MANAGEMENT OF MAIZE WEEVIL, *Sitophilus zeamais* (MOTSCH.) (CURCULIONIDAE: COLEOPTERA) BY WEED EXTRACTS AND A CHEMICAL INSECTICIDE

A THESIS
BY

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Roll No. 1605365
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Semester: January-June, 2018

MASTER OF SCIENCE (M.S.)
IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR - 5200

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Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfillment of the requirements for the degree of

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DEPARTMENT OF ENTOMOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR - 5200

JUNE, 2018

Dedicated to

My

Beloved Parents and Brothers

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"Alhamdulillah" All compliments and thanks are due to the Glorified, "Allah ta-ala" the creator of the heavens and the earth. Who is the most kind, the most merciful and grant me the power and ability to complete the research work and this manuscript successfully for the degree of Master of Science (MS) in Entomology.

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The authoress

MANAGEMENT OF MAIZE WEEVIL, *Sitophilus zeamais* (MOTSCH.) (CURCULIONIDAE: COLEOPTERA) BY WEED EXTRACTS AND A CHEMICAL INSECTICIDE

ABSTRACT

The study was conducted to evaluate the efficacy of five indigenous weed extracts, viz. water hyacinth (*Eichhornia crassipes*), swamp smartweed (*Polygonum coccineum*), ariach (*Cassia tora*), wild capsicum (*Croton bonplandianum*) and hill glory bower (*Clerodendrum viscosum*) in hexane solvent and an insecticide lambda cyhalothrin for their toxicity, residual and repellent effects against the maize weevil, *Sitophilus zeamais* Motsch. (Curculionidae: Coleoptera) in the laboratories of the department of Entomology, HSTU, during May to December 2017. The 4 concentrations of weed extracts (0.5, 1.0, 2.0 and 3.0 % w/v) and 3 concentrations of lambda cyhalothrin (0.01, 0.1 and 0.2% w/v) along with a control were applied in bioassay. The results indicated that all the weed extracts had toxic, residual and repellent effect on maize weevil in storage. Among the weed extracts, the highest toxicity (53.33±7.90%) was found in wild capsicum whereas hill glory bower showed the lowest (21.35±4.59%). The order of the toxicity of the weed extracts were found as wild capsicum > swamp smartweed > water hyacinth > ariach > hill glory bower. Mortality percentages were directly proportional to the concentration level and hours after treatment (HAT). On the other hand the highest average mortality (84.44±2.94%) was found at the maximum concentration (0.2%) of lambda cyhalothrin but the lowest (54.44±4.84%) at the lower concentration (0.01%). All weed extracts showed good protection of maize seeds by reducing adult emergence and seed damage over control. Based on the adult emergence and seed damage the wild capsicum showed the highest residual toxicity whereas lambda cyhalothrin possessed 100% inhibition of adult emergence and seed damage. Hill glory bower showed the highest repellency (41.50±5.39%) while swamp smartweed was the lowest (26.33±5.84%). On the basis of repellency class, hill glory bower was in the repellency class III but the other extracts were in class II. In case of lambda cyhalothrin the mean repellency (41.33±4.81%) was found at 0.1% concentration of class III. Considering the toxic and residual effects, wild capsicum and for repellent effect bhat extracts were more effective against maize weevil. Beside this, lambda cyhalothrin was highly effective in showing toxic, residual and repellent effects against maize weevil.

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CHAPTER- I

INTRODUCTION

Among the foods of human being the stored grains are the main (Padin *et al*., 2002). But stored product insect caused post harvest losses up to 9% in developed countries to 20% over more in developing countries every year (Phillips and Throne, 2010). Storage loss is one of the major problems in developing countries like Bangladesh as well as all over the world. In Bangladesh, the annual grain loss cost as over taka 100 crores (Alam, 1971). It is also reported that more than 70% of cereal production is stored in farms level in developing countries (Kavita, 2004). The infestation of pests creates a serious problem in grain stocking and its derived industry (Perez *et al*., 2004).

Several species of insects may infest the grain in storage. There are over 200 major species of insects and mites infesting important crops and stored products (Das, 1998). There is a continuous need to protect the stored products from deterioration, especially loss of quality and weight during storage. Quantitative and qualitative losses of stored products may result from the feeding by insects, mites, birds, rodents and or from the development of microorganisms all of which are influenced by environmental conditions (Mohale *et al*., 2010).

Maize (*Zea mays* L: Gramineae) is a major staple crop for many smallholder farmers over the world. Maize consumption by human has an increasing trend due to global population growth and its alternative uses that include animal feed, fiber, and ethanol production. The demand for maize as feed ingredient is growing fast in Bangladesh. It has been observed that maize production is highly concentrated especially in Dinajpur, Rangpur and Bogra districts (Quasem, 1999). Maize consumption is expected to increase by 2.3% per acre in the 2014/15-2017/18 period compared to 1.5% for wheat and 1.7% for barley (IGC, 2013) thus making maize very important to humans. According to Kearney (2010), maize consumption has been increasing and it will reach its peak by 2050 due to industrial countries and as feedstock for biofuels. Maize, being cheaper than other cereals such as rice and wheat, is used as a commodity for food aid in developing countries.

The maize weevil, *Sitophilus zeamais* (Motsch.) is one of the most serious cosmopolitan pest of stored cereal grain, especially of maize (*Zea mays* L.), in tropical and sub-tropical regions (Throne, 1994). It is 2.4 to 4.5 mm long (Tefera *et al*., 2010), reddish brown to black snout weevil. In maize or sorghum, attack may start in the mature crop when the moisture content (MC) of the grain has fallen to 18-20% (Parugrug and Roxas, 2008). In stored maize, heavy infestation of this pest may cause weight losses of as much as 30-40% (Casey Sclar, 1994).

Presently, chemical control is the main emphasis to control this weevil. Synthetic chemical insecticides and fumigants have been applied to control maize weevil in store (Udo, 2005; Abebe *et al*., 2009; Pereira *et al*., 2009; Nukenine, 2010). But chemical control of insect pests in storage has serious drawbacks (Sahayaraj, 1994; Khanam *et al*., 1990; Haque and Hussain, 1993). However, the use of insecticides to control of maize weevil is being threatened by development of maize weevil resistance (Fragoso *et al*., 2005; Pereira *et al*., 2009) and the chemical products are also mostly beyond the reach of smallholder farmers (Dhliwayo and Pixley, 2003).

To prevail over these problems, alternatives to chemical pesticides for controlling insect pest of storage are necessary. Plant based botanical pesticides can be effective and safe, which are locally available, less hazardous with low toxicity. In addition, plant-based pesticides are renewable in nature and cheaper. Also, some plants have more than one chemical as an active principle responsible for their biological properties. Now a day, this is originating a worldwide interest in the advancement of alternative strategies to find out the new types of insecticides that are using as an age-old traditional botanical pest control agents (Heyde *et al*., 1983). There is a broad history of applying plants and their products to control insect pests and the compounds liable for activity (Belmin *et al*., 2001; Isman, 2006). Moreover plant-derived pesticides can be transferred into practical applications in natural crop protection, which can help the small-scale farmers (Binggeli, 1999).

Many botanical extracts contain various types of bioactive ingredients and chemicals which are toxic to stored product insects including *Sitophilus zeamais.* However, there are many research work done on the evaluation of different indigenous plant extracts against stored product pest (Faskin, 2003; Pandey and Brave, 2011; Ali *et al.*, 2012; Arya and Tiwari, 2013). Under these circumstances, an investigation was undertaken to determine the toxicity, repellency and residual effects of leaf extracts of some weed plants such as (i) water hyacinth (*Eichhornia crassipes*), (ii) swamp smartweed (*Polygonum coccineum*), (iii) ariach (*Cassia tora*), (iv) wild capsicum (*Croton bonplandianum*), (v) hill glory bower (*Clerodendrum viscosum*) and an insecticide (vi) lambda cyhalothrin against *Sitophilus zeamais* Motsch.

These weed plants are available in everywhere of Bangladesh, create disturb to crop plants and less toxicant to the mammals. So, it is a cheapest method of pest management. Beside weed extracts, an insecticide has been used in this experiment to evaluate its toxicity level on maize weevil. The use of synthetic chemicals as a method of controlling pests is effective yet expensive, dangerous to human health and may create other problems in post harvest industry.

The specific objectives of the present research works are given bellow:

1. To determine the toxicity of weed extracts and an insecticide against maize weevil.
2. To evaluate the repellent and residual toxicity of the weed extracts and an insecticide against maize weevil.
3. To investigate the suitable pesticide(s) and its dose for the management of maize weevil in storage.

CHAPTER- II

REVIEW OF LITERATURE

Maize weevil (*Sitophilus zeamais*) is a critical pest in developing countries. Different control measures have been employed to manage maize weevil especially in storage. Various reports have been published on the use of botanicals against *Sitophilus zeamais* while the use of chemical has been the major method of controlling maize weevil (Rozman *et al*., 2007). In this experiment leaf extracts of some weed plants and a chemical insecticide have been used to manage maize weevil. Numerous research works which have been performed on the effects of botanical extracts and chemical insecticide against *Sitophilus zeamais* are reviewed carefully in this section.

2. 1 Water hyacinth

Plate 1: Water hyacinth, *Eichhornia crassipes* Mart.

Scientific name: *Eichhornia crassipes*

Family: Pontederiaceae

2.1.1 Morphology and distribution

Eichhornia crassipes, commonly known as common water hyacinth, is an aquatic plant native to the Amazon basin, and is often a highly problematic invasive species outside its native range.

The genus *Eichhornia* contains a number of other species, all of which are aquatic, but only *E. crassipes* has become a serious weed (Coetzee *et al*., 2009b). The leaves are 10–20 cm across and float above the water surface and are comprised of smooth, glossy, circular to kidney-shaped lamina and a swollen, spongy petiole. The petiole contains air, causing plants to float on the water surface. Stolons grow horizontally to produce daughter plants from terminal buds. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers with six petals. The bisexual flowers are bluish purple with a yellow centre and the single spike is up to 60 cm in length (Julien *et al*., 1999). The flowers can be self-fertilized. The roots are long, fibrous and feather-like, and often dark-colored (Wright and Purcell, 1995).

The inflorescence bears between 8 and 15 violet and yellow flowers. Each inflorescence produces 3000-4500 seeds (Hill, 1999) and a single rosette can produce several inflorescences each year (Barrett, 1980). The seeds remain viable for 5-20 years (Gopal, 1987). Seeds sink following release from the seed capsule and may subsequently germinate as water levels change (Wright and Purcell, 1995). Water hyacinth seeds germinate in backwater areas, in ditches and channels, and in other moist habitats. The seedlings develop into plants with their own leaves and root systems within 40 days after germination (Barrett, 1980).

Rani and Jamil (1989) observed that Petroleum ether extract of *Eichhornia crassipes* retarded development and caused mortality in the fourth instar larvae of *Tribolium castaneum* (Herbst) and *Corcyra cephalonica* (Stainton).

Allotey and Azalekor (2000) said that in experiments to assess the insecticidal potential of three plant materials against *Corcyra cephalonica* (Stainton), *Eichhornia crassipes* powder showed a higher efficacy than both *Citrus sinensis* peel powder and the leaf powder of *Chromolaena odorata* at dosages of 0.5±2.0 g per 40 g of legume seed.

Mukanga *et al*. (2010) indicated that the percentage reduction in the adult insect numbers of the larger grain borer, *Prostephanus truncatus* ranged from 37.2 to 99.2% and was highest in the neem, tephrosia and water hyacinth treatments.

Annie *et al*. (2015) examined that amongst the crude leaf extracts of *Eichhornia crassipes* tested (62.5, 125, 250 and 500 mg/L.), the hexane and methanol extract was found to be the most effective at 62.5 and 500 mg/L and LC50 values were 80.54 and 137.50 mg/L respectively against *Culex quinquefasciatus* after 48 hours.

2.2 Swamp smartweed

Plate 2: Swamp smartweed, *Polygonum coccineum*

Scientific name: *Polygonum coccineum*

Family: Polygonaceae

2.2.1 Morphology and distribution

Swamp smartweed is a weed plant which can be found in wet areas such as along lakes, ponds, rivers and ditches, but can also persist in poorly drained depressional areas in cultivated fields throughout the country.

Like all members of the smartweed family (i.e. lady's-thumb, wild buckwheat etc.) swamp smartweed will have an ocrea at the base of each leaf stem. An ocrea is a membranous "skin-like" piece of tissue that surrounds the stem at each node. Swamp smartweed will be distinguished from other annual smartweeds (i.e. lady's thumb) by the presence of rhizomes. Swamp smartweed can be most often confused with water smartweed; however swamp smartweed lacks a "leaf-like" flange at the top of its ocrea which is characteristic of water smartweed (Anonymous, 2016). It is a perennial weed reproducing by seed and by underground horizontal roots (i.e. rhizomes).

2.2.2 Uses

Several species can be eaten cooked, for example during famines (Łukasz Łuczaj, 2008). The species *Polygonum cognatum*, known locally as "madimak", is regularly consumed in central parts of Turkey. In Chinese medicine, a *Polygonum* extract called Rèlínqīng Kēlì is used to treat urinary tract infections. Chinese medicine also uses a *Polygonum multiflorum* extract called Fo-Ti (https:// en.wikipedia. org/wiki/ Special: Book Sources/0-226-64091-4, 25.05.2018).

Rouf *et al.* (1996) investigated the toxicity of the leaf powder of neem, nishinda, and biskatali against *C. chinensis* on lentil seeds. Result showed that 4 g of bishkatali leaf powder/ 50g of lentil seeds were the most effective in reducing oviposition, adult emergence. At low doses (1-2g) these 3 plant materials applied either alone or in combination were found to be less effective.

Hussain *et al.* (1995) reported that the extracts of *Ploygonum hydropiper* and *Annona squamosa* have strong repellent effect on adults of *T. castaneum*.

Bhuiyah (2001) reported that the oils of neem, royna and castor at 6 and 8 ml/kg and leaf powder of bishkatali, marigold and castor at 5% w/w were most effective in preventing the egg laying in lentil and chickpea and leaf powder of bishkatali, marigold, castor, and mango at 5% were most effective in reducing the adult emergence in lentil and chickpea, whereas the adult emergence were nil in pre and post storage release methods.

Bhuiyah and Quinones (1990) treated the corn with leaf powder of biskatali and found that the leaves powder of biskatali was effective on oviposition and adult emergence of *S. zeamais.*

2.3 Ariach

Plate 3: Ariach, *Cassia tora* Linn.

Scientific name: *Cassia tora* Linn.

Family: Caesalpiniaceae

2.3.1 Morphology and distribution

Cassia tora Linn. is an annual herb, a legume belonging to the *Caesalpiniaceae* family, 30-39 cm high growing in India as wasteland rainy season weed. The leaf is dark green in color, pinnately compound, length is 6-10 cm and slightly bitter in test. Leaf texture is smooth and odorless (Mazumder *et al*., 2005).

Cassia tora Linn. is a semi-wild annual herb grown widely in different places of south-east Asia including India, Northern Australia and Americas (Sarwa *et al.*, 2014).

2.3.2 Nutrient content and uses

It grows wild mostly in the tropics and is considered a weed in many places. Wild plants play an important role in the diet of most rural dwellers in Nigeria. Throughout the year, the plants play an important role in supplying nutrients and calories especially during the dry season when cultivated vegetables are scarce (Freiberger *et al*., 1998).

This plant species is well known for having potential in traditional medicine practices for the treatment of a variety of disorders and ailments ranging from simple cough, hypertension to diabetes. Recent scientific investigation reveals its phytochemical as well as biological potential. *Cassia tora* has been proven to be medicinally effective for having antimicrobial, antiantioxidant, antihypertensive, antidiabetic and antimutagenic activities, just to name a few (Sarwa *et al*., 2014).

The use of *Cassia tora* seeds in beverages such as coffee, tea etc. is very popular in some parts of the world (Sharma *et al*., 2005 and Ahn, 1998).

Ahad *et al*. (2016a) investigated the toxicity of the n-hexane extracts of the weeds 'bhatpata' *Clerodendrum viscosum,* 'kashiature' *Cassia tora,* 'dhakishak' *Dryoptris filix-max,* 'bonmorich' *Croton bonpalandianum* and 'ghagra' *Xanthium strumarium* for suppressing pulse beetle, *Callosobruchus chinensis* reared on mung bean *Vigna radiata* grains.

Xu-Hanghong and Zhao-Shanhuan (1994) reported that the cassia oil mixed with wheat flour at 0.1-0.2% (w/w) completely inhibited the reproduction of *S. zeamais*, *R. dominica* and *T. castaneum*.

Mazumder *et al*. (2005) said that, the leaves and seeds of *Cassia tora* are found to be used in leprosy, ring worm, flatulence, colic, dyspepsia, constipation, cough, bronchitis and cardiac disorders in the Ayurvedic system of medicine.

Acharya (1975) observed that the leaves of *Cassia tora* are used as antifungal agent due to presence of chrysophanic acid –9-anthrone.

Hatano *et al*. **(**1999) noticed that seed extract of *Cassia tora* is also found to have antibacterial effect due to its phenolic constituents.

Phongpaichit *et al*. (2004) observed that methanol extracts of leaves possesses antifungal activities on pathogenic fungi *M. gypseum*, *T. rubrum* and *Penicillium marneffei* with the 50% inhibition concentration (IC50) of hyphal growth at 1.2, 1.8 and 1.8 mg/mL, respectively. Leaves extract also affected *M. gypseum* conidial germination.

2.4 Wild Capsicum

Plate 4: Wild Capsicum, *Croton bonplandianum* Baill.

Scientific Name: *Croton bonplandianum* Baill.

Family: Euphorbiaceae

2.4.1 Morphology and distribution

The plant *Croton bonplandianum* (synonym *C. bonplandianus, C. sporsiflorus* Morong) commonly known as Ban-tulsi, Kala bhanghra or Paitiya (Marma). C. *bonplandianum* is a much branched, woody herb, 22-50 cm tall, branches stellate hairy to glabrous. Flowers of this plant are tiny, peach color, tiny globe shaped, flower buds arranged in up right spikes with green fruits (Dutta *et al*., 2013).

This perennial herb grows mainly as a bush, profoundly grows around the canal, river bank, wastelands and road side area. The plant is native to the southern Bolivia, Paraguay, South Western Brazil and Northern America but also found in the Sub-Himalayan region of West Bengal, India (Dutta *et al*., 2013).

2.4.2 Nutrient content and uses

There are several bio-molecules or bio-active compounds present in *C. bonplandianum,* responsible for preventing many diseases. Phyto-chemically the plant has been reported to contain rutin, crotsporinine, crotosparine and its methyl derivatives aphorbol play a key role in wound healing activity (Divya *et al*., 2011). *C. bonplandianum* is a good source of steroids, unsaturated steroids, phenolics, alkaloids, flavon, flavonols, carotinoids, leuco-anthocyanine and flavonoids (Islam *et al*., 2011). The plant also contains two groups of compounds, terpinoids and glycosides. *C. bonplandianum* is rich in bio-polymars such as cellulose, hemi-cellulose and lignin. Oil and ethanol can be obtained from this plant. 3-α hydroxyl-urs 12, 15-dien of ursane skeleton, oleanolic acid, ursolic acid and β-sitosterol are the isolated compounds from the root of C. *bonplandianum* (Ghosh *et al*., 2013) and 3-methoxy 4, 6-hydroxymorphinandien-7-one, norsinoacutin are the alkaloids isolated from the extract of C. *bonplandianum.*

Susrata Sanhita and Charaka Sanhita the core of the Ayurvedic medicinal system, mentioned therapeutic uses of different medicinal plants. One of such plant mentioned in Ayurveda is *Croton bonplandianum* Baill. C. *bonplandianum* has many medicinal usages including the repellent property against the insect (Jeeshna *et al*., 2010). It has also antibacterial (Vadlapudi, 2010), anti-fungal (Asthana *et al*., 1989), anti-oxidant (Divya *et al*., 2011), analgesic (Saggoo *et al*., 2010), nematicide (Maria *et al*., 2008), anti-coronary (Bhakat and Sen, 2008; Nishanta *et al*., 2002), hepatoprotective (Das *et al*., 2008) and wound healing activities (Chandel *et al*., 1996; Reddy, 1995). In the remote areas of West Bengal, local people use its root as a medicine against snake venom and the leaf extract used as a medicine for high fever (Ghosh *et al*., 2013). *C.*

bonplandianum have been used to cure liver diseases against ring worm and skin diseases. Leaves of this plant have got high medicinal value and are used for controlling blood pressure, cuts and wounds. The seeds of *C. bonplandianum* are used for the treatment of jaundice, acute constipation, abdominal dropsy and internal abscesses. The fresh juice of this plant is used by tribal populations to cure head acne (Divya *et al*., 2011). The plant is also used by some migratory workers for the treatment of skin disorders. Less commonly, the juice of this plant is used against helminthiasis and toothache (Singh *et al*., 2011).

Ahad *et al*. (2016b) experimented with n-hexane extracts of 10 weeds such as *Clerodendrumviscosum*, *Xanthium indicum, Mimosa pudica, Polygonum hydropiper*, *Argemonemexicana, Croton bonpalandianum, Leucus aspara, Dryoptrisfilix-max*, *Cassia tora*, *Blumealacera* against lesser grain borer, *Rhizopertha dominica* F. (bostrichidae: coleoptera) on wheat in storage.

Jeeshna *et al*. (2010) investigated the level of larvicidal activity of methanolic extract of *Croton bonplandianus* at different concentration. It is observed that IC 50 value obtained at 124 ppm is effective against the mosquito *Aedes aegypti*. They proposed that the leaf extract of *C. bonplandianus* at 124 ppm is better for mosquito control.

Antioxidant activity of *C. bonplandianus* was evaluated by Sridhar *et al*., 2013. They proposed that the plant extract has DPPH scavenging activity with IC 50 value 416.82 μg/ml when compared to standard BHT.

Dutta *et al.* (2013) performed the phytochemical analysis of leaf of *C. bonplandianus* and identified the presence of a wide range of phytochemicals such as phenolics, glycosides, alkaloids, tannin, flavonoid, etc. Quantification of these phytochemicals revealed the presence of 59.60±4.79 g/100 g alkaloid, 75.29±3.19 mg/g phenolics and 4.36±0.48 mg/g flavonoid in the leaves.

Saggoo *et al*. (2010) observed that Leaf extract of *Croton bonplandianus* made in chloroform and benzene were most effective against *Bacillus subtilis, B. megaterium, Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa and Staphylococcus aureus.*

According to Singh *et al.* (2011) *C. bonplandianus* aqueous extract inhibis the growth of *Aspergillus niger* approximately MIC 100 mg/ml.

Divya *et al.* (2011) suggested that, the latex of *C. bonplandianus* (1.5 v/v in 50 % acetone) showed anti-fungal activity against *Microsporum gypseum* and *Trichophyton mentagrophytes*.

2.5 Hill glory bower

Plate 5: Hill glory bower, *Clerodendrum viscosum* Vent.

Scientific Name: *Clerodendrum viscosum* Vent.

Family: Verbenaceae

2.5.1 Morphology and distribution

Clerodendrum viscosum Vent. (Bengali name-Bhat, Ghetu; Family-Verbenaceae) is a small shrub, about 4 feet high, with broadly ovate leathery leaves, pinkish white flowers and small fruits enclosed in red bracts, grows commonly in waste places and graveyards in all areas of the country.

2.5.2 Nutrient content and uses

The plant contains saponin, flavonoids, alkaloids, a new glycoside, cleodendroside, lupeol, benzoic acid derivatives and beta-sitosterol. Roots contain the antifungal flavonoids, cabruvin and quercetin. The seeds contain fatty oil in which the major fatty acids are palmitic, oleic and linoleic acids. Cleroden-droside has hypotensive property.

Leaf juice is used as strong anthelmentic, emetic, mild laxative and cholagogue. It is externally used for tumors, skin diseases, snake bite and scorpion-sting (Ghani, 2003).

Leaf extract of *C. viscosum* possesses repellent properties to adult and larvae of *T. castaneum* (Husain and Hasan, 2008).

From the investigation of Ahad *et al*. (2016a), the order of toxicity of the n-hexane extracts of the weeds ‘bhatpata’ *Clerodendrum viscosum*, ‘kashiature’ *Cassia tora*, ‘dhakishak’ *Dryoptris filix-max,* ‘bonmorich’ *Croton bonpalandianum* and ‘ghagra’ *Xanthium strumarium* for suppressing pulse beetle, *Callosobruchus chinensis* reared on mung bean *Vigna radiata* grains was ghagra > bonmorich > dhakishak > kashiature > bhatpata at 24h, 48h and 72h post treatment.

Husain and Hasan (2008) observed that both the larvae and adults of flour beetle, *T. confusum* were repelled by contact with different food media when mixed with leaf dusts of the *C. viscosum* plant. The above findings of the present study are in general agreement with the findings of (Haque *et al*., 2010).

According to Waliullah *et al*. (2014), their research reveled that the *C. viscosum* extracts has strong insecticidal and repellent effect against *T. castaneum.* They also said that their previous study indicated promising antibacterial and antifungal properties of *C. infortunatum* against life threatening pathogens.

2.6 Chemical Insecticide

Plate 6: Chemical insecticide- lambda cyhalothrin

Common name: Lambda cyhalothrin

Trade name: Tasla (10 WP), Charge, Excaliber, Grenade, Hallmark, Icon, Karate, matador, OMS 0321, PP321, Saber, Samurai and Sentinel (Meister, 1992; Royal Society of Chemistry, 1991).

Chemical name: (RS)-alpha-cyano-3-phenoxybenzy l3-(2-chloro-3,3,3-trifluoropropenyl)-2, 2-dimethylcyclopropanecarboxylate (Royal Society of Chemistry, 1991).

2.6.1 Description

Lambda-cyhalothrin belongs to a group of chemicals called pyrethroids is an insecticide registered by the U.S. Environmental Protection Agency (EPA) in 1988. It is a colorless to beige solid that has a mild odor. It has low water solubility and is nonvolatile (World Health Organization, 1990; A World Compendium: The Pesticide Manual, 1997). Scientists developed pyrethroid insecticides to have properties better than those of the natural insecticides pyrethrins (World Health Organization, 1990).

Lambda cyhalothrin is a synthetic pyrethroid insecticide and acaricide used to control a wide range of pests in a variety of applications. Pests controlled include aphids, Colorado beetles and butterfly larvae. It may also be used for structural pest management or in public health applications to control insects such as cockroach, mosquitoes, ticks and flies which may act as disease vectors. Crops on which it may be applied include cotton, cereals, hops, ornamentals, potatoes, vegetables or others (Royal Society of Chemistry, 1991). Signal words for products containing lambda-cyhalothrin range from Caution to Danger (Pest-Bank Pesticide Product Data, 2000).

2.6.2 Available form

Lambda cyhalothrin is available as an emulsifiable concentrate (EC), wettable powder (WP) or ULV liquid. It can be found in other forms including pellets, small capsules, and ear tags containing the chemical (Pest-Bank Pesticide Product Data, 2000).

2.6.3 Mode of action

Lambda-cyhalothrin mainly acts as a contact as well as stomach poison. By disrupting the nervous system of insects, lambda-cyhalothrin may cause paralysis or death .Temperature influences insect paralysis and the toxicity of lambda-cyhalothrin (Toth *et al*., 1990). It affects a variety of indoor and outdoor insects when they eat or touch the chemical and also has properties that may repel insects (A World Compendium: The Pesticide Manual, 1997).

According to World Health Organization report (1990), lambda-cyhalothrin is highly toxic to bees when they eat or contact the chemical. However, no increased risk was noted to bees in a field study conducted with a lambda-cyhalothrin product.

Mueller-Beilschmidt D. (1990) said that pyrethroids are toxic to insects including bees as they have a strong repellant action against them by affecting their feeding behavior.

Sayeed *et al*. (2003) demonstrated that pyrethroids have a devastating effect on aquatic invertebrates with most LC50 values less than 1.0 parts per billion (ppb). These LC50s are similar to those for mosquito, black fly and tsetse fly larvae, for which pyrethroids are often used in vector control.

Arthur (1998a, b) observed that survival of *T. castaneum* was greater than survival of *T. confusum* at both the 1- and 2-h exposure intervals on concrete treated with the cyfluthrin WP at both label rates for all residual bioassays except at 6 weeks, indicating that *T. confusum* was more susceptible than *T. castaneum* to cyfluthrin WP.

Poonam *et al*. (2013) stated that the LD50 ranged from 30 to 140 mg/kg body weight (b.wt) in rats, with a minimum toxic dose of 10 mg/kg bw causing mild salivation when treated with the cyfluthrin WP.

According to Zettler *et al*. (1997), carbonyl sulfide was toxic at fairly low doses in 24 h fumigations to a variety of post harvest pests: 5th instars of *Amyelois transitella* walker (navel orange worm) and adults of *T. confusum*, *Lasioderma serricorne* (F.) (cigarette beetle), *Carpophilus hemipterus* (L.) (driedfruit beetle) and *Oryzaephilus surinamensis* (L) (sawtooth grain beetle). Adult beetles were more tolerant than were 5th instars of *A. transitella*. Of the 4 species of beetles, *T. confusum* was the most tolerant with an LC50 of 11.38 mg/L and LC95 of 16.74 mg/L.

He *et al*. (1989) observed that, lambda-cyhalothrin may cause irritation to the skin, throat, nose, and other body parts if exposed. Skin tingling, burning, and prickling feelings, particularly around the face, are unique temporary symptoms of exposure. Other symptoms may include dizziness, headache, nausea, lack of appetite, and fatigue. In severe poisonings, seizures and coma may occur.

Maund *et al*. (1998) noticed that, lambda-cyhalothrin is highly toxic to fish. Laboratory studies indicate that cyhalothrin has the potential to accumulate in fish (World Health Organization, 1990).

Bell and Savvidou (1999) also demonstrated that eggs of *Ephestia kuehniella* (Mediterranean flour moth) showed a range of susceptibility to sulfuryl fluoride and concluded that the most tolerant ages were one- to two- day- old eggs followed by two- to three-day-old eggs.

Reichmuth *et al*. (1999); Schneider and Hartsell (1999); Williams and Schneider (1999) observed that, extending the fumigation time from 24 to 48 hr greatly improves sulfuryl fluoride toxicity to postharvest pests.

Leesch and Zettler (2000) stated that, disinfestation fumigations of *C. pomonella*-infested walnuts with the methyl bromide fumigation protocol showed that sulfuryl fluoride was highly toxic to the diapausing larvae; the minimum effective dose was 8 mg/L (C+T=217 mgh/L) compared with the methyl bromide quarantine dose of 56 mg/L.

2.7 The Test Insect

The present study was conducted by using a major stored grain pest, maize weevil.

2.7.1 Maize weevil

2.7.2 Systematic position

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Curculionidae

Subfamily: Dryophthorinae

Genus: *Sitophilus*

Species: *S. zeamais*

Scientific name: *Sitophilus zeamais* Motschulsky

2.7.3 Importance of maize weevil

Maize weevil occurs throughout warm, humid regions around the world, especially in locations where maize is grown. The maize weevil (*Sitophilus zeamais*) is an important pest in developing countries with yield losses ranging from 5 to 15% (Tigar *et al*., 1994). In the tropics, yield losses of more than 80% have been reported, especially in untreated grain in storage facilities (Pingali and Pandey, 2001). Pest infestation starts in the field and is carried over to the storage facilities (CIMMYT, 2000; Dhliwayo and Pixley, 2003; Demissie *et al*., 2008).

2.7.4 Morphology

Maize weevil belongs to the order Coleoptera and family Curculionidae. The pest has a body size of between 2.4 to 4.5mm (Tefera *et al*., 2010). The body is mostly reddish brown, dark brown or black in colour. It has a long snout with clubbed segmented elbowed antennae and four light reddish brown oval spots on the elytra (Khare, 1994). The lifecycle is on average 36 days at 27±10˚C, and 69±3% relative humidity (RH) (Sharifi and Mills, 1971; Mason, 2003). According to Parugrug and Roxas (2008) the total development period of the maize weevils emerged from both treated and untreated corn grains was 39 days.

Plate 7: Maize weevil, *Sitophilus zeamais* (Motsch.)

2.7.5 Biology

The life cycle of maize weevils consists of four stages: egg, pupa, larva and adult. The duration of various stages in the life cycle differ with the prevailing temperature and humidity conditions in a year. Usually they complete the generation from April to October. Adult maize weevil feeds creating a 1.5-mm hole in the pericarp (Kranz *et al*., 1997) and lives between four to five months (Tefera *et al*., 2010) or more such as 5 to 8 months (Peng *et al*., 2003).

The female weevil bores through the pericarp of undamaged kernels. She then deposits a small oval white egg and covers the hole as the ovipositor is removed, with a waxy secretion that creates a plug (Maceljski and Korunic, 1973). The plug quickly hardens and leaves a small raised area on the seed surface. This provides the only visible evidence that the kernel is infested (Mason, 2003). When the egg hatches into a white, legless grub, it will remain inside and begin feeding on the grain. The larvae will pupate while inside, then chew a circular exit hole (Proctor, 1971) and emerge as an adult beetle. When the adults emerge, the females move to a high surface and release sex pheromones. Males are then attracted to this pheromone (Mason, 2003). Maize weevil has a pre-oviposition period of three days and females can lay up to four eggs in a kernel. A single female may lay 300 to 400 eggs during her lifetime.

2.7.6 Host range

The maize weevil commonly attacks standing crops, in particular, maize before harvest and is also commonly associated with rice. It infests raw or processed cereals such as wheat, oats, barley, sorghum, rye and buckwheat.

CHAPTER- III

MATERIALS AND METHODS

The experiments were conducted in the laboratories of the Departments of Entomology and Agricultural chemistry, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during May-December 2017.

3.1. Collection of weeds: Leaves of water hyacinth (*Eichhornia crassipes*), swamp smartweed (*Polygonum coccineum*), ariach (*Cassia tora*), wild capsicum (*Croton bonplandianum*) and hill glory bower (*Clerodendrum viscosum*) were collected from HSTU Campus. These collected materials were washed in running tap water and then air dried. Finally, the dried plant materials were powdered by the Mortar.

Water hyacinth   Swamp smartweed   Ariach   Wild capsicum   Hill glory bower

Plate 8: Leaves of five weed plants

Plate 9: Powder of tested weeds

3.2. Preparation of weed extracts

The leaf powder of 100g of each was taken separately in 1.5 liter separated funnel and 130 ml n-hexane were added and kept for 72 hours with interval of shaking. After 72 hours it was then filtered by Whatman paper No.1 (diameter 40). Then the aqueous extracts were collected in beakers.

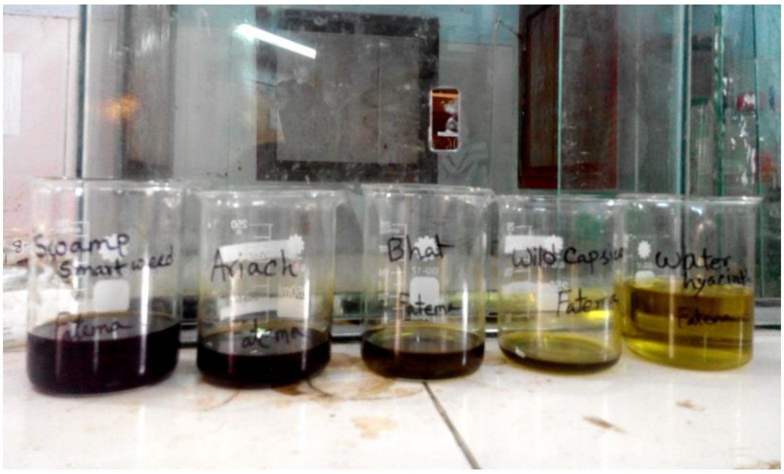


Plate 10: Filtrated aqueous weed extracts

3.3. Isolation of crude extracts

After collecting the aqueous extracts into beaker, the solvents were evaporated by using thin film rotary evaporator under reduced pressure. The condensed crude extracts were then preserved in tightly corked vials and stored in refrigerator at 4˚C for further investigation.

Plate 11: Crude of weed extracts

3.4. Preparation of doses

The crude extracts were weighted in the electronic balance and dissolved in hexane solvent for making different concentrations (0.5, 1.0, 2.0 and 3.0% w/v) of weed extracts and the chemical insecticide at different concentrations (0.01, 0.1 and 0.2% w/v) were prepared along with control (Plate 4). Prior to conducting study, a pilot experiment was done to obtain the appropriate dose.

Plate 12: Dose preparation from the crude and lambda cyhalothrin

3.5. Rearing of test insects and maintenance

The maize weevil, *Sitophilus zeamais* was used for the present experiments. Small populations of weevils were obtained from the entomology laboratory stock. They were reared in the laboratory at room temperature (30±2°C and with 70±5% RH) on maize seeds in a Jar (28 cm × 13 cm). Initially, 50 pairs of 1-2 day-old adults were placed in a jar containing maize seeds. The jar was sealed with net cloth and a maximum of 7 days were allowed for mating and oviposition. Then parent stocks were removed and maize seeds containing eggs were transferred to fresh maize seeds in another jar and again covered with pieces of net cloth fastened with rubber bands to prevent the contamination and escape of insects. The subsequent progenies of the weevils were used for all the experiments.


Plate 13: Rearing of test insects

3.6. Direct toxicity test

Residual film method describe by Busvine (1971) was used to toxicity test of different weed extracts against the adult of maize weevil. Different concentrations (0.5, 1.0, 2.0 and 3.0% w/v) of weed extracts and lambda cyhalothrin (0.01, 0.1 and 0.2% w/v) were made and 1 ml liquid of each dose was dropped separately on the petridishes (60 mm) with the help of pipette. Then the weed extracts were covered uniformly to the whole area of the petridishes internally. The petridishes were then kept open for sometimes to evaporate the solvent fully. Two days old 10 adult weevils from stock culture were released in each petridish. Control petridishes were treated with n-hexane solvent only. Three replications were made for each concentration of weed extracts including control treatment. The Petri-dishes were then kept without food. Insect mortality was recorded at 24, 48, and 72 hours after treatment (HAT). The percentage of mortality was corrected using Abbott's formula (Abbott, 1987).

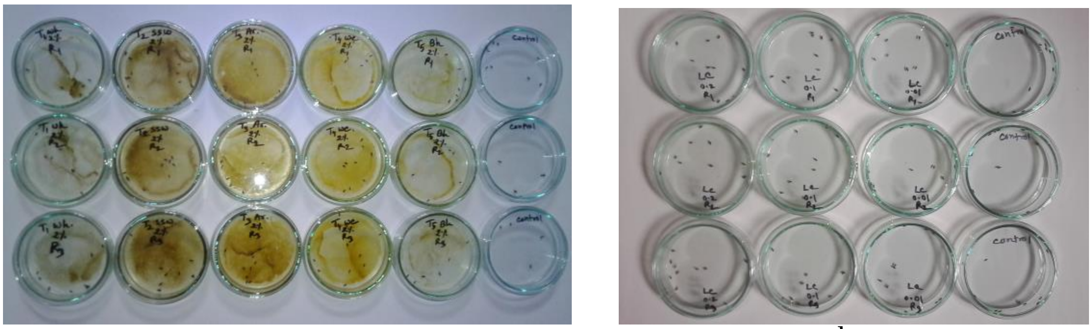
$$P = \frac{p' - C}{100 - C} \times 100$$

Where,

P= Percentage of corrected mortality

P'= Observed mortality (%)

C= Mortality (%) at control.



a b

Plate 14: Direct toxicity test with a) weed extracts and b) chemical insecticide

3.7. Residual toxicity effect

The weed extracts were mixed with maize seed at the rate of 0.5%, 1%, 2% and 3% (w/v) and lambda cyhalothrin 0.01, 0.1 and 0.2% (w/v). The treated maize seeds were air dried for 20 minutes and then put into separate plastic pots (6×7 cm^2), so that each pot contained 30 g of maize seeds. Five-day old weevils of 5 pair were released into the plastic pot. After 7 days, dead and alive weevils were removed from each pot and kept the pots undisturbed in the laboratory for the emergence of new adult weevils.

a b

Plate 15: Residual toxicity effect test with a) weed extracts and b) chemical insecticide

3.7.1. Adult emergence inhibition rate

The maize weevils were started to emerge after 36-40 days of egg lying. The emerged weevils were counted and removed after 40, 47 and 54 days after the experiment set up. The adult emergence rate was recorded and the inhibition rate (IR%) was calculated by using the following formula as stated by Talukder and Howse (1993).

IR (%) = Cn-Tn/Cn × 100

Where,

Cn = Number of insects in control plastic pot.

Tn= Number of insects in treated plastic pot.

3.7.2. Seed damage inhibition rate

The seed was taken out from the pot to determine the hole(s) on each seed carefully. Seeds containing hole(s) were considered as damaged seeds. The numbers of damaged seeds were counted from the random sample of 100 seeds at the end of the experiment and were recorded for each replication. Then inhibition rate (DI%) was calculated by using the following formula Talukder and Howse (1993).

DI (%) = Cn-Tn/Cn x 100

Where,

Cn = Number of damaged seeds in control plastic pot.

Tn= Number of damaged seeds in treated plastic pot.

3.8. Repellency Test

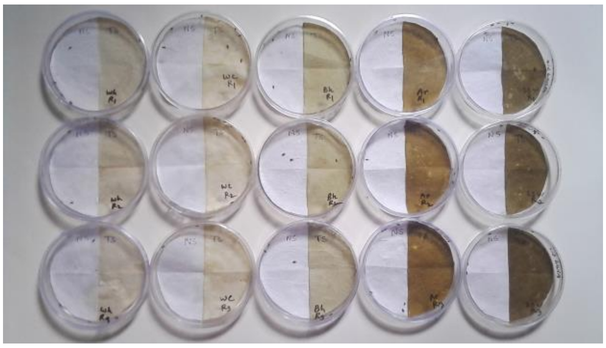
The repellency test was conducted according to the method of Talukder and Howse (1993). For this test, respective doses of tested weed extracts and lambda cyhalothrin (0.5, 1.0, 2.0 and 3.0% w/v extract and 0.01, 0.1 and 0.2% w/v insecticide) were prepared. The filter paper (Whatman no. 1) was cut into two half, and 1 ml solution of each concentration was applied to one half uniformly with the help of micropipette. The treated and control filter papers then air dried for 20 minutes to evaporate the solvent completely. The treated half was then attached with the untreated half and placed to 90 mm petridish. Ten weevils of five days old were released at the centre of each petridish and a cover was placed on the petridish. There were three replications for each pesticides and each dose. Then the insects present on each portion were counted at hourly intervals up to fifth hour. The data were expressed as percentage repulsion (PR) by the following formula:

PR (%) = (NC-50) × 2

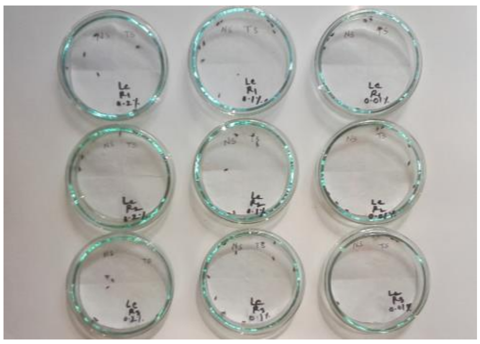
Where, NC = the percentage of insects present in the control half.

Positive (+) values expressed repellency and negative (-) values attractions. Data (PR %) was analyzed using analysis of variance (ANOVA). The average values were then categorized according to the following scale (McDonald *et al*., 1970).

Class	Repellency (%)
0	0 > 0.01 to 0.1
I	0.1 to 20
II	20.1 to 40
III	40.1 to 60
IV	60.1 to 80
V	80.1 to 100



a



b

Plate 16: Repellency test with a) weed extracts and b) chemical Insecticide

3.9. Statistical analyses

The data obtained from the experiments were statistically analyzed by MSTAT and SPSS computer program following completely randomized design (CRD) method. The significance of the mean differences was tested by DMRT. The observed mortality was also subjected to probit analysis.

CHAPTER- IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the toxicity effect of five indigenous weed extracts (water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower) and an insecticide (lambda cyhalothrin) against maize weevil (*Sitophilus zeamais*). The outcomes of the experiment are presented and discussed under the following sub-headings.

4.1 Direct toxicity effect of different weed extracts against the adult of *S. zeamais*

Toxicity effect of different weed extracts, doses and their interaction at different time intervals against the adult of *Sitophilus zeamais* are presented in the Tables 1-3. The average mortality percentage differed statistically among all the weed extracts. Mortality percentages were increased proportionally with the increased time intervals. The wild capsicum extract provided the highest average mortality (53.33±7.90%) whereas hill glory bower extract was the lowest (21.35±4.59%) presented in Table 1. On the basis of insect mortality the order of the toxic effect of five tested weed extracts against maize weevil were found as wild capsicum > swamp smartweed > water hyacinth > ariach > hill glory bower. Mortality of maize weevil also differed significantly among all the concentrations level at different time intervals (Table 2). The highest average mortality (57.78±3.89%) was found at the maximum concentration (3%) on the other hand the lowest average mortality (17.56±4.55%) was found at the lowest concentration (0.5%). No mortality was recorded in untreated control at 24, 48 and 72 HAT. The average mortality percentage of concentration directly proportional to the level of concentration of different weed extracts. The interaction effects of weed, dose and time indicated that there was a significant different among the toxicity of the weed extracts when applied against the adult weevil. Average value indicated that the highest mortality (83.33±1.93%) was found in wild capsicum extracts at highest dose (3%) whereas water hyacinth weed extract the lowest mortality (8.867±2.94%) at lowest dose (0.5%) which was statistically different from all other weed extracts at different concentrations level. No adult mortality was found at control treatments at 24, 48 and 72 HAT (Table 3).

The tested five weed extracts showed toxicity effect on maize weevil, but wild capsicum extracts could be most effective against maize weevil.

Moreira *et al*. (2007) conducted an experiment on three coleopteran stored product pests with eight plant extracts and evaluated that, only hexane extract of *Ageratum conyzoides* showed toxicity to *Sitophilus zeamais*, *Rhyzopertha dominica* and *Oryzaephilus surinamensis*. They also found that, the toxicity of coumarin (extracted from *A. conyzoides*) in *S. zeamais*, *R. dominica*, and *O. surinamensis* was higher in the evaluations at 24 hours, based on LD_{50} and LD_{90} estimations, than at 6 and 12 hours of exposure. Bouda *et al*. (2001) also observed insecticide activity of essential oils of *A. conyzoides* against *S. zeamais* at concentrations of 0.013, 0.025, 0.05 and 0.10%.

Table 1: Direct toxic effect of different weed extracts against *S. zeamais* at different HAT

Plant extracts	Insect mortality (%) in different time intervals			Average mortality (%)
	24 HAT	48 HAT	72 HAT	
Water hyacinth	10.00±2.93 b	25.33±6.75 b	38.00±7.76 d	24.43±5.66 bc
Swamp smartweed	10.00±3.52 b	22.00±5.53 b	50.00±9.01 b	27.34±5.64 b
Ariach	6.00±2.14 b	19.33±5.47 bc	44.00±8.77 c	23.12±5.15 c
Wild capsicum	40.00±7.43 a	54.67±7.98 a	65.33±9.09 a	53.33±7.90 a
Hill glory bower	6.667±2.11 b	12.67±3.45 c	44.67±8.78 c	21.35±4.59 c
LSD	4.87	7.04	4.79	3.33
CV %	45.64	35.79	13.50	20.58

HAT= Hours after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 2: Direct toxic effect of weed extracts of different doses against *S. zeamais* at different HAT

Doses %	Insect mortality (%) in different time intervals			Average mortality (%)
	24 HAT	48 HAT	72 HAT	
0.5	7.33±2.48 c	14.67±5.93 d	30.67± 5.56 d	17.56±4.55 d
1.0	10.67±3.84 c	24.00±5.24 c	49.33±4.73 c	28.01±4.31 c
2.0	21.33±6.46 b	40.67±5.89 b	76.67±2.87 b	46.22±4.49 b
3.0	33.33±5.75 a	54.67±5.33 a	85.33±1.92 a	57.78±3.89 a
Control	0.00±0.00 e	0.00±0.00 e	0.00±0.00 e	0.00±0.00 e
LSD	4.865	7.035	4.79	4.52
CV %	45.64	35.79	13.50	20.58

HAT= Hours after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 3: Combined direct toxic effect of different weed extracts and doses against *S. zeamais* at different HAT

Plant extracts	Doses (%)	Insect mortality (%) at different time intervals			Average mortality (%)
		24 HAT	48 HAT	72 HAT	
Water hyacinth	0.5	3.33±3.33 gh	6.67±3.33 gh	16.67± 3.33 g	8.867±2.94 gh
	1.0	6.667±3.33fgh	13.33±3.33 fgh	33.33±3.33 ef	17.77±2.23 g
	2.0	13.33±6.67efg	40.00±5.773 de	60.00±0.00 d	37.77±3.99 de
	3.0	26.67±3.33bcd	66.67±3.33 bc	80.00±0.00bc	57.77±2.23 b
Swamp smartweed	0.5	3.333±3.33 gh	3.33±3.33 h	23.33±3.33fg	10.00±1.91 gh
	1.0	3.33±3.33 gh	23.33±3.33 efg	60.00±5.77 d	28.90±2.20 ef
	2.0	10.00±5.77fgh	30.00±10.00 ef	80.00±5.77bc	40.00±5.77 cd
	3.0	33.33±3.33 bc	53.33±3.33 cd	86.67±3.33ab	57.80±1.10 b
Ariach	0.5	3.33±3.33 gh	3.33±3.33 h	20.00±5.77 g	8.90±4.00 gh
	1.0	3.33±3.33 gh	16.67±3.33 fgh	40.00±3.33 e	20.03±5.77 fg
	2.0	6.67±6.67 fgh	36.67±17.64 de	80.00±5.77bc	41.13±9.87 cd
	3.0	16.67±3.33def	40.00±5.77 de	80.00±5.77bc	45.53±3.99 cd
Wild capsicum	0.5	23.33±3.33cde	56.67±8.82 bc	70.00±5.77cd	50.00±5.09 bc
	1.0	36.67±6.67 b	60.00±5.77 bc	76.67±3.33bc	57.77±3.99 b
	2.0	66.67±3.33 a	73.33±3.33 ab	86.67±3.33ab	75.53±2.23 a
	3.0	73.33±3.33 a	83.33±3.33 a	93.33±3.33 a	83.33±1.93 a
Hill glory bower	0.5	3.33±2.94 gh	3.33±3.33 h	23.33±3.33fg	10.03±3.33 gh
	1.0	3.33±3.33 gh	6.67±3.33 gh	36.67±3.33 e	15.57±3.33 g
	2.0	10.00±5.77fgh	23.33±3.33 efg	76.67±3.33bc	36.67±3.33 de
	3.0	16.67±3.33def	30.00±5.77 ef	86.67±3.33ab	44.47±3.99 cd
	Control	0.00±0.00 h	0.00±0.00 h	0.00±0.00 h	0.00±0.00 h
LSD		10.88	15.73	10.71	10.10
CV %		45.64	35.79	13.50	20.58

HAT= Hours after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.2 Direct toxicity effect of lambda cyhalothrin against the adult of *S. zeamais*

Mortality of maize weevil differed significantly among all the concentrations level at different time intervals (Table 4). The highest average mortality (84.44±2.94%) was found at the maximum concentration (0.2%) of lambda cyhalothrin but the lowest (54.44±4.84%) was found at the lower concentration (0.01%). No mortality was recorded in untreated control at 24, 48 and 72 HAT.

Table 4: Direct toxic effect of lambda cyhalothrin of different doses against *S. zeamais* at different HAT

Doses (%)	Insect mortality (%) in different time intervals			Average mortality (%)
	24 HAT	48 HAT	72 HAT	
0.01	23.33±3.33 c	60.00±11.55 b	80.00±5.77 b	54.44±4.84 b
0.1	66.67±3.33 b	76.67±3.33 ab	90.00±0.00 ab	77.78±2.23 a
0.2	76.67±3.33 a	83.33±3.33 a	93.33±3.33 a	84.44±2.94 a
Control	0.00±0.00 d	0.00±0.00 c	0.000±0.00 c	0.00±0.00 c
LSD	9.41	20.34	10.87	9.92
CV %	12.00	19.64	8.77	9.73

HAT= Hours after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.3 Probit analysis of different weed extracts against adult of *S. zeamais* for direct toxic effect

The probit analysis for the estimation of LD_{50} values, chi-square values and their 95% confidence limits at 24, 48 and 72 HAT for the mortality of maize weevil are presented in Table 5. The LD_{50} values of tested extract at 24 HAT indicated that wild capsicum (1.34 mg/cm^2) weed extract was the most toxic while hill glory bower showed the lowest (15.84 mg/cm^2). The LD_{50} values at 48 HAT indicated that wild capsicum (1.34 mg/cm^2) weed extract was the most toxic followed by water hyacinth and swamp smartweed extract. Among the five indigenous weed extracts wild capsicum weed extract also performed the highest toxicity as compared the LD_{50} values at 72 HAT (0.21 mg/cm^2). The chi-square values were insignificant at 5% level of probability of different weed extracts at different HAT and mortality data did not show any heterogeneity.

From the above probit results it was observed that all the tested weed extracts were more or less effective but wild capsicum was the most effective for controlling maize weevil. The lowest LD_{50} values of wild capsicum extract indicated that the highest toxic effects against maize weevil.

Table 5: Probit analysis of different weed extracts against *S. zeamais* at indicated HAT

Weed extracts used	No. of insect used	LD 50 values (mg/cm^2)	95% confidence limits		χ^2 values
			Lower	Upper	
		24 HAT			
Water hyacinth	120	8.13	2.35	28.10	0.42
Swamp smartweed	120	5.72	2.61	12.54	2.80
Ariach	120	18.64	1.46	238.10	0.88
Wild capsicum	120	1.34	1.00	1.79	0.43
Hill glory bower	120	15.84	1.67	150.42	0.49
		48 HAT			
Water hyacinth	120	2.25	1.75	2.89	1.47
Swamp smartweed	120	2.94	1.99	4.36	1.87
Ariach	120	3.47	2.12	5.69	0.96
Wild Capsicum	120	1.34	1.00	1.79	0.43
Hill glory bower	120	5.59	2.45	12.75	0.29
		72 HAT			
Water hyacinth	120	1.44	1.13	1.85	0.59
Swamp smartweed	120	0.92	0.70	1.19	0.90
Ariach	120	1.15	0.90	1.47	1.41
Wild Capsicum	120	0.21	0.05	0.82	0.38
Hill glory bower	120	1.10	0.87	1.39	1.27

HAT = Hours after treatment

Values were based on five concentrations, three replications of 10 insects each.

χ^2 = Goodness of fit

4.4 Probit analysis of chemical insecticide (lambda cyhalothrin) against the adult of *S. zeamais* for direct toxic effect

The probit analysis was done for the estimation of LD_{50} values, chi-square values and their 95% confidence limits at 24, 48 and 72 HAT for the mortality of maize weevil and is presented in Table 6. The LD_{50} values of lambda-cyhalothrin for 24 HAT (0.442 mg/cm^2), 48 HAT (0.0299 mg/cm^2) and 72 HAT (0.0027 mg/cm^2) indicated that, the highest toxicity occurred at 72 HAT. The chi-square values were insignificant at 5% level of probability at different HAT and mortality data did not show any heterogeneity. The lowest LD_{50} values of lambda-cyhalothrin indicated that the highest toxic effects against maize weevil.

Table 6: Probit analysis of lambda cyhalothrin against *S. zeamais* at indicated HAT

Insecticide used	No. of insect used	LD_{50} values (mg/cm^2)	95% confidence limits		χ^2 values
			Lower	Upper	
		24 HAT			
Lambda-cyhalothrin	90	0.442	0.02	0.790	0.151
		48 HAT			
Lambda-cyhalothrin	90	0.0299	0.00151	0.591	0.711
		72 HAT			
Lambda-cyhalothrin	90	0.0027	0.00000654	0.11	0.391

HAT = Hours after treatment

Values were based on three concentrations, three replications of 10 insects each.

χ^2 = Goodness of fit

4.5 Probit regression lines for weed extracts

The probit regression lines for the bioefficacy of five indigenous weed extracts (water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower) against maize weevil at 24, 48 and 72 HATs are presented in figures 1-3. The calculated probit regression equation lines of different weed extracts against maize weevil at 24 HAT were Y= -0.416x+4.765, Y= -0.492x+4.86, Y= -0.319x+4.25, Y= -0.482x+6.2, Y= -0.339x+4.35 for water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower, respectively. Among the five lines, the regression line for wild capsicum weed extract showed the highest probit mortality while hill glory bower weed extract showed the lowest. The probit regression lines for five weed extracts against maize weevil at 48 HAT are given in figure 2. The regression equations were Y= -0.664x+6.055, Y= -0.61x+5.76, Y= -0.551x+5.525, Y= -0.482x+6.2, Y= -0.482x+5.05 for water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower extracts, respectively. Comparing among the five weed extracts at 48 HAT for probit mortality, wild capsicum weed extract showed the highest probit mortality whereas hill glory bower weed extract showed the lowest. Wild capsicum weed extract was also maintained its highest probit mortality when the probit regression lines were compared at 72 HAT (Figure 3).

The insect mortality rate showed positive correlation with the doses in all treatments. The probit regression lines of five weed extracts showed a clear linear relationship between probit mortality and their log doses and the regression lines become sleeper as doses increased, because the adult insects were treated with more toxins for the same period at higher doses.

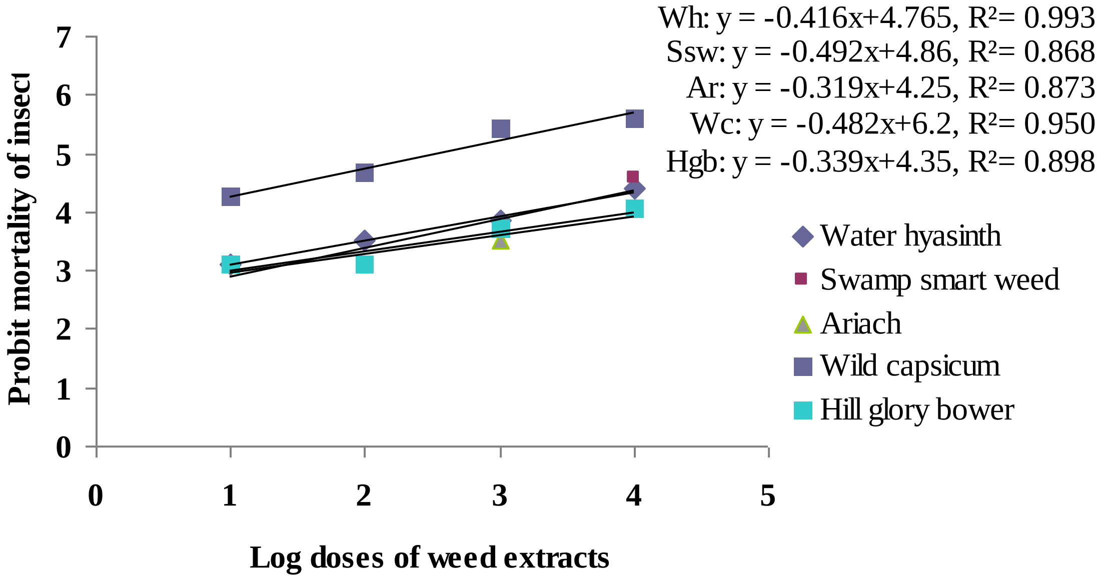


Fig. 1. Relationship between probit mortality and log doses of different weed extracts on *S. zeamais* at 24 HAT

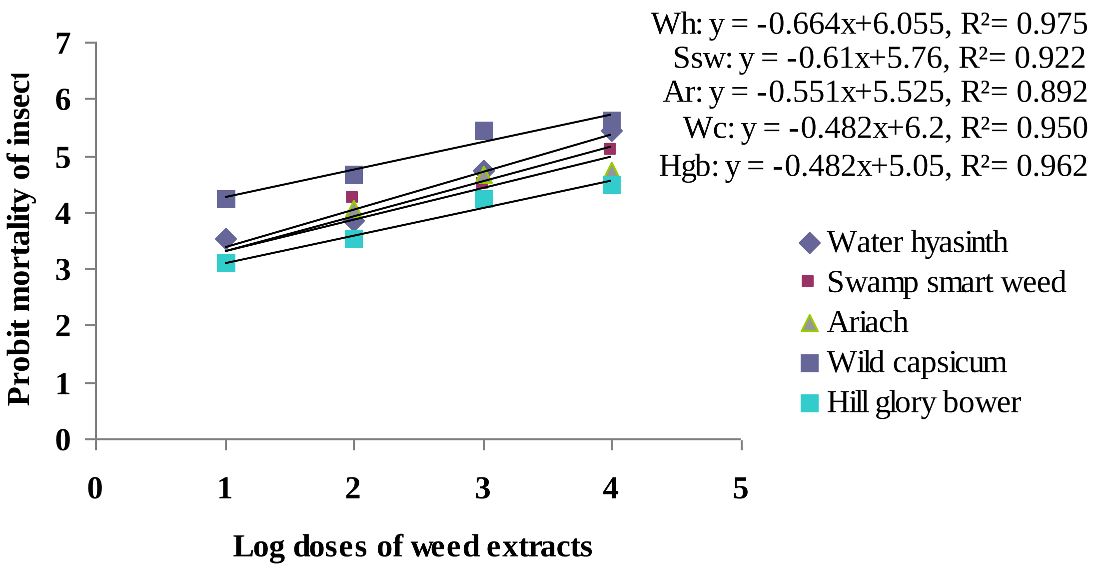


Fig. 2. Relationship between probit mortality and log doses of different weed extracts on *S. zeamais* at 48 HAT

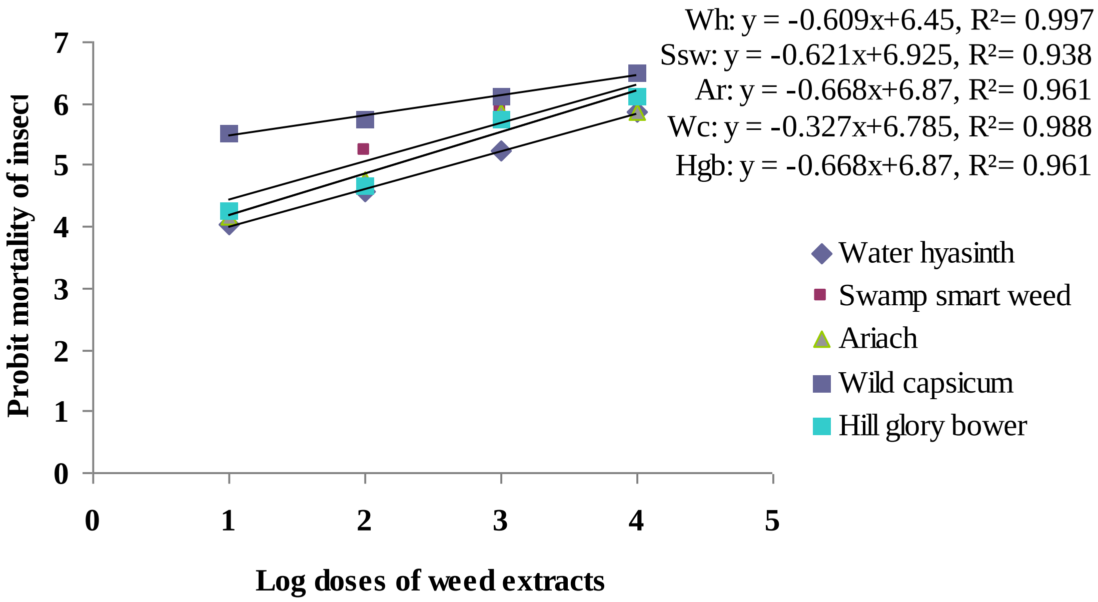


Fig. 3. Relationship between probit mortality and log doses of different weed extracts on *S. zeamais* at 72 HAT

4.6 Probit regression lines for lambda cyhalothrin

The probit regression lines for the insecticide lambda-cyhalothrin against maize weevil at 24, 48 and 72 HAT are presented in figures 1, 2 and 3. The calculated probit regression equation lines for the bioefficacy of different plant extracts against maize weevil at 24 HAT were Y= 4.265+1.148X, 48 HAT were Y= 5.243+0.526 X and 72 HAT were Y= 5.842+0.470X.

The insect mortality rate showed positive correlation with the doses in all treatments. The probit regression lines of insecticide lambda-cyhalothrin showed a clear linear relationship between probit mortality and its log doses and the regression line become sleeper as doses increased, because the adult insects were treated with more toxins for the same period at higher doses.

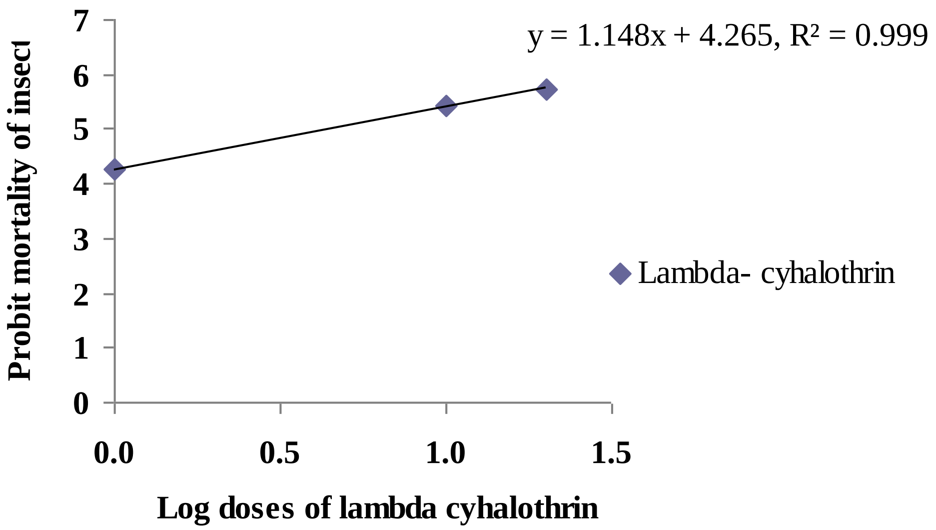


Fig.4. Relationship between probit mortality and log doses of lambda-cyhalothrin at different doses on *S. zeamais* at 24 HAT

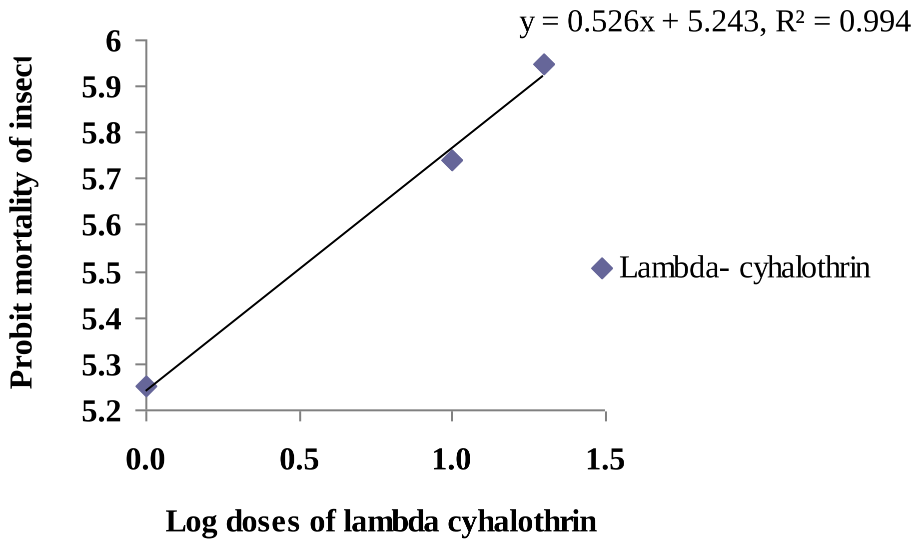


Fig. 5. Relationship between probit mortality and log doses of lambda-cyhalothrin at different doses on *S. zeamais* at 48 HAT

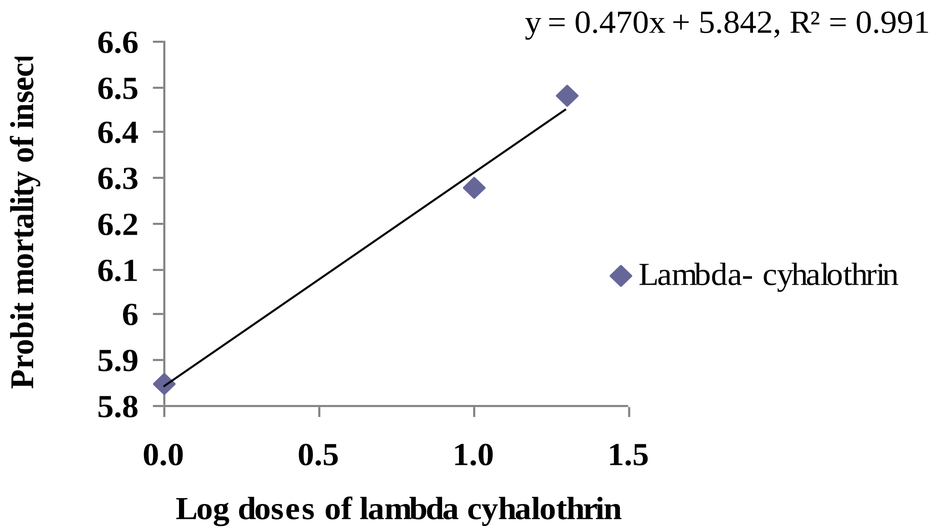


Fig.6. Relationship between probit mortality and log doses of lambda-cyhalothrin at different doses on *S. zeamais* at 72 HAT

4.7 Residual effects of pesticides against maize weevil

4.7.1 (a) Adult emergence and inhibition against *S. zeamais* treated with different weed extracts

The result of residual toxic effects of water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower weed extracts on maize weevil, *Sitophilus zeamais* at different days after treatment (DAT) are presented in Tables 7-9. The average numbers of adult emergence not statistically different among the weed extracts (Table 7). Among the treatments, the lowest numbers of adult emergence was found in wild capsicum (20.05±4.77) while the highest from ariach (25.51±4.28). The highest inhibition was found in wild capsicum (78.60±3.42%) but the lowest in ariach (65.94±4.55%) (Table 7). The highest number of adult emergence is in control (54.00±1.15). Among the doses the lowest (5.67±0.62) adult emergence was recorded at 3% while the highest (23.60±1.13) at 0.5% (Table 8). The highest (94.44±0.72) inhibition of adult emergence was found in wild capsicum at 3% dose on the other hand the lowest in ariach (43.42±3.52) at 0.5% dose (Table 9). The average adult emergence and the percentage of infestation inhibition among all the weed extracts in all level of concentrations were statistically significant.

Considering the interaction of weed extracts, doses and time, wild capsicum extract possessed the highest residual effect followed by swamp smartweed, water hyacinth and hill glory bower extracts against maize weevil at maximum dose.

The results of present study are more or less similar to that of Bbosa (2014). From the maize-amaranth experiment, he concluded that blending maize with amaranth during storage reduced maize weevil population growth by 46% compared to storing maize alone.

Table 7: Residual toxicity on adult emergence and inhibition against *S. zeamais* treated with different weed extracts at different DAT

Weed extracts used	Mean number of adult emergence (DAT)			Average	IR (%)
	40 DAT	47 DAT	54 DAT		
Water hyacinth	17.13±4.51bc	22.33±4.55 b	30.40±4.39 ab	23.29±4.45 b	71.09±3.97 c
Swamp smartweed	16.53±4.57 c	21.93±4.48 b	29.53±4.56 b	22.67±4.49bc	72.53±3.78 bc
Ariach	19.13±4.26 a	25.33±4.29 a	32.07±4.48 a	25.51±4.28 a	65.94±4.55 d
Wild capsicum	16.67±4.58 c	19.80±4.76 c	23.67±4.99 c	20.05±4.77 d	78.60±3.42 a
Hill glory bower	18.00±4.42ab	21.87±4.53 b	25.27±4.73 c	21.71± 4.55 c	74.74±3.36 b
LSD	1.21	1.43	1.86	1.25	2.49
CV %	9.43	8.78	8.99	7.54	4.15

DAT= Days after treatment

Table 8: Residual toxicity on adult emergence and inhibition against *S. zeamais* treated with different doses of weed extracts at different DAT

Doses (%)	Mean number of adult emergence (DAT)			Average	IR (%)
	40 DAT	47 DAT	54 DAT		
0.5	16.00±0.70 b	23.60±1.25 b	31.20±1.86 b	23.60±1.13 b	56.29±2.097d
1.0	11.47±0.35 c	16.67±0.44 c	25.00±1.26 c	17.71±0.58 c	67.20±1.07 c
2.0	7.13±0.45 d	11.80±0.66 d	17.80±1.196 d	12.25±0.64 d	77.32±1.19 b
3.0	3.20±0.61 e	5.53±0.63 e	8.27±0.75 e	5.667±0.62 e	89.50±1.15 a
Control	49.67±0.45 a	53.67±0.55 a	58.67±0.50 a	54.00±0.44 a	-
LSD	1.21	1.43	1.86	1.25	2.223
CV %	9.43	8.78	8.99	7.54	4.15

DAT = Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 9: Combined residual toxicity on adult emergence and inhibition against *S. zeamais* treated with weed extracts and doses at different DAT

Weed extracts used	Doses (%)	Mean number of adult emergence (DAT)			Average	IR (%)
		40 DAT	47 DAT	54 DAT		
Water hyacinth	0.5	15.00±1.15 c	24.67±1.45 c	33.67±1.20 c	24.45±0.399 c	54.73±0.74 g
	1.0	11.67±1.20 de	16.67±0.88 f	28.00±1.53 ef	18.78±0.99 e	65.22 ±1.83 e
	2.0	7.00±1.15 g	12.00±1.15 ghi	22.67±1.45 gh	13.89±1.25 fgh	74.28±2.31cd
	3.0	2.33±0.33 i	4.67±0.33 k	9.00±0.58 kl	5.33±0.33j	90.12±0.62 a
Swamp smartweed	0.5	13.67±0.88 cd	21.00±0.58 de	32.67±1.45 cd	22.44±0.68 c	58.44±1.25g
	1.0	11.33±0.67 de	17.67±0.33 ef	29.33±1.20cde	19.44±0.29 de	63.99±0.54ef
	2.0	6.00±0.58 gh	11.67±0.88 hi	19.33±0.88 hi	12.33±0.69 gh	77.16±1.28 c
	3.0	2.00±0.58 i	5.67±1.20 jk	7.67±1.45 kl	5.11±0.95 j	90.53±1.76 a
Ariach	0.5	19.33±0.88 b	31.33±0.88 b	41.00±4.04 b	30.55±1.89 b	43.42±3.52 h
	1.0	12.00±0.58 de	17.67±1.45 ef	28.33±1.45 de	19.33±1.07 de	64.19±1.98 ef
	2.0	7.67±1.45 fg	15.00±1.53 fgh	20.67±1.76 gh	14.45±1.35 fgh	73.25±2.51cd
	3.0	7.00±0.58 g	9.00 ±1.15 ij	11.67±2.33 jk	9.223±1.35 i	82.92±2.51 b
Wild capsicum	0.5	14.00± 1.15 cd	18.33±1.20 ef	23.67±0.67fgh	18.67±0.84 e	65.43±1.56 e
	1.0	12.00±0.58 de	15.33±0.88 fg	19.67±0.88 hi	15.67±0.58 f	70.98±1.07 d
	2.0	6.67±0.88 g	9.00±0.58 ij	11.00±0.58 jk	8.89±0.40 i	83.53±0.74 b
	3.0	1.00±0.00 i	2.667±0.33 k	5.33±0.88 l	3.00±0.39 j	94.44±0.72 a
Hill glory bower	0.5	18.00±0.58 b	22.67±1.45 cd	25.00±1.15 efg	21.89±1.06 cd	59.46±1.96 fg
	1.0	10.33±0.88 ef	16.00±1.00 f	19.67±0.88 hi	15.33±0.88 fg	71.60±1.63 d
	2.0	8.33±0.88 fg	11.33±1.20 i	15.33±0.67 ij	11.67±0.88 hi	78.39±1.63 bc
	3.0	3.67±1.20 hi	5.67±0.67 jk	7.67±0.33 kl	5.67±0.67 j	89.50±1.24 a
	Contro	49.67±1.20 a	53.67±1.45 a	58.67±1.33 a	54.00±1.15 a	-
LSD		2.70	3.20	4.16	2.80	4.97
CV %		9.43	8.78	8.99	7.54	4.15

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5 % level of probability.

4.7.1 (b) Adult emergence and inhibition against *S. zeamais* treated with lambda cyhalothrin

The result of residual toxic effect of lambda cyhalothrin against *S. zeamais* at different days after treatment (DAT) is presented in Table 10. Adult emergence inhibited 100±0.00% in the treated corn at the dose level of 0.2% and 0.1%. A lower number of adult emerged at the dose level 0.01% which indicated 97.94±0.55% inhibition.

The introduced adult maize weevils were not able to lay their eggs on the corn grains. While escaping maize weevils 7 days after introduction, it was found that all insects died due to contact toxicity of lambda cyhalothrin.

The results of present study are almost similar to that of Parugrug M. L. and Roxas A. C (2008). They conducted an experiment against maize weevil with five plants extracts and carbaryl (a synthetic insecticide). From their result, antioviposition action of the tested materials provided 100% insect survival in all treatments except carbaryl. The introduced adult maize weevils were not able to lay their eggs on the corn grains because a day after insect introduction, all insects died due to contact toxicity of carbaryl.

Table 10: Residual toxicity on adult emergence and inhibition against *S. zeamais* treated with different doses of lambda cyhalothrin at different DAT

Doses	Mean number of adult emergence (DAT)			Average	IR (%)
(%)	40 DAT	47 DAT	54 DAT		
0.01	0.67±0.33 a	1.33±0.33 a	1.33±0.33 a	1.11±0.29 a	97.94±0.55 b
0.1	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	100.0±0.00 a
0.2	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	100.0±0.00 a
Control	49.67±0.45 a	53.67±0.55 a	58.67±0.50 a	54.00±0.44 a	-
LSD	0.67	0.67	0.67	0.59	1.098
CV %	150.00	75.00	75.00	79.27	0.55

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.7.2 (a) Seed damage and inhibition against *S. zeamais* treated with different weed extracts

The result of seed damage inhibition effects of water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower weed extracts on *Sitophilus zeamais* at different days after treatment (DAT) are presented in Tables 11-13. The average numbers of adult emergence were not statistically different among the weed extracts (Table 11). The lowest average numbers of seed damage was found in wild capsicum (16.40±3.86) whiles the highest from ariach (21.42±3.41). The highest damage inhibition was found in wild capsicum (78.40±3.20%) but the lowest damage inhibition was found in ariach (64.35±4.41%) (Table 11).The highest number of seed damage is in control (44.00±0.44). Damage inhibition was highest (88.23±1.15) at the dose level of 3% while lowest (57.64±2.23) at the dose level of 0.5% followed by at the dose level of 1% and 2% (Table 12) .The interaction seed damage inhibition effects of weed and dose is shown in (table 13). The highest mean seed damage effect was found on 0.5% dose of ariach extract (25.67±1.17) where as the lowest mean seed damage effect was found on 3% dose of wild capsicum (3.00±0.39) (Table 13). The average seed damage and the percentage of seed damage inhibition among all the weed extracts in all level of concentrations were statistically significant.

Considering the interaction of weed extracts, doses and time, wild capsicum extract possessed the highest seed damage inhibition effect followed by swamp smartweed, water hyacinth and hill glory bower extracts against maize weevil at maximum dose.

Table 11: Residual toxicity on seed damage and inhibition against *S. zeamais* treated with different weed extracts at different DAT

Weed extracts used	Mean number of seed damage (DAT)			Average	DI (%)
	40 DAT	47 DAT	54 DAT		
Water hyacinth	14.47±3.63bc	17.87±3.73 b	22.73±3.61 b	18.35±3.64 b	72.85±3.48 c
Swamp smartweed	13.60±3.74 c	17.73±3.69 b	21.27±3.77 bc	17.53±3.72 b	75.18±3.26 b
Ariach	16.33±3.38 a	21.40±3.43 a	26.53±3.60 a	21.42±3.41 a	64.35±4.41 d
Wild capsicum	13.67±3.74 c	16.20±3.88 c	19.33±3.97 d	16.40±3.86 c	78.40±3.20 a
Hill glory bower	15.07±3.56 b	18.20±3.64 b	20.73±3.74 cd	18.00±3.64 b	73.86±3.07bc
LSD	0.91	1.11	1.49	0.99	2.02
CV %	8.47	8.28	9.19	7.35	3.36

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 12: Residual toxicity on seed damage and inhibition against *S. zeamais* treated with different doses of weed extracts at different DAT

Doses (%)	Mean number of seed damage (DAT)			Average	DI (%)
	40 DAT	47 DAT	54 DAT		
0.5	12.93±0.51 b	18.93±1.07 b	24.27±1.66 b	18.71±1.0 b	57.64±2.23 d
1.0	10.27±0.34 c	13.73±0.49 c	17.87±0.72 c	13.96±0.44 c	68.28±0.99 c
2.0	6.33±0.42 d	9.67±0.52 d	13.60±0.77 d	9.87±0.51 d	77.57±1.17 b
3.0	2.93±0.53 e	5.07±0.52 e	7.53±0.57 e	5.18±0.51 e	88.23±1.15 a
Control	40.67±0.25 a	44.00±0.44 a	47.33±0.67 a	44.00±0.44 a	-
LSD	0.91	1.11	1.49	0.99	1.81
CV %	8.47	8.28	9.19	7.35	3.36

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 13: Combined residual toxicity on seed damage and inhibition against *S. zeamais* treated with weed extracts and doses at different DAT

Weed extracts used	Doses (%)	Mean number of seed damage (DAT)			Average	DI (%)
		40 DAT	47 DAT	54 DAT		
Water hyacinth	0.5	12.33±0.88 cd	18.67±1.33 c	24.67±1.20 c	18.55±0.39c	57.83±0.91i
	1.0	10.33±0.88 def	13.33±0.67fg	18.67±0.67defg	14.11±0.62e	67.93±1.40fg
	2.0	6.67±0.88 hi	9.00±0.58 hi	15.00±0.58 ghi	10.22±0.67 f	76.77 ±1.53e
	3.0	2.33±0.33 kl	4.33±0.33 kl	8.00±0.58 klm	4.89±0.11 ij	88.88±0.25b
Swamp smartweed	0.5	11.67±0.88 de	17.00±0.58 cd	21.67±0.88cde	16.78±0.48 cd	61.86±1.10 hi
	1.0	9.00±0.58 fg	13.33±0.67 fg	18.00±0.58efgh	13.44±0.11e	69.44±0.26 fg
	2.0	5.00±0.58 ij	9.67±0.88 hi	13.00±0.58 ij	9.22±0.62 fg	79.03±1.41cde
	3.0	1.67±0.33 kl	4.67±0.88 kl	6.33±0.88 lm	4.22±0.58 ij	90.40±1.34 ab
Ariach	0.5	15.33±0.88 b	26.00±0.58 b	35.67±2.18 b	25.67±1.17b	42.49±1.84 j
	1.0	11.67±0.33 de	16.33±0.88cde	22.00±1.15 cd	16.67±0.77cd	62.12±1.75hi
	2.0	7.67±1.45 gh	12.67±1.20 fg	17.33±1.45fgh	12.55 ±1.18 e	71.47±2.67f
	3.0	6.33±0.33 hi	8.00±0.58 ij	10.33± 1.45 jk	8.22±0.78 fg	81.31±1.77cd
Wild capsicum	0.5	11.33±0.88 de	15.00±0.58 def	18.67±0.67defg	15.00±0.51de	65.90±1.16 gh
	1.0	10.00±0.58 ef	11.67±0.88 gh	16.00±0.58 ghi	12.56±0.48e	71.46±1.09 f
	2.0	5.33±0.33 ij	7.67±0.33 ij	9.33±0.33 kl	7.47±0.22gh	83.07±0.51 c
	3.0	1.00 ±0.00 l	2.67±0.33 l	5.33±0.88 m	3.00±0.38 j	93.18±0.88 a
Hill glory bower	0.5	14.00± 0.58 bc	18.00±1.53 c	20.67±1.20 def	17.56±1.06c	60.10±2.40 i
	1.0	10.33±0.88 def	14.00±0.58 efg	14.67±0.33 hi	13.00±0.51e	70.45±1.16 f
	2.0	7.00±0.58 ghi	9.33±0. 33 hi	13.33±0.67 ij	9.89±0.40 f	77.52±0.91 de
	3.0	3.33±0.88 jk	5.67± 0.67 jk	7.67±0.33 klm	5.57±0.56 hi	87.37±1.26 b
	Control	40.67±0.67 a	44.00±1.15 a	47.33±1.76 a	44.00±1.15a	-
LSD		2.031	2.48	3.34	2.21	4.05
CV %		8.47	8.28	9.19	7.35	3.36

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.7.2 (b) Seed Damage and Inhibition against *S. zeamais* treated with lambda cyhalothrin

The results of residual toxic effects of lambda cyhalothrin for seed damage inhibition effect on maize weevil are presented in Tables 14. Damage inhibition was similar to the adult emergence inhibition rate i.e. 100±0.00% seed damage inhibition occurred at 0.2 and 0.1% doses whereas 97.47±0.67% occurred at 0.01% dose.

Table 14: Residual toxicity effect on seed damage and inhibition against *S. zeamais* treated with different doses of lambda cyhalothrin at different DAT

Doses	Mean number of seed damage (DAT)			Average	% DI
(%)	40 DAT	47 DAT	54 DAT		
0.01	0.67±0.33 a	1.33±0.33 a	1.33±0.33 a	1.11± 0.29 a	97.47±0.67 b
0.1	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	100.0±0.00 a
0.2	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	100.0 ±0.00 a
Control	40.67±0.25 a	44.00±0.44 a	47.33±0.67 a	44.00±0.44 a	-
LSD	0.67	0.67	0.67	0.59	1.34
CV %	150.00	75.00	75.00	79.27	0.68

DAT= Days after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.8 Repellent effect of different weed extracts against the adult of *S. zeamais*

The repellency effect of five indigenous weed extracts on maize weevil is presented in Table 15. Water hyacinth, swamp smartweed, ariach, wild capsicum and hill glory bower extracts showed different repellent effects against maize weevil. Among the five indigenous weed extracts tested, hill glory bower showed the highest mean repellent effect (41.50±5.39%) whereas swamp smartweed showed the lowest mean repellent effect (26.33±5.84%). On the basis of repellency rate, it was found that hill glory bower extract showed the highest repellency class i.e. class III and the remaining weed extracts were in the same class i.e. class II.

However, these differences were statistically significant. In some cases, repellency rate decreased which depends on with the progress of time. The rate of repellency always differed with the extract type. Repellency rate did not increase uniformly with the doses. The highest (51.33±4.39%) repellency was found with 3% dose extract but the lowest (16.53±1.95%) at 0.5% (Table 16). Interaction repellent effects of different weed extracts and their doses on maize weevil at different HAT are presented in (Table 17). From the data it was found that repellency rate did not increase proportionally with the doses. However, the highest (66.00±3.06%) repellency was found on 3.0% dose of hill glory bower extract whereas the lowest (9.33±1.33%) on 0.5% of swamp smartweed extract (Table 17). The repellency class of different weed extracts at different concentration level varied between I to IV.

The study of repellent effect of weed extracts was also agreed by the observation of Waliullah *et al*. (2014). The repellent activity was done using ethyl alcohol fraction of *Clerodendrum viscosum.* All the extracts (root, leaf and stem) showed 100% repellency (class V category repellency) in dose no 1 to dose no 5 except stem. The degree of repellency response among the three parts against test insect was significantly different ($P < 0.05$).

Table 15: Repellent effect of different weed extracts against *S. zeamais* using treated and untreated filter paper at different HAT

Weed extracts used	Repellency rate %					% Mean repell.	Repell. classes
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
Water hyacinth	23.3±4.8 ab	23.3±8.5ab	30.0±6.7 ab	38.3±7.9 ab	50.0±6.7 a	33.0±5.3ab	II
Swamp smartweed	15.0±5.6 b	28.3±7.9 ab	26.7±7.5 ab	26.7±5.7 b	35.0±8.6 ab	26.3±5.8 b	II
Ariach	23.3±9.5 ab	31.7±8.3 a	41.7±7.6 a	40.0±8.2 ab	20.0±6.9 b	31.3±4.8 b	II
Wild capsicum	31.7±9.9 ab	13.3±4.5 b	21.7±6.7 b	31.7±5.2 b	43.3±8.8 a	28.3±3.2 b	II
Hill glory bower	38.3±8.3 a	39.2±7.2 a	43.3±5.4 a	53.3±9.9 a	33.3±6.7 ab	41.5±5.4 a	III
LSD	19.98	16.05	15.66	15.66	17.57	8.55	
CV %	91.98	71.60	58.08	49.93	58.60	32.26	

HAT= Hours after treatment
Mean followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table16: Repellent effect of different weed extracts of different doses against *S. zeamais* using treated and untreated filter paper at different HAT

Doses %	Repellency rate %					% Mean repell.	Repell. classes
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
0.5	13.3±2.5b	12.0±3.3 c	17.3±5.5c	18.7±4.6c	21.3±4.6b	16.5±1.9 d	I
1.0	17.3±6.4 b	13.3±4.6 c	30.7±5.5bc	32.0±5.8bc	30.7±6.4 b	24.8±2.8 c	II
2.0	37.3±8.9 a	29.3±4.7 b	36.0±5.6ab	38.7±5.3b	37.3±8.2 b	35.7±2.6 b	II
3.0	37.3±7.3 a	54.0±7.7 a	46.7±6.7a	62.7±7.0a	56.0±5.9 a	51.3±4.4 a	III
LSD	17.88	14.35	14.00	14.00	15.71	7.64	
CV %	91.98	71.60	58.08	49.93	58.60	32.26	

HAT= Hours after treatment

Mean followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 17: Repellent effect of different weed extracts at different doses against *S. zeamais* using treated and untreated filter paper at different HAT

Weed extracts used	Doses %	Repellency rate %					% Mean repell.	Repell. Classes
		1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
Water hyacinth	0.5	13.3±6.7bcd	13.3±13.3cd	6.7±6. 7d	20.0±11.5cde	26.7±6.7bcd	16.0±4.6fg	I
	1.0	13.3±6.7bcd	6.7±6.7d	40.0±11.5a-d	13.3±6.7de	33.3±6.7a-d	21.3±1.3d-g	II
	2.0	33.3±6.7bcd	13.3±6.7cd	20.0±11.5bcd	53.3±6.7bc	73.3± 6.7a	38.7±5.8b-e	II
	3.0	33.3±13.3bcd	60.0±20.0ab	53.3±6.7ab	66.7±13.3ab	66.7±6.7ab	56.0±8.0ab	III
Swamp smartweed	0.5	6.7±6.7cd	6.7±6.7 d	6.7±6.7d	13.3±6.7de	13.3±6.7cd	9.3±1.3g	I
	1.0	6.7±6.7cd	6.7±6.7 d	13.3±6.7cd	6.7±6.7e	26.7±13.3bcd	12.0±2.3fg	I
	2.0	6.7±6.7cd	33.3±6.7a-d	33.3±13.3a-d	40.0±0.0b-e	33.3±24.0a-d	29.3±4.8c-g	II
	3.0	40.0±11.5a-d	66.7±6.7a	53.3±17.6ab	46.7±6.7bcd	66.7±6.7ab	54.7±8.1ab	III
Ariach	0.5	13.3±6.7bcd	6.7±6.7d	40.0±11.5 a-d	26.7±6.7cde	6.7±6.7 d	18.7±4.8efg	I
	1.0	0.0±0.0d	20.0±11.5cd	40.0±11.5a-d	33.3±6.7b-e	40.0±20.0a-d	26.7±7.1d-g	II
	2.0	53.3±29.1abc	40.0±0.0a-d	20.0±11.5bcd	33.3±176 b-e	13.3±13.3cd	32.0±4.0c-f	II
	3.0	26.7±17.6a-d	60.0±23.1ab	66.7±17.6a	66.7±24.0ab	20.0±11.5cd	48.0±14.0abc	III
Wild capsicum	0.5	20.0±0.0bcd	13.3±6.7cd	6.7±6.7d	13.3±6.7de	33.3±17.6 a-d	17.3±3.5fg	I
	1.0	33.3±24.0a-d	6.67±6.67d	13.3±13.3cd	53.3±6.7bc	13.3±13.3cd	24.0±0.0d-g	II
	2.0	60.0±30.5ab	13.3±13.3cd	53.3±6.7ab	20.0±0.0cde	53.3±13.3abc	40.0±6.9bcd	II
	3.0	13.3±6.7bcd	20.0±11.55cd	13.3±6.7cd	40.0±0.0b-e	73.3±6.7a	32.0±4.6c-f	II
Hill glory bower	0.5	13.3±6.7bcd	20.0±0.0cd	26.7±17.6bcd	20.0±20.0cde	26.7±6.7bcd	21.3±5.8d-g	II
	1.0	33.3±17.6a-d	26.7±17.6bcd	46.7±6.7abc	53.3±6.7bc	40.0±20.0a-d	40.0±4.6 bcd	II
	2.0	33.3±6.7a-d	46.7±6.7abc	53.3±6.7ab	46.7±17.6bcd	13.3±6.7cd	38.7±8.1b-e	II
	3.0	73.3±13.3a	63.3±14.5ab	46.7±6.7abc	93.3±6.7a	53.3±6.7abc	66.0±3.1a	IV
LSD		39.97	32.10	31.31	31.31	35.14	17.09	
CV %		91.98	71.60	58.08	49.93	58.60	32.26	

HAT = Hours after treatment

Mean followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.9 Repellent effect of lambda cyhalothrin against the adult of *S. zeamais*

Mean repellent effect of lambda cyhalothrin in different dose level on maize weevils was also presented in Table 18. Repellency rate did not increase uniformly with the doses. The highest (41.33%) mean repellency was found with 0.1% dose of lambda cyhalothrin but the lowest (38.67%) mean repellency was found with 0.2% dose (Table 18). Repellency class at different dose level varied between class II and III.

Table18: Repellent effect of lambda cyhalothrin at different doses against *S. zeamais* using treated and untreated filter paper at different HAT

Doses %	Repellency rate %					% Mean repell.	Repell. classes
	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT		
0.01	46.67±13.33 a	26.67±6.67 a	33.33±13.33 a	40.00±11.55 a	53.33±6.67 a	40.00±6.93 a	II
0.1	33.33±24.04 a	40.00±11.55 a	26.67±13.33 a	46.67±29.06 a	60.00±0.00 a	41.33±4.81 a	III
0.2	33.33±0.67 a	26.67±13.33 a	40.00±11.55 a	53.33±13.33 a	40.00±0.00 b	38.67±5.81 a	II
LSD	56.51	37.67	44.18	67.92	13.32	20.46	
CV %	74.87	60.61	66.33	72.84	13.04	25.60	

HAT = Hours after treatment

Mean followed by the same letter(s) did not differ significantly at 5% level of probability by DMRT.

CHAPTER- V

SUMMARY AND CONCLUSION

The experiment was carried out in the laboratories of the Departments of Entomology and Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during May to December 2017 for the management of maize weevil through indigenous weed extracts, namely, water hyacinth (*Eichhornia crassipes*), swamp smartweed (*Polygonum coccineum*), ariach (*Cassia tora*), wild capsicum (*Croton bonplandianum*), hill glory bower (*Clerodendrum viscosum*) and an insecticide lambda cyhalothrin. Hexane solvent was used with the weed extracts at 4 concentrations viz. 0.5, 1.0, 2.0 and 3.0% w/v while lambda cyhalothrin at 3 concentrations viz. 0.01, 0.1 and 0.2% w/v along with a control were used for their toxicity, residual and repellent effects against *Sitophilus zeamais* Motsch.

Average mortality percentage of maize weevil at 24, 48 and 72 HAT indicated that wild capsicum weed extract possessed the highest (53.33±7.90%) toxic effect among all the weed extracts whereas hill glory bower showed the lowest toxicity effect (21.35±4.59%). Mortality percentage was also found directly proportional to the hours after treatment. The order of the toxicity of the weed extracts were wild capsicum > swamp smartweed > water hyacinth > ariach > hill glory bower. On the other hand lambda cyhalothrin showed the highest average mortality (84.44±2.94%) at maximum concentration (0.2%) while the lowest mortality (54.44±4.84%) was found at lower concentration (0.01%).

In the probit analysis the LD_{50} values at 24, 48 and 72 HAT **(**1.34, 1.34 and 0.21 mg/cm^2**)** indicated that wild capsicum extract possessed highest toxic effects. In case of lambda cyhalothrin, LD_{50} values at 24, 48 and 72 HAT (0.442, 0.0299 and 0.0027 mg/cm^2) indicated highest toxic effects against *S. zeamais*. The χ^2 values of different weed extracts at different hours after treatment (HAT) were insignificant at 5% level of probability and did not show any heterogeneity of the mortality.

The weed extracts of water hyacinth, swamp smartweed, ariach, wild capsicum, hill glory bower and an insecticide lambda cyhalothrin possessed residual toxic effect on maize weevil. The lowest average number of adult emergence was observed in wild capsicum (20.05±4.77) while the highest number found in ariach (25.51±4.28). Similarly, the highest infestation inhibition was found in wild capsicum (78. 60±3.42

%) other then the lowest infestation inhibition was observed in ariach (65.94±4.55%). On the other hand, lambda cyhalothrin treated corn showed zero adult emergence i.e. 100±0.00% inhibition at the dose level 0.2% and 0.1% moreover 97.94 ±0.55% inhibition occurred at the dose level 0.01%. In the same case, seed damage inhibition effects among five weed extracts wild capsicum showed the highest (78.40±3.20%) inhibition where as the lowest in ariach (64.35±4.41%). The insecticide lambda cyhalothrin showed 100±0.00% damage inhibition at the dose level of 0.2% and 0.1%.

The highest mean repellency was observed in hill glory bower weed extract (41.50±5.39%) while swamp smartweed extract is the lowest (26.33±5.84%). Repellency rate did not increase uniformly with the doses and exposure period. The repellency class of different weed extracts at different concentration level varied between I to IV. In case of lambda cyhalothrin the highest mean repellency effect (41.33±4.81%) was found with 0.1% dose. Repellency rate did not increase uniformly with the doses. Repellency class at different dose level varied between Class II and III.

From the above study we find that the weed extracts of water hyacinth, swamp smartweed, ariach, wild capsicum, hill glory bower and lambda cyhalothrin were effective against the maize weevil. The uses of this botanical pesticide have a great economic and environmental importance also. Because the preparation cost of this botanical pesticides is comparatively low and environmentally safe than the chemical insecticide. For this reason the botanical extracts can be used as insecticides and it will benefit our agricultural sector. In this study the tested weed extracts had direct toxic, repellent and residual toxic effect against maize weevil as well as other stored product pests also. Among the five weed extracts wild capsicum showed the highest toxic and residual effects while hill glory bower showed the highest repellent effect against maize weevil. So we can use botanical materials as insecticides.

The findings of the present investigation reveal the broad spectrum toxic properties of the tested indigenous weed extracts against the adult of *S. zeamais.* However, further studies need to be conducted to isolate and evaluate the compound with its mode of action of these botanicals.

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APPENDICES

Appendix table 1: Doses mortality data of *S. zeamais* Motsch adult treated with water hyacinth weed extract in hexane solvent at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	8	26.67	27	4.39	4.277	4.388	15.09	4.296
2	1.301	30	4	13.33	13	3.87	4.005	3.873	13.17	4.009
1	1	30	2	6.67	7	3.52	3.541	3.519	8.07	3.520
0.5	0.699	30	1	3.33	3	3.12	3.077	3.135	3.93	3.030

LD-50 is 8.132796 95% confidence limits are 2.35354 to 28.10335

Y = 1.893851 + 1.626052 X χ^2 is 0 .4164457 with 2 df

Appendix table 2: Doses mortality data of *S. zeamais* Motsch adult treated with water hyacinth weed extract in hexane solvent at 48 HAT.

Dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	20	66.66	67	5.44	5.278	5.462	18.81	5.332
2	1.301	30	12	40	40	4.75	4.844	4.760	18.81	4.866
1	1	30	4	13.33	13	3.87	4.101	3.904	14.13	4.069
0.5	0.699	30	2	6.67	7	3.52	3.356	3.572	6.24	3.271

LD-50 is 2.247335 95% confidence limits are 1.74672 to 2.891426

Y = 1.419973 + 2.6486 X χ^2 is 1.474323 with 2 df

Appendix table 3: Doses mortality data of *S. zeamais* Motsch adult treated with water hyacinth weed extract in hexane solvent at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	24	80	80	5.85	5.742	5.830	15.96	5.720
2	1.301	30	18	60	60	5.25	5.341	5.240	18.48	5.321
1	1	30	10	33.33	33	4.56	4.656	4.551	18.03	4.638
0.5	0.699	30	5	16.67	17	4.05	3.971	4.062	12.15	3.955

LD-50 is 1.444374 95% confidence limits are 1.127347 to 1.850552

Y = 2.37011 + 2.267774 X χ^2 is 0.588007 with 2 df

Appendix table 4: Doses mortality data of *S. zeamais* Motsch adult treated with swamp smartweed extract in hexane solvent at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	10	33.33	33	4.56	4.391	4.586	15.96	4.391
2	1.301	30	3	10	10	3.72	4.009	3.750	13.17	4.008
1	1	30	1	3.33	3	3.12	3.357	3.148	6.24	3.353
0.5	0.699	30	1	3.33	3	3.12	2.705	3.379	2.28	2.698

LD-50 is 5.719706 95% confidence limits are 2.609525 to 12.53677

Y = 1.1783 + 2.174666 X χ^2 is 2.802199 with 2 df

Appendix table 5: Doses mortality data of *S. zeamais* Motsch adult treated with swamp smartweed extract in hexane solvent at 48 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	16	53.33	53	5.08	5.017	5.075	19.11	5.017
2	1.301	30	9	30	30	4.48	4.653	4.470	18.03	4.647
1	1	30	7	23.34	23	4.26	4.030	4.283	13.17	4.015
0.5	0.699	30	1	3.33	3	3.12	3.407	3.180	7.14	3.382

LD-50 is 2.944002 95% confidence limits are 1.985779 to 4.364608

Y = 1.913551 + 2.101143 X χ^2 is 1.869896 with 2 df

Appendix table 6: Doses mortality data of *S. zeamais* Motsch adult treated with swamp smartweed extract in hexane solvent at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	26	86.66	87	6.13	6.227	6.077	11.1	6.198
2	1.301	30	24	80	80	5.85	5.806	5.800	15.09	5.788
1	1	30	18	60	60	5.25	5.088	5.250	19.11	5.088
0.5	0.699	30	7	23.34	23	4.26	4.369	4.266	15.96	4.388

LD-50 is 0.9167339 95% confidence limits are 0.7004102 to 1.19987

Y = 2.761788 + 2.326035 X χ^2 is 0.9022217 with 2 df

Appendix table 7: Doses mortality data of *S. zeamais* Motsch adult treated with ariach weed extract in hexane solvent at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	5	16.67	17	4.05	3.865	4.077	11.10	3.936
2	1.301	30	2	6.67	7	3.52	3.662	3.529	9.06	3.700
1	1	30	1	3.33	3	3.12	3.315	3.148	6.24	3.297
0.5	0.699	30	1	3.33	3	3.12	2.968	3.172	3.30	2.893

LD-50 is 18.64037 95% confidence limits are 1.459289 to 238.1046

Y = 1.956164 + 1.340629 X χ^2 is 0. 8803368 with 2 df

Appendix table 8: Doses mortality data of *S. zeamais* Motsch adult treated with ariach weed extract in hexane solvent at 48 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	12	40	40	4.75	4.861	4.760	18.81	4.876
2	1.301	30	11	36.67	37	4.67	4.525	4.656	17.43	4.534
1	1	30	5	16.67	17	4.05	3.951	4.062	12.15	3.948
0.5	0.699	30	1	3.33	3	3.12	3.376	3.148	6.24	3.362

LD-50 is 3.472679 95% confidence limits are 2.11729 to 5.695723

Y = 2.001415 + 1.946293 X χ^2 is 0.9596911 with 2 df

Appendix table 9: Doses mortality data of *S. zeamais* Motsch adult treated with ariach weed extract in hexane solvent at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	24	80	80	5.85	6.008	5.80	13.17	5.972
2	1.301	30	24	80	80	5.85	5.587	5.78	17.43	5.560
1	1	30	12	40	40	4.75	4.867	4.76	18.81	4.856
0.5	0.699	30	6	20	20	4.16	4.148	4.17	14.13	4.153

LD-50 is 1.151907 95% confidence limits are 0.9002884 to 1.47385

Y = 2.518581 + 2.337835 X χ^2 is 1.410002 with 2 df

Appendix table 10: Doses mortality data of *S. zeamais* Motsch adult treated with wild capsicum weed extract in hexane solvent at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	22	73.34	73	5.61	5.654	5.610	16.74	5.651
2	1.301	30	20	66.66	67	5.44	5.329	5.422	18.48	5.323
1	1	30	11	36.67	37	4.67	4.775	4.662	18.48	4.763
0.5	0.699	30	7	23.34	23	4.26	4.220	4.252	15.09	4.203

LD-50 is 1.34051 95% confidence limits are 1.000435 to 1.795759

Y = 2.902832 + 1.86048 X χ^2 is 0.433754 with 2 df

Appendix table 11: Doses mortality data of *S. zeamais* Motsch adult treated with wild capsicum weed extract in hexane solvent at 48 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	22	73.34	73	5.61	5.654	5.610	16.74	5.651
2	1.301	30	20	66.66	67	5.44	5.329	5.422	18.48	5.323
1	1	30	11	36.67	37	4.67	4.775	4.662	18.48	4.763
0.5	0.699	30	7	23.34	23	4.26	4.220	4.252	15.09	4.203

LD-50 is 1.34051 95% confidence limits are 1.000435 to 1.795759

Y = 2.902832 + 1.86048 X χ^2 is 0.433754 with 2 df

Appendix table 12: Doses mortality data of *S. zeamais* Motsch adult treated with wild capsicum weed extract in hexane solvent at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	28	93.34	93	6.48	6.403	6.491	9.06	6.381
2	1.301	30	26	86.66	87	6.13	6.189	6.132	12.15	6.170
1	1	30	23	76.66	77	5.74	5.822	5.698	15.09	5.809
0.5	0.699	30	21	70	70	5.52	5.456	5.510	18.03	5.448

LD-50 is 0.2117459 95% confidence limits are 0.0546361 to 0.8206354

Y = 4.609247 + 1.199312 X χ^2 is 0.382133 with 2 df

Appendix table 13: Doses mortality data of *S. zeamais* Motsch adult treated with bhat weed extract in hexane solvent at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	5	16.67	17	4.05	3.952	4.062	12.15	4.000
2	1.301	30	3	10	10	3.72	3.731	3.720	10.08	3.757
1	1	30	1	3.33	3	3.12	3.353	3.148	6.24	3.340
0.5	0.699	30	1	3.33	3	3.12	2.975	3.172	3.30	2.924

LD-50 is 15.84452 95% confidence limits are 1.668942 to 150.424

Y = 1.95706 + 1.383231 X χ^2 is 0.4939838 with 2 df

Appendix table 14: Doses mortality data of *S. zeamais* Motsch adult treated with bhat weed extract in hexane solvent at 48 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	9	30	30	4.48	4.502	4.460	17.43	4.504
2	1.301	30	7	23.34	23	4.26	4.179	4.284	14.13	4.181
1	1	30	2	6.67	7	3.52	3.626	3.529	9.06	3.629
0.5	0.699	30	1	3.33	3	3.12	3.073	3.135	3.93	3.077

LD-50 is 5.589574 95% confidence limits are 2.45137 to 12.74526

Y = 1.794934 + 1.834214 X χ^2 is 0.2873144 with 2 df

Appendix table 15: Doses mortality data of *S. zeamais* Motsch adult treated with bhat weed extract in hexane solvent at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
3	1.477	30	26	86.66	87	6.13	6.104	6.132	12.15	6.092
2	1.301	30	23	76.66	77	5.74	5.659	5.730	16.74	5.649
1	1	30	11	36.67	37	4.67	4.899	4.682	18.81	4.892
0.5	0.699	30	7	23.34	23	4.26	4.138	4.284	14.13	4.134

LD-50 is 1.104051 95% confidence limits are 0.8738204 to 1.394942

Y = 2.375581 + 2.516248 X χ^2 is 1.272783 with 2 df

Appendix table 16: Doses mortality data of *S. zeamais* Motsch adult treated with lambda cyhalothrin at 24 HAT.

dose (%)	log dose	number	kill	% kill	corr %	emp probit	expt probit	wrk probit	weight	final probit
0.2	1.301037	30	23	76.66	77	5.74	5.760	5.734	15.96	5.753
0.1	1.00001	30	20	66.66	67	5.44	5.414	5.429	18.03	5.407
0.01	2.062321E-05	30	7	23.34	23	4.26	4.266	4.252	15.09	4.258

LD-50 is 4.22999E-02 95% confidence limits are 0.0247564 to 7.902165E-02

Y = 4.258026 + 1149071 X χ^2 is 1.512718E-02 with 1df

Appendix table 17: Doses mortality data of *S. zeamais* Motsch adult treated with lambda cyhalothrin at 48 HAT.

dose (%)	log dose	number	kill	% kill	corr %	emp probit	expt probit	wrk probit	weight	final probit
0.2	1.301037	30	25	83.34	83	5.95	5.928	5.984	14.13	5.940
0.1	1.00001	30	23	76.66	77	5.74	5.769	5.734	15.96	5.785
0.01	2.062321E-05	30	18	60	60	5.25	5.243	5.28	18.81	5.270

LD-50 is 2.989296E-03 95% confidence limits are 1.51077E-04 to 5.914796E-02

Y = 5.270004 + 0.5148509 X $\chi^2$is 7.107306E-02 with 1df

Appendix table 18: Doses mortality data of *S. zeamais* Motsch adult treated with lambda cyhalothrin at 72 HAT.

dose (%)	log dose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
0.2	1.301037	30	28	93.34	93	6.48	6.455	6.491	9.0599	6.450
0.1	1.00001	30	27	90	90	6.28	6.313	6.25	10.08	6.298
0.01	2.062321E-05	30	24	80	80	5.85	5.842	5.8	15.09	5.723

LD-50 is 2.701022E-04 95% confidence limits are 6.538778E-07 to 0.1115732

Y = 5.792585 + 0.5053227 X χ^2 is 3.909254E-02 with 1df

Appendix table 19: ANOVA table of the toxic effect of different weed extracts against the adult of *S. zeamais* Motsch at 24 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	12365.333	3091.333	70.2576	0.0000
4	Factor B	4	10165.333	2541.333	57.7576	0.0000
6	AB	16	5528.000	345.500	7.8523	0.0000
-7	Error	50	2200.000	44.000		
	Total	74	30258.667			

Coefficient of Variation: 45.64%

Appendix table 20: ANOVA table of the toxic effect of different weed extracts against the adult of *S. zeamais* Motsch at 48 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	15858.667	3964.667	43.0942	0.0000
4	Factor B	4	27632.000	6908.000	75.0870	0.0000
6	AB	16	5941.333	371.333	4.0362	0.0001
-7	Error	50	4600.00	92.000		
	Total	74	54032.000			

Coefficient of Variation: 35.79%

Appendix table 21: ANOVA table of the toxic effect of different weed extracts against the adult of *S. zeamais* Motsch at 72 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	6461.333	1615.333	37.8594	0.0000
4	Factor B	4	72314.667	18078.667	423.7187	0.0000
6	AB	16	5098.667	318.667	7.4687	0.0000
-7	Error	50	2133.333	42.667		
	Total	74	86008.000			

Coefficient of Variation: 13.50%

Appendix table 22: ANOVA table of the repellent effect of different weed extracts against the adult of *S. zeamais* Motsch at 1 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	3826.667	956.667	1.6307	0.1854
4	Factor B	3	7380.000	2460.000	4.1932	0.0114
6	AB	12	10520.000	876.667	1.4943	0.1668
-7	Error	40	23466.667	586.667		
	Total	59	45193.333			

Coefficient of Variation: 91.98%

Appendix table 23: ANOVA table of the repellent effect of different weed extracts against the adult of *S. zeamais* Motsch at 2 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	4460.000	1115.000	2.9471	0.0317
4	Factor B	3	17191.667	5730.556	15.1468	0.0000
6	AB	12	4233.333	352.778	0.9325	
-7	Error	40	15133.333	378.333		
	Total	59	41018.333			

Coefficient of Variation: 71.60%

Appendix table 24: ANOVA table of the repellent effect of different weed extracts against the adult of *S. zeamais* Motsch at 3 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	4306.667	1076.667	2.9907	0.0299
4	Factor B	3	6693.333	2231.111	6.1975	0.0015
6	AB	12	9773.333	814.444	2.2623	0.0266
-7	Error	40	14400.000	360.000		
	Total	59	35173.333			

Coefficient of Variation: 58.08%

Appendix table 25: ANOVA table of the repellent effect of different weed extracts against the adult of *S. zeamais* Motsch at 4 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	4893.333	1223.333	3.3981	0.0175
4	Factor B	3	15280.000	5093.333	14.1481	0.0000
6	AB	12	8386.667	698.889	1.9414	0.0581
-7	Error	40	14400.000	360.000		
	Total	59	42960.000			

Coefficient of Variation: 49.93%

Appendix table 26: ANOVA table of the repellent effect different weed extracts against the adult of *S. zeamais* Motsch at 5 HAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	6160.000	1540.000	3.3971	0.0175
4	Factor B	3	9673.333	3224.444	7.1127	0.0006
6	AB	12	10426.667	868.889	1.9167	0.0617
-7	Error	40	18133.333	453.333		
	Total	59	44393.333			

Coefficient of Variation: 58.60%

Appendix table 27: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with different weed extracts at 40 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	70.213	17.553	6.4534	0.0003
4	Factor B	4	20779.547	5194.887	1909.8848	0.0000
6	AB	16	86.987	5.437	1.9988	0.0321
-7	Error	50	136.000	2.720		
	Total	74	21072.747			

Coefficient of Variation: 9.43%

Appendix table 28: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with different weed extracts at 47 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	236.453	59.113	15.5017	0.0000
4	Factor B	4	21129.787	5282.447	1385.2570	0.0000
6	AB	16	183.280	11.455	3.0039	0.0015
-7	Error	50	190.667	3.813		
	Total	74	21740.187			

Coefficient of Variation: 8.78%

Appendix table 29: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with different weed extracts at 54 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	760.853	190.213	29.5975	0.0000
4	Factor B	4	21794.320	5448.580	847.8081	0.0000
6	AB	16	448.880	28.055	4.3654	0.0000
-7	Error	50	321.333	6.427		
	Total	74	23325.387			

Coefficient of Variation: 8.99%

Appendix table 30: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with different weed extracts at 40 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	76.613	19.153	12.4913	0.0000
4	Factor B	4	13582.080	3395.520	2214.4696	0.0000
6	AB	16	36.187	2.262	1.4750	0.1471
-7	Error	50	76.667	1.533		
	Total	74	13771.547			

Coefficient of Variation: 8.47%

Appendix table 31: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with different weed extracts at 47 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	218.053	54.513	23.7703	0.0000
4	Factor B	4	13970.987	3492.747	1523.0000	0.0000
6	AB	16	113.413	7.088	3.0908	0.0012
-7	Error	50	114.667	2.293		
	Total	74	14417.120			

Coefficient of Variation: 8.28%

Appendix table 32: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with different weed extracts at 54 DAT

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	454.053	113.513	27.4629	0.0000
4	Factor B	4	14156.587	3539.147	856.2452	0.0000
6	AB	16	330.613	20.663	4.9992	0.0000
-7	Error	50	206.667	4.133		
	Total	74	15147.920			

Coefficient of Variation: 9.19%

Appendix table 33: ANOVA table of the toxic effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 24 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	3	11766.667	3922.222	156.889	0.0000
Within	8	200.000	25.000		
Total	11	11966.667			

Coefficient of Variation: 12.00%

Appendix table 34: ANOVA table of the toxic effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 48 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	3	12966.667	4322.222	37.048	0.0000
Within	8	933.333	116.667		
Total	11	13900.000			

Coefficient of Variation: 19.64%

Appendix table 35: ANOVA table of the toxic effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 72 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	3	17625.000	5875.000	176.250	0.0000
Within	8	266.667	33.333		
Total	11	17891.667			

Coefficient of Variation: 8.77%

Appendix table 36: ANOVA table of the repellent effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 1 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	355.556	177.778	0.222	-
Within	6	4800.000	800.000		
Total	8	5155.556			

Coefficient of Variation: 74.87%

Appendix table 37: ANOVA table of the repellent effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 2 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	355.556	177.778	0.500	-
Within	6	2133.333	355.556		
Total	8	2488.889			

Coefficient of Variation: 60.61%

Appendix table 38: ANOVA table of the repellent effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 3 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	266.667	133.333	0.273	-
Within	6	2933.333	488.889		
Total	8	3200.000			

Coefficient of Variation: 66.33%

Appendix table 39: ANOVA table of the repellent effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 4 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	266.667	133.333	0.115	-
Within	6	6933.333	1155.556		
Total	8	7200.000			

Coefficient of Variation: 72.84%

Appendix table 40: ANOVA table of the repellent effect of lambda cyhalothrin against the adult of *S. zeamais* Motsch at 5 HAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	622.222	311.111	7.000	-
Within	6	266.667	44.444		
Total	8	888.889			

Coefficient of Variation: 13.04%

Appendix table 41: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 40 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	0.889	0.444	4.000	0.0787
Within	6	0.667	0.111		
Total	8	1.556			

Coefficient of Variation: 150.00%

Appendix table 42: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 47 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	3.556	1.778	16.000	0.0039
Within	6	0.667	0.111		
Total	8	4.222			

Coefficient of Variation: 75.00%

Appendix table 43: ANOVA table of the adult emergence and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 54 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	3.556	1.778	16.000	0.0039
Within	6	0.667	0.111		
Total	8	4.222			

Coefficient of Variation: 75.00%

Appendix table 44: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 40 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	0.889	0.444	4.000	0.0787
Within	6	0.667	0.111		
Total	8	1.556			

Coefficient of Variation: 150.00%

Appendix table 45: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 47 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	3.556	1.778	16.000	0.0039
Within	6	0.667	0.111		
Total	8	4.222			

Coefficient of Variation: 75.00%

Appendix table 46: ANOVA table of the seed damage and inhibition against *S. zeamais* Motsch treated with lambda cyhalothrin at 54 DAT

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Between	2	3.556	1.778	16.000	0.0039
Within	6	0.667	0.111		
Total	8	4.222			

Coefficient of Variation: 75.00%