000	
	Total	240.917	11		
14	Between doses	1016.000	3	338.667	17.74(P<0.01)
	Error	152.667	8	19.083	
	Total	1168.667	11		
21	Between doses	1433.667	3	477.889	51.66(P<0.001)
	Error	74.000	8	9.250	
	Total	1507.667	11		

App. Table 15. Analysis of variance on the mortality of 16 days larvae of *T. castaneum* after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	8.667	3	2.889	1.651(P>0.05)
	Error	14.000	8	1.750	
	Total	22.667	11		
7	Between doses	111.333	3	37.111	9.475(P<0.01)
	Error	31.333	8	3.917	
	Total	142.667	11		
14	Between doses	106.000	3	35.333	8.154(P<0.01)
	Error	34.667	8	4.333	
	Total	140.667	11		
21	Between doses	1461.583	3	487.194	110.308(P<0.001)
	Error	35.333	8	4.417	
	Total	1496.917	11		

App. Table 16. Analysis of variance on the mortality of male *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	SV	SS	df	MS	F alues
3	Between doses	147.000	3	49.000	8.16(P<0.01)
	Error	48.000	8	6.000	
	Total	195.000	11		
7	Between doses	890.000	3	296.667	19.34(P<0.01)
	Error	122.667	8	15.333	
	Total	1012.667	11		
14	Between doses	1224.250	3	408.083	195.88(P<0.001)
	Error	16.667	8	2.083	
	Total	1240.917	11		
21	Between doses	1563.000	3	521.000	89.31(P<0.001)
	Error	46.667	8	5.833	
	Total	1609.667	11		

App. Table 17. Analysis of variance on the mortality of female *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	Source	SS	df	MS	F values
3	Between doses	180.250	3	60.083	4.68(P<0.05)
	Error	102.667	8	12.833	
	Total	282.917	11		
7	Between doses	552.000	3	184.000	10.66(P<0.01)
	Error	138.000	8	17.250	
	Total	690.000	11		
14	Between doses	1120.250	3	373.417	49.24(P<0.001)
	Error	60.667	8	7.583	
	Total	1180.917	11		
21	Between doses	1263.000	3	421.000	54.32(P<0.001)
	Error	62.000	8	7.750	
	Total	1325.000	11		

App. Table 18. Analysis of variance on the mortality of Unsexed *T. castaneum* adults after 3, 7, 14 and 21 days of exposure to *P. erosus* seed powder by TFM

Exposure periods	SV	SS	df	MS	F values
3	Between doses	255.583	3	85.194	29.21(P<0.001)
	Error	23.333	8	2.917	
	Total	278.917	11		
7	Between doses	512.000	3	170.667	28.05(P<0.001)
	Error	48.667	8	6.083	
	Total	560.667	11		
14	Between doses	962.250	3	320.750	98.69(P<0.001)
	Error	26.000	8	3.250	
	Total	988.250	11		
21	Between doses	1528.917	3	509.639	94.08(P<0.001)
	Error	43.333	8	5.417	
	Total	1572.250	11		

App. Table 19. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	8	8	0.447	3.495	3.630	23.8	3.458
0.55	0.740	100	12	12	0.740	3.835	3.822	37.0	3.814
1.11	1.045	100	17	17	1.045	4.189	4.056	47.1	4.184
2.21	1.344	100	30	30	1.344	4.536	4.460	58.1	4.547
4.42	1.645	100	50	50	1.645	4.885	5.020	62.7	4.912

$Y = 2.915 + 1.213X$
Log Ld_{50} = 1.718
Ld_{50} is = 5.218

$X^2 = 2.645$ (3df)
95% conf. limits = 3.438 to 7.920
No significant heterogeneity

App. Table 20. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	9	9	3.66	3.272	3.883	18.00	3.283
0.55	0.740	100	14	14	3.92	3.860	3.924	37.00	3.869
1.11	1.045	100	20	20	4.16	4.472	4.180	55.80	4.478
2.21	1.344	100	43	43	4.82	5.073	4.825	63.70	5.075
4.42	1.645	100	87	87	6.13	5.677	6.030	55.80	5.676

$Y = 2.390 + 1.996X$
Log Ld_{50} = 1.307
Ld_{50} = 2.026

$X^2 = 2.250$ (3df)
95% conf. limits = 1.316 to 3.121
No **sig**nificant heterogeneity

App. Table 21. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	7	7	3.52	3.481	3.54	23.8	3.463
0.55	0.740	100	13	13	3.87	3.861	3.873	37.0	3.848
1.11	1.045	100	21	21	4.19	4.255	4.184	50.3	4.248
2.21	1.344	100	34	34	4.59	4.642	4.578	60.1	4.640
4.42	1.645	100	54	54	5.10	5.031	5.100	63.7	5.035

$Y = 2.876579 + 1.311633 X$
Log Ld_{50} = 1.619
Ld_{50}= 4.158

$X^2 = 0.870$ (3df)
95% conf. limits = 2.965 to 5.832
No significant heterogeneity

App. Table 22. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	12	7	3.52	3.315	3.572	20.8	3.219
0.55	0.740	100	18	14	3.92	3.894	3.924	37.0	3.817
1.11	1.045	100	25	21	4.19	4.496	4.210	55.8	4.438
2.21	1.344	100	45	42	4.80	5.086	4.800	63.7	5.048
4.42	1.645	100	86	85	6.04	5.680	5.970	55.8	5.662

$Y = 2.307 + 2.038X$
Log Ld_{50}= 1.321
Ld_{50} = 2.094

X^2= 1.515 (3df)
95% conf. limits = 1.473 to 2.975
No **sig**nificant heterogeneity

App. Table 23. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	8	8	3.59	3.533	3.596	26.9	3.497
0.55	0.740	100	15	15	3.96	3.904	3.970	40.5	3.880
1.11	1.045	100	20	20	4.16	4.289	4.150	50.3	4.278
2.21	1.344	100	32	32	4.53	4.667	4.524	60.1	4.668
4.42	1.645	100	58	58	5.20	5.047	5.200	63.7	5.061

$Y = 2.913 + 1.305X$
Log Ld_{50} = 1.598
Ld_{50} = 3.965

X^2 = 3.893 (3df)
95% conf. limits = 2.850 to 5.517
No significant heterogeneity

App. Table 24 Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.28	0.447	100	15	15	3.96	3.834	3.975	37	3.811
0.55	0.740	100	25	25	4.33	4.306	4.33	53.2	4.286
1.11	1.045	100	33	33	4.56	4.797	4.558	61.6	4.780
2.21	1.344	100	57	57	5.18	5.279	5.202	62.7	5.265
4.42	1.645	100	83	83	5.95	5.763	5.926	53.2	5.753

$Y = 3.08603 + 1.620X$
Log Ld_{50} = 1.180
Ld_{50} = 1.516

X^2 = 5. (3df)
95% conf. limits = 1.273 to 1.805
No significant heterogeneity

App. Table 25. Probit analysis on the dose mortality response of male *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	7	7	3.52	3.586	3.519	26.9	3.625
4.42	0.645	100	13	13	3.87	3.855	3.873	37	3.880
8.86	0.947	100	21	21	4.19	4.125	4.208	47.1	4.136
17.69	1.248	100	30	30	4.48	4.393	4.49	53.2	4.390
35.39	1.549	100	33	33	4.56	4.662	4.551	60.1	4.645

$Y = 3.333223 + .8468456\ X$
Log Ld_{50} = 1.968218
Ld_{50} = 9.294328

X^2 = 1.614086 (3df)
95% conf. limits = 3.878966 to 2.227
No significant heterogeneity

App. Table 26. Probit analysis on the dose mortality response of male *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	11	11	3.77	3.767	3.778	33.6	3.771
4.42	0.645	100	18	18	4.08	4.079	4.078	43.9	4.081
8.86	0.947	100	27	27	4.39	4.392	4.394	53.2	4.392
17.69	1.248	100	38	38	4.69	4.703	4.688	61.6	4.701
35.39	1.553	100	51	51	5.03	5.019	5.025	63.7	5.016

$Y = 3.415688 + 1.030518\ X$
Log Ld_{50} = 1.537395
Ld_{50} = 34.46631

X^2 = 1.872253E-02 (3df)
95% conf. limits = 22.39909 to 53.03456
No significant heterogeneity

App. Table 27. Probit analysis on the dose mortality response of male *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	13	13	3.87	3.712	3.894	33.6	3.691
4.42	0.645	100	21	21	4.19	4.250	4.184	50.3	4.221
8.86	0.947	100	35	35	4.61	4.789	4.610	61.6	4.753
17.69	1.248	100	59	59	5.23	5.326	5.214	61.6	5.281
35.39	1.549	100	85	85	6.04	5.864	5.970	50.3	5.811

$Y = 3.084742 + 1.760471\ X$
Log Ld_{50} = 1.087923
Ld_{50} = 12.244

X^2 = 4.249283 (3df)
95% conf. limits = 10.39401 to 14.42327
No significant heterogeneity

App. Table 28. Probit analysis on the dose mortality response of female *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	6	6	3.45	3.554	3.442	26.9	3.581
4.42	0.645	100	17	17	4.05	3.861	4.077	37.0	3.878
8.86	0.947	100	19	19	4.12	4.169	4.132	47.1	4.176
17.69	1.248	100	28	28	4.42	4.475	4.420	55.8	4.472
35.39	1.549	100	42	42	4.80	4.782	4.792	61.6	4.769

$Y = 3.241625 + .9863731\ X$
Log Ld_{50} = 1.782667
Ld_{50} = 60.62713

Chi-squared = 2.259651 with 3 degrees of freedom
95% conf. limits = 32.69365 to 112.427
No sig heterogeneity

App. Table 29. Probit analysis on the dose mortality response of female *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	13	13	3.87	3.846	3.873	37	3.838
4.42	0.645	100	22	22	4.23	4.156	4.246	47.1	4.151
8.86	0.947	100	26	26	4.36	4.467	4.360	55.8	4.464
17.69	1.248	100	37	37	4.67	4.776	4.662	61.6	4.776
35.39	1.549	100	58	58	5.20	5.086	5.200	63.7	5.089

$Y = 3.480 + 1.038X$
Log Ld_{50} = 1.463
Ld_{50} = 29.050

X^2 = 2.669087 (3df)
95% conf. limits = 19.65846 to 42.92917
No significant. heterogeneity

App. Table 30. Probit analysis on the dose mortality response of female *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	17	17	4.05	4.152	4.056	47.1	4.187
4.42	0.645	100	45	45	4.87	4.669	4.875	60.1	4.682
8.86	0.947	100	56	56	5.15	5.187	5.140	63.4	5.179
17.69	1.248	100	72	72	5.58	5.703	5.574	53.2	5.673
35.39	1.549	100	90	90	6.28	6.220	6.230	37.0	6.168

$Y = 3.620 + 1.64X$
Log Ld_{50} = 0.83
Ld_{50} = 6.897

$X^2 = 3.799$ (3df)
95% conf. limits = 5.801 to 8.201
No significant heterogeneity

App. Table 31. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	8	8	3.59	3.594	3.596	26.9	3.584
4.42	0.645	100	16	16	4.01	3.933	4.016	40.5	3.923
8.86	0.947	100	22	22	4.23	4.273	4.218	50.3	4.264
17.69	1.248	100	30	30	4.48	4.611	4.470	60.1	4.603
35.39	1.549	100	52	52	5.05	4.950	5.040	63.4	4.942

$Y = 3.195 + 1.127X$
Log Ld_{50} = 1.600
Ld_{50} = 39.814

$X^2 = 2.120$ (3df)
95% conf. limits = 25.86 to 61.29
No significant heterogeneity

App. Table 32. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	10	10	3.72	3.594	3.75	26.9	3.542
4.42	0.645	100	18	18	4.08	4.023	4.078	43.9	3.985
8.86	0.947	100	24	24	4.29	4.453	4.300	55.8	4.430
17.69	1.248	100	32	32	4.53	4.881	4.552	62.7	4.873
35.39	1.549	100	74	74	5.64	5.309	5.604	61.6	5.317

$Y = 3.034 + 1.473X$
Log Ld_{50} = 1.334
Ld_{50} = 21.579

$X^2 = 14.033$ (3df)
95% conf. limits = 12.908 to 36.076
No significant heterogeneity

Ap. Table 33. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2.21	0.344	100	14	14	3.92	3.678	3.998	30.2	3.639
4.42	0.645	100	20	20	4.16	4.249	4.15	50.3	4.208
8.86	0.947	100	34	34	4.59	4.821	4.604	62.7	4.778
17.69	1.248	100	56	56	5.15	5.390	5.136	61.6	5.345
35.39	1.549	100	90	90	6.28	5.962	6.25	47.1	5.914

$Y = 2.988782 + 1.88843 X$
Log Ld_{50} is 1.065022
Ld_{50} is 11.61506

$X^2 = 13.97063$ (3df)
95% conf. limits = 8.355106 to 16.14697
No significant heterogeneity

App. Table 34. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	5	5	3.36	3.468	3.36	23.8	3.514
35.39	1.549	100	11	11	3.77	3.704	3.778	33.6	3.734
70.77	1.850	100	17	17	4.05	3.940	4.062	40.5	3.955
141.15	2.150	100	21	21	4.19	4.175	4.208	47.1	4.175
283.08	2.452	100	25	25	4.33	4.412	4.330	55.8	4.396

$Y = 2.599 + 0.733X$
Log $Ld_{50} = 3.275$
$Ld_{50} = 1885.114$
$X^2 = 1.387$ (3df)
95% conf. limits = 437.575 to 8121.233
No significant heterogeneity

App. Table 35. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	14	14	3.92	3.956	3.924	40.5	3.963
35.39	1.549	100	31	31	4.50	4.529	4.488	58.1	4.531
70.77	1.850	100	58	58	5.20	5.102	5.190	63.4	5.098
141.15	2.150	100	76	76	5.71	5.673	5.700	55.8	5.663
283.08	2.452	100	88	88	6.18	6.249	6.128	37.0	6.232

$Y = 1.611 + 1.884X$
Log $Ld_{50} = 1.797$
$Ld_{50} = 62.796$
$X^2 = 1.185$ (3df)
95% conf. limits = 54.003 to 73.022
No significant heterogeneity

App. Table 36. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	9	9	3.66	3.600	3.673	26.9	3.599
35.39	1.549	100	11	11	3.77	3.852	3.771	37.0	3.852
70.77	1.850	100	19	19	4.12	4.104	4.132	47.1	4.105
141.15	2.150	100	25	25	4.33	4.355	4.330	53.2	4.358
283.08	2.452	100	36	36	4.64	4.608	4.632	60.1	4.612

$Y = 2.549 + .841X$
Log $Ld_{50} = 2.913$
$Ld_{50} = 819.519$
$X^2 = 0.489$ (3df)
95% conf. limits = 328.319 to 2045.605
No significant heterogeneity

App. Table 37. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	18	9	3.66	3.708	3.662	33.6	3.734
35.39	1.549	100	30	22	4.23	4.293	4.218	50.3	4.312
70.77	1.850	100	57	52	5.05	4.878	5.072	62.7	4.890
141.15	2.150	100	72	69	5.50	5.461	5.483	60.1	5.465
283.08	2.452	100	85	83	5.95	6.049	5.923	43.9	6.045

$Y = 1.340 + 1.918X$
Log $Ld_{50} = 1.907$
$Ld_{50} = 80.786$
$X^2 = 3.378$ (3df)
95% conf. limits = 69.615 to 93.749
No significant heterogeneity

App. Table 38. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	5	5	3.36	3.406	3.36	23.8	3.423
35.39	1.549	100	10	10	3.72	3.668	3.73	30.2	3.680
70.77	1.850	100	15	15	3.96	3.930	3.97	40.5	3.938
141.15	2.150	100	20	20	4.16	4.191	4.17	47.1	4.194
283.08	2.452	100	29	29	4.45	4.454	4.45	55.8	4.453

$Y = 2.354 + 0.855X$
Log Ld_{50} = 3.091
Ld_{50} = 1233.456

X^2 = 0.238 (3df)
95% conf. limits = 412.415 TO 3689.032
No significant heterogeneity

App. Table 39. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
17.69	1.248	100	12	12	3.82	3.816	3.822	37.0	3.819
35.39	1.549	100	26	26	4.36	4.426	4.360	55.8	4.426
70.77	1.850	100	53	53	5.08	5.036	5.075	63.7	5.032
141.15	2.150	100	77	77	5.74	5.644	5.730	55.8	5.636
283.08	2.452	100	88	88	6.18	6.257	6.128	37.0	6.245

$Y = 1.305 + 2.014X$
Log Ld_{50} = 1.833
Ld_{50} = 68.192

X^2 = 1.357 (3df)
95% conf. limits = 59.165 to 78.59
No significant heterogeneity

App. Table 40. Probit analysis on the dose mortality response of male *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	01	01	2.67	2.838	2.692	9.2	2.835
70.77	1.850	100	03	03	3.12	3.188	3.116	15.4	3.185
141.15	2.150	100	08	08	3.59	3.536	3.596	26.9	3.535
283.08	2.452	100	16	16	4.01	3.887	4.026	37.0	3.887
566.17	2.753	100	20	20	4.16	4.237	4.150	50.3	4.238

$Y = 1.029 + 1.165X$
Log Ld_{50} = 3.406
Ld_{50} = 2552.597

X^2 = 1.465 (3df)
95% conf. limits = 970.799 to 6711.748
No significant heterogeneity

App. Table 41. Probit analysis on the dose mortality response of male *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	5	5	3.36	3.320	3.360	20.8	3.295
70.77	1.850	100	10	10	3.72	3.715	3.720	33.6	3.697
141.15	2.150	100	18	18	4.08	4.109	4.094	47.1	4.098
283.08	2.452	100	27	27	4.39	4.505	4.376	58.1	4.502
566.17	2.753	100	50	50	5.00	4.900	4.990	63.4	4.905

$Y = 1.223 + 1.337X$
Log Ld_{50} = 2.824
Ld_{50} = 667.057

X^2 = 1.493 (3df)
95% conf. limits = 456.579 to 974.565
No significant heterogeneity

App. Table 42. Probit analysis on the dose mortality response of male *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	14	14	3.92	3.918	3.924	40.5	3.943
70.77	1.850	100	36	36	4.64	4.518	4.628	58.1	4.515
141.15	2.150	100	51	51	5.03	5.116	5.015	63.4	5.084
283.08	2.452	100	70	70	5.52	5.719	5.510	53.2	5.659
566.17	2.753	100	93	93	6.48	6.319	6.424	33.6	6.231

$Y = 0.999 + 1.900X$
Log Ld_{50} = 2.105
Ld_{50} = 127.416

X^2 = 3.497 (3df)
95% conf. limits = 109.57 to 148.157
No significant heterogeneity

App. Table 43. Probit analysis on the dose mortality response of female *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	02	02	2.95	3.072	2.950	13.1	3.137
70.77	1.850	100	06	06	3.45	3.339	3.466	20.8	3.381
141.15	2.150	100	09	09	3.66	3.605	3.663	30.2	3.623
283.08	2.452	100	14	14	3.92	3.873	3.924	37.0	3.868
566.17	2.753	100	17	17	4.05	4.140	4.056	47.1	4.111

$Y = 1.884 + 0.808X$
Log Ld_{50} = 3.851
Ld_{50} = 7103.778

X^2 = 0.919 (3df)
95% conf. limits = 1119.601 to 45072.96
No significant heterogeneity

App. Table 44. Probit analysis on the dose mortality response of female *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	08	08	3.59	3.708	3.604	33.6	3.751
70.77	1.850	100	20	20	4.16	4.059	4.160	43.9	4.084
141.15	2.150	100	31	31	4.50	4.409	4.510	55.8	4.417
283.08	2.452	100	40	40	4.75	4.761	4.740	61.6	4.752
566.17	2.753	100	52	52	5.05	5.112	5.040	63.4	5.086

$Y = 2.033 + 1.108X$
Log Ld_{50} = 2.675
Ld_{50} = 473.993

X^2 = 1.599 (3df)
95% conf. limits = 327.048 to 686.960
No significant heterogeneity

App. Table 45. Probit analysis on the dose mortality response of female *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	16	16	4.01	3.947	4.016	40.5	3.950
70.77	1.850	100	35	35	4.61	4.625	4.605	60.1	4.617
141.15	2.150	100	59	59	5.23	5.302	5.214	61.6	5.281
283.08	2.452	100	82	82	5.92	5.984	5.946	47.1	5.951
566.17	2.753	100	96	96	6.75	6.663	6.720	23.8	6.618

$Y = 0.517 + 2.215X$
Log Ld_{50} = 2.022
Ld_{50} = 105.368

X^2 = 0.711 (3df)
95% conf. limits = 92.006 to 120.671
No significant heterogeneity

App. Table 46. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 24h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	02	02	2.95	2.948	2.945	11.0	2.982
70.77	1.850	100	03	03	3.12	3.197	3.116	15.4	3.222
141.15	2.150	100	07	07	3.52	3.445	3.54	23.8	3.462
283.08	2.452	100	11	11	3.77	3.695	3.797	30.2	3.703
566.17	2.753	100	13	13	3.87	3.944	3.878	40.5	3.943

$Y = 1.745 + 0.798X$
$\text{Log } Ld_{50} = 4.076$
$Ld_{50} = 11931.10$
$X^2 = 0.775$ (3df)
95% conf. limits = 1156.557 to 1230.82
No significant heterogeneity

App. Table 47. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 48h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	05	05	3.36	3.452	3.36	23.8	3.482
70.77	1.850	100	14	14	3.92	3.806	3.924	37.0	3.826
141.15	2.150	100	21	21	4.19	4.159	4.208	47.1	4.168
283.08	2.452	100	30	30	4.48	4.514	4.460	58.1	4.513
566.17	2.753	100	44	44	4.85	4.868	4.864	62.7	4.857

$Y = 1.713 + 1.141X$
$\text{Log } Ld_{50} = 2.878$
$Ld_{50} = 755.87$
$X^2 = 0.955$ (3df)
95% conf. limits = 471.419 to 1211.96
No significant heterogeneity

App. Table 48. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 72h of exposure to different doses of *S. macrophylla seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	11	11	3.77	3.843	3.771	37.0	3.865
70.77	1.850	100	32	32	4.53	4.480	4.540	55.8	4.494
141.15	2.150	100	57	57	5.18	5.116	5.165	63.4	5.121
283.08	2.452	100	78	78	5.77	5.756	5.766	53.2	5.753
566.17	2.753	100	91	91	6.34	6.394	6.308	33.6	6.383

$Y = 0.625 + 2.091X$
$\text{Log } Ld_{50} = 2.091$
$Ld_{50} = 123.494$
$X^2 = 0.759$ (3df)
95% conf. limits = 107.417 to 141.979
No significant heterogeneity

App. Table 49. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.55	0.740	100	6	6	3.45	3.406	3.45	23.8	3.374
1.11	1.045	100	14	14	3.92	3.858	3.924	37.0	3.834
2.21	1.344	100	20	20	4.16	4.302	4.170	53.2	4.286
4.42	1.645	100	37	37	4.67	4.748	4.662	61.6	4.741
8.86	1.947	100	62	62	5.31	5.196	5.290	63.4	5.197

$Y = 2.25+1.510X$
$\text{Log } Ld_{50}=1.816$
$Ld_{50} = 6.56$
$X^2 = 2.083$ (3df)
95% conf. limits = 5.076 to 8.480
No significant heterogeneity

App. Table 50. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Dose $\mu g/cm^2$	Log dose	No. used	% Kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
0.55	0.740	100	10	10	3.72	3.588	3.75	26.9	3.551
1.11	1.045	100	19	19	4.12	4.105	4.132	47.1	4.069
2.21	1.344	100	31	31	4.50	4.612	4.497	60.1	4.578
4.42	1.645	100	41	41	4.77	5.122	4.765	63.4	5.090
8.86	1.947	100	83	83	5.95	5.634	5.91	55.8	5.603

$Y = 2.291 + 1.700X$
Log Ld_{50} = 1.592
Ld_{50}=3.914

X^2 =13.581 (3df)
95% conf. limits = 2.66 to 5.74
No significant heterogeneity

App. Table 51. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.55	0.740	100	4	4	3.25	3.348	3.254	20.8	3.404
1.11	1.045	100	15	15	3.96	3.845	3.975	37.0	3.882
2.21	1.344	100	26	26	4.36	4.334	4.362	53.2	4.351
4.42	1.645	100	43	43	4.82	4.825	4.838	62.7	4.823
8.86	1.947	100	61	61	5.28	5.318	5.266	61.6	5.297

$Y = 2.242 + 1.568X$
Log Ld_{50} = 1.758
Ld_{50} = 5.732

X^2 = 0.865 (3df)
95% conf. limits = 4.548 to 7.224
No significant heterogeneity

App. Table 52. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.55	0.740	100	12	7	3.52	3.345	3.572	20.8	3.271
1.11	1.045	100	17	13	3.87	3.954	3.878	40.5	3.897
2.21	1.344	100	31	27	4.39	4.552	4.376	58.1	4.510
4.42	1.645	100	53	51	5.03	5.153	5.015	63.4	5.128
8.86	1.947	100	84	83	5.95	5.756	5.926	53.2	5.748

$Y = 1.751 + 2.052X$
Log Ld_{50} = 1.582
Ld_{50}=3.828

X^2 = 5.44 (3df)
95% conf. limits = 3.291 to 4.452
No significant heterogeneity

App. Table 53 Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses $\mu g/cm^2$	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.55	0.740	100	11	11	3.77	3.641	3.797	30.2	3.609
1.11	1.045	100	15	15	3.96	3.967	3.970	40.5	3.948
2.21	1.344	100	18	18	4.08	4.288	4.082	50.3	4.280
4.42	1.645	100	32	32	4.53	4.610	4.524	60.1	4.615
8.86	1.947	100	54	54	5.10	4.934	5.09	63.4	4.950

$Y = 2.786 + 1.111X$
Log Ld_{50} = 1.992
Ld_{50} = 9.819

X^2 = 4.794 (3df)
95% conf. limits = 6.370 to 15.135
No significant heterogeneity

App. Table 54. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
0.55	0.740	100	13	13	3.87	3.668	3.931	30.2	3.637
1.11	1.045	100	18	18	4.08	4.177	4.094	47.1	4.147
2.21	1.344	100	32	32	4.53	4.676	4.524	60.1	4.647
4.42	1.645	100	48	48	4.95	5.178	4.94	63.4	5.150
8.86	1.947	100	83	83	5.95	5.682	5.91	55.8	5.654

Y = 2.40 + 1.67X
Log Ld_{50}=1.555
Ld_{50} = 3.596774

X^2 = 10.074 (3df)
95% conf. limits = 2.596 to 4.982
No significant heterogeneity

App. Table 55. Probit analysis on the dose mortality response of male *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	6	6	3.45	3.597	3.442	26.9	3.643
2.21	0.344	100	16	16	4.01	3.904	4.016	40.5	3.933
4.42	0.645	100	26	26	4.36	4.213	4.354	50.3	4.224
8.86	0.947	100	31	31	4.5	4.523	4.488	58.1	4.516
17.69	1.248	100	40	40	4.75	4.832	4.76	62.7	4.806

Y = 3.599 + 0 .967X
95% conf. limits = 15.382 to 51.182
No significant heterogeneity

X^2 = 2.404 (3df) Log Ld_{50} = 1.448
Ld_{50} = 28.0592

App. Table 56. Probit analysis on the dose mortality response of male *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	13	13	3.87	3.837	3.873	37.0	3.837
2.21	0.344	100	20	20	4.16	4.164	4.170	47.1	4.165
4.42	0.645	100	31	31	4.50	4.493	4.510	55.8	4.496
8.86	0.947	100	38	38	4.69	4.824	4.708	62.7	4.828
17.69	1.248	100	60	60	5.25	5.152	5.240	63.4	5.158

Y = 3.787 + 1.09X
Log Ld_{50} = 1.104
Ld_{50} = 12.705

X^2 = 1.389 (3df)
95% conf. limits = 9.01 to 17.917
No significant heterogeneity

App. Table 57. Probit analysis on the dose mortality response of male *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	15	15	3.96	3.909	3.970	40.5	3.923
2.21	0.344	100	28	28	4.42	4.383	4.426	53.2	4.382
4.42	0.645	100	41	41	4.77	4.859	4.786	62.7	4.843
8.86	0.947	100	58	58	5.20	5.337	5.188	61.6	5.307
17.69	1.248	100	83	83	5.95	5.812	5.902	50.3	5.768

Y = 3.853 + 1.534X
Log Ld_{50} =0 .747
Ld_{50} = 5.586

X^2 = 2.180 (3df)
95% conf. limits=4.655 to 6.703
No significant heterogeneity

App. Table 58. Probit analysis on the dose mortality response of female *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	8	8	3.59	3.617	3.596	30.2	3.631
2.21	0.344	100	16	16	4.01	3.960	4.016	40.5	3.967
4.42	0.645	100	24	24	4.29	4.305	4.298	53.2	4.306
8.86	0.947	100	36	36	4.64	4.652	4.632	60.1	4.646
17.69	1.248	100	50	50	5.00	4.996	4.990	63.4	4.984

Y = 3.579 + 1.125X
Log Ld_{50} = 1.261
Ld_{50}= 18.270
Control-0

X^2 = 0.149 (3df)
95% conf. limits = 12.108 to 27.567
No significant heterogeneity

App. Table 59. Probit analysis on the dose mortality response of female *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	13	13	3.87	3.767	3.894	33.6	3.753
2.21	0.344	100	19	19	4.12	4.171	4.132	47.1	4.157
4.42	0.645	100	32	32	4.53	4.577	4.516	58.1	4.564
8.86	0.947	100	43	43	4.82	4.985	4.815	63.4	4.972
17.69	1.248	100	71	71	5.55	5.390	5.526	61.6	5.378

Y = 3.691 + 1.351X
Log Ld_{50} = 0.96
Ld_{50}=9.29

X^2 =3.747 (3df)
95% conf. limits = 7.316 to 11.808
No significant heterogeneity

App. Table 60. Probit analysis on the dose mortality response of female *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	18	18	4.08	3.949	4.108	40.5	3.944
2.21	0.344	100	30	30	4.48	4.439	4.480	55.8	4.423
4.42	0.645	100	39	39	4.72	4.931	4.715	63.4	4.905
8.86	0.947	100	58	58	5.20	5.425	5.186	60.1	5.389
17.69	1.248	100	88	88	6.18	5.916	6.174	47.1	5.870

Y = 3.87 + 1.60X
Log Ld_{50} = 0.70
Ld_{50} = 5.068

X^2 = 10.394 (3df)
95% conf. limits = 3.670 to 6.997
No significant heterogeneity

App. Table 61. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	8	8	3.59	3.485	3.63	23.8	3.445
2.21	0.344	100	12	12	3.82	3.866	3.822	37.0	3.840
4.42	0.645	100	20	20	4.16	4.249	4.15	50.3	4.238
8.86	0.947	100	32	32	4.53	4.634	4.524	60.1	4.637
17.69	1.248	100	56	56	5.15	5.016	5.150	63.7	5.033

Y = 3.385 + 1.320X
Log Ld_{50} = 1.222
Ld_{50} = 16.69

X^2 = 2.843 (3df)
95% conf. limits = 11.926 to 23.372
No significant heterogeneity

App. Table 62. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	9	9	3.66	3.469	3.72	23.8	3.406
2.21	0.344	100	14	14	3.92	3.971	3.924	40.5	3.922
4.42	0.645	100	24	24	4.29	4.477	4.30	55.8	4.442
8.86	0.947	100	40	40	4.75	4.984	4.74	63.4	4.964
17.69	1.248	100	78	78	5.77	5.488	5.726	60.1	5.483

$Y = 3.327 + 1.727X$
Log $Ld_{50} = 0.968$
$Ld_{50} = 9.293$
$X^2 = 10.218$ (3df)
95% conf. limits = 6.553 to 13.180
No significant heterogeneity

App. Table 63. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of chloroform by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
1.11	4.532E-02	100	12	12	3.82	3.890	3.822	37.0	3.921
2.21	0.344	100	32	32	4.53	4.486	4.54	55.8	4.504
4.42	0.645	100	56	56	5.15	5.087	5.15	63.7	5.091
8.86	0.947	100	76	76	5.71	5.689	5.70	55.8	5.680
17.69	1.248	100	89	89	6.23	6.288	6.179	37.0	6.266

$Y = 3.83 + 1.95X$
Log $Ld_{50} = 0.598$
$Ld_{50} = 3.969$
$X^2 = 0.953$ (3df)
95% conf. limits = 3.424 to 4.600
No significant heterogeneity

App. Table 64. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	3	3	3.12	3.288	3.121	18.0	3.377
17.69	1.248	100	12	12	3.82	3.627	3.864	30.2	3.684
35.39	1.549	100	17	17	4.05	3.966	4.062	40.5	3.992
70.77	1.850	100	22	22	4.23	4.306	4.234	53.2	4.300
141.15	2.150	100	35	35	4.61	4.644	4.605	60.1	4.607

$Y = 2.407 + 1.023X$
Log $Ld_{50} = 2.533$
Ld_{50}=341.742
$X^2 = 2.585$ (3df)
95% conf. limits = 165.124 to 707.273
No significant heterogeneity

App. Table 65. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	14	14	3.92	3.934	3.924	40.5	3.930
17.69	1.248	100	30	30	4.48	4.524	4.46	58.1	4.518
35.39	1.549	100	57	57	5.18	5.116	5.165	63.4	5.107
70.77	1.850	100	78	78	5.77	5.708	5.766	53.2	5.696
141.15	2.150	100	89	89	6.23	6.297	6.179	37.0	6.282

$Y = 2.077 + 1.956X$
Log $Ld_{50} = 1.494$
$Ld_{50} = 31.205$
$X^2 = 1.066$ (3df)
95% conf. limits = 26.964 to 36.112
No significant heterogeneity

App. Table 66. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	6	6	3.45	3.468	3.45	23.8	3.481
17.69	1.248	100	11	11	3.77	3.768	3.778	33.6	3.775
35.39	1.549	100	19	19	4.12	4.068	4.119	43.9	4.069
70.77	1.850	100	25	25	4.33	4.368	4.330	53.2	4.363
141.15	2.150	100	37	37	4.67	4.668	4.659	60.1	4.656

$Y = 2.555 + 0.976X$
Log $Ld_{50} = 2.501$
$Ld_{50} = 317.607$
$X^2 = 0.192$ (3df)
95% conf. limits = 154.61 to 652.42
No significant heterogeneity

App. Table 67. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	18	14	3.92	3.850	3.924	37.0	3.843
17.69	1.248	100	34	31	4.50	4.488	4.510	55.8	4.477
35.39	1.549	100	52	49	4.97	5.128	4.965	63.4	5.112
70.77	1.850	100	79	78	5.77	5.768	5.766	53.2	5.746
141.15	2.150	100	93	93	6.48	6.405	6.491	30.2	6.379

$Y = 1.845 + 2.108X$
Log $Ld_{50} = 1.495$
$Ld_{50} = 31.328$
$X^2 = 2.068$ (3df)
95% conf. limits = 27.268 to 35.991
No significant heterogeneity

App. Table 68. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	05	05	3.96	3.308	3.360	20.8	3.279
17.69	1.248	100	08	08	3.59	3.603	3.596	30.2	3.589
35.39	1.549	100	13	13	3.87	3.898	3.873	37.0	3.899
70.77	1.850	100	18	18	4.08	4.193	4.094	47.1	4.210
141.15	2.150	100	34	34	4.59	4.488	4.600	55.8	4.519

$Y = 2.302 + 1.031X$
Log Ld_{50} i= 2.616
$Ld_{50} = 413.193$
$X^2 = 1.161$ (3df)
95% conf. limits = 186.411 to 915.87
No significant heterogeneity

App. Table 69. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
8.86	0.947	100	16	16	4.01	3.906	4.016	40.5	3.902
17.69	1.248	100	27	27	4.39	4.464	4.390	55.8	4.451
35.39	1.549	100	50	50	5.00	5.024	5.000	63.7	5.002
70.77	1.850	100	67	67	5.44	5.584	5.416	58.1	5.552
141.15	2.150	100	90	90	6.28	6.141	6.270	40.5	6.101

$Y = 2.169 + 1.828X$
Log $Ld_{50} = 1.547$
$Ld_{50} = 35.299$
$X^2 = 2.976$ (3df)
95% conf. limits = 30.277 to 41.156
No significant heterogeneity

App. Table 70. Probit analysis on the dose mortality response of male *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	6	6	3.45	3.596	3.442	26.9	3.643
70.77	1.850	100	16	16	4.01	3.905	4.016	40.5	3.934
141.15	2.150	100	26	26	4.36	4.213	4.354	50.3	4.223
283.08	2.452	100	31	31	4.50	4.523	4.448	58.1	4.516
566.17	2.753	100	40	40	4.75	4.832	4.760	62.7	4.806

$Y = 2.145 + 0.966X$
Log Ld_{50}=2.953
Ld_{50} = 897.65

X^2 = 2.394 (3df)
95% conf. limits = 491.99 to 1637.82
No significant heterogeneity

App. Table 71. Probit analysis on the dose mortality response of male *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	13	13	3.87	3.836	3.873	37.0	3.836
70.77	1.850	100	20	20	4.16	4.165	4.170	47.1	4.167
141.15	2.150	100	31	31	4.50	4.493	4.510	55.8	4.496
283.08	2.452	100	38	38	4.69	4.823	4.708	62.7	4.828
566.17	2.753	100	60	60	5.25	5.152	5.240	63.4	5.158

$Y = 2.135 + 1.097X$
Log Ld_{50} = 2.608
Ld_{50}=406.342

X^2 = 1.38 (3df)
95% conf. limits = 288.083 to 573.146
No significant heterogeneity

App. Table 72. Probit analysis on the dose mortality response of male *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	15	15	3.96	3.908	3.97	40.5	3.922
70.77	1.850	100	28	28	4.42	4.384	4.426	53.2	4.384
141.15	2.150	100	41	41	4.77	4.858	4.786	62.7	4.843
283.08	2.452	100	58	58	5.20	5.336	5.188	61.6	5.307
566.17	2.753	100	83	83	5.95	5.812	5.902	50.3	5.768

$Y = 1.547 + 1.533X$
Log Ld_{50} =2.251
Ld_{50} = 178.56

X^2 = 2.161 (3df)
95% conf. limits = 148.79 to 214.29
No significant heterogeneity

App. Table 73. Probit analysis on the dose mortality response of female *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	8	8	3.59	3.616	3.596	30.2	3.630
70.77	1.850	100	16	16	4.01	3.961	4.016	40.5	3.969
141.15	2.150	100	24	24	4.29	4.305	4.298	53.2	4.306
283.08	2.452	100	36	36	4.64	4.651	4.632	60.1	4.646
566.17	2.753	100	50	50	5.00	4.996	4.99	63.4	4.984

$Y = 1.887 + 1.124X$
Log Ld_{50} = 2.766
Ld_{50} = 584.410

X^2 = 0.142 (3df)
95% conf. limits = 387.22 to 882.00
No significant heterogeneity

App. Table 74. Probit analysis on the dose mortality response of female *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	13	13	3.87	3.766	3.894	33.6	3.752
70.77	1.850	100	19	19	4.12	4.172	4.132	47.1	4.158
141.15	2.150	100	32	32	4.53	4.577	4.516	58.1	4.563
283.08	2.452	100	43	43	4.82	4.984	4.815	63.4	4.971
566.17	2.753	100	71	71	5.55	5.390	5.526	61.6	5.378

$Y = 1.659 + 1.350X$
Log Ld_{50} = 2.473
Ld_{50} = 297.194

$X^2 = 3.742$ (3df)
95% conf. limits = 233.89 to 377.620
No significant heterogeneity

App. Table 75. Probit analysis on the dose mortality response of female *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	18	18	4.08	3.948	4.108	40.5	3.942
70.77	1.850	100	30	30	4.48	4.440	4.480	55.8	4.424
141.15	2.150	100	39	39	4.72	4.930	4.715	63.4	4.904
283.08	2.452	100	58	58	5.20	5.424	5.186	60.1	5.388
566.17	2.753	100	88	88	6.18	5.917	6.174	47.1	5.870

$Y = 1.462 + 1.601X$
Log Ld_{50} =2.209
Ld_{50}=161.99

$X^2 = 10.36$ (3df)
95% conf. limits = 117.36 to 223.57
No significant heterogeneity

App. Table 76. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 24h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	8	8	3.59	3.484	3.630	23.8	3.444
70.77	1.850	100	12	12	3.82	3.867	3.822	37.0	3.841
141.15	2.150	100	20	20	4.16	4.249	4.150	50.3	4.237
283.08	2.452	100	32	32	4.53	4.633	4.524	60.1	4.636
566.17	2.753	100	56	56	5.15	5.016	5.150	63.7	5.033

$Y = 1.399 + 1.319X$
Log Ld_{50} = 2.727
Ld_{50} = 534.02

$X^2 = 2.83$ (3df)
95% conf. limits = 381.38 to 747.73
No significant heterogeneity

App. Table 77. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 48h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	9	9	3.66	3.468	3.72	23.8	3.404
70.77	1.850	100	14	14	3.92	3.973	3.924	40.5	3.924
141.15	2.150	100	24	24	4.29	4.476	4.300	55.8	4.442
283.08	2.452	100	40	40	4.75	4.983	4.740	63.4	4.964
566.17	2.753	100	78	78	5.77	5.489	5.726	60.1	5.483

$Y = .730 + 1.726X$
Log Ld_{50}=2.472
Ld_{50} = 297.138

$X^2 = 10.19$ (3df)
95% conf. limits = 209.55 to 421.33
No significant heterogeneity

App. Table 78. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 72h of exposure to different doses of *P.erosus seed* extracts of methanol by RFM

Doses µg/cm^2	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
35.39	1.549	100	12	12	3.82	3.889	3.822	37.0	3.920
70.77	1.850	100	32	32	4.53	4.488	4.540	55.8	4.506
141.15	2.150	100	56	56	5.15	5.086	5.150	63.7	5.090
283.08	2.452	100	76	76	5.71	5.688	5.700	55.8	5.679
566.17	2.753	100	89	89	6.23	6.288	6.179	37.0	6.266

Y = .900 + 1.948X
Log Ld_{50}=2.103
Ld_{50} = 126.840

X^2 = 0.94 (3df)
95% conf. limits = 109.41 TO 147.03
No significant heterogeneity

App. Table 79. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	5	5	3.36	3.470	3.36	23.8	3.509
5000	3.699	100	11	11	3.77	3.664	3.797	30.2	3.687
10000	3.100	100	14	14	3.92	3.858	3.924	37.0	3.864
20000	4.301	100	17	17	4.05	4.052	4.037	43.9	4.042
40000	4.602	100	21	21	4.19	4.246	4.184	50.3	4.219

Y = 1.505 + 0.589X
Log Ld_{50} = 5.925
Ld_{50} = 842391.60

X^2 = 1.09 (3df)
95% conf. limits = 66150.31 to 1.07E+07
No significant heterogeneity

App. Table 80. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	9	9	3.66	3.734	3.662	33.6	3.756
5000	3.699	100	17	17	4.05	3.939	4.062	40.5	3.952
10000	3.100	100	19	19	4.12	4.144	4.132	47.1	4.148
20000	4.301	100	26	26	4.36	4.349	4.362	53.2	4.344
40000	4.602	100	32	32	4.53	4.554	4.516	58.1	4.540

Y = 1.543 + .651X
Log Ld_{50} = 5.307
Ld_{50} = 203127.3

X^2 = 0.84 (3df)
95% conf. limits = 49270.29 to 837435.90
No significant heterogeneity

App. Table 81. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 7 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	19	19	4.12	4.274	4.116	50.3	4.277
5000	3.699	100	39	39	4.72	4.739	4.714	61.6	4.752
10000	3.100	100	70	70	5.52	5.204	5.54	62.7	5.226
20000	4.301	100	76	76	5.71	5.669	5.700	55.8	5.701
40000	4.602	100	83	83	5.95	6.134	5.948	40.5	6.176

Y = -1.081 + 1.576X
Log Ld_{50} = 3.856
Ld_{50} = 7186.128

X^2 = 9.65 (3df)
95% conf. limits = 5193.808 to 9942.68
No significant heterogeneity

App. Table 82. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	4	4	3.25	3.406	3.27	23.8	3.463
5000	3.699	100	10	10	3.72	3.596	3.75	26.9	3.636
10000	3.100	100	14	14	3.92	3.786	3.952	33.6	3.809
20000	4.301	100	15	15	3.96	3.976	3.97	40.5	3.981
40000	4.602	100	18	18	4.08	4.166	4.094	47.1	4.154

$Y = 1.513 + 0.573X$
Log Ld_{50} = 6.076031
Ld_{50} is 1191326

X^2 =2.10 (3df)
95% conf. limits = 65734.28 to 2.159E+07
No significant heterogeneity

App. Table 83. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	8	8	3.59	3.654	3.596	30.2	3.683
5000	3.699	100	15	15	3.96	3.898	3.975	37.0	3.917
10000	3.100	100	21	21	4.19	4.142	4.208	47.1	4.151
20000	4.301	100	26	26	4.36	4.386	4.362	53.2	4.386
40000	4.602	100	35	35	4.61	4.630	4.605	60.1	4.620

$Y = 1.037 + 0.778X$
Log Ld_{50} = 5.089808
Ld_{50} = 122972.30

X^2 = 0.54 (3df)
95% conf. limits = 45249.27 to 334197.60
No significant heterogeneity

App. Table 84. Probit analysis on the dose mortality response of 12days old *T. castaneum* larvae after 7days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	16	16	4.01	4.196	4.018	47.1	4.223
5000	3.699	100	45	45	4.87	4.676	4.875	60.1	4.697
10000	3.100	100	60	60	5.25	5.156	5.240	63.4	5.172
20000	4.301	100	73	73	5.61	5.636	5.610	55.8	5.647
40000	4.602	100	85	85	6.04	6.116	6.040	40.5	6.121

$Y = -1.134 + 1.576X$
Log Ld_{50}=3.890
Ld_{50} is 7777.573

X^2 =4.50 (3df)
95% conf. limits = 6499.019 to 9307.644
No significant heterogeneity

App. Table 85. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	4	4	3.25	3.288	3.248	18.0	3.311
5000	3.699	100	7	7	3.52	3.475	3.540	23.8	3.489
10000	3.100	100	9	9	3.66	3.662	3.663	30.2	3.667
20000	4.301	100	13	13	3.87	3.849	3.873	37.0	3.843
40000	4.602	100	16	16	4.01	4.036	3.996	43.9	4.021

$Y = 1.310 + 0.588X$
Log Ld_{50}=6.264
Ld_{50} = 18403.13

X^2 =0.19 (3df)
95% conf. limits = 67532.08 to 5.01E+07
No significant heterogeneity

App. Table 86. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	7	7	3.52	3.538	3.519	26.9	3.546
5000	3.699	100	12	12	3.82	3.789	3.836	33.6	3.792
10000	3.100	100	18	18	4.08	4.040	4.078	43.9	4.038
20000	4.301	100	21	21	4.19	4.291	4.184	50.3	4.283
40000	4.602	100	34	34	4.59	4.542	4.572	58.1	4.529

$Y = 0.773 + 0.815X$
Log Ld_{50}=5.179
Ld_{50} = 151075.10
X^2 =0.75 (3df)
95% conf. limits = 52465.66 to 435021.2
No significant heterogeneity

App. Table 87. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 7 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	17	13	3.87	3.750	3.894	33.6	3.724
5000	3.699	100	27	23	4.26	4.350	4.266	53.2	4.327
10000	3.100	100	45	42	4.80	4.950	4.790	63.4	4.930
20000	4.301	100	75	74	5.64	5.550	5.612	58.1	5.532
40000	4.602	100	89	88	6.18	6.150	6.178	40.5	6.135

$Y = -3.077 + 2.001X$
Log Ld_{50} = 4.035
Ld_{50}=10843.02
X^2 =2.84 (3df)
95% conf. limits = 9398.082 to 12510.10
No significant heterogeneity

App. Table 88. Probit analysis on the dose mortality response of male *T. castaneum* adult after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	5	5	3.36	3.400	3.36	23.8	3.441
10000	3.100	100	9	9	3.66	3.687	3.663	30.2	3.711
20000	4.301	100	18	18	4.08	3.974	4.108	40.5	3.981
40000	4.602	100	24	24	4.29	4.261	4.286	50.3	4.251
80000	4.903	100	30	30	4.48	4.548	4.460	58.1	4.521

$Y = 0.1237 + 0.896X$
Log Ld_{50} = 5.437
Ld_{50}=273728.80
X^2 =1.15 (3df)
95% conf. limits = 106635.50 to 702651.1
No significant heterogeneity

App. Table 89. Probit analysis on the dose mortality response of male *T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	9	9	3.66	3.788	3.662	33.6	3.832
10000	3.100	100	22	22	4.23	4.102	4.246	47.1	4.131
20000	4.301	100	31	31	4.50	4.416	4.510	55.8	4.429
40000	4.602	100	38	38	4.69	4.730	4.688	61.6	4.728
80000	4.903	100	50	50	5.00	5.044	5.000	63.7	5.027

$Y = 0.1587 + 0.992X$
Log Ld_{50}=4.875
Ld_{50} = 75083.34
X^2 =2.10 (3df)
95% conf. limits=48382.18 to 116520.30
No significant heterogeneity

App. Table 90. Probit analysis on the dose mortality response of male *T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	16	16	4.01	4.032	3.996	43.9	4.020
10000	3.100	100	32	32	4.53	4.554	4.516	58.1	4.545
20000	4.301	100	56	56	5.15	5.076	5.150	63.7	5.071
40000	4.602	100	73	73	5.61	5.598	5.584	58.1	5.597
80000	4.903	100	86	86	6.08	6.120	6.086	40.5	6.123

$Y = -2.442 + 1.747X$
Log Ld_{50} = 4.260
Ld_{50} = 18203.93

X^2 = 0.53 (3df)
95% conf. limits = 1.5520.79 to 21350.92
No significant heterogeneity

App. Table 91. Probit analysis on the dose mortality response of female *T. castaneum* adult after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	6	6	3.45	3.602	3.462	30.2	3.667
10000	3.100	100	16	16	4.01	3.899	4.026	37.0	3.939
20000	4.301	100	25	25	4.33	4.196	4.360	47.1	4.216
40000	4.602	100	31	31	4.50	4.493	4.510	55.8	4.492
80000	4.903	100	38	38	4.69	4.790	4.688	61.6	4.768

$Y = 0.265 + 0.918X$
Log Ld_{50} = 5.155
Ld_{50} = 142946.9

X^2 =2.89 (3df)
95% conf. limits = 73076.50 to 279622.10
No significant heterogeneity

App. Table 92. Probit analysis on the dose mortality response of female *T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	12	12	3.82	3.968	3.832	40.5	4.008
10000	3.100	100	30	30	4.48	4.325	4.490	53.2	4.348
20000	4.301	100	40	40	4.75	4.682	4.740	60.1	4.689
40000	4.602	100	51	51	5.03	5.039	5.025	63.7	5.029
80000	4.903	100	63	63	5.33	5.396	5.318	61.6	5.370

$Y = -0.177 + 1.131X$
Log Ld_{50}=4.575
Ld_{50}=37667.05

X^2 = 2.64 (3df)
95% conf. limits = 28737.03 to 49372.08
No significant heterogeneity

App. Table 93. Probit analysis on the dose mortality response of male *T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	18	18	4.08	4.198	4.094	47.1	4.226
10000	3.100	100	43	43	4.82	4.737	4.818	61.6	4.755
20000	4.301	100	65	65	5.39	5.276	5.41	62.7	5.284
40000	4.602	100	79	79	5.81	5.815	5.766	50.3	5.813
80000	4.903	100	90	90	6.28	6.354	6.25	33.6	6.343

$Y = -2.274 + 1.757X$
Log Ld_{50} = 4.139
Ld_{50}=13776.73

X^2 =2.45 (3df)
95% conf. limits =11649.17 to 16292.84
No significant heterogeneity

App. Table 94. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 3 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	5	5	3.36	3.454	3.36	23.8	3.491
10000	3.100	100	12	12	3.82	3.719	3.836	33.6	3.741
20000	4.301	100	17	17	4.05	3.984	4.062	40.5	3.991
40000	4.602	100	21	21	4.19	4.249	4.184	50.3	4.240
80000	4.903	100	31	31	4.50	4.514	4.488	58.1	4.490

$Y = 0.423 + 0.829X$
Log Ld_{50}=5.518
Ld_{50} = 329612.20
X^2 =1.07 (3df)
95% conf. limits = 111213.30 to 976899.10
No significant heterogeneity

App. Table 95. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	10	10	3.72	3.764	3.72	33.6	3.772
10000	3.100	100	20	20	4.16	4.095	4.16	43.9	4.098
20000	4.301	100	28	28	4.42	4.426	4.42	55.8	4.424
40000	4.602	100	40	40	4.75	4.757	4.74	61.6	4.750
80000	4.903	100	53	53	5.08	5.088	5.075	63.7	5.076

$Y = -0.233 + 1.083X$
Log Ld_{50} = 4.832
Ld_{50} = 68010.71
X^2 = 0.26 (3df)
95% conf. limits = 46400.02 to 99686.48
No significant heterogeneity

App. Table 96. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	16	16	4.01	4.006	3.996	43.9	3.991
10000	3.100	100	31	31	4.50	4.496	4.510	55.8	4.489
20000	4.301	100	48	48	4.95	4.986	4.940	63.4	4.987
40000	4.602	100	70	70	5.52	5.476	5.510	60.1	5.485
80000	4.903	100	83	83	5.95	5.966	5.984	47.1	5.983

$Y = -2.127 + 1.654X$
Log Ld_{50} = 4.308
Ld_{50}=20367.13
X^2 = 0.20 (3df)
95% conf. limits = 17252.80 to 24043.66
No significant heterogeneity

App. Table 97. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	4	4	3.25	3.294	3.248	18.0	3.309
10000	3.100	100	8	8	3.59	3.496	3.630	23.8	3.509
20000	4.301	100	9	9	3.66	3.698	3.663	30.2	3.710
40000	4.602	100	13	13	3.87	3.900	3.873	37.0	3.910
80000	4.903	100	19	19	4.12	4.102	4.132	47.1	4.110

$Y = 0.848 + 0.66X$
Log Ld_{50} = 6.240054
Ld_{50} = 1738018
X^2 = 0.55 (3df)
95% conf. limits = 149926.6 to 2.01E+07
No significant heterogeneity

App. Table 98. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 7 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	9	9	3.66	3.667	3.663	30.2	3.67
10000	3.100	100	14	14	3.92	3.887	3.924	37.0	3.890
20000	4.301	100	19	19	4.12	4.108	4.132	47.1	4.110
40000	4.602	100	22	22	4.23	4.329	4.234	53.2	4.329
80000	4.903	100	35	35	4.61	4.550	4.600	58.1	4.549

$Y = 0.969 + 0.730X$
Log Ld_{50} = 5.520
Ld_{50}=331638.60
X^2 = 0.70 (3df)
95% conf. limits = 100067.80 to 109909.60
No significant heterogeneity

App. Table 99. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	15	15	3.96	3.966	3.97	40.5	3.952
10000	3.100	100	32	32	4.53	4.592	4.516	58.1	4.587
20000	4.301	100	59	59	5.23	5.220	5.254	62.7	5.223
40000	4.602	100	85	85	6.04	5.847	5.970	50.3	5.859
80000	4.903	100	91	91	6.34	6.474	6.357	30.2	6.494

$Y = -3.858 + 2.111X$
Log Ld_{50} = 4.195
Ld_{50} = 15681.36
X^2 = 1.56 (3df)
95% conf. limits = 13635.80 to 18033.78
No significant heterogeneity

App. Table 100. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	5	5	3.36	3.368	3.360	20.8	3.370
10000	3.100	100	8	8	3.59	3.576	3.596	26.9	3.581
20000	4.301	100	11	11	3.77	3.784	3.778	33.6	3.792
40000	4.602	100	16	16	4.01	3.992	4.016	40.5	4.003
80000	4.903	100	21	21	4.19	4.200	4.208	47.1	4.214

$Y = 0.777 + 0.700X$
Log Ld_{50}= 6.025
Ld_{50} =1059280
X^2 = 2.31E-02 (3df)
95% conf. limits = 142765.60 to 7859561
No significant heterogeneity

App. Table 101. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 7days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	6	6	3.45	3.388	3.466	20.8	3.366
10000	3.100	100	10	10	3.72	3.686	3.73	30.2	3.672
20000	4.301	100	12	12	3.82	3.984	3.832	40.5	3.979
40000	4.602	100	23	23	4.26	4.282	4.252	50.3	4.285
80000	4.903	100	37	37	4.67	4.580	4.656	58.1	4.591

$Y = -0.396 + 1.017X$
Log Ld_{50}=5.305
Ld_{50} = 201850.90
X^2 =1.47 (3df)
95% conf. limits = 95676.28 to 425850.50
No significant heterogeneity

App. Table 102. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	17	17	4.05	4.036	4.037	43.9	4.027
10000	3.100	100	34	34	4.59	4.590	4.572	58.1	4.575
20000	4.301	100	55	55	5.13	5.144	5.115	63.4	5.123
40000	4.602	100	75	75	5.67	5.698	5.67	55.8	5.672
80000	4.903	100	90	90	6.28	6.252	6.23	37.0	6.220

$Y = -2.708 + 1.820X$
$\text{Log } Ld_{50} = 4.233$
$Ld_{50} = 17108.07$
$X^2 = 1.26E\text{-}02$ (3df)
95% conf. limits = 14645.07 to 19985.29
No significant heterogeneity

App. Table 103. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	7	7	3.52	3.508	3.519	26.9	3.507
10000	3.100	100	10	10	3.72	3.714	3.720	33.6	3.715
20000	4.301	100	13	13	3.87	3.920	3.878	40.5	3.923
40000	4.602	100	20	20	4.16	4.126	4.170	47.1	4.131
80000	4.903	100	25	25	4.33	4.332	4.330	53.2	4.339

$Y = 0.949 + 0.69X$
$\text{Log } Ld_{50} = 5.858$
$Ld_{50} = 721788.2$
$X^2 = 1.62$ (3df)
95% conf. limits = 133517.30 to 3901954
No significant heterogeneity

App. Table 104. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 7 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	11	11	3.77	3.778	3.778	33.6	3.784
10000	3.100	100	16	16	4.01	3.996	4.016	40.5	3.998
20000	4.301	100	22	22	4.23	4.214	4.218	50.3	4.212
40000	4.602	100	27	27	4.39	4.432	4.390	55.8	4.426
80000	4.903	100	37	37	4.67	4.650	4.659	60.1	4.640

$Y = 1.155 + 0.710X$
$\text{Log } Ld_{50} = 5.410$
$Ld_{50} = 257105.70$
$X^2 = 0.11$ (3df)
95% conf. limits = 85960.15 to 768999.80
No significant heterogeneity

App. Table 105. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	18	18	4.08	4.068	4.078	43.9	4.066
10000	3.100	100	35	35	4.61	4.675	4.605	60.1	4.673
20000	4.301	100	64	64	5.36	5.282	5.384	62.7	5.281
40000	4.602	100	81	81	5.88	5.889	5.834	50.3	5.888
80000	4.903	100	93	93	6.48	6.496	6.491	30.2	6.496

$Y = -3.399 + 2.018X$
$\text{Log } Ld_{50} = 4.161$
$Ld_{50} = 14514.44$
$X^2 = 1.10$ (3df)
95% conf. limits = 12537.44 to 16803.19
No significant heterogeneity

App. Table 106. Probit analysis on the dose mortality response of male *T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	5	5	3.36	3.426	3.36	23.8	3.447
10000	3.100	100	10	10	3.72	3.642	3.73	30.2	3.654
20000	4.301	100	13	13	3.87	3.858	3.873	37.0	3.861
40000	4.602	100	18	18	4.08	4.074	4.078	43.9	4.068
80000	4.903	100	23	23	4.26	4.290	4.252	50.3	4.275

$Y = 0.903 + 0.687X$
$\text{Log } Ld_{50} = 5.957$
$Ld_{50} = 907779.60$
$X^2 = 0.39$ (3df)
95% conf. limits = 138914.5 to 5932159
No significant heterogeneity

App. Table 107. Probit analysis on the dose mortality response of male *T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	11	11	3.77	3.798	3.778	36.6	3.806
10000	3.100	100	18	18	4.08	4.051	4.078	43.9	4.058
20000	4.301	100	24	24	4.29	4.304	4.298	53.2	4.309
40000	4.602	100	35	35	4.61	4.557	4.600	58.1	4.561
80000	4.903	100	41	41	4.77	4.810	4.786	62.7	4.812

$Y = 0.715 + 0.835X$
$\text{Log } Ld_{50} = 5.127$
$Ld_{50} = 134222$
$X^2 = 0.18$ (3df)
95% conf. limits = 66451.31 to 271109
No significant heterogeneity

App. Table 108. Probit analysis on the dose mortality response of male *T. castaneum* adult after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	18	18	4.08	4.212	4.082	50.3	4.238
10000	3.100	100	46	46	4.90	4.729	4.896	61.6	4.746
20000	4.301	100	60	60	5.25	5.246	5.280	62.7	5.253
40000	4.602	100	78	78	5.77	5.763	5.766	53.2	5.761
80000	4.903	100	89	89	6.23	6.280	6.179	37.0	6.269

$Y = -2.001 + 1.686X$
$\text{Log } Ld_{50} = 4.150$
$Ld_{50} = 14148.92$
$X^2 = 2.95$ (3df)
95% conf. limits = 11928.98 to 16781.99
No significant heterogeneity

App. Table 109. Probit analysis on the dose mortality response of female *T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	7	7	3.52	3.546	3.519	26.9	3.554
10000	3.100	100	11	11	3.77	3.757	3.778	33.6	3.765
20000	4.301	100	17	17	4.05	3.968	4.062	40.5	3.976
40000	4.602	100	18	18	4.08	4.179	4.094	47.1	4.187
80000	4.903	100	28	28	4.42	4.390	4.426	53.2	4.399

$Y = 0.961 + 0.701X$
$\text{Log } Ld_{50} = 5.760$
$Ld_{50} = 576764.50$
$X^2 = 0.78$ (3df)
95% conf. limits = 120985.10 to 2749576
No significant heterogeneity

App. Table 110. Probit analysis on the dose mortality response of female *T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	10	10	3.72	3.704	3.72	33.6	3.683
10000	3.100	100	16	16	4.01	4.002	3.996	43.9	3.989
20000	4.301	100	24	24	4.29	4.300	4.286	50.3	4.295
40000	4.602	100	32	32	4.53	4.598	4.516	58.1	4.601
80000	4.903	100	48	48	4.95	4.896	4.968	62.7	4.907

$Y = -0.074 + 1.015X$
Log $Ld_{50} = 4.994$
$Ld_{50} = 98836.11$
$X^2 = 0.70$ (3df)
95% conf. limits = 59882.24 to163129.60
No significant heterogeneity

App. Table 111. Probit analysis on the dose mortality response of female *T. castaneum* adult after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	19	19	4.12	4.152	4.132	47.1	4.178
10000	3.100	100	42	42	4.80	4.715	4.792	61.6	4.725
20000	4.301	100	61	61	5.28	5.278	5.306	62.7	5.272
40000	4.602	100	76	76	5.71	5.841	5.664	50.3	5.819
80000	4.903	100	93	93	6.48	6.404	6.491	30.2	6.366

$Y = -2.542 + 1.816X$
Log Ld_{50}=4.151
Ld_{50}=14162.24
$X^2 = 2.12$ (3df)
95% conf. limits = 12052.81 to 16640.82
No significant heterogeneity

App. Table 112. Probit analysis on the dose mortality response of unsexed*T. castaneum* adult after 5 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	5	5	3.36	3.482	3.36	23.8	3.527
10000	3.100	100	14	14	3.92	3.759	3.952	33.6	3.786
20000	4.301	100	17	17	4.05	4.036	4.037	43.9	4.044
40000	4.602	100	24	24	4.29	4.313	4.298	53.2	4.303
80000	4.903	100	33	33	4.56	4.590	4.544	58.1	4.562

$Y = 0.346 + 0.859X$
Log Ld_{50}=5.412
$Ld_{50} = 258659.7$
$X^2 = 1.61$ (3df)
95% conf. limits = 99451.24 to 672740.1
No significant heterogeneity

App. Table 113. Probit analysis on the dose mortality response of unsexed*T. castaneum* adult after 7 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	11	11	3.77	3.874	3.771	37.0	3.899
10000	3.100	100	23	23	4.26	4.123	4.284	47.1	4.140
20000	4.301	100	27	27	4.39	4.372	4.394	53.2	4.382
40000	4.602	100	34	34	4.59	4.621	4.578	60.1	4.623
80000	4.903	100	44	44	4.85	4.870	4.864	62.7	4.864

$Y = 0.934 + 0.801X$
Log Ld_{50}=5.072
$Ld_{50} = 118204.5$
$X^2 = 1.70$ (3df)
95% conf. limits = 59600.55 TO 234432
No significant heterogeneity

App. Table 114. Probit analysis on the dose mortality response of unsexed*T. castaneum* adult after 14 days of exposure to different doses of *S. macrophylla seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
5000	3.699	100	16	16	4.01	4.052	3.996	43.9	4.045
10000	3.100	100	36	36	4.64	4.580	4.628	58.1	4.573
20000	4.301	100	55	55	5.13	5.108	5.115	63.4	5.101
40000	4.602	100	72	72	5.58	5.636	5.58	55.8	5.629
80000	4.903	100	88	88	6.18	6.164	6.178	40.5	6.158

Y= -2.445 +1.754X
Log Ld_{50} = 4.243
Ld_{50}=17511.07

X^2 = 0.44 (3df)
95% conf. limits = 14919.99 TO 20552.14
No significant heterogeneity

App. Table 115. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	6	6	3.45	3.506	3.442	26.9	3.521
5000	3.699	100	13	13	3.87	3.790	3.894	33.6	3.799
10000	3.100	100	18	18	4.08	4.074	4.078	43.9	4.076
20000	4.301	100	25	25	4.33	4.358	4.330	53.2	4.353
40000	4.602	100	36	36	4.64	4.642	4.632	60.1	4.631

Y = 0.391 + 0.921X
Log Ld_{50} = 5.003
Ld_{50} = 100701.8

X^2 = 0.50 (3df)
95% conf. limits = 45623.17 to 222274.40
No significant heterogeneity

App. Table 116. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
Dose ppm	Log dose	# used	% Kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
2500	3.398	100	9	9	3.66	3.802	3.669	37.0	3.878
5000	3.699	100	24	24	4.29	4.120	4.322	47.1	4.150
10000	3.100	100	31	31	4.50	4.438	4.510	55.8	4.453
20000	4.301	100	38	38	4.69	4.756	4.688	61.6	4.755
40000	4.602	100	52	52	5.05	5.074	5.05	63.7	5.058

Y = 0.433 + 1.004X
Log Ld_{50}=4.544
Ld_{50} = 35028.3

X^2 = 3.03 (3df)
95% conf. limits = 23068.52 to 53188.61
No significant heterogeneity

App. Table 117. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Dose ppm	Log dose	No. used	% Kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
2500	3.398	100	17	17	4.05	4.032	4.037	43.9	4.018
5000	3.699	100	35	35	4.61	4.551	4.600	58.1	4.537
10000	3.100	100	47	47	4.92	5.070	4.925	63.7	5.055
20000	4.301	100	74	74	5.64	5.589	5.612	58.1	5.574
40000	4.602	100	87	87	6.13	6.108	6.132	40.5	6.093

Y = -1.837 + 1.723X
Log Ld_{50} = 3.967
Ld_{50} = 9285.846

X^2 =1.47 (3df)
95% conf. limits = 7901.858 to 10912.23
No significant heterogeneity

App. Table 118. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	7	7	3.52	3.564	3.519	26.9	3.573
5000	3.699	100	13	13	3.87	3.805	3.873	37.0	3.807
10000	3.100	100	17	17	4.05	4.046	4.037	43.9	4.041
20000	4.301	100	23	23	4.26	4.287	4.252	50.3	4.275
40000	4.602	100	32	32	4.53	4.528	4.516	58.1	4.510

$Y = 0.92 + 0.77X$
Log Ld_{50} =5.23
Ld_{50} = 170650.40

X^2 =0.27 (3df)
95% conf. limits = 53825.33 to 541037.90
No significant heterogeneity

App. Table 119. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	11	11	3.77	3.804	3.771	37.0	3.796
5000	3.699	100	20	20	4.16	4.078	4.160	43.9	4.075
10000	3.100	100	26	26	4.36	4.352	4.362	53.2	4.355
20000	4.301	100	31	31	4.50	4.626	4.497	60.1	4.634
40000	4.602	100	49	49	4.97	4.900	4.994	62.7	4.913

$Y = 0.642 + 0.928X$
Log Ld_{50}=4.695
Ld_{50} = 49582.25

X^2 = 1.87 (3df)
95% conf. limits = 28767.89 to 85456.36
No significant heterogeneity

App. Table 120. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	18	18	4.08	4.004	4.078	43.9	3.993
5000	3.699	100	34	34	4.59	4.613	4.578	60.1	4.597
10000	3.100	100	53	53	5.08	5.222	5.098	62.7	5.201
20000	4.301	100	81	81	5.88	5.831	5.834	50.3	5.806
40000	4.602	100	93	93	6.48	6.440	6.491	30.2	6.410

$Y = -2.827 + 2.007X$
Log Ld_{50}=3.899
Ld_{50}=7937.273

X^2 =1.25 (3df)
95% conf. limits = 6869.615 to 9170.863
No significant heterogeneity

App. Table 121. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	7	7	3.52	3.490	3.540	23.8	3.483
5000	3.699	100	11	11	3.77	3.750	3.778	33.6	3.745
10000	3.100	100	15	15	3.96	4.01	3.955	43.9	4.007
20000	4.301	100	21	21	4.19	4.270	4.184	50.3	4.269
40000	4.602	100	35	35	4.61	4.530	4.600	58.1	4.530

$Y = 0.526 + 0.869X$
Log Ld_{50}=5.141
Ld_{50} = 138608.5

X^2 =0.87 (3df)
95% conf. limits = 52369.89 to 366858.3
No significant heterogeneity

App. Table 122. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	11	11	3.77	3.734	3.778	33.6	3.727
5000	3.699	100	18	18	4.08	4.047	4.078	43.9	4.041
10000	3.100	100	22	22	4.23	4.360	4.234	53.2	4.355
20000	4.301	100	38	38	4.69	4.673	4.686	60.1	4.669
40000	4.602	100	51	51	5.03	4.986	5.015	63.4	4.983

$Y = 0.181 + 1.043X$
Log Ld_{50} = 4.618
Ld_{50} = 41528.31

X^2 = 1.008 (3df)
95% conf. limits = 26657.79 to 64694.09
No significant heterogeneity

App. Table 123. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	15	15	3.96	4.014	3.955	43.9	4.017
5000	3.699	100	32	32	4.53	4.582	4.516	58.1	4.582
10000	3.100	100	64	64	5.36	5.150	5.340	63.4	5.146
20000	4.301	100	75	75	5.67	5.718	5.670	53.2	5.711
40000	4.602	100	89	89	6.23	6.286	6.179	37.0	6.275

$Y = -2.354 + 1.875X$
Log Ld_{50} = 3.921
Ld_{50} = 8355.355

X^2 =3.2 (3df)
95% conf. limits = 7176.7 to 9727.57
No significant heterogeneity

App. Table 124. Probit analysis on the dose mortality response of male *T. castaneum* adult after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	7	7	3.52	3.574	3.519	26.9	3.596
5000	3.699	100	14	14	3.92	3.864	3.924	37.0	3.878
10000	3.100	100	21	21	4.19	4.154	4.208	47.1	4.160
20000	4.301	100	28	28	4.42	4.444	4.420	55.8	4.442
40000	4.602	100	39	39	4.72	4.734	4.714	61.6	4.724

$Y = 0.414 + 0.936X$
Log Ld_{50} = 4.896
Ld_{50}=78824.55

X^2 = 0.37 (3df)
95% conf. limits = 39427.83 to 157586.60
No significant heterogeneity

App. Table 125. Probit analysis on the dose mortality response of male *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	12	12	3.82	3.920	3.832	40.5	3.954
5000	3.699	100	29	29	4.45	4.337	4.458	53.2	4.355
10000	3.100	100	43	43	4.82	4.754	4.818	61.6	4.756
20000	4.301	100	54	54	5.10	5.171	5.090	63.4	5.157
40000	4.602	100	72	72	5.58	5.588	5.556	58.1	5.558

$Y = -0.570 + 1.331X$
Log Ld_{50}=4.183
Ld_{50} = 15247.38

X^2 = 1.68 (3df)
95% conf. limits = 12303.82 to 18895.13
No significant heterogeneity

App. Table 126. Probit analysis on the dose mortality response of male *T. castaneum* adult after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	18	18	4.08	4.148	4.094	47.1	4.165
5000	3.699	100	38	38	4.69	4.663	4.686	60.1	4.671
10000	3.100	100	60	60	5.25	5.178	5.240	63.4	5.177
20000	4.301	100	77	77	5.74	5.693	5.730	55.8	5.683
40000	4.602	100	87	87	6.13	6.208	6.077	37.0	6.190

$Y = -1.549 + 1.681X$
Log $Ld_{50} = 3.894$
$Ld_{50} = 7845.682$
$X^2 = 1.09$ (3df)
95% conf. limits = 6629.012 to 9285.662
No significant heterogeneity

App. Table 127. Probit analysis on the dose mortality response of female *T. castaneum* adult after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	8	8	3.59	3.580	3.596	26.9	3.563
5000	3.699	100	14	14	3.92	3.892	3.924	37.0	3.881
10000	3.100	100	20	20	4.16	4.204	4.150	50.3	4.1995
20000	4.301	100	30	30	4.48	4.516	4.460	58.1	4.518
40000	4.602	100	45	45	4.87	4.828	4.890	62.7	4.836

$Y = -3.104E-02 + 1.057X$
Log $Ld_{50} = 4.756$
$Ld_{50} = 57126.19$
$X^2 = 0.59$ (3df)
95% conf. limits = 33854.57 to 96394.78
No significant heterogeneity

App. Table 128. Probit analysis on the dose mortality response of female *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	No. Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	13	13	3.87	3.990	3.878	40.5	4.030
5000	3.699	100	31	31	4.50	4.413	4.510	55.8	4.445
10000	3.100	100	48	48	4.95	4.836	4.968	62.7	4.860
20000	4.301	100	60	60	5.25	5.259	5.280	62.7	5.275
40000	4.602	100	73	73	5.61	5.682	5.610	55.8	5.690

$Y = -0.655 + 1.378X$
Log $Ld_{50} = 4.101$
$Ld_{50} = 12625.62$
$X^2 = 2.26$ (3df)
95% conf. limits = 10350.77 to 15400.42
No significant heterogeneity

App. Table 129. Probit analysis on the dose mortality response of female *T. castaneum* adult after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	19	19	4.12	4.274	4.116	50.3	4.302
5000	3.699	100	49	49	4.97	4.802	4.994	62.7	4.816
10000	3.100	100	66	66	5.41	5.330	5.396	61.6	5.331
20000	4.301	100	79	79	5.81	5.858	5.766	50.3	5.846
40000	4.602	100	91	91	6.34	6.386	6.308	33.6	6.361

$Y = -1.508 + 1.709X$
Log $Ld_{50} = 3.806$
$Ld_{50} = 6401.527$
$X^2 = 4.38$ (3df)
95% conf. limits = 5377.466 to 7620.606
No significant heterogeneity

App. Table 130. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 3 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	5	5	3.36	3.504	3.365	26.9	3.558
5000	3.699	100	14	14	3.92	3.788	3.952	33.6	3.821
10000	3.100	100	20	20	4.16	4.072	4.160	43.9	4.083
20000	4.301	100	26	26	4.36	4.356	4.362	53.2	4.346
40000	4.602	100	33	33	4.56	4.640	4.551	60.1	4.608

$Y = 0.596 + 0.871X$
Log Ld_{50} = 5.05
Ld_{50} = 112592.60

X^2 =2.05 (3df)
95% conf. limits = 46954.49 to 269986.20
No significant heterogeneity

App. Table 131. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	9	9	3.66	3.812	3.669	37.0	3.849
5000	3.699	100	25	25	4.33	4.216	4.320	50.3	4.238
10000	3.100	100	40	40	4.75	4.620	4.740	60.1	4.626
20000	4.301	100	51	51	5.03	5.024	5.025	63.7	5.015
40000	4.602	100	63	63	5.33	5.428	5.321	60.1	5.403

$Y = -0.53 + 1.29X$
Log Ld_{50} = 4.28
Ld_{50} = 19478.63

X^2 = 2.73 (3df)
95% conf. limits = 15281.78 to 24828.06
No significant heterogeneity

App. Table 132. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 7 days of exposure to different doses of *P.erosus seed* extracts of chloroform by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	20	20	4.16	4.376	4.170	53.2	4.399
5000	3.699	100	53	53	5.08	4.880	5.099	62.7	4.895
10000	3.100	100	70	70	5.52	5.384	5.5	61.6	5.392
20000	4.301	100	81	81	5.88	5.888	5.834	50.3	5.888
40000	4.602	100	90	90	6.28	6.392	6.25	33.6	6.384

$Y = -1.200 + 1.648X$
Log Ld_{50} = 3.762
Ld_{50} = 5786.453

X^2 = 6.841 (3df)
95% conf. limits = 4805.328 to 6967.90
No significant heterogeneity

App. Table 133. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	4	4	3.25	3.298	3.248	18.0	3.330
5000	3.699	100	8	8	3.59	3.577	3.596	26.9	3.598
10000	3.100	100	14	14	3.92	3.856	3.924	37.0	3.866
20000	4.301	100	20	20	4.16	4.135	4.170	47.1	4.134
40000	4.602	100	26	26	4.36	4.414	4.360	55.8	4.402

$Y = 0.303 + 0.890X$
Log Ld_{50}=5.273
Ld_{50} = 187709.3

X^2 = 0.40 (3df)
95% conf. limits = 61466.22 to 573238
No significant heterogeneity

App. Table 134. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	8	8	3.59	3.592	3.596	26.9	3.601
5000	3.699	100	13	13	3.87	3.857	3.873	37.0	3.863
10000	3.100	100	19	19	4.12	4.122	4.132	47.1	4.124
20000	4.301	100	26	26	4.36	4.387	4.362	53.2	4.386
40000	4.602	100	37	37	4.67	4.652	4.659	60.1	4.648

$Y = 0.648 + 0.868X$
Log Ld_{50} = 5.007
Ld_{50} = 101754.10

X^2 =4.55E-02 (3df)
95% conf. limits = 43885.98 to 23592
No significant heterogeneity

App. Table 135. Probit analysis on the dose mortality response of 9 days old *T. castaneum* larvae after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	19	19	4.12	3.974	4.154	40.5	3.970
5000	3.699	100	30	30	4.48	4.593	4.46	58.1	4.578
10000	3.100	100	54	54	5.10	5.212	5.124	62.7	5.186
20000	4.301	100	79	79	5.81	5.831	5.766	50.3	5.794
40000	4.602	100	94	94	6.55	6.45	6.558	30.2	6.402

$Y = -2.891 + 2.019X$
Log Ld_{50} = 3.907
Ld_{50} = 8087.91

X^2 =3.19 (3df)
95% conf. limits = 6994.12 to 9352.754
No significant heterogeneity

App. Table 136. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	4	4	3.25	3.364	3.254	20.8	3.409
5000	3.699	100	10	10	3.72	3.616	3.730	30.2	3.646
10000	3.100	100	14	14	3.92	3.868	3.924	37.0	3.883
20000	4.301	100	20	20	4.16	4.120	4.170	47.1	4.120
40000	4.602	100	24	24	4.29	4.372	4.298	53.2	4.357

$Y = 0.735 + 0.786X$
Log Ld_{50}=5.418
Ld_{50} = 262368.70

X^2 =1.07 (3df)
95% conf. limits = 64756.60 to 1063019
No significant heterogeneity

App. Table 137. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	8	8	3.59	3.624	3.596	30.2	3.641
5000	3.699	100	14	14	3.92	3.878	3.924	37.0	3.889
10000	3.100	100	19	19	4.12	4.132	4.132	47.1	4.137
20000	4.301	100	28	28	4.42	4.386	4.426	53.2	4.386
40000	4.602	100	35	35	4.61	4.64	4.605	60.1	4.635

$Y = 0.837 + 0.825X$
Log Ld_{50} = 5.044
Ld_{50} = 110887.50

X^2 =0.24 (3df)
95% conf. limits=44773.44 to 274628.10
No significant heterogeneity

App. Table 138. Probit analysis on the dose mortality response of 12 days old *T. castaneum* larvae after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	17	17	4.05	4.078	4.037	43.9	4.088
5000	3.699	100	38	38	4.69	4.641	4.686	60.1	4.646
10000	3.100	100	58	58	5.20	5.204	5.228	62.7	5.203
20000	4.301	100	77	77	5.74	5.767	5.734	53.2	5.760
40000	4.602	100	91	91	6.34	6.330	6.308	33.6	6.318

$Y = -2.203 + 1.851X$
Log Ld_{50} = 3.890
Ld_{50}=7767.862

X^2 = 0.28 (3df)
95% conf. limits = 6645.434 to 9079.868
No significant heterogeneity

App. Table 139. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	5	5	3.36	3.354	3.36	20.8	3.360
5000	3.699	100	8	8	3.59	3.611	3.596	30.2	3.617
10000	3.100	100	13	13	3.87	3.868	3.873	37.0	3.873
20000	4.301	100	20	20	4.16	4.125	4.170	47.1	4.130
40000	4.602	100	26	26	4.36	4.382	4.362	53.2	4.386

$Y = 0.466 + 0.851X$
Log Ld_{50} = 5.322
Ld_{50} = 210356.10

X^2 = 0.12 (3df)
95% conf. limits =63021.02 to 702141.4
No significant heterogeneity

App. Table 140. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	7	7	3.52	3.468	3.54	23.8	3.463
5000	3.699	100	10	10	3.72	3.768	3.72	33.6	3.764
10000	3.100	100	16	16	4.01	4.068	3.996	43.9	4.065
20000	4.301	100	28	28	4.42	4.368	4.426	53.2	4.366
40000	4.602	100	37	37	4.67	4.668	4.659	60.1	4.667

$Y = 6.45E\text{-}02 + 1.00X$
Log Ld_{50} = 4.93
Ld_{50} = 86033.14

X^2 = 0.61 (3df)
95% conf. limits = 43167.12 to 171465.90
No significant heterogeneity

App. Table 141. Probit analysis on the dose mortality response of 16 days old *T. castaneum* larvae after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	15	15	3.96	3.846	3.975	37.0	3.847
5000	3.699	100	27	27	4.39	4.475	4.390	55.8	4.461
10000	3.100	100	52	52	5.05	5.104	5.040	63.4	5.075
20000	4.301	100	74	74	5.64	5.733	5.638	53.2	5.688
40000	4.602	100	93	93	6.48	6.362	6.424	33.6	6.302

$Y = -3.080 + 2.038X$
Log Ld_{50} = 3.963
Ld_{50} = 9191.049

X^2 =1.59 (3df)
95% conf. limits = 7971.95 to 10596.55
No significant heterogeneity

App. Table 142. Probit analysis on the dose mortality response of male *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	11	11	3.77	3.690	3.797	30.2	3.690
5000	3.699	100	13	13	3.87	3.929	3.878	40.5	3.930
10000	3.100	100	19	19	4.12	4.168	4.132	47.1	4.171
20000	4.301	100	26	26	4.36	4.407	4.360	55.8	4.412
40000	4.602	100	39	39	4.72	4.646	4.713	60.1	4.653

$Y = 0.972 + 0.799X$
$\text{Log } Ld_{50}=5.036$
$Ld_{50}=108727.10$
$X^2 = 0.90$ (3df)
95% conf. limits = 43191.75 to 273700.20
No significant heterogeneity

App. Table 143. Probit analysis on the dose mortality response of male *T. castaneum* adult after7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Dose ppm	Log dose	No. used	% Kill	Corr %	Emp probit	Expt probit	Work probit	Weight	Final probit
2500	3.398	100	15	15	3.96	3.964	3.970	40.5	3.965
5000	3.699	100	22	22	4.23	4.226	4.218	50.3	4.226
10000	3.100	100	30	30	4.48	4.488	4.480	55.8	4.487
20000	4.301	100	41	41	4.77	4.750	4.766	61.6	4.748
40000	4.602	100	50	50	5.00	5.012	5.00	63.7	5.009

$Y = 1.01 + 0.86X$
$\text{Log } Ld_{50} = 4.59$
$Ld_{50}=39082.01$
$X^2 = 3.20E\text{-}02$ (3df)
95% conf. limits = 23442.40 to 65155.62
No significant heterogeneity

App. Table 144. Probit analysis on the dose mortality response of male *T. castaneum* adult after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	18	18	4.08	3.994	4.108	40.5	3.994
5000	3.699	100	32	32	4.53	4.584	4.516	58.1	4.572
10000	3.100	100	53	53	5.08	5.174	5.065	63.4	5.150
20000	4.301	100	78	78	5.77	5.764	5.766	53.2	5.728
40000	4.602	100	92	92	6.41	6.354	6.366	33.6	6.306

$Y = -2.532 + 1.920X$
$\text{Log } Ld_{50} = 3.921$
$Ld_{50}=8352.781$
$X^2 = 1.363$ (3df)
95% conf. limits=7185.667 to 9709.454
No significant heterogeneity

App. Table 145. Probit analysis on the dose mortality response of female *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	6	6	3.45	3.542	3.442	26.9	3.576
5000	3.699	100	14	14	3.92	3.839	3.924	37.0	3.860
10000	3.100	100	21	21	4.19	4.136	4.208	47.1	4.144
20000	4.301	100	29	29	4.45	4.433	4.45	55.8	4.428
40000	4.602	100	37	37	4.67	4.730	4.662	61.6	4.712

$Y = 0.37 + 0.94X$
$\text{Log } Ld_{50} = 4.90$
$Ld_{50}=80917.33$
$X^2 = 1.00$ (3df)
95% conf. limits = 40346.17 to 162285.70
No significant heterogeneity

App. Table 146. Probit analysis on the dose mortality response of female *T. castaneum* adult after 7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	9	9	3.66	3.696	3.663	30.2	3.707
5000	3.699	100	18	18	4.08	4.007	4.078	43.9	4.013
10000	3.100	100	24	24	4.29	4.318	4.298	53.2	4.318
20000	4.301	100	35	35	4.61	4.629	4.605	60.1	4.624
40000	4.602	100	48	48	4.95	4.940	4.94	63.4	4.930

$Y = 0.257 + 1.015X$
Log Ld_{50} = 4.671
Ld_{50}=46938.07

X^2 =0.29 (3df)
95% conf. limits = 28841.32 to 76389.69
No significant heterogeneity

App. Table 147. Probit analysis on the dose mortality response of female *T. castaneum* adult after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	16	16	4.01	3.926	4.016	40.5	3.933
5000	3.699	100	34	34	4.59	4.583	4.572	58.1	4.589
10000	3.100	100	57	57	5.18	5.239	5.202	62.7	5.245
20000	4.301	100	80	80	5.85	5.896	5.800	50.3	5.901
40000	4.602	100	97	97	6.88	6.552	6.759	26.9	6.557

$Y = -3.473 + 2.179X$
Log Ld_{50}=3.887
Ld_{50} = 7717.702

X^2 =2.02 (3df)
95% conf. limits = 6734.606 to 8844.314
No significant heterogeneity

App. Table 148. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 5 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	6	6	3.45	3.456	3.45	23.8	3.469
5000	3.699	100	10	10	3.72	3.748	3.72	33.6	3.754
10000	3.100	100	18	18	4.08	4.040	4.078	43.9	4.040
20000	4.301	100	26	26	4.36	4.332	4.362	53.2	4.326
40000	4.602	100	34	34	4.59	4.624	4.578	60.1	4.611

$Y = 0.245 + 0.948X$
Log Ld_{50} = 5.011
Ld_{50}=102758.30

X^2 =0.24 (3df)
95% conf. limits=46949.64 to 224906.40
No significant heterogeneity

App. Table 149 Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 7 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	8	8	3.59	3.630	3.596	30.2	3.651
5000	3.699	100	16	16	4.01	3.986	4.016	40.5	3.999
10000	3.100	100	27	27	4.39	4.342	4.394	53.2	4.346
20000	4.301	100	38	38	4.69	4.698	4.686	60.1	4.694
40000	4.602	100	51	51	5.03	5.054	5.025	63.7	5.042

$Y = -0.273 + 1.154X$
Log Ld_{50} =4.565
Ld_{50} = 36796.80

X^2= 0.24 (3df)
95% conf. limits = 25250.09 to 53623.76
No **sig**nificant heterogeneity

App. Table 150. Probit analysis on the dose mortality response of unsexed *T. castaneum* adult after 14 days of exposure to different doses of *P.erosus seed* extracts of methanol by TFM

Doses ppm	Log doses	No. used	% Kill	Corr % kill	Emp probit	Expt. probit	Wkg probit	Weight	Final probit
2500	3.398	100	19	19	4.12	4.114	4.132	47.1	4.133
5000	3.699	100	42	42	4.80	4.726	4.792	61.6	4.730
10000	3.100	100	60	60	5.25	5.338	5.240	61.6	5.327
20000	4.301	100	81	81	5.88	5.950	5.908	47.1	5.924
40000	4.602	100	95	95	6.64	6.562	6.605	26.9	6.521

$Y = -2.60 + 1.98X$
Log Ld_{50}=3.83
Ld_{50} = 6843.061
X^2=0.90 (3df)
95% conf. limits = 5888.594 to 7952.241
No significant heterogeneity

App. Table 151. Repellent action of *S.macrophylla* seed powder on the different stages of *T. castaneum* (TFM with area preference method) (N=30)

Life stages	Dose (%) w/w	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.5	6.00±2.00a	60.00	4.67±0.58a	46.71	6.00±1.00b	60.00
	1	6.33±1.53a	63.30	7.67±1.53a	76.71	8.67±1.15a	86.70
	2	8.33±1.15a	83.31	6.33±1.53a	63.30	9.33±1.15a	93.30
12 days larvae	0.5	5.67±3.06a	56.70	5.67±0.58a	56.70	6.33±0.58a	63.30
	1	5.00±1.00a	50.01	6.33±0.58a	63.30	7.00±1.00a	69.99
	2	7.00±1.00a	69.99	7.33±1.53a	73.29	8.67±1.53a	86.70
16 days larvae	0.5	5.00±2.65a	50.01	4.67±0.58b	46.71	5.33±0.58b	53.31
	1	6.00±1.00a	60.00	7.00±1.00a	69.99	7.33±0.38a	73.29
	2	7.00±1.73a	69.99	7.33±0.58a	73.29	8.33±0.65a	83.31
Adult male	0.5	6.33±1.15a	63.30	8.33±1.53a	83.31	8.67±1.53a	86.70
	1	6.67±1.53a	66.69	7.33±1.53a	73.29	9.00±1.00a	90.00
	2	8.00±0.002a	80.01	8.00±1.00a	80.01	10.00±0.25a	99.99
Adult female	0.5	6.00±2.00a	60.00	9.00±1.00a	90.00	8.33±2.08a	83.31
	1	6.33±0.58a	63.30	9.00±1.00a	90.00	9.00±1.00a	90.00
	2	8.00±1.00a	80.01	7.33±1.53a	73.29	9.33±0.58a	93.30
Adult unsexed	0.5	5.33±1.53a	53.31	7.33±1.53a	73.29	8.33±0.58a	83.31
	1	5.00±1.73a	50.01	8.00±1.73a	80.01	8.67±0.25a	86.70
	2	6.00±1.00a	60.00	8.00±1.00a	80.01	9.67±0.36a	96.69

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05

App. Table 152. Analysis of variance on the repellent effects of *S.macrophylla* seed powder on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	9.556	2	4.778	1.870(P>0.05)
	Error	15.333	6	2.556	
	Total	24.889	8		
1H	Between doses	13.556	2	6.778	4.067 (P>0.05)
	Error	10.000	6	1.667	
	Total	23.556	8		
24H	Between doses	18.667	2	9.333	7.636(P<0.05)
	Error	7.333	6	1.222	
	Total	26.000	8		

App. Table 153. Analysis of variance on the repellent effects of *S. macrophylla* seed powder on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.222	2	3.111	0.824 (P>0.05)
	Error	22.667	6	3.778	
	Total	28.889	8		
1H	Between doses	4.222	2	2.111	2.111 (P>0.05)
	Error	6.000	6	1.000	
	Total	10.222	8		
24H	Between doses	8.667	2	4.333	3.545 (P>0.05)
	Error	7.333	6	1.222	
	Total	16.000	8		

App. Table 154. Analysis of variance on the repellent effects of *S. macrophylla* seed powder on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.000	2	3.000	0.818 (P>0.05)
	Error	22.000	6	3.667	
	Total	28.000	8		
1H	Between doses	12.667	2	6.333	11.400 (P<0.01)
	Error	3.333	6	.556	
	Total	16.000	8		
24H	Between doses	14.000	2	7.000	21.000 (P<0.01)
	Error	2.000	6	.333	
	Total	16.000	8		

App. Table 155. Analysis of variance on the repellent effects of *S. macrophylla* seed powder on male *T. castaneum* adults after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	4.667	2	2.333	1.909 (P>0.05)
	Error	7.333	6	1.222	
	Total	12.000	8		
1H	Between doses	1.556	2	.778	0.412 (P>0.05)
	Error	11.333	6	1.889	
	Total	12.889	8		
24H	Between doses	2.889	2	1.444	1.300 (P>0.05)
	Error	6.667	6	1.111	
	Total	9.556	8		

App. Table 156. Analysis of variance on the repellent effects of *S. macrophylla* seed powder on female *T. castaneum* adults after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.889	2	3.444	1.938 (P>0.05)
	Error	10.667	6	1.778	
	Total	17.556	8		
1H	Between doses	24.222	2	12.111	0.732 (P>0.05)
	Error	99.333	6	16.556	
	Total	123.556	8		
24H	Between doses	1.556	2	.778	0.412 (P>0.05)
	Error	11.333	6	1.889	
	Total	12.889	8		

App. Table 157. Analysis of variance on the repellent effects of *S. macrophylla* seed powder on unsexed *T. castaneum* adults after 30M, 1h and 24h of exposure

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	1.556	2	.778	0.368 (P>0.05)
	Error	12.667	6	2.111	
	Total	14.222	8		
1H	Between doses	.889	2	.444	0.211 (P>0.05)
	Error	12.667	6	2.111	
	Total	13.556	8		
24H	Between doses	2.889	2	1.444	4.333 (P>0.05)
	Error	2.000	6	.333	
	Total	4.889	8		

App. Table 158. Repellent action of *P.erosus* seed powder on the different stages of *T.castaneum* (TFM with area preference method) (N=30)

Life stages	Dose (%) w/w	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.5	4.33±0.58b	43.29	5.00±2.00a	50.01	6.67±1.53a	66.69
	1	5.67±0.58ab	56.70	7.00±1.00a	69.99	8.33±0.58a	83.31
	2	7.00±1.00a	69.99	8.33±1.15a	83.31	9.00±1.00a	90.00
12 days larvae	0.5	3.33±0.58b	33.30	5.00±1.00b	50.01	7.00±1.00a	69.99
	1	5.00±1.00ab	50.01	7.00±1.00ab	69.99	7.67±1.15a	76.71
	2	7.33±1.53a	73.29	8.33±0.58a	83.31	8.67±1.15a	86.70
16 days larvae	0.5	3.67±1.15a	36.69	5.00±1.00b	50.01	7.00±1.00b	69.99
	1	5.00±1.00a	50.01	6.67±0.58ab	66.69	7.67±0.58ab	76.71
	2	6.67±1.53a	66.69	8.00±1.00a	80.01	9.33±0.58a	93.30
Adult male	0.5	4.00±1.00a	39.99	6.00±1.00a	60.00	6.67±0.58b	66.69
	1	4.67±0.58a	46.71	6.67±1.15a	66.69	8.67±0.58a	86.70
	2	5.33±0.58a	53.31	6.67±0.58a	66.69	9.00±1.00a	90.00
Adult female	0.5	3.00±1.00a	30.00	6.67±1.15a	66.69	6.33±0.58a	63.30
	1	4.33±0.58a	43.29	5.33±1.53a	53.31	7.33±1.15a	73.29
	2	4.67±0.58a	46.71	7.00±1.00a	69.99	7.67±0.58a	76.71
Adult unsexed	0.5	2.67±0.58a	26.70	5.00±2.00a	50.01	6.33±0.58b	63.30
	1	3.33±0.58a	33.30	7.00±1.00a	69.99	8.67±0.58a	86.70
	2	3.67±1.53a	36.69	5.00±1.00a	50.01	9.00±1.00a	90.00

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05 .

App. Table 159. Analysis of variance on the repellent effects of *P. erosus* seed powder on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	10.667	2	5.333	9.600 P<0.05)
	Error	3.333	6	0.556	
	Total	14.000	8		
1H	Between doses	16.889	2	8.444	4.000 (P>0.05)
	Error	12.667	6	2.111	
	Total	29.556	8		
24H	Between doses	8.667	2	4.333	3.545 (P>0.05)
	Error	7.333	6	1.222	
	Total	16.000	8		

App. Table 160. Analysis of variance on the repellent effects of *P. erosus* seed powder on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	24.222	2	12.111	9.909 P<0.05)
	Error	7.333	6	1.222	
	Total	31.556	8		
1H	Between doses	16.889	2	8.444	10.857 P<0.05)
	Error	4.667	6	.778	
	Total	21.556	8		
24H	Between doses	4.222	2	2.111	1.727 (P>0.05)
	Error	7.333	6	1.222	
	Total	11.556	8		

App. Table 161. Analysis of variance on the repellent effects of *P. erosus* seed powder on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	13.556	2	6.778	4.357 (P>0.05)
	Error	9.333	6	1.556	
	Total	22.889	8		
1H	Between doses	13.556	2	6.778	8.714 P<0.05)
	Error	4.667	6	.778	
	Total	18.222	8		
24H	Between doses	8.667	2	4.333	7.800 P<0.05)
	Error	3.333	6	.556	
	Total	12.000	8		

App. Table 162. Analysis of variance on the repellent effects of *P. erosus* seed powder on male *T. castaneum* adults after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	2.667	2	1.333	2.400 (P>0.05)
	Error	3.333	6	.556	
	Total	6.000	8		
1H	Between doses	.889	2	0.444	0.500^{N} (P>0.05)
	Error	5.333	6	0.889	
	Total	6.222	8		
24H	Between doses	9.556	2	4.778	8.600 P<0.05)
	Error	3.333	6	0.556	
	Total	12.889	8		

App. Table 163. Analysis of variance on the repellent effects of *P. erosus* seed powder on female *T. castaneum* adults after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	4.667	2	2.333	4.200 (P>0.05)
	Error	3.333	6	.556	
	Total	8.000	8		
1H	Between doses	4.667	2	2.333	1.500 (P>0.05)
	Error	9.333	6	1.556	
	Total	14.000	8		
24H	Between doses	2.889	2	1.444	2.167 (P>0.05)
	Error	4.000	6	.667	
	Total	6.889	8		

App. Table 164. Analysis of variance on the repellent effects of *P. erosus* seed powder on unsexed *T. castaneum* adults after 30M, 1h and 24h of exposure by TFM

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	1.556	2	0.778	0.778 (P>0.05)
	Error	6.000	6	1.000	
	Total	7.556	8		
1H	Between doses	8.000	2	4.000	2.000 (P>0.05)
	Error	12.000	6	2.000	
	Total	20.000	8		
24H	Between doses	12.667	2	6.333	11.400(P<0.01)
	Error	3.333	6	0.556	
	Total	16.000	8		

App. Table 165. Repellent action of *S.macrophylla* seed extract (Chloroform) on the different stages of *T.castaneum* (Disc method, McDonald, 1970) (N=30)

Life stages	Dose µg/cm^2	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.98	5.33±0.58a	53.31	6.00±0.00b	60.00	7.00±1.00a	69.99
	1.97	5.67±2.52a	56.7	6.67±2.08ab	66.69	8.00±2.00a	80.01
	3.93	7.33±1.53a	73.29	9.67±0.58a	96.69	7.67±2.52a	76.71
12 days larvae	0.98	5.33±1.53a	53.31	6.00±1.73b	60.00	8.33±2.89a	83.31
	1.97	7.33±0.58a	73.29	9.00±1.00ab	90.00	8.33±0.58a	83.31
	3.93	8.00±2.00a	80.01	9.67±0.58a	96.69	8.67±1.53a	86.70
16 days larvae	0.98	6.67±3.06a	66.69	7.00±1.00a	69.99	7.67±2.08a	76.71
	1.97	8.00±0.00a	80.01	5.33±2.08a	53.31	8.33±0.58a	83.31
	3.93	9.00±1.73a	90.00	8.33±2.08a	83.31	8.00±2.00a	80.01
Adult male	0.98	5.67±2.08a	56.70	7.00±1.73a	69.99	8.33±1.53a	83.31
	1.97	7.00±1.00a	69.99	8.33±1.53a	83.31	9.67±0.58a	96.69
	3.93	8.00±1.00a	80.01	9.67±0.58a	96.69	9.33±0.58a	93.30
Adult female	0.98	7.67±2.08a	76.71	7.33±0.58b	73.29	7.67±0.58b	76.71
	1.97	8.00±1.00a	80.01	7.67±0.58b	76.71	9.33±0.58a	93.3
	3.93	9.33±1.15a	93.30	9.33±0.58a	93.30	10.00±0.00a	99.99
Adult unsexed	0.98	5.33±0.58a	53.31	6.33±0.58a	63.30	7.33±1.15a	73.29
	1.97	6.00±2.65a	60.00	6.67±3.06a	66.69	8.00±1.00a	80.01
	3.93	8.33±1.53a	83.31	7.00±1.00a	69.99	9.00±1.00a	90.00

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05 .

App. Table 166. Analysis of variance onthe repellent effects of *S. macrophylla* chloroform seed extract on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.889	2	3.444	1.148 (P>0.05)
	Error	18.000	6	3.000	
	Total	24.889	8		
1H	Between doses	22.889	2	11.444	7.357 P<0.05)
	Error	9.333	6	1.556	
	Total	32.222	8		
24H	Between doses	1.556	2	.778	0.206 (P>0.05)
	Error	22.667	6	3.778	
	Total	24.222	8		

App. Table 167. Analysis of variance on the repellent effects of *S. macrophylla* chloroform seed extract on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	11.556	2	5.778	2.600 (P>0.05)
	Error	13.333	6	2.222	
	Total	24.889	8		
1H	Between doses	22.889	2	11.444	7.923 P<0.05)
	Error	8.667	6	1.444	
	Total	31.556	8		
24H	Between doses	.222	2	.111	.030 (P>0.05)
	Error	22.000	6	3.667	
	Total	22.222	8		

App. Table 168. Analysis of variance on the repellent effects of *S. macrophylla* chloroform seed extract on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	8.222	2	4.111	1.000 (P>0.05)
	Error	24.667	6	4.111	
	Total	32.889	8		
1H	Between doses	13.556	2	6.778	2.103 (P>0.05)
	Error	19.333	6	3.222	
	Total	32.889	8		
24H	Between doses	.667	2	0.333	0.115 (P>0.05)
	Error	17.333	6	2.889	
	Total	18.000	8		

App. Table 169. Analysis of variance on the repellent effects of *S. macrophylla* chloroform seed extract on male *T. castaneum* adults after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	8.222	2	4.111	1.947 (P>0.05)
	Error	12.667	6	2.111	
	Total	20.889	8		
1H	Between doses	10.667	2	5.333	2.824 (P>0.05)
	Error	11.333	6	1.889	
	Total	22.000	8		
24H	Between doses	2.889	2	1.444	1.444 (P>0.05)
	Error	6.000	6	1.000	
	Total	8.889	8		

App. Table 170. Analysis of variance on the repellent effects of *S. macrophylla* chloroform seed extract on female *T. castaneum* adults after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	4.667	2	2.333	1.050 (P>0.05)
	Error	13.333	6	2.222	
	Total	18.000	8		
1H	Between doses	6.889	2	3.444	10.333 P<0.05)
	Error	2.000	6	.333	
	Total	8.889	8		
24H	Between doses	8.667	2	4.333	19.500 (P<0.01)
	Error	1.333	6	.222	
	Total	10.000	8		

App. Table 171. Analysis of variance on the repellent effects of *S. macrophylla* chloroform seed extract on unsexed *T. castaneum* adults after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	14.889	2	7.444	2.310 (P>0.05)
	Error	19.333	6	3.222	
	Total	34.222	8		
1H	Between doses	.667	2	0.333	0.09 (P>0.05)
	Error	21.333	6	3.556	
	Total	22.000	8		
24H	Between doses	4.222	2	2.111	1.90 (P>0.05)
	Error	6.667	6	1.111	
	Total	10.889	8		

App. Table 172. Repellent action of *S.macrophylla* seed extract (methanol) on the different stages of *T. castaneum* (Disc method) (N=30)

Life stages	Dose µg/cm^2	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.98	3.33±1.53b	33.30	6.33±3.21a	63.30	7.00±2.65a	69.99
	1.97	6.67±2.08ab	66.69	5.33±2.52a	53.31	8.00±3.46a	80.01
	3.93	9.67±0.58a	96.69	9.00±1.00a	90.00	8.33±1.53a	83.31
12 days larvae	0.98	3.67±1.53a	36.69	5.33±4.04a	53.31	6.67±3.06a	66.69
	1.97	6.33±1.53a	63.30	7.33±2.52a	73.29	8.67±1.53a	86.70
	3.93	7.67±3.21a	76.71	7.67±1.53a	76.71	9.67±0.58a	96.69
16 days larvae	0.98	6.67±1.53a	66.69	8.33±2.89a	83.31	8.00±2.65a	80.01
	1.97	5.67±1.53a	56.70	8.33±1.53a	83.31	7.00±1.00a	69.99
	3.93	7.67±3.21a	76.71	9.00±1.00a	90.00	8.67±2.31a	86.70
Adult male	0.98	5.33±0.58a	53.31	7.67±3.21a	76.71	7.67±2.52a	76.71
	1.97	6.67±1.15a	66.69	8.00±1.00a	80.01	9.33±1.15a	93.30
	3.93	7.33±1.53a	73.29	9.67±0.58a	96.69	8.33±0.58a	83.31
Adult female	0.98	5.00±4.36a	50.01	5.67±2.52a	56.70	8.67±1.53a	86.70
	1.97	6.00±2.00a	60.00	8.00±1.73a	80.01	9.00±1.00a	90.00
	3.93	8.33±2.89a	83.31	8.67±1.15a	86.70	9.33±1.15a	93.30
Adult unsexed	0.98	4.67±4.62a	46.71	7.33±0.58a	73.29	7.67±2.52a	76.71
	1.97	7.33±2.31a	73.29	6.67±3.21a	66.69	8.00±2.00a	80.01
	3.93	6.33±3.51a	63.30	8.33±1.53a	83.31	9.33±0.58a	93.30

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05 .

App. Table 173. Analysis of variance on the repellent effects of *S. macrophylla* methanol seed extract on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	60.222	2	30.111	12.905 P<0.05)
	Error	14.000	6	2.333	
	Total	74.222	8		
1H	Between doses	21.556	2	10.778	1.830 (P>0.05)
	Error	35.333	6	5.889	
	Total	56.889	8		
24H	Between doses	2.889	2	1.444	0.203 (P>0.05)
	Error	42.667	6	7.111	
	Total	45.556	8		

App. Table 174. Analysis of variance onthe repellent effects of *S. macrophylla* methanol seed extract on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	24.889	2	12.444	2.489 (P>0.05)
	Error	30.000	6	5.000	
	Total	54.889	8		
1H	Between doses	9.556	2	4.778	0.573 (P>0.05)
	Error	50.000	6	8.333	
	Total	59.556	8		
24H	Between doses	14.000	2	7.000	1.750 (P>0.05)
	Error	24.000	6	4.000	
	Total	38.000	8		

App. Table 175. Analysis of variance onthe repellent effects of *S. macrophylla* methanol seed extract on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.000	2	3.000	0.600 (P>0.05)
	Error	30.000	6	5.000	
	Total	36.000	8		
1H	Between doses	.889	2	.444	0.114 (P>0.05)
	Error	23.333	6	3.889	
	Total	24.222	8		
24H	Between doses	4.222	2	2.111	0.475 (P>0.05)
	Error	26.667	6	4.444	
	Total	30.889	8		

App. Table 176. Analysis of variance on the repellent effects of *S. macrophylla* methanol seed extract on male *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	6.222	2	3.111	2.33 (P>0.05)
	Error	8.000	6	1.333	
	Total	14.222	8		
1H	Between doses	6.889	2	3.444	0.886 (P>0.05)
	Error	23.333	6	3.889	
	Total	30.222	8		
24H	Between doses	4.222	2	2.111	0.792 (P>0.05)
	Error	16.000	6	2.667	
	Total	20.222	8		

App. Table 177. Analysis of variance on the repellent effects of *S. macrophylla* methanol seed extract on female *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	17.556	2	8.778	0.840 (P>0.05)
	Error	62.667	6	10.444	
	Total	80.222	8		
1H	Between doses	14.889	2	7.444	2.094 (P>0.05)
	Error	21.333	6	3.556	
	Total	36.222	8		
24H	Between doses	.667	2	.333	.214 (P>0.05)
	Error	9.333	6	1.556	
	Total	10.000	8		

App. Table 178. Analysis of variance on the repellent effects of *S. macrophylla* methanol seed extract on unsexed *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	10.889	2	5.444	0.419 (P>0.05)
	Error	78.000	6	13.000	
	Total	88.889	8		
1H	Between doses	4.222	2	2.111	0.487 (P>0.05)
	Error	26.000	6	4.333	
	Total	30.222	8		
24H	Between doses	4.667	2	2.333	0.656 (P>0.05)
	Error	21.333	6	3.556	
	Total	26.000	8		

App. Table 179. Repellent action of *P.erosus* seed extract (Chloroform) on the different stages of *T.castaneum* (Disc method) (N=30)

Life stages	Dose µg/cm^2	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.98	6.67±1.53a	66.69	6.33±2.52a	63.30	7.67±2.31a	76.71
	1.97	6.67±3.06a	66.69	8.00±2.00a	80.01	8.67±2.31a	86.70
	3.93	7.67±1.53a	76.71	9.67±0.58a	96.69	10.00±0.00a	99.99
12 days larvae	0.98	5.33±0.58a	53.31	6.33±3.51a	63.30	7.33±2.52a	73.29
	1.97	8.00±1.73a	80.01	7.67±2.08a	76.71	9.33±1.15a	93.30
	3.93	8.33±1.53a	83.31	7.33±2.08a	73.29	9.33±1.15a	93.30
16 days larvae	0.98	5.67±3.79a	56.70	5.67±4.04a	56.70	6.67±2.31a	66.69
	1.97	6.67±1.53a	66.69	8.00±1.00a	80.01	8.33±1.15a	83.31
	3.93	6.33±3.21a	63.30	9.33±1.15a	93.30	8.67±1.53a	86.70
Adult male	0.98	6.00±1.00a	60.00	6.67±1.53a	66.69	7.33±1.53a	73.29
	1.97	8.00±1.00a	80.01	8.33±1.15a	83.31	7.67±2.08a	76.71
	3.93	8.67±1.53a	86.70	7.33±1.15a	73.29	9.00±1.00a	90.00
Adult female	0.98	6.00±1.00a	60.00	6.67±2.31a	66.69	7.00±2.65a	69.99
	1.97	7.00±2.00a	69.99	8.00±0.03a	80.01	8.00±2.00a	80.01
	3.93	8.67±2.31a	86.70	9.00±1.00a	90.00	9.00±1.73a	90.00
Adult unsexed	0.98	5.33±1.53a	53.31	6.67±1.15a	66.69	8.00±1.00a	80.01
	1.97	6.00±1.00a	60.00	6.67±1.53a	66.69	8.33±1.53a	83.31
	3.93	6.33±0.58a	63.30	7.67±3.21a	76.71	9.33±1.15a	93.30

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05 .

App. Table 180. Analysis of variance on the repellent effects of *P. erosus* chloroform seed extract on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	2.000	2	1.000	0.214 (P>0.05)
	Error	28.000	6	4.667	
	Total	30.000	8		
1H	Between doses	16.667	2	8.333	2.344 (P>0.05)
	Error	21.333	6	3.556	
	Total	38.000	8		
24H	Between doses	8.222	2	4.111	1.156 (P>0.05)
	Error	21.333	6	3.556	
	Total	29.556	8		

App. Table 181. Analysis of variance on the repellent effects of *P. erosus* chloroform seed extract on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	16.222	2	8.111	4.294 (P>0.05)
	Error	11.333	6	1.889	
	Total	27.556	8		
1H	Between doses	2.889	2	1.444	0.206 (P>0.05)
	Error	42.000	6	7.000	
	Total	44.889	8		
24H	Between doses	8.000	2	4.000	1.333 (P>0.05)
	Error	18.000	6	3.000	
	Total	26.000	8		

App. Table 182. Analysis of variance on the repellent effects of *P. erosus* chloroform seed extract on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	1.556	2	.778	0.086 (P>0.05)
	Error	54.000	6	9.000	
	Total	55.556	8		
1H	Between doses	20.667	2	10.333	1.661 (P>0.05)
	Error	37.333	6	6.222	
	Total	58.000	8		
24H	Between doses	6.889	2	3.444	1.148 (P>0.05)
	Error	18.000	6	3.000	
	Total	24.889	8		

App. Table 183. Analysis of variance onthe repellent effects of *P. erosus* chloroform seed extract on male *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	11.556	2	5.778	4.000 (P>0.05)
	Error	8.667	6	1.444	
	Total	20.222	8		
1H	Between doses	4.222	2	2.111	1.267 (P>0.05)
	Error	10.000	6	1.667	
	Total	14.222	8		
24H	Between doses	4.667	2	2.333	.913 (P>0.05)
	Error	15.333	6	2.556	
	Total	20.000	8		

App. Table 184. Analysis of variance on the repellent effects of *P. erosus* chloroform seed extract on female *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	10.889	2	5.444	1.581 (P>0.05)
	Error	20.667	6	3.444	
	Total	31.556	8		
1H	Between doses	8.222	2	4.111	1.947 (P>0.05)
	Error	12.667	6	2.111	
	Total	20.889	8		
24H	Between doses	6.000	2	3.000	0.643 (P>0.05)
	Error	28.000	6	4.667	
	Total	34.000	8		

App. Table 185. Analysis of variance onthe repellent effects of *P. erosus* chloroform seed extract on unsexed *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	1.556	2	0.778	0.636 (P>0.05)
	Error	7.333	6	1.222	
	Total	8.889	8		
1H	Between doses	2.000	2	1.000	0.214 (P>0.05)
	Error	28.000	6	4.667	
	Total	30.000	8		
24H	Between doses	2.889	2	1.444	0.929 (P>0.05)
	Error	9.333	6	1.556	
	Total	12.222	8		

App. Table 186. Repellent action of *P. erosus* seed extract (methanol) on the different stages of *T.castaneum* (Disc method) (N=30)

Life stages	Dose µg/cm^2	Repellency after treatment					
		30M*	%	1H*	%	24H*	%
9 days larvae	0.98	5.33±1.53a	53.31	6.00±2.00a	60.00	8.00±3.02a	80.01
	1.97	6.33±3.21a	63.30	7.33±1.53a	73.29	8.33±1.65a	83.31
	3.93	9.00±1.00a	90.00	8.00±3.46a	80.01	6.33±0.68a	63.30
12 days larvae	0.98	6.00±1.00a	60.00	3.33±1.53b	33.30	6.67±2.08a	66.69
	1.97	8.33±2.08a	83.31	6.67±2.08ab	66.69	7.67±0.58a	76.71
	3.93	9.33±0.58a	93.30	9.67±0.58a	96.69	8.33±1.53a	83.31
16 days larvae	0.98	5.00±4.36a	50.01	6.33±3.21a	63.30	6.67±3.06a	66.69
	1.97	5.33±0.58a	53.31	6.67±1.53a	66.69	8.00±1.00a	80.01
	3.93	9.00±1.00a	90.00	9.67±0.58a	96.69	9.00±1.00a	90.00
Adult male	0.98	4.33±4.93a	43.29	3.33±0.58b	33.3	6.33±3.21a	63.30
	1.97	5.33±1.53a	53.31	6.67±1.53a	66.69	8.33±1.53a	83.31
	3.93	8.00±2.65a	80.01	7.33±1.53a	73.29	9.33±1.15a	93.30
Adult female	0.98	5.67±4.04a	56.70	6.00±2.65a	60.00	5.33±2.52a	53.31
	1.97	6.00±1.73a	60.00	8.33±2.08a	83.31	7.33±2.12a	73.29
	3.93	8.67±2.31a	86.70	8.67±1.53a	86.70	7.67±2.41a	76.71
Adult unsexed	0.98	3.33±3.21a	33.30	4.67±1.53a	46.71	6.33±3.21a	63.30
	1.97	5.00±3.00a	50.01	6.00±2.65a	60.00	6.67±1.53a	66.69
	3.93	9.33±0.58a	93.30	7.67±1.53a	76.71	9.00±1.73a	90.00

M-Minutes after treatment
H-Hour after treatment
The means followed by the same letter in the same column of each developmental stage are not significantly different byTukey's multiple comparison tests. P>0.05 .

App. Table 187. Analysis of variance onthe repellent effects of *P. erosus* methanol seed extract on 9 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	21.556	2	10.778	2.366 (P>0.05)
	Error	27.333	6	4.556	
	Total	48.889	8		
1H	Between doses	6.222	2	3.111	0.509 (P>0.05)
	Error	36.667	6	6.111	
	Total	42.889	8		
24H	Between doses	6.889	2	3.444	1.192 (P>0.05)
	Error	17.333	6	2.889	
	Total	24.222	8		

App. Table 188. Analysis of variance onthe repellent effects of *P. erosus* methanol seed extract on 12 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	17.556	2	8.778	4.647 (P>0.05)
	Error	11.333	6	1.889	
	Total	28.889	8		
1H	Between doses	60.222	2	30.111	12.905 P<0.05)
	Error	14.000	6	2.333	
	Total	74.222	8		
24H	Between doses	4.222	2	2.111	0.905 (P>0.05)
	Error	14.000	6	2.333	
	Total	18.222	8		

App. Table 189. Analysis of variance onthe repellent effects of *P. erosus* methanol seed extract on 16 days larvae of *T. castaneum* after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	29.556	2	14.778	2.180 (P>0.05)
	Error	40.667	6	6.778	
	Total	70.222	8		
1H	Between doses	20.222	2	10.111	2.333 (P>0.05)
	Error	26.000	6	4.333	
	Total	46.222	8		
24H	Between doses	8.222	2	4.111	1.088 (P>0.05)
	Error	22.667	6	3.778	
	Total	30.889	8		

App. Table 190. Analysis of variance onthe repellent effects of *P. erosus* methanol seed extract on male *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	21.556	2	10.778	0.960 (P>0.05)
	Error	67.333	6	11.222	
	Total	88.889	8		
1H	Between doses	27.556	2	13.778	8.267 P<0.05)
	Error	10.000	6	1.667	
	Total	37.556	8		
24H	Between doses	14.000	2	7.000	1.500 (P>0.05)
	Error	28.000	6	4.667	
	Total	42.000	8		

App. Table 191. Analysis of variance on the repellent effects of *P. erosus* methanol seed extract on female *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	16.222	2	8.111	0.986 (P>0.05)
	Error	49.333	6	8.222	
	Total	65.556	8		
1H	Between doses	12.667	2	6.333	1.390 (P>0.05)
	Error	27.333	6	4.556	
	Total	40.000	8		
24H	Between doses	9.556	2	4.778	0.754 (P>0.05)
	Error	38.000	6	6.333	
	Total	47.556	8		

App. Table 192. Analysis of variance on the repellent effects of *P. erosus* methanol seed extract on unsexed *T. castaneum* adult after 30M, 1h and 24h of exposure by disc method

Exposure periods	SV	SS	df	MS	F values
30M	Between doses	57.556	2	28.778	4.39 (P>0.05)
	Error	39.333	6	6.556	
	Total	96.889	8		
1H	Between doses	13.556	2	6.778	1.74 (P>0.05)
	Error	23.333	6	3.889	
	Total	36.889	8		
24H	Between doses	12.667	2	6.333	1.213 (P>0.05)
	Error	31.333	6	5.222	
	Total	44.000	8		

App. Table 193. The average number of eggs laid by *T. castaneum* females at intervals of 3 days over a period of 45 days. Adult reared on fresh medium (control) and treated medium (N=15)

Dose/Treatment	Eggs laid on every 3days														Mean	
	3rd	6th	9th	12th	15th	18th	21th	24th	27th	30th	33th	36th	39th	42th	45th	
Control (Untreated)	18.25	21.56	23.90	25.80	26.20	26.89	27.90	29.50	28.45	30.50	29.65	30.55	31.60	29.66	30.75	27.41±0.94
Control (Chloroform)	22.21	18.40	22.54	22.89	23.60	25.64	27.63	26.47	28.35	30.69	30.20	31.95	30.87	30.60	31.32	26.89±1.04
KSP .03%	16.25	17.3	18.00	19.21	19.50	21.35	22.40	25.00	23.45	21.22	20.00	18.21	15.25	11.00	8.00	18.41±1.13
MSP .12%	17.11	18.20	18.45	20.00	22.25	24.50	25.00	26.20	27.46	25.00	23.45	21.33	20.50	16.45	15.50	21.43±0.94
KSP .03%+ MSP .12%	11.50	15.45	16.00	16.87	18.56	20.00	21.36	24.50	22.31	19.84	16.45	15.00	13.28	10.20	9.15	16.70±1.12
KCE 250ppm	10.75	14.80	15.60	17.00	17.50	18.25	22.21	23.00	20.90	18.50	16.30	14.65	12.50	9.89	8.75	16.04±1.07
MCE 2000ppm	18.30	20.00	21.22	21.90	23.44	24.25	24.75	25.60	26.00	23.41	24.00	18.30	12.50	14.70	14.00	20.82±1.09
KCE250ppm+ MCE2000ppm	9.60	13.50	14.00	15.56	18.00	19.23	20.50	23.20	20.45	17.44	16.00	15.30	12.10	8.66	7.20	15.38±1.16

KSP- kesur seed powder, MSP- mahogany seed powder, KCE- chloroform extract of kesur, MCE- chloroform extract of mahogany

App. Table 194.The mean number of eggs laid by *T. castaneum* females reared on fresh medium (control) and medium treated mahogany seed powder, kesur seed powder, chloroform extract of mahogany seed, chloroform extract of kesur seed alone and their combinations

Treatment	Eggs laid / day / female		
	Mean±SE	Minimum	Maximum
Control (untreated)	9.14±0.32a	6.08	10.53
Control(chloroform)	8.96±0.35a	6.13	10.65
KSP 0.03%	6.14±0.38c	2.67	8.33
MSP 0.12%	7.14±0.32b	5.17	9.15
KSP 0.03% + MSP 0.12%	5.57±0.37d	3.05	8.17
KCE 250ppm	5.35±0.36de	2.92	7.67
MCE 2000ppm	6.94±0.36b	4.17	8.67
MCE 2000ppm+KCE 250ppm	5.13±0.39e	2.40	7.73

Colum for mean number of eggs showed that the same letters at different values indicate no significant difference between them (DMRT). (P>0.05)

App. Table 195. Analysis of variance of the mean number of eggs laid by *T. castaneum* females reared on mahogany and kesur seed powders and extracts treated medium

Source	SS	df	MS	F value
Treatment	51.344	7	7.335	135.946(P<0.001)
Error	.863	16	.054	
Total	52.207	23		

App. Table 196.The numbers and percent of egg hatching in *T. castaneum* reared on fresh medium (control) and medium treated with mahogany seed powder, kesur seed powder, chloroform extract of mahogany seed, chloroform extract of kesur seed alone and their combinations

Treatments	Total eggs used	Egg hatching	
		Total egg hatched	% hatching
Control (untreated)	6169	5890	95.48a
Control(chloroform)	6048	5902	97.58a
KSP 0.03%	4144	2530	62.06c
MSP 0.12%	4819	3850	79.80b
KSP 0.03% + MSP 0.12%	3759	2045	54.40cd
KCE 250ppm	3611	2015	55.80cd
MCE 2000ppm	4684	3612	77.11b
KCE 250ppm + MCE 2000ppm	3462	1465	42.32d

Each experiment consists of 15 pairs (male: female=1:1) adult and eggs collected at intervals of 3 days over a period 45 days.

Colum for % of hatching showed that the same letters at different values indicate no significant (P>0.05) difference between them (DMRT).

App. Table 197. Analysis of variance of the mean number of eggs laid by *T. castaneum* females reared on mahogany and kesur seed powders and extracts treated medium

Source	SS	df	MS	F value
Treatment	8484.351	7	1212.050	1616.067(P<0.001)
Error	12.000	16	.750	
Total	8496.351	23		

App. Table 198. Analysis of variance of the percentage of deformed male adults emerged from *T. castaneum* larvae reared on fresh medium (control) and medium treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	1221.573	7	174.510	7.910 (P<0.001)
Error	353.009	16	22.063	
Total	1574.582	23		

App. Table 199. Analysis of variance of the percentage of deformed female adults emerged from *T. castaneum* larvae reared on fresh medium (control) and medium treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	2067.412	7	295.345	14.458(P<0.001)
Error	326.845	16	20.428	
Total	2394.257	23		

App. Table 200. Analysis of variance of the percentage of deformed male adults emerged from *T. castaneum* pupae exposed to the filter paper treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	2191.282	7	313.040	16.135 (P<0.001)
Error	310.416	16	19.401	
Total	2501.698	23		

App. Table 2001. Analysis of variance of the percentage of deformed female adults emerged from *T.castaneum* pupae exposed to the filter paper treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	3640.140	7	520.020	47.273(P<0.001)
Error	176.006	16	11.000	
Total	3816.146	23		

App. Table 202. Analysis of variance of the percentage of deformed male adults emerged from *T. castaneum* pupae exposed to the food medium treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	475.481	7	67.926	9.022 (P<0.001)
Error	120.459	16	7.529	
Total	595.941	23		

App. Table 203. Analysis of variance of the percentage of deformed female adults emerged from *T. castaneum* pupae exposed to the food medium treated with different combinations of mahogany and kesur seed powder and extracts

Source	SS	df	MS	F value
Treatment	573.259	7	81.894	17.940 (P<0.001)
Error	73.040	16	4.565	
Total	646.298	23		

App. Table 204. Potency of *S.macrophylla* and *P.erosus* seed powders at different doses on population of *T.castaneum* (N=20#)

Powders	Doses % (w/w)	Average population of the different stages and PRC values							
		Larvae		Pupae		Adult		Total population	
		Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values
S.macrophylla Seed	0.03	215.33	32.71	9.33	6.70	276.00	1.43	500.66	17.92
	0.06	152.00	52.5	8.67	13.30	248.00	11.43	408.67	33.00
	0.12	132.67	58.54	8.00	20.00	252.67	9.76	393.34	35.52
P.erosus seed	0.015	217.33	32.08	12.00	20.00	197.33	29.53	426.66	30.06
	0.03	184.67	42.29	8.00	20.00	156.00	44.29	348.67	42.84
	0.06	148.00	53.75	8.67	13.30	121.33	56.67	278.00	54.43
	Cont.(0)	320.00	0.00	14.00	0.00	280.00	0.00	610.00	0.00

App. Table 205. Analysis of variance of the potency of *S.macrophylla* and *P.erosus* seed powders at different doses on larval population of *T.castaneum*

Source	SS	df	MS	F value
Treatment	73749.132	6	12291.522	10137.338 (P<0.001)
Error	16.975	14	1.213	
Total	73766.107	20		

App. Table 206. Analysis of variance of the potency of *S.macrophylla* and *P.erosus* seed powders at different doses on pupal population of *T.castaneum*

Source	SS	df	MS	F value
Treatment	35.810	6	5.968	42.919 (P<0.001)
Error	1.947	14	.139	
Total	37.756	20		

App. Table 207. Analysis of variance of the potency of *S.macrophylla* and *P.erosus* seed powders at different doses on adult population of *T.castaneum*

Source	SS	df	MS	F value
Treatment	68763.810	6	11460.635	8409.271 (P<0.001)
Error	19.080	14	1.363	
Total	68782.890	20		

App. Table 208. Analysis of variance of the potency of *S.macrophylla* and *P.erosus* seed powders at different doses on total population of *T.castaneum*

Source	SS	df	MS	F value
Treatment	205936.547	6	34322.758	35813.628 (P<0.001)
Error	13.417	14	.958	
Total	205949.964	20		

App. Table 209. Potency of *S. macrophylla* seed extracts at different doses on population of *T. castaneum* (N=20#)

Extracts	Doses ppm	Average population of the different stages and PRC values							
		Larvae		Pupae		Adult		Total population	
		Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values
Chloroform Extract	500	47.33	46.23	17.33	3.73	232.00	31.76	296.66	35.60
	1000	31.33	64.30	12.67	29.61	219.33	35.49	263.33	57.17
	2000	53.33	39.30	18.00	0.00	238.67	29.8	310.00	58.51
Metanol extract	500	46.00	47.73	12.00	33.33	243.33	28.43	301.33	37.54
	1000	38.00	56.82	10.67	40.72	272.00	20.00	320.67	40.75
	2000	47.33	46.23	16.00	11.11	197.33	41.96	260.66	56.72
	Cont.(0)	88.00	0.00	20.00	0.00	340.00	0.00	444.00	0.00

App. Table 210. Analysis of variance of the potency of *S. macrophylla* seed extracts at different doses on larval population of *T. castaneum*

Source	SS	df	MS	F
Treatment	5932.686	6	988.781	2365.397 (P<0.001)
Error	5.852	14	.418	
Total	5938.538	20		

App. Table 211. Analysis of variance of the potency of *S. macrophylla* seed extracts at different doses on pupal population of *T. castaneum*

Source	SS	df	MS	F value
Treatment	219.810	6	36.635	241.929 (P<0.001)
Error	2.120	14	.151	
Total	221.930	20		

App. Table 212. Analysis of variance of the potency of *S. macrophylla* seed extracts at different doses on adult population of *T. castaneum*

Source	SS	df	MS	F value
Treatment	38362.286	6	6393.714	15644.393 (P<0.001)
Error	5.722	14	.409	
Total	38368.007	20		

App. Table 213. Analysis of variance of the potency of *S. macrophylla* seed extracts at different doses on total population of *T. castaneum*

Source	SS	df	MS	F value
Treatment	68500.716	6	11416.786	21778.260 (P<0.001)
Error	7.339	14	.524	
Total	68508.056	20		

App. Table 214. Potency of *P. erosus* seed extracts at different doses on population of *T. castaneum* (N=20)

Extracts	Doses ppm	Average population of the different stages and PRC values							
		Larvae		Pupae		Adult		Total population	
		Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values	Mean No.	PRC values
Chloroform Extract	125	50.67	25.48	6.67	66.65	191.33	46.66	248.67	35.6
	250	38.00	44.11	7.33	63.35	146.00	59.29	191.33	57.17
	500	37.33	45.1	4.67	76.65	143.33	60.04	185.33	58.51
Metanol extract	125	27.67	59.3	9.33	53.35	242.00	32.53	279.00	37.54
	250	52.67	22.54	14.00	30.00	198.00	44.8	264.67	40.75
	500	58.00	14.71	8.00	60.00	127.33	64.6	193.33	56.72
	Cont.(0)	68.00	0.00	20.00	0.00	358.67	0.00	446.67	0.00

App. Table 215. Analysis of variance of the potency of *P.erosus* seed extracts at different doses on larval population of *T. castaneum*

Source	SS	df	MS	F
Treatment	3462.635	6	577.106	1935.483 (P<0.001)
Error	4.174	14	.298	
Total	3466.810	20		

App. Table 216. Analysis of variance of the potency of *P.erosus* seed extracts at different doses on pupal population of *T. castaneum*

Source	SS	df	MS	F
Treatment	501.120	6	83.520	634.008 (P<0.001)
Error	1.844	14	.132	
Total	502.964	20		

App. Table 217. Analysis of variance of the potency of *P.erosus* seed extracts at different doses on adult population of *T. castaneum*

Source	SS	df	MS	F
Treatment	115263.745	6	19210.624	28986.543 (P<0.001)
Error	9.278	14	.663	
Total	115273.023	20		

App. Table 218. Analysis of variance of the potency of *P.erosus* seed extracts at different doses on total population of *T. castaneum*

Source	SS	df	MS	F
Treatment	150225.636	6	25037.606	39435.215 (P<0.001)
Error	8.889	14	.635	
Total	150234.525	20		