Sudan University of Science and Technology

College of Graduate Studies

Bioactivity, Synergism and Potentiation of the Botanical Extracts, Nimbecidine and *Bacillus thuringiensis* Against the African Bollworm *Helicoverpa armigera* Hübner

الفاعلية الإحيائية و التنشيط و التقوية للمستخلصات النباتية، النيمبيسيدين و بكتريا الباسلس ضد دودة اللوز الافريقية.

A Thesis Submitted in Partial fulfillment of the Requirements for the Ph.D. Degree in Plant Protection

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الآيـة

قال تعالي:

فَبَدَأَ بِأَوْعِيَتِهِمْ قَبْلَ وِعَاءِ أَخِيهِ ثُمَّ اسْتَخْرَجَهَا مِنْ وِعَاءِ أَخِيهِ ۚ كَذَٰلِكَ كِدْنَا لِيُوسُفَ ۖ مَا كَانَ لِيَأْخُذَ أَخَاهُ فِي دِينِ الْمَلِكِ إِلَّا أَنْ يَشَاءَ اللَّهُ ۚ نَرْفَعُ دَرَجَاتٍ مَنْ نَشَاءُ ۗ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ.

صدق الله العظيم

سورة يوسف الآية (76)

DEDICATION

To my mother, father and brothers

To my extended family

To all my teachers and friends with great regard and respect.

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ABSTRACT

African bollworm *Helicoverpa armigera* Hübner is a worldwide-spread species that shows a high degree of polyphagia and it is considered as one of the main agricultural pests in the world. Laboratory experiments were conducted in the Research Laboratory, College of Agricultural Studies, Sudan University of Science and Technology to investigate, through laboratory screening, the insecticidal activity of the ethanolic extracts of *Cyperus rotundus*, *Datura stramonium, Cassia occidentalis* and *Ricinus communis* and their co-toxicity as well as the synergistic effect of sesame oil against the second larval instar of *H. armigera*. Furthermore, the joint action of *Bacillus thuringiensis var. kurstaki (Btk),* Nimbecidine® and the ethanolic extracts of the tested plants were also studied. Experiments were also conducted to evaluate the efficacy of aqueous extracts of *Balanites eagyptiaca*, *Solenostemma argel, Eucalyptus camaldulensis* and *Acacia nilotica* on the mortality of the same larval instar. In each experiment five concentrations were used as followed 4%, 6%, 8%, 10% and 12% for ethanolic extracts, 1.8%, 3.75%, 7.5%, 15% and 30% for aqueous extracts, 0.62, 1.25, 2.5, 5 and 10 mg/ml for *Bt* and 1.25, 2.5, 5, 10 and 20 ml/L for Nimbecidine®. The experiments were conducted in a Completely Randomized Design and the mortality percentages were recorded after 24, 48, 72 and 96 hrs of application.

The study findings clearly showed that all tested plant extracts, *Bt* and Nimbecidine® generated a significantly higher mortality percentage than that of the control. It was also noted that the mortality percentage increases with the increase of both concentration and exposure period. Probit analysis of the mortality data showed that the median lethal concentrations (LC_{50}) of the extracts vary from one plant to another whether plant extract used alone or mixed with sesame oil. Tubers ethanolic extract of *C. rotundus* scored the lowest LC_{50} value (4.2 %) followed by *R. communis* (6.4%), *D. stramonium* (7.1 %) and *C. occidentalis*(7.1 %). However,

when sesame oil was added to each concentration of the ethnolic extract it exhibited a synergistic effect and significantly reduced their LC_{50} values.

Upon testing the joint action of the tested ethanoic extracts, the results showed that all combinations (plant/plant or plant *Bt*) gave a higher mortality percentage either through potentiation or additive effect. The binary mixture of *R. communis* and *D.stramonium* caused a potentiation effect throughout the experimental period. *R. communis* and *C. occidentalis* mixture gave an additive effect however, a potentiation effect was generated after 48 hrs of application. However, the binary mixture of *C. rotundus* and all other plant extracts(*R. communis, D.stramonium* and *C. occidentalis*) induced an additive effect throughout the experimental period. The obtained data proved that the binary mixture of *Bt* and *R. communis* as well as *Bt* and Nimbecidine® induced a potentaition effect throughout the experimental period. On the otherhand the binary mixture of *Bt and C. rotundus, Bt* and *D.stramonium* and *Bt* and *C. occidentalis* induced an additive effect.

The results also showed that the aqueous extract of *Balanites eagyptiaca* was significantly more toxic than its counterparts of tested plants. In fact, after 96 hrs of exposure the LC_{50} values were 12.3%, 15.4%, 24.5% 27.9% for *Balanites eagyptiaca, Solenostemma argel, Eucalyptus camaldulensis* and *Acacia nilotica* respectively.

الملخص

تعتبر دودة اللوز الافريقية من الا فات الزراعية متعددة العوائل و اسعة الإنتشار كما تعتبر احد الافات الرئيسية في العالم. اجريت تجارب معملية بالعمل البحثي بكلية الدراسات الزراعية، جامعة السودان للعلوم و التكنولوجيا لتقييم فاعلية المستخلصات الإيثانولية لنباتات: السعدة (*Cyperus rotundus*)، السيكران (*Datura stramonium*)، السوريب (*Cassia occidentalis*) و الخروع (*Ricinus communis*) و سميتها المشتركة بالإضافة للاثر التنشيطي لزيت السمسم على هذه المستخلصات ضد الطور اليرقي الثاني لدودة اللوز الافريقية (*H. armigera*). هذا بالإضافة لدراسة الفعل المشترك للمستخلصات الايثانولية المختبرة و بكتريا (*Bacillus thuringiensis var. kurstaki (Btk)*) و مبيد النمبيسيدين.

كما اجريت تجارب اخرى لتقييم فاعلية المستخلصات المائية للهجليج (*Balanites eagyptiaca*)، الحرجل (*Solenostemma argel*)، الكافور (*Eucalyptus camaldulensis*) و السنط (*Acacia nilotica*) على نفس الطور اليرقي. استخدمت خمسة تركيزات لكل تجربة كالاتي 4%، 6%، 8%، 10% و 12% للمستخلصات الإيثانولية، 1.8%، 3.75%، 7.5%، 15% و 30% للمستخلصات المائية، 0.625، 1.25، 2.5، 5، و 10مجم/مل للبكبتريا و 1.2، 2.5، 5، 10 و 20 مل/ لتر لمبيد النيمبيسيدين. اجريت التجارب بإستخدام التصميم العشوائي الكامل و سجلت نسب الموت بعد 24، 48، 72 و 96 ساعة من المعاملة.

أوضحت النتائج المتحصل عليها ان كل المستخلصات النباتية المختبرة، بكتريا (*Btk*) و مبيد النيمبيسيدين سببت نسبة موت عالية معنوياً مقارنة بالشاهد خلال فترة التجربة، كما ان نسبة الموت تزيد بزيادة كل من التركيز و زمن التعرض.

كما أوضحت البيانات المتحصل عليها ان قيمة التركيز النصفي القاتل (LC_{50}) تختلف من نبات لاخر و من مستلخص مفرد او ممزوج مع زيت السمسم. سجل المستخلص الإيثانولي للسعدة اقل قيمة للتركيز النصفي القاتل (4.2%) يليه الخروع (6.4%)، السيكران (7.1%) و السوريب (7.1%). عندما اضيف زيت السمسم للمستخلصات الإيثانولية احدث اثر تنشيطي لهذه المستخلصات اذ ادى الى خفض قيم (LC_{50}) بصورة معنوية مقارنة بنظرائها مفردة.

فيما يتعلق بالفعل المشترك للمستخلصات الإيثانولية، اوضحت النتائج ان مزيج الخروع و السيكران احدث اثر تقوية (Potentiation effect) خلال فترة التجربة. بينما سبب مزيج الخروع و السوريب اثر اضافي (Additive effect) بعد 24 ساعة الا انه احدث اثر تقوية بعد 48 ساعة من المعاملة. لقد اعطى مزيج

السعدة و بقية المستخلصات (السيكران, السوريب و الخروع) اثرا اضافي خلال فترة التعرض. كما اعطت النتائج المتحصل عليها ان المزيج الثنائي لكل من بكتريا (*Btk*) و الخروع و البكتريا و مبيد النيمبيسيدين اثر تقوية (Potentiation effect) خلال الفترة التجريبية في حين اعطى مزيج البكتريا والسعدة، البكتريا و السيكران و البكتريا و السوريب اثر اضافياً.

ايضاً اوضت النتائج المتحصل عليها ان المستخلص المائي للهجليج اكثر سمية من نظرائه من النباتات المختبرة، حيث كانت قيمة التركيز النصفي القاتل (LC_{50}) بعد 96 ساعة من المعاملة كالاتي 12.3%، 15.4%، 24.5% و 27.9% لكل من الهجليج، الحرجل، الكافور و السنط على التوالي.

CHAPTER ONE

INTRODUCTION

Helicoverpa armigera Hübner (Lepidoptera: Noctuidae) is one of the most destructive pests of field crops worldwide. It is a highly polyphagous multivoltine and economically important pest of cotton and other crops and has developed resistance against most of the modern classes of synthetic insecticides (Abedi *et al*., 2014). The larval stage causes direct damage to flowers, buds and fruits and incurs heavy yield losses in crops. Heavy yield losses have been reported by many researchers on different crops and vegetables by this pest. In semiarid tropics the annual losses caused by this pest estimated by US$ 2 billion, even though US$ 500 million worth pesticides are applied to control this pest (Kassi *et al*., 2018).

The African bollworm has been reported on 35 crops and 25 wild host plants in Eastern and Southern Africa. In the Sudan, attacked crops include cotton, sunflower, French beans, dry beans, okra, peas, legumes, maize, sorghum, tobacco and tomato (Suliman and Bakheit, 2013). Also it was reported as the main insect pest attacking chickpea, where its larvae feed on leaves and developing seeds. Economics losses ascribed to direct yield reduction and cost of chemical application to control this pest are considerable (Ali and Mohamed, 2014).

The problem of this pest is magnified due to its direct attack on fruiting structures, voracious feeding habits, high mobility, fecundity and multivoltine overlapping generations. Besides, it had developed resistance to broad spectrum of insecticides due to exposure of successive generations while moving from one crop to another, which made this pest highly resistant to many pesticides such as cyclodiene, pyrethroids, organophosphates, carbamates etc (Rabari *et al*., 2017).

Some synthetic insecticides including Carbaryl, Karate, Cypermethrin, Dimethoate and Monocrotophos have been used to control this pest (Degri and Mailafiya, 2013), Cyprofen 220 UL (Suliman and Bakheit, 2013) and Kung Fu 5% EC and

Karate Zeon 10% (Mohamed , 2011). However because of the hazards of synthetic insecticides, recently the pesticidal effects of botanical extracts have been investigated by several researchers worldwide (Sadiq *et al*., 2012 Taiwo *et al*., 2013 and Usman *et al*., 2018).

In the two last decades more than 81 chemical insecticides were recommended to control *Bemisia tabaci* and *H. armigera* on tomato under Sudan conditions. Botanicals have long been proposed as attractive alternatives to synthetic chemical insecticides for pest management because they are reputed to pose little threat to the environment or to human health. More than 1000 species of plants have been reported to have chemicals in leaves, stems, flowers, seeds and roots which have insecticidal properties, but only a few of them have been used for practical insect control on a commercial scale in the past (Mardi and Sulaiman, 2018).

Insecticide synergists have been used not only to monitor the insecticide resistance mechanisms but also as an admixture in these insecticides for the control of many insects. They contribute significantly to the improvement of insecticides efficacy, particularly when problems of resistance need to be addressed. Piperonyl butoxide which is isolated from sesame oil has been used as a synergist with many organophosphates and pyrethroid insecticides to control various pests (Elnour, 2014). Insecticide synergists and synergistic action among botanical extracts have been studied by many researchers worldwide (Ahmed and Irfanullah 2007; Mansour *et al.,* 2011; Islam and Aktar 2013 and Aïzoun *et al.,* 2014). Also the combined effects between botanicals and *Bacillus thuringiensis* (*Bt*) have been explored by several researchers (Nathana *et al*., 2006; Zibaee *et al*., 2010 and Al-Zahrani and Abuldahab, 2011).

The objectives of this study are to:

1- Investigate, through a laboratory screening, the potential use of *Bacillus thuringiensis* var. *kurstaki* and botanical extracts against the 2nd larval instars of the African bollworm *Helicoverpa armigera*.

2- Evaluate the lethal effects of these extracts and determine their LC_{50} and LC_{90} values against tested larval instars.
3- Investigate the joint action (synergistic, potentiation and additive effect) of *Bacillus thuringiensis sub sp. kurstaki* and the ethanolic extracts of *Cyperus rotundus, Datura strammonium, Cassia occidentalis* and *Ricinus communis* against the 2^{nd} larval instars of the African bollworm.
4- Evaluate the synergistic effect of sesame oil on the ethanolic extracts of the tested plants.
5- Evaluate the aqueous extracts of *Balanites eagyptiaca, Solenostemma argel, Eucalyptus camaldulensis* and *Acacia nilotica* against the 2^{nd} larval instars of the African bollworm.

CHAPTER TWO

LITERATURE REVIEW

2-1- *Helicoverpa armigera* (African bollworm)

2-1-1-Back ground:

Helicoverpa armigera Hübner (Lepidoptera: Noctuidae) is one of the most destructive pests of field crops worldwide. It is a highly polyphagous multivoltine, and economically important pest of cotton and other crops and has developed resistance against most of the modern classes of synthetic insecticides (Abedi *et al*., 2014).

2-1-2-Taxonomy:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus : Helicoverpa

Species : armigera

S. N : *Helicoverpa armigera* (Hübner)

C. N : African bollworm / American bollworm

2-1-3- Geographical distribution:

Helicoverpa armigera is a worldwide-spread species that shows a high degree of polyphagia and it considered as one of the main agricultural pests in the world. Its presence has been reported in diverse continents, such as Africa, Europe, Asia and Oceania (Gomes *et al*., 2017). Its outbreaks/ damage has also been reported in Hungary , Sicily, Romania , Slovakia, Spain, Sweden, Switzerland and the United Kingdom (Kambrekar, 2016). In Sudan it was earlier recorded in Shambat, Meridi, Nuba Mountains, Yambio, Gash Delta, Gedarif area, White Nile and Gezira Schemes (Mohamed , 2011) and it found in all cotton growing areas (Hassan *et al*., 2018).

2-1-4-Morphology:

2-1-4-1- Adult :

The adults are medium in size, possessing yellowish brown forewings with a series of dots on the margins. There is a black kidney-shaped mark on the underside of each forewing. Hind wings are light in color and each possesses a dark color patch at the apical end. Body length of male moths ranges from 15.40 to 18.75 mm, whereas the width varies from 33.40 to 39.15mm. In case of the female, the body length ranges from 18.40 to 22.2 mm and the width from 38.39 to 49.90 mm (Patel, *et al*., 2011). There is a distinguished color pattern for male and female moths. Males are greenish-grey in color, whereas, females are orange-brown and also identified by the presence of tuft of hairs on the tip of the abdomen (Ali *et al*., 2009).

2-1-4-2- Egg:

The freshly laid eggs are yellowish-white and glistening at first but changed to dark brown before hatching. The apical area of the egg is smooth and the rest of the surface is sculptured in the form of longitudinal ribs; the egg size varies from 0.42- 0.60 mm in length and 0.40-0.55 mm in width (Ali *et al*., 2009).

After emergence of the larva, the egg shell becames transparent with a tiny emergence hole made by the larva (Patel *et al*., 2011).

2-1-4-3- Larva:

The freshly emerged larvae are semi-translucent, yellowish white in colour with yellowish orange longitudinal lines on the dorsal surface of the body. The head, thoracic and anal shields and legs are brown in colour. The body length of the first larval instar varies from 1.42 to 1.50mm. Morphologically the second larval instar is closely resembles that of the first larval instar, and the larvae are yellowish brown in colour with somewhat darker head than the general body colour (Patel *et al*., 2011).

The third larval insitar are generally green brown in colour, however as they pass through 4^{th}, 5^{th} and 6^{th} larval instar their body colour changes according to the food consumed and the colour can be blue-green, yellow green, yellow, light green, pink or light brown to reddish brown (Mohamed, 2011). The prolegs are developed in the third larval instar at the 3rd, 4th, 5th, 6th and 10th abdominal segments and remain until the last larval instar. The average length of a full grown larva is 32.5 mm. The larvae in this instar are straw-yellow to green with lateral brown strips. The head as well as the prothoracic legs are dark brown to black in color. Tubercles and spiracles of the larvae are also brown to black, giving them a spotted appearance (Ali *et al*., 2009).

2-1-4-4- Puapa:

The pupa is obtect type with mahogany-brown color. The surface is smooth and rounded both anteriorly and posteriorly, with two tapering parallel spines at the posterior tip with an average length of 19 mm (Ali *et al*., 2009). The abdomen is distinctly marked into ten segments. Also a well defined dark brown spiracles are visible on 4th to 9th abdominal segments (Patel *et al*., 2011).

2-1-5 -Biology:

The biology of *H. armigera* was studied by many workers including (Ali *et al*.,2009; Patel *et al*., 2011 and Ali & Ali, 2013). They found that the succession of stages through which the species passes in order to complete its development is eggs, larvae, pupae and adults. The pre-oviposition period varies from 2 to 4 days with an average of 2.76 ± 0.83 days (Patel *et al*., 2011). The oviposition period lasts for 5 to 24 days, and a female may lay up to 3000 eggs mainly at night and usually laid singly on leaves, flowers, and pods. The eggs incubation period depends on temperature and varies between 2 and 5 days (usually 3 days). The duration of larval development depends not only on the temperature but also on the nature and quality of the host plant. It takes about 15.2 days on maize and 23.8 days on tomato. The number of larval instars varies from 5 to 7, with 6 being most common (Patil *et al*. 2017).

The pre-pupal period lasts for 1 to 3 days with an average of 2.15 ± 0.16 days. In this stage, the full grown larva becomes sluggish, wrinkled with suspended feeding and movement. The pre-pupa is light green yellowish in color but later on it turned to dark brown. The duration of pupal stage varies from 10 to 14 days (Ali *et al*., 2009). The diapausing period for pupae can last for several months. Female moths generally live longer than males. In the laboratory, longevity varies from 1 to 23 days for males and 5 to 28 days for females (Patil *et al*. 2017). Diapausing pupae are tolerant to harsh weather conditions like cold and dry conditions. Photoperiods of 11.5-12.5 hrs, accompanied by low or decreasing mean temperatures of 19-23 ◦C, are optimal for diapause induction. Diapause defines the seasonal occurrence of *H. armigera* in many areas and contributes to their pest status by maintaining local population during periods when hosts are unavailable or conditions are not conducive to reproduction and population survival (Karim, 2000).

In subtropical Australia, it undergoes diapauses during the winter when temperatures are low. High temperatures can also induce diapause. It enters a true summer

diapause when the larvae are exposed to very high temperatures (43 °C for 8 h daily), although the proportion of females entering diapause is nearly half compared with that of males (Patil *et al*., 2017). The total life cycle of male ranges from 35 to 45 days with an average of 39.40 ±2.33 days and in case of female it range from 37 to 48 days with an average of 42.96 ± 2.47 days. Thus, the duration of life cycle of female is longer than that of the male. The average longevity of a male varies from 4 to 8 days with an average of 5.40 ± 1.04 days, whereas in case of a female it varies from 5 to 11 days with an average of 8.84 ± 1.91 days. The sex ratio of male: female recorded in laboratory as 1: 0.72 (Patel *et al*., 2011).

In Sudan, Ali and Ali (2013) studied the biology of the African bollworm on three sunflower varieties and they found that the pre-oviposition period ranged between 2 -5 days and the oviposition period took about 3- 8 days. The number of eggs per female were about 467 – 893, the incubation period ranged between 2 -3 days. The larva had six larval instars and it completed its development in 10 – 15 days. Pupation period lasted for 8-9 days. The whole life cycle was completed within 22 – 46 days.

2-1-6-Host plants:

The African bollworm have been reported from over 67 host families, including Asteraceae, Fabaceae, Malvaceae, Poaceae and Solanaceae and this pest can cause losses to economically important crops such as cotton, legumes, sorghum, maize, tomato, soybean, ornamental plants, and fruit trees (Ganai *et al*., 2017).

It was also reported on 35 crops and 25 wild host plants in Eastern and Southern Africa. In the Sudan it attacks many crops such as cotton, sunflower, French beans, dry beans, okra, peas, legumes, maize, sorghum, tobacco and tomato (Suliman and Bakheit, 2013).

2-1-7-Damage and economic importance:

The larval stage causes direct damage to flowers, buds and fruits and incurs heavy yield losses in crops. Heavy yield losses have been reported by many researchers on different crops and vegetables by this pest. In semiarid tropics the annual losses caused by this pest is estimated by US$ 2 billion, even though US$ 500 million worth pesticides are applied to control this pest (Kassi *et al*., 2018). The larvae of *H. armigera* feed on leaves and stems but, they prefer buds, inflorescences, fruits and pods, thus causing significant damage to both vegetative and reproductive plant parts (Agale *et al*., 2017).

The problem of this pest is magnified due to its direct attack on fruiting structures, voracious feeding habits, high mobility, fecundity and multivoltine overlapping generations. Besides, it develop resistance to broad spectrum of insecticides (Rabari *et al*., 2017). In addition to feeding on high value crops it is an extremely dangerous pest because its reproduction rate is extremely high and it can migrate over a long distance (Saraf *et al*., 2015).

In Sudan the major cultivated hosts for the pest are cotton, maize *(Zea mays* L.), sorghum, sunflower (*Helianthus annuus* L.), pigeon pea and tomato. Also, there are some wild hosts which play a significant role in the carryover of this pest during the dry season (Mohamed *et al*., 2016). Also it was reported as the main insect pest attacking chickpea, where its larvae feed on leaves and developing seeds. Economics losses ascribed to direct yield reduction and cost of chemical application to control this pest are considerable (Ali and Mohamed, 2014). Flower feeding can prevent seeds formation. In fruits, caterpillars usually bore clean, circular holes and excrements (faeces / waste) of feeding are placed away from damaged plant parts. The holes serve as entry points for secondary infection by diseases causing fruit decay. The severity of the damage varies between crops, regions and locations, and between seasons (Suliman and Bakheit, 2013).

2-1-7-Control Measures:

2-1-7- 1- Cultural control:

A number of cultural practices such as time of sowing, spacing, fertilizer application, deep ploughing, inter-culture and flooding have been reported to reduce the survival and damage by *Helicoverpa* spp. Intercropping or strip cropping with marigold, sunflower, linseed, mustard and coriander can minimize the extent of damage to the main crop. Strip-cropping also increases the efficiency of chemical control. Hand-picking of large sized larvae can also be practiced to reduce *Helicoverpa* damage. Trap crops are managed in the same way as commercial crops, but destroyed by cultivation before larvae begin to pupate. The trap crops reduce the size of the local *H. armigera* population before it can infest summer crops and start to increase in size. Habitat diversification to enhance pest control has been attempted in Australia (Kambrekar, 2016).

The planting of crop cultivars that are resistant or tolerant to *H.armigera* is very important for integrated pest management . Most of host plant resistance research in tomato has been carried out at the Asian Vegetable Research and Development Center since 1980 (Mohamed , 2011). In Sudan Ali and Mohamed (2014) conducted a field trial during the winter season 2013/014, to evaluate eighteen chickpea genotypes, including the eight released varieties and ten advanced genotypes provided by ICARDA, for resistance against *Helicoverpa armigera* and they found that genotypes Atmore and Flip03-139c recorded higher resistance against pod borer than the Mattama, Hawata, Selwa, Wad Hamed, Jabel Marra, Flip03-127c and Flip04-9c, which showed moderate resistance to this pest. Another study was conducted by Nureldaem (2016) in central and northern Sudan to evaluate seventeen maize genotypes and revealed that the genotypes VMH2000 ,VMH4040, PAC339, PAC999 ,PR89B5655 had potential tolerance or resistance to the infestation by the African boll worm.

Two *Bt*-cotton genotypes, a Seeni 1 (Chinese 1 open- pollinated) and Seeni 2 (Chinese 2 -Hybrid) cotton introduced by CATDC for evaluation and release for commercial production in Sudan. The *Cry*1A *Bt*- gene in the two genotypes CN-C01 and CN-C02 has sufficiently protected the cotton crop against the bollworms and bollworms damage has never exceeded 5% even in artificially inoculated cages. This confirms that *Bt* gene *Cry*1A is expressed in the environment adequately to kill both African and Egyptian bollworms in Sudan. Therefore, the CN-C01 and CN-C02 can be grown without the need for the intensive insecticides spraying for bollworms control. As a consequence, the cost of production will be drastically reduced by up to 25%, and the environmental pollution, hazards to humans, animals and beneficial field organisms will also be reduced (Suliman *et al*., 2015).

2-1-7- 2- Botanical control:

Botanicals have long been proposed as attractive alternatives to synthetic chemical insecticides for pest management because they are reputed to pose little threat to the environment or to human health (Mardi and Sulaiman, 2018). The most well-known and commonly used plant extract is azadirachtin, isolated from the seed, wood, bark, leaves, and fruits of the neem tree (*Azadirachta indica*). Azadirachtin has both anti-feedent and growth-retarding properties and can lead to death at any stage in the life cycle, probably by interfering with the neuroendocrine control of metamorphosis in insects. Applying Neem Seed Kernel Extract (NSKE 5%) reduced the *H. armigera* population in chickpea (Patil *et al*., 2017).

Usman *et al*., (2018) study the efficacy of five botanical extracts (*Melia azedarach*, *Thymus volgaris*, *Eucalyptus tereticornis*, *Allium cepa* and *Capsicum annum*) on *H. armigera* and its associated natural enemies in tomato crop in Pakistan and they found that all the tested plant were significantly effecive in reducing the larval population. In Sudan, Mardi and Sulaiman (2018) stated that a significant control of white fly, African boll worm and tomato leaf curl virus disease on to-

mato fields can be achieved by spraying aqueous extract of *Solenostermma argel* shoot powder at 40 g/ L of water + 50 ml of 5% gum Arabic.

2-1-7- 3- Biological control:

Biological control occurs in nature when populations are limited through the action of parasites, predators and pathogens. As an applied science, biological control often involves releases of exotic natural enemies in an attempt to suppress introduced pest species but it is also implemented through the augmentation or conservation of natural enemies. Conservation, augmentation and release are the three main steps in biological control of *Helicoverpa* (Karim, 2000).

A number of parasitic Hymenoptera (Trichogrammatidae and Braconidae) and parasitic Diptera (Tachindae and Phoridae) are recorded as parasites on *H. armigera*. Also several predators which prey on the eggs and young larvae of this pest related to five insect orders namely Diptera (Asilidae), Neuroptera (Chrysopidae), Hemiptera (Miridae, Nabidae and Anthocoridae),Coleoptera (Carabidae and Coccinellidae) and Hymenoptera (Eumenidae and Formicidae) are reported in Gezira, Sudan. The eggs parasitoid, *Trichogramma pretiosum* was introduced from Texas, USA and released in cotton fields at Rahad, Gezira and New Halfa agricultural schemes during 1988, 1989 and 1990 (Mohamed , 2011).

The Ichneumonid, *Campoletis chlorideae* (Uchida), is probably the most important larval parasitoid on *H. armigera* in chickpea. *Carcelia illota* (Curran), *Goniophthalmus halli* Mesnil and *Palexorista laxa* (Curran) have also been reported to parasitize up to 54% larvae on chickpea in India. Also Predators such as *Chrysopa spp., Chrysoperla spp., Nabis spp., Geocoris spp., Orius spp*. and *Polistes spp*. are also reported on *H. armigera* (Kambrekar, 2016). The use of microbial pathogens including *H. armigera* nuclear polyhedrosis virus (*Ha*NPV), entomopathogenic fungi, *Bt* and nematodes have shown some potential to control *H. armigera*. In Australia, specific control of *H. armigera* and *H. punctigera* on

chickpea is being achieved using the commercially available *Ha*NPV. *Bt* formulations are also used as a spray to control *Helicoverpa* (Kambrekar, 2016).

The bio-agent *Beauveria bassiana* and *Metarhizium anisopliae* constitute about 68 per cent of the entomopathogenic fungi as microbial pesticides. The performed lab tests for the isolates of *M. anisopliae* and *B. bassiana* on larvae of *H. armigera* reported mortality rates ranging from 58% to 74 % (Agale, *et al*., 2017).

The efficacy of *Bt* can be enhanced by incorporating suitable quantities of acids, salts, oils, adjuvant, thuringiensin (exotoxin of *Bt*), and chemical insecticides. Applying DiPel 2X and DiPel ES at 1.6 and 1.5 l ha−1, respectively at early stages of crop infestation with at least two applications at 7-day intervals resulted in increased chickpea yield. It appears that *Bt*-based insecticides can act as effective IPM tools if awareness is developed among farmers about the critical time and methods of their safe application (Patil *et al*., 2017).

In Sudan El Shafie and Abdelraheem (2012) carried out a field evaluation of three biopesticides namely XenTari® 1kg/ha (*Bacillus thuringiensis*), Spinosad® 2L/ha (*Saccaroplyspora spinosa*) and NeemAzal®-T/S 2L/ha for integrated management of major pests of tomato and revealed that almost all treatments significantly reduced the populations of whitefly, aphids and African bollworm. The treatments also significantly reduced the per cent of fruits damaged by the APW.

2-1-7-4- Chemical control:

Insecticides are widely used for controlling *H.armigera* on tomato and several other crops including cotton. As a result, this insect has now developed resistance to a wide range of insecticides (Mohamed , 2011).

Rabari *et al*. (2017) noted that the exposure of successive generations while moving from one crop to another has made this pest highly resistant to many pesticides such as cyclodiene, pyrethroids, organophosphates, carbamates etc. Management of *Helicoverpa* in India and Australia in chickpea and other high value crops relies heavily on insecticides. Endosulfan, cypermethrin, fenvalerate, thiodi-

carb, profenophos, spinosad and indoxacarb have been found to be effective for *H. armigera* control on chickpea in Australia (Kambrekar, 2016).

Additionally, other synthetic insecticides including Carbaryl, Karate, Cypermethrin, Dimethoate and Monocrotophos have been documented to effectively protect tomato fruits (Degri and Mailafiya, 2013).

Sattar *et al*., (2017) study the effect of emamectin benzoate (Emamectin benzoate® 1.9 EC), lufenuron (Match® 50EC), flubendiamide (Belt 480® SC), spinosad (Tracer® 240 SC), indoxacarb (Steward® 150 EC), deltaphos (Deltaphos® 36 EC) and thiodicarb (Larvin® 80 DF) against 2nd instar *H. armigera* larvae under laboratory conditions and found that the emamectin benzoate is most potent, followed by flubendiamide, lufenuron, spinosad, indoxacarb. The pest expressed mild level of tolerance against deltaphos and thiodicarb.

In Sudan in the last two decades more than 81 chemical insecticides were recommended to control *B. tabaci* and *H. armigera* on tomato under Sudan conditions (Mardi and Sulaiman, 2018). Suliman and Bakheit (2013) recommended that Cyprofen 220 UL (cypermethrin 20g/L /profenfos 200 g/L) at the rate of 0.75 L/fed. (15/ 150 g.a.i/fed.s) for the control of the African bollworm on sunflower crop in the Sudan. Treatment with Kung Fu 5% EC at 0.15 litre/fed and Karate Zeon 10% at 0.75 litre/fed., significantly reduce the infestation level on tomato (Mohamed , 2011).

The old Economic Threshold Level (ETL) for pesticide spray is 10 eggs or small larvae/100 leaves and the new ETL is 30 eggs or 10 small larvae/100 leaves. The number of insecticides sprays for bollworms ranges between 2 to 4 per season in Sudan (Suliman *et al*., 2015).

2-2- *Cassia occidentalis* (Coffee senna)

Cassia is a genus of flowering plants in the legume family, in which pecies are known commonly as cassias. There are hundreds of *Cassia* species. Among them, *Cassia occidentalis* Linn is an annual or perennial plant which is used in several traditional medicines to cure various diseases (Latha *et al*. 2016). *Cassia occidentalis* are candidate plants which may possess chemical compounds possibly oils, with insecticidal properties (Okonkwo and Ohaeri, 2018). In the Sudan, this genus is represented by at least 13 species (Omer *et al*., 2012).

2-2-1-Taxonomy:

Family: Caesalpinaceae

Genus: Cassia

Species: occidentalis

S. N: *Cassia occidentalis* L.

C. N: Coffee senna

2-2-2- Botanical description:

It is a straight, somewhat branched, smooth, semi-woody, fetid herb, 0.8-1.5m tall, hard, stout, with a few lateral roots on mid section 5–7. The stem of the plant is reddish purple. Leaves are alternate, even pinnately compound, each one with 4–6 pairs of nearly sessile, opposite leaflets with a fetid smell when crushed. Each leaflet 4–6 cm long, 1.5–2.5 cm wide, ovate or oblong, lanceolate with a pointed tip and fine white hairs on the margin. Stipules are 5–10 mm long, often leaving an oblique scar. Inflorescence is a compound of axillary and terminal racemes. The flower is perfect, 2 cm long with 5 yellowish green sepals with distinct red veins and 5 yellow petals. The fruit is a dry, dehiscent, transversely partitioned, faintly recurved, laterally compressed, sickle shaped legume (pod), 7–12 cm long, 8–10 mm wide, with rounded tip and containing 25–50 seeds. Seeds are oval shaped, 3.5–4.5 mm wide, flattened, pale to dark brown, smooth and with a round pointed tip (Singh *et al*., 2016).

2-2-3-Geographical distribution:

C. occidentalis is an annual shrub native to tropical and subtropical region of America, but has naturalized in Africa, Asian, Australia and Southern and Eastern USA (Temitope *et al*., 2017). It also grows throughout the tropics and subtropics including the United States from Texas to Iowa eastward, Hawaii, the Pacific Island territories, Puerto Rico, and the U.S. Virgin Islands. It appears to be of South American or New World origin (Singh *et al*., 2013). This plant are most commonly found in savannah areas of Africa and are utilized for various purposes and is found in many parts of the Sudan and commonly known as Soreib (Mariod and Matthäus, 2008).

2-2-4-Cultivation:

C. occidentalis can flower and fruit throughout the year or only periodically, depending on rainfall and temperature conditions and seasons. In cold or dry climates, the life cycle of *C. occidentalis* is complete in 6 to 9 months. In warm continually moist areas the plants may last a full year. Well-dried seed stored in airtight containers remain viable for more than three years. Seed should be treated to enhance germination. The distal end of each seed should be nipped or the seed can be immersed in concentrated sulphuric acid for 10 minutes and then rinsed with plenty of water. Seed should germinate between 5 and 36 days after sowing. *C. occidentalis* is planted in hedges and as an ornamental, but has the potential to become a weed in farmland and is often found in disturbed areas. It should therefore be managed carefully. The species can be controlled with broadleaf herbicides (Dharani *et al*., 2010).

2-2-5-Chemistry:

Phytochemical screening of the plant showed the presence of carbohydrates, saponins, sterols, flavonoids, resins, alkaloids, terpenes, anthraquinones, glycoside and balsam (Singh *et al*., 2016). The stem bark and leaf extracts of *C. occidentalis*

contain phytochemicals such as anthraquinones, reducing sugar, glycosides, cardiac glycosides, steroids, alkaloids, flavanoids, saponins, tannins, phenols, phytosterols, gum and mucilage (Temitope *et al*., 2017). This plant also include a wide range of chemical compounds such as achrosin, aloe-emodin, emodin, anthrones, apigenin, aurantiobtusin, campesterol, cassiollin, chryso-obtusin, chrysophanic acid, chrysarobin, chrysophanol and chrysoeriol. Anthraquinone derivatives reported mainly from leaves, seeds and roots (Dave and Ledwani, 2012). A toxic albumin besides chrysophanol has been detected in the seeds of *C. occidentalis*. From the seeds carbohydrates: maltose, lactose, sucrose and raffinose were also detected. Amixture of C-flavonoids of apigenin, among them probably vitexin and a 7-heteroside of vitexin, chrysophanol and emodin as well as their glycosides and free physcion have been reported from the leaves of *C. occidentalis* (Singh *et al*., 2016).

2-2-6-Medicinal uses:

C. occidentalis leaves are used for the treatment of yaws, scabies, itches and ringworm among the Yoruba tribe of Southwestern Nigeria. In addition to this, the leaves are also known to be effective against jaundice, headache and toothache. Infusion of leaves is used as an effective treatment for hepatitis among the rural dwellers in northern part of Nigeria (Taiwo *et al*., 2013). Leaves are widely used for various medicinal purposes including typhoid fever, malaria, liver and heart diseases, diabetes and arthritis (Sheshe *et al*., 2019). Also, leaves have ethno medical importance like wound healing, treatment of sores, cutaneous diseases, bone fracture, fever, and throat infection. It also used as a diuretic and in the treatment of snake-bite (Yadava and Satnami, 2011). *C. occidentalis* has long been used as natural medicine in rainforests and other tropical regions for the treatment of inflammation, liver disorders, constipation, worms, fungal infections, ulcers, and respiratory infections (Dave and Ledwani, 2012).

C. occidentalis also used to cure sore eyes, hematuria, rheumatism, typhoid, asthma, cure leprosy and disorder of haemoglobin. An infusion of the plant bark is given by the folklore in diabetes (Sini *et al*., 2011). Aqueous extract of stem and leaves of this plant showed a suppressive effect on *Trypanosoma cruzi* infected rats (Ibrahim *et al*., 2010). The ethanol extract of this plant has also been found to show a significant antihepatotoxic activity against carbon tetrachloride and thioacetamide as hepatotoxins and antidiabetic activity in normal and alloxan induced diabetic rats (Mustapha *et al*., 2013).

2-2-7- Uses in pest control:

The leaves of this plant are used for various disease treatments as well as in the control of some stored product insects especially in many parts of Africa (Abdullahi, 2011). In Senegal the leaves of *C. occidentalis* are used to protect cowpea seeds against *Callosobruchus maculatus* . Both fresh and dry leaves as well as whole and ground seeds had no contact toxicity on the cowpea beetle, in contrast the seeds oil induced an increase in mortality of *C. maculatus* eggs and first larval instars at the concentration of 10 ml/kg cowpea (Lienard, *et al*., 1993 , Latha *et al*., 2016).

The insecticidal efficacy of *C. occidentalis* oil is likely due to the presence of Decane, Oleic acid, 4, 7-methano-1H-indene, 3a, 4, 7, 7a-tetrahydro and n-hexadecanoic acid. Crude leaf extract has been reported to show growth regulating and adulticidal potential in *Anopheles stephensi* and suppressed wood damage by termites and causing mortality of worker termites within the shortest duration of application. *C. occidentalis* oil gave LD_{50} and LD_{90} (mg/kg) of 0.889 and 1.689 for *Periplaneta americana* (American cockroach), 1.013 and 1.973 for *Tettigonia virdissima* (great green bush cricket) and 0.722 and 1.847 for *Anopheles gambaie* (Okonkwo and Ohaeri, 2018).

2-2-8- Other uses:

C. occidentalis is used as a flowering shrub for landscape purposes. It is also used as a coffee substitute, where it has some medicinal uses as its seeds are brewed into the coffee-like beverage which is used for asthma (Nassar *et al*., 2011).The leaves are widely used as a leaf vegetable and are eaten either raw or mixed with coconut, chilli, and onion (Nassar *et al*., 2013). The gum derived from seed endosperm can be potentially utilized in a number of industries to replace the conventional gum (Gupta *et al*., 2005).

2-2-9-Animal toxicity:

Toxicity studies on the aerial parts, leaves and roots of *C. occidentalis* reported that various leaf and root extracts given to mice (administered orally and injected at up to 500mg/kg) cause mortality (Sadiq *et al*., 2012). Also all parts of the plant are toxic and most poisoning occurs when animals eat the pods and beans or fed on green chop containing *Cassia* plants. The toxic effects are seen on skeletal muscles, liver, kidney and heart in animals. One interesting attribute of *C. occidentalis* poisoning in animals is its propensity to cause different manifestations of toxicity in different animal species. However, the physiologic systems involved in toxicity depend also upon the dose of the beans consumed. When the dose is low the animal develops features of mild liver damage and myodegeneration and at higher doses (Vashishta *et. al*., 2009).

In another study the leaf extract was observed to be potentially toxic to mice with an intraperitoneal LD_{50} of 1000mg/kg body weight (Mustapha *et al*., 2013). Apparently all toxic effects are acute and it is believed that the toxins do not accumulate in body tissues. However, when consumed repeatedly over time the ill effects would be seen as chronic, but in fact it is the result of repeated acute poisoning due to the inclusion of *Cassia* vegetation in fresh green feed install fed animals (Vashishta *et al*., 2009).

2-3- *Datura stramonium* (Jimsonweed)

Datura is a genus of 12 or 14 species comprising of annual or perennial herbs and rarely shrubs or trees. *D. stramonium* is a cosmopolitan weed of cultivated fields, gardens, waste places, barnyards, and other disturbed habitats. It is characterized by its narcotic, hallucinogenic, and medicinal properties, as well as its effects in human poisonings (Hassan and Amer, 2019).

2-3-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Solanales

Family: Solanaceae

Genus: Datura

Species: stramonium

S. N: *Datura stramonium* L.

C.N. : Jimsonweed

2-3-2- Botanical description:

Datura stramonium L. is herbal plant with a height of 30 to 80 cm. This plant sometimes grows over one meter in height. It may reach the height of 3 – 4 feet on rich soil. The stem is green or purple, hairless, cylindrical, erect and leafy, smooth, branching repeatedly in a forked manner (Ganie *et al*., 2016).

The root is long, thick, fibrous and white. The leaves are about 8 to 20 cm long smooth, toothed, soft, and irregularly undulated. The upper surface of the leaves is a darker green and the bottom is a light green. The egg-shaped seed capsule is about 3 to 8 cm in diameter and either covered with spines or bald. At maturity it splits into four chambers each with dozens of small, black seeds (Miraj, 2016).

2-3-3-Geographical distribution:

Jimsonweed is a naturally fast growing weed and is widely distributed in all warm regions of the world. Its presence has been sighted along the boundaries and hedges of the cultivating fields (Dafaallah *et al*., 2019). It originates in the Americas but is now found around the world including the warmer regions of North, Central and South America, Europe, Asia, and Africa (Al-Snafi, 2017).

2-3-4-Chemistry:

The phytochemical screening revealed that it contains phenols, flavonoids, tannins, saponins, alkaloids, steroids and glycosides. All parts of the plant are toxic, but the ripe seeds contained the highest amount of alkaloids (Jawalkar *et al*., 2016). The toxic compounds found in all parts of the plant especially in the seeds are tropane alkaloids which possess strong anticholinergic properties. These alkaloids include hyoscyamine, hyoscine, atropine (d, l-hyoscyamine) and scopolamine (l-hyoscine (Benouadah *et al*., 2016).

Seeds of *Datura* contain the alkaloid daturine and it also contain fatty oil from which a new fatty acid, daturic acid (C17H34O2), was isolated. Two new tropane alkaloids, 3-phenylacetoxy-6, 7-epoxynortropane and 7- hydroxyapoatropine were tentatively identified. The alkaloids scopoline, 3-(hydroxyacetoxy) tropane, 3-hydroxy-6-(2 methylbutyryloxy) tropane, 3â-tigloyloxy-6-hydroxytropane,3,7-dihydrox y-6-tigloyloxytropane, 3-tigloyloxy-6- propionyloxytropane, 3-phenylacetoxy-6,7- epoxytropane, 3-phenylacetoxy-6-hydroxytropane, aponorscopolamine, 3â,6â-ditigloyloxytropane and 7-hydroxyhyoscyamine are reported for the first time for this species (Mukhtar *et al*., 2019).

2-3-5-Medicinal uses:

Datura stramonium is one of the widely distributed well-known folklore medicinal herb. An extract made from the leaves is taken orally for the treatment of sinus infections, asthma and stripped bark are applied externally to treat swelling, burns and ulcers (Jawalkar *et al*., 2016). Its leaves are mixed with mustard oil for the

treatment of skin disorders. Juice obtained from the flower petals is used to cure ear pain. Seeds are effective to relieve asthma, fever and cough and for narcotic purposes. Its roots and shoot extracts show high anti-microbial and anti-fungal activities (Bakht *et al*., 2019). In West Africa the whole plants are used for anti-inflammatory and for treatment of dental pain and skin infections. The dried pulverized leaves are sprinkled on wounds or mixed with ointment for healing (Aboluwodi *et al*., 2017). The juice of the leaves in warm milk was used to expel intestinal worms including cestodes. Seeds with palm oils used externally for insect bites and stings in Nigeria. In Ayurvedic medicine the plant was used for the treatment of ulcers, wounds, inflammation, sciatica, bruises and swellings, rheumatism, gout, asthma bronchitis and toothache (Al-Snafi, 2017).

In Western Nepal the leaves of *Datura* along with the leaves of *Cannabis sativa* and stem of *Neopicrorhiza scrofulariflora* are pounded with water and applied to treat headaches. *Datura* seeds are crushed with grains of rice and taken orally to relieve indigestion. Juice from the leaves is given with warm milk to expel intestinal worms specifically tapeworm (Gaire and Subedi, 2013). Other ethnomedicinal uses of the plant are its anti-inflammatory property where all parts of the plants are used for stimulation of the central nervous system, respiratory decongestion, treatment of dental and skin infections (Mukhtar *et al*., 2019).

2-3-6- Uses in pest control:

The ethanolic extracts of leaves of *Datura stramonium* were evaluated for larvicidal and mosquito repellent activities against *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus*. The LD_{50} values for larvicidal activity were found to be 86.25, 16.07 and 6.25 ppm against *Aedes aegypti*, *Anopheles stephensi and Culex quinquefasciatus* respectively. The ethanolic leaves extract of *Datura stramonium* provided complete protection time (Mosquito repellency) of 2.73, 71.66, 117.7 mins against these insects at 1% concentration (Al-Snafi, 2017).

Jawalkar *et al*. (2016) Stated that the ethanol, chloroform and acetone extract of *D. stramonium* seeds was effective against *S. oryzae* with LC_{50} and LC_{90} values of 1680 and 534.62 ppm respectively. *Datura stramonium* was found equally effective at inhibiting motility of *Meloidogyne incognita* and *Meloidogyne javanica*, but inhibition occurred more quickly for *M. incognita* (Oplos *et al*., 2018).

Acetone extracts of *D. stramonium* have been reported to have antifungal activity against several fungi including *Penicillium expansum*, *Aspergillus niger*, *Aspergillus parasiticus*, *Colletotrichum gloeosporioides*, *Fusarium oxysporum*, *Trichoderma harzianum*, *Phytophthora nicotiana*, *Pythium ultimum* and *Rhizoctonia solani*. The MIC of *D. stramonium* extracts ranges from 1.25 to 2.5 mg/mL. The ethanolic extracts of *D. stramonium* leaf and seed showed potent acaricidal, repellent, and oviposition deterrent activity against adult two-spotted spider mites *Tetranychus urticae* under laboratory conditions (Gaire and Subedi, 2013).

Sakadzo *et al*. (2018) conclude that *D. stramonium* leaf aqueous extracts have both pre-emergence and early post emergence herbicidal effects towards the weeds *Tagetes minuta* and *Amaranthus hybridus* in Zimbabwe.

2-3-7- Toxicity:

The toxicity of *D. stramonium* in grazing animals have been suspected by livestock owners and field veterinarians especially at time of drought or after ingesting freshly harvested maize that will be used for ensiling and heavily contaminated with young *D. stramonium* (Al-Rubaye *et al*., 2018). Consumption of *D. stramonium* interferes and obstructs the action of neurotransmitters in the nervous system. *Datura* toxins cross the blood-brain barrier and inhibit acetycholine. Children are especially vulnerable to atropine poisoning and their prognosis is likely to be fatal symptoms likely to be produced by tropane alkaloids such as scopolamine, hyoscyamine, and atropine include urinary retention, dry mouth, throat, and skin, blurred vision, headache and nausea, dizziness, convulsions, fever, euphoria, hallucinations, short-term memory loss, delirium, hyperthermia, rapid heartbeat,

agitation, including bizarre, inexplicable, and possibly violent behavior and severe hyper-dilation of the eye pupil, with resultant painful photophobia that can last several days unconsciousness and coma (Mukhtar *et al*., 2019).

Acute poisoning symptoms include dryness of the mouth and extreme thirst, dryness of the skin, pupil dilate ion, impaired vision, urinary retention, rapid heartbeat, confusion, restlessness, hallucinations, and loss of consciousness. Overdosing on Jimsonweed will lead to: Visual hallucinations, Disorientation, Speech incomprehension, dilated pupils and can be fatal. Many cases of severe acute anticholinergic toxidrome, delirium, agitation and seizures (Muhammad *et al*., 2019).

2-4- *Cyperus rotundus* (Nut sedge)

Although *C. rotundus* is growing commonly and considered as noxious weed but at the same time it contains tremendous important medicinal as well as pharmacological properties. The most effective parts of this perennial herb are rhizomes and tubers. The presence of various secondary metabolites makes it important and of great value for medicinal purpose (Bajpay *et al*., 2018).

2-4-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta

Class: : Liliopsida

Order: : Cyperales

Family: Cyperaceae

Genus: *Cyperus*

Species: *rotundus*

S. N: *Cyperus rotundus* L.

C. N.: Nut sedge

2-4-2- Botanical description:

Cyperus rotundus L also known as purple nut sedge or nut grass is a common perennial weed with slender, scaly creeping rhizomes, bulbous at the base and arising singly from the tubers which are about 1 – 3 cm long. The tubers are externally blackish in colour and reddish white inside with a characteristic odour. The stems grow to about 25 cm tall and the leaves are linear, dark green and grooved on the upper surface (Kabbashi *et al*., 2015).

The flowers are borne in clusters (inflorescences) at the ends of the stems. The inflorescence consists of around three to nine stalks of varying lengths, at the ends of which are reddish-brown to purple (spikelets). Each spikelet 3.5 cm in length and consists of 10 to 40 flowers which lack petals but instead it have dry, membranous, oval-shaped bracts, known as (glumes). It produces a dry, single-seeded fruit which is up to two millimeters long and brown to black with a network of grey lines (Al-Snafi, 2016).

2-4-3-Geographical distribution:

C.rotundus is a cosmopolitan weed found in tropical, subtropical and temperate regions and grows well in continents like Asia, Africa, Europe and America (Hana and Hifzul, 2018). It is a noxious weed of tropical and subtropical regions of the world and it reported in 52 different crops in 92 countries (Baloch *et al*., 2015).

2-4-4-Chemistry:

C. rotundus contain many secondary metabolites such as sesquiterpenes (with diverse skeletons such as patchoulane, rotundane, eudesmane, guaiane, cadinane and caryophyllene types), quinones, flavonoids (visnagin, khellin, ammiol, isorhamnetin, and tricin), saponins, alkaloids, phenolic acids (salicylic acid, protocatechuic acid, caffeic acid and *p* coumaric acid), coumarins and steroids (steroidal glycoside, sitosteryl-(6'-hentriacontanoyl)-*β*-dgalactopyranoside) (Bajpay *et al*., 2018).

Fifty two compounds were isolated from *C. rotundus* from Egypt (+) oxo-α-ylangene (9.35%), (+) α-cyperone (9.07%) trans-pinocarveol (7.92%) and cyperene (7.83%) were the major constituents in the oil of *C. rotundus*. Sesquiterpene compounds represented the largest amounts in the oil. Among the oil constituents, cyperene (16.9%), caryophyllene oxide (8.9%), α-longipinane (8.4%) and β-selinene (6.6%) represented the major components (Al-Snafi, 2016).

The aqueous extract of *C. rotundus* contains active substances that include Resins, Saponins, Tannins, Alkaloids, Coumarin, Flavonoids and Phenols. volatile oils, terpenes, steroids (Aldulaimi and Husain, 2019).

2-4-5-Medicinal uses:

In oriental traditional medicine *C. rotundus* is used as an antioxidant and anti-inflammatory, anti-diabetic, anti-diarrheal, anti-malarial and anti-pyretic and analgesic. The tubers are used to treat dysmenorrheal and menstrual irregularities. The leaves are used by local folks of Middle East and Southeast Asia to flavor food where it is an important component in their daily diet. The seeds are also used as a curries and pickling spices in India and Southeast Asia. Seeds have digestive properties and are used for cure of minor digestive problems and for hemorrhoids and painful joints (Baloch *et al*., 2015).

In Sudan the tubers of *C. rotundus* L. are used in stomach disorders and bowels irritation. An infusion of the tubers is used in dyspepsia, diarrhea, dysentery, ascites, vomiting, cholera and fevers. The tubers are given in large doses as an anthelmintic. A poultice of the fresh tubers is used to cure wounds, ulcers and sores; it is also applied to the breast to promote the flow of milk (Kabbashi *et al*., 2015).

The roots and rhizomes of *C. rotundus* are useful in diarrhea, dyspepsia, cholera, inflammation, dysentery, skin rashes and excess bleeding while fresh tubers in the form of paste or plasters are applied on the breast, scorpion sting and spreading ulcers. The tubers traditionally used as; antiemetic, anthelmintic, antipyretic, hypertensive and smooth muscle relaxant (Hussain *et al*., 2018).

2-4-6- Uses in pest control:

Petroleum ether and ethyl alcohol extracts of *C. rotundus* showed good mosquito larvicidal potential. Petroleum ether exhibits LC_{50} 443.80 ppm and ethyl alcohol exhibits LC_{50} 594.22 ppm against *Aedes aegypti* larvae. The LC_{50} against 2^{nd} and 3^{rd} instar larvae of diamondback moth was 7‑12 ppm (Imam *et al*., 2013).

Acetone leaves extracts at 50% exhibited significant mortality percentage of 46.66 and 51.6 repellency against rice grains weevils *Sitophilus Oryzae* (El Monairyand Kamel, 2011). Also the ovicidal and larvicidal effect of essential oils extracted from the tubers of *C. rotundus* was studied on eggs and fourth instar larvae of *Aedes albopictus* at concentration ranging from 5 to 150 ppm and the results showed a remarkable ovicidal and larvicidal activities against *Aedes albopictus* (Hana and Hifzul, 2018).

Essential oil of *C. rotundus* were screened for their antibacterial activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilisand Staphylococcus aurous*, and anti-fungal activity against *Candida albican*, *Aspergillusniger*, *Fusarium oxysporum* and *Aspergillus flavus* (Bajpay *et al*., 2018).

2-4-7- Toxicity:

The acute and subacute toxicities of the ethanol extract from *Cyperus rotundus* were evaluated in rats. A single oral administration of the ethanol extract at a dose of 5000 mg/kg did not produce signs of toxicity, behavioral changes, mortality and differences on gross appearance of internal organs. In subacute toxicity all rats were received a repeated oral dose of 1000 mg/kg of the ethanol extract over 14 days. The results showed that the extract did not cause changes in terms of general behaviors, mortality, weight gain, hematological and clinical blood chemistry parameters (Al-Snafi, 2016).

The phytotoxicity of *C.rotundus* was tested against the growth of number of crop plants. Aqueous tuber extracts of reduced seed germination and seedling growth of rice, corn, cucumber, tomato, sorghum, and onion (Kavitha *et al*., 2012).

2-5- *Ricinus communis* (Castor Bean)

Castor bean (*Ricinus communis* L) has traditionally been used in agriculture. In fact it is a unique species of the genus *Ricinus* in the family Euphorbiaceae as its seeds contain 2.8–3% toxic substances such as ricin, a potent inhibitor of protein synthesis and agglutinin-1and source of lipid reserves, secondary metabolites and fuels in the pharmaceutic and oil industry. (Martin-Gómez *et al*., 2016). The name of the genus "*Ricinus*" comes from the Latin word meaning "dog tick" because of the seed that resembles the prevalent dog pest (Barad *et al*., 2019).

2-5-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta (Flowering Plants)

Class: Magnoliopsida (Dicotyledons)

Order: Malpighiales

Family: Euphorbiaceae

Genus: Ricinus

Species: *communis*

S. N: *Ricinus communis* L.

C. N. : Castor bean

2-5-2- Botanical description:

Castor is a perennial erect, branched herb, typically less than 2 meters in height. Large leaves are alternate, palmately lobed with 5-11 toothed lobes. Leaves are glossy and often red or bronze tinted when young. Flowers appear in clusters at the end of the main stem in late summer. The fruit consists of an oblong spiny pod which contains three seeds on average. Seeds are oval and light brown, mottled or streaked with light and dark brown and resemble a pinto bean (Warra, 2018).

R. communis is a shrub-like plant with reddish to purple stems that may reach 4–5 m in height. It has separate male and female flowers on the same individual. There are no petals and each female flower consists of a little spiny ovary and a bright red structure with stigma lobes that receives pollen from male flowers. Each male flower consists of a cluster of many stamens which literally smoke as they shed pollen in a gust of wind. Seed size ranges from 0.08-0.9 g by weight and 0.8-1.9 cm by height and there are two varieties: small seeded variety and large seeded variety(Saadaoui *et al*., 2017).

2-5-3-Geographical distribution:

It originated from East Africa and Ethiopia and it cultivated mainly in subtropical regions and has a high adaptability in cultivation even in bad environment. India is the largest producer of castor beans, followed by China and Brazil, while in South Korea (Jeong *et al*., 2019). Its widely distributed in the Mediterranean region, the Middle East, Eastern Africa and the Indian sub-continent (Hajrah *et al*., 2019).

2-5-4-Chemistry:

GC-MS analysis of *Ricinus communis* revealed the existence of the1,2,3,4-Butanetetrol, [S-(R*,R*)]-, Ribitol, 3-Ethoxy-1,2-propanediol, DL-Arabinose, p-Dioxane-2,3-diol, D-Limonene, Dodecanoic acid, 3-hydroxy-, Methyl 6-oxoheptanoate, Dithiocarbamate, S-methyl-, N-(2-methyl-3-oxobutyl)-, (5β)Pregnane-3,20β-diol,14α,18α-[4-methyl-3-oxo-(1-oxa-4- , 3-(N,N-Dimethllaurylammonio) propanesulfonate, Cetene, Gibberellic acid, Geranyl iso-valerate, Phenol,4-(1,1,3,3-tetramethylbutyl)-, Picrotoxinin, and α-N-Normethadol. The FTIR analysis of *Ricinus communis* leaves proved the presence of alkanes, and alkyl halide, Amine, Aldehyde, and Alkane (Hussein *et al*., 2018). The phytochemical investigation showed the presence of alkaloids, glycosides, proteins, free amino acids, lignin, carbohydrates, flavonoids, tannins and phenolic compound (Parajapati *et al*., 2018).

Castor bean contains steroids, saponins, alkaloids, flavonoids, tannins, phenols, phytates, oxalates and glycosides in different parts of the plant including roots, leaves and seeds (Rashmi *et al*., 2019).

2-5-5-Medicinal uses:

Every part of the plant has been used for medicinal purposes and it is a multipurpose folk herbal plant with a number of medicinal properties. The application of castor oil in India has been documented since 2000 BC as a laxative, purgative, cathartic and for curing arthritic diseases in the Ayurvedic ethnomedical system. Castor seed and its oil have also been used in China for centuries as traditional medicine for internal use or for use in dressings. The seed oil of *Ricinus* has been used as folk therapy for tumours, warts, whitlows; an infusion from leaves is used as an eye lubricant, to treat jaundice and also for relief of stomach ache. The roots are used for various purposes such as a powerful purgative in the form of decoction and for relief of toothache. It also proved to possess strong anticancer, anti-inflammatory and antidiabetic activities (Hajrah *et al*., 2019).

A poultice of caster seeds can be applied with gratifying results to gouty and rheumatic swellings and also it applied to scrofulous sores and boils due to tuberculosis of lymph nodes. A decoction of its roots with carbonate of potash is useful in the treatment of lumbago, rheumatism and sciatica. A paste of kernel without the embryo boiled in milk is also given as medicine. The hot leaves can be applied over guinea – worm sores to extract the worm (Ladda and Kamthane, 2014).

Ricinus communis possess good antimicrobial activities against pathogenic bacterial strains such as *Staphylococcus aureus*, *Streptococcus progenies*, *Bacillus subtilis* as well as *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Proteus vulgaris*, *Salmonella typhimurium*, *Escherichia coli* and many others. Also it shows antimicrobial activity against some fungal pathogens i.e. *Candida albicans*, *Aspergillus niger* etc. (Rashmi *et al*., 2019).

Ricinoleic acid has been shown to be effective in preventing the growth of numerous species of viruses, bacteria, yeasts and molds. This will explain high degree of success in the topical use of the oil for treating ailments such as ringworm, keratoses (non-cancerous, wart-like skin growths), skin inflammation, abrasions, fungal-infected finger and toe nails, acne and chronic pruritus (itching). Therapeutically, modern drugs are rarely given in a pure chemical state. Most of the active ingredients are combined with additives. Castor oil or a castor oil derivative such as Cremophor EL (polyethoxylated castor oil, a nonionic surfactant), is added to many modern drugs including Miconazole, an antifungal agent, aclitaxel, a mitotic inhibitor used in cancer chemotherapy etc. (Ramanjaneyulu *et al*., 2017). In the northern part of Nigeria rural dwellers occasionally utilize the bark and leaves of this plant for local treatment of malaria (Ahmed *et al*., 2018).The seeds are used traditionally to treat conjuctivitis, diarrhea, anaemia constipation and headache. A gel prepared from the oil is traditionally useful in skin diseases particularly dermatitis and eczema and is also used to make contraceptive jellies and creams (Warra, 2018).

2-5-6- Uses in pest control:

Extract of *R. communis* exhibited acaricidal and insecticidal properties against the adult of *Haemaphysalis bispinosa* Neumann (Acarina: Ixodidae) and hematophagous fly *Hippobosca maculata* Leach (Diptera: Hippoboscidae). Castor cake when applied to the soil protect the plants from soil nematodes, insects, and parasites by acting as a natural repellant. The population of plant parasitic nematodes and the frequency of the pathogenic fungi significantly reduced in chickpea and wheat fields due to application of castor cake (Ramanjaneyulu *et al*., 2017). Also antimicrobial and anticarcinogenic properties of the essential oil have been showed. Castor bean leaves are used in preparing long acting biocide compounds which are safe and stable and can completely control pests such as mosquitoes, flies, cockroaches, ants, fleas and lice in 24 hours (Saadaoui *et al*., 2015).

Singh and Kaur (2016) Studied the toxicity of leaf extracts of *Ricinus communis* L against the third instar larvae of *Musca domestica* L. and they found that the LC_{50} values recorded in case of dipping method were 3g/100ml, 2.5g/100ml, 1.5g/100ml, 5.5g/100ml in methanol, ethyl acetate, chloroform and petroleum ether extract respectively. Also they stated that the *Ricin* is the most toxic bioactive component present in seeds but ricinine which is an effective insecticide is located in all parts of the plant. The leaf extract of *R. communis* has been shown to posses insecticidal properties against insect pests like *Spodoptera frugiperda*, *Callosobruchus chinensis* and *Cosmopolites sordidus*(Coleoptera: Curculionidae). The LD_{50} against *C. maculatus* was 0.14 (0.05-0.22) µl per 50 grams seeds. Application of castor seed oil at the rate of 0.7- 1.5 µl per 50 g bambara groundnut seed gave significantly high percentage oviposition inhibition rate and this indicate that castor seed oil could be used to control *C. maculatus* in stored bambara groundnut (Babarinde *et al*., 2016).

The aqueous leaves extracts of *R. communis* possess suitable larvicidal activity against *Anopheles arabiensis*, *Callosobruchus chinensis* and *Culex Quinquefasciatus* mosquitoes. Also the leaf extract possess molluscicidal activity against *Lymnaea acuminata* and the seed extracts showed better insecticidal activity than the leaf extracts against *S. frugiper* (Parajapati *et al*., 2018). The aqueous leaves and seed extracts at 30% concentration significantly reduced root gall index in tomato and the author concluded that this plant can serve as good alternative for the management of root knot nematode *Meloidogyne incognita* (Oluwatayo *et al*., 2019).

2-5-7- Toxicity:

The castor beans are known for their high toxicity for centuries. In ancient times farmers knew to keep their livestock away from the castor plant or else they would risk losing them (Bhakta and Das, 2015).

The toxicity of raw castor beans due to the presence of ricin is well-known. Although the lethal dose in adults is considered to be 4 to 8 seed. If castor bean is ingested symptoms may be delayed by up to 36 hours but commonly begin within 2–4 hours. These include a burning sensation in mouth and throat, abdominal pain, purging and bloody diarrhea. Within several days there is dehydration, a drop in blood pressure and a decrease in urine. Unless treated death can be expected to occur within 3–5 days however, in most cases a full recovery can be made (Muhammad *et al*., 2015).

The component that causes the toxication is ricin which is a glycoprotein structure that consists of two chains (Chain A: protein synthesis inhibitor and Chain B: cell-surface bond function). When ricin inhaled can cause nausea, exhaustion, respiratory problems, coughs, and pulmonary edema that may lead to death. If ricin taken orally, it can cause abdominal pain, nausea, vomiting, diarrhea, liver and kidney dysfunctions, and rare cases of hematemesis and melena. When injected into tissue, it can cause local pain, allergic reactions, liver and kidney dysfunctions, and necrosis. The lethal toxin dose is 3 to 5 μg/kg when inhaled and 20 mg/kg when taken orally. Unripe *R. communis* seeds are more toxic than ripe seeds. For the seeds to display toxic features, their shell must be broken by crushing or chewing before swallowing. Evidence shows that 1 g of seed consists of 9.9 mg of toxin on average (Boğan *et al*., 2019).

2-6-*Bacillus thuringiensis* (*Bt*)

Bacillus thuringiensis (*Bt*) is a Gram-positive bacterium that produces insecticidal crystal proteins (ICPs) during sporulation. ICPs are mostly *Cry* proteins an important component of *Bt* biopesticides and vital tools for insect control in transgenic crops. The identified *Cry* proteins have been classified into *Cry1−Cry*78 on the basis of amino acid sequence identity. Among these *Cry*1, *Cry*2, and *Cry*9 proteins exhibit strong insecticidal activity against lepidopteran pests. *Cry*1 proteins have been widely applied in transgenic cotton, corn, and soybean to control lepidopteran pests over the last 22 years (Shan *et al*., 2019).

2-6-1-Classification:

Kingdom: Bacteria

Phylum : Firmicutes

Class: Bacilli

Order: Bacillales

Family: Bacillaceae

S. N : *Bacillus thuringiensis* Berliner.

2-6-2-Morhology:

Bt is an aerobic Gram-positive and rod-shaped bacterium, with a vegetative cell of 1.0–1.2 μm wide and 3.0–5.0 μm in length, usually mobile by means of peritrichous flagella, naturally not numerous. The flagella may bind to insect cells and is important in virulence. The spores of this bacterium has an ellipsoidal shape but mostly are cylindrical and is located in the central or paracentral region when inside the mother cell. The species is non-strict aerobic with a temperature range of growth between 10–5 °C and 40–45 °C. The main characteristic that distinguishes this species from the others of the same genus is the intracellular presence of a protein crystal. Cells grown on glucose nutrient agar produce large amount of storage material, giving a vacuolated or foamy appearance (Rabinovitch *et al*., 2017).

2-6-3-Ecology and Prevalence of *B. thuringiensis* :

Bt occurs naturally and it can also be artificially added to an ecosystem to achieve insect control. For this reason the prevalence of *Bt* in nature can be defined as "natural" and "artificial". *Bt* is indigenous to many environments including soils and insect cadavers, stored product dust, leaves of plants, and aquatic environments. Moreover *Bt* has recently been isolated from marine sediments and soils of Antarctica. Thus, it is obvious that it is widespread in nature. However, the normal habitat of the organism is soil. The organism grows naturally as a saprophyte feeding on dead-organic matter therefore, the spores of *Bt* persist in soil and vegetative growth occurs when nutrients are available (Osman *et al*., 2015).

2-6-4-*Bt* Toxins :

2-6-4-1- Crystal Toxins (δ-endotoxins):

Crystal proteins are formed as parasporal crystalline inclusions during the stationary phase of growth. The most widely known are the δ-endotoxins, including *Cry* and *Cyt* toxins. *Cry* toxins do not belong to a single, homologous family of proteins. The largest group comprises the well-known three-domain *Cry* proteins. There are 73 different types (*Cry*1 to *Cry*73) of *Cry* proteins including three-domain with individual toxins showing well documented toxicity against lepidopterans, coleopterans, hemipterans, dipterans, nematodes and some snails. The *Cyt* (cytotoxic) proteins constitute a smaller and distinct group of crystal proteins with insecticidal activity against several dipteran larvae particularly mosquitoes and black flies; additionally some *Cyt* toxins are capable of synergizing the insecticidal activity of other *Bt* proteins. In contrast to *Cry* proteins and *Cyt* proteins exhibit a general cytolytic (hemolytic) activity in vitro and predominantly dipteran specificity in vivo(Palma *et al*., 2014).

2-6-4-2- Vegetative insecticidal proteins (Vip) toxins:

In addition to -indotoxins (*Cry* and *Cyt* toxins) *Bt* produces a novel family of insecticidal proteins named vegetative insecticidal proteins (Vip) during its vegetative stage. Two classes of Vip toxins were described. The first consists of a binary system composed of two proteins namely Vip 1 and Vip 2 which are 100 kDa and 52 kDa in size respectively. These proteins are highly toxic to certain coleopteran. The second class is of a 88.5 kDa protein (Vip 3) and active against a wide range of lepidopteran insects. These two classes of proteins do not display sequence homology with *Cry* or *Cyt* proteins. There are about 82 identified *Vip* genes. The Vip toxins do not form crystals. Currently available *Bt* cotton varieties produce either or both *Cry* toxins and Vip toxins that target specific caterpillar pests such as beet armyworm, *Spodoptera exigua*; cotton bollworm, *Helicoverpa armeigera*; and tobacco budworm, *Heliothis virescens* (Abbas, 2018).

2-6-5-Toxin specificity :

There is a good correlation between *Bt* subspecies and insect host range at the family level. For example most *Bt kurstaki* strains are specific for lepidopteran insects whereas *israelensis* strains are specific for dipterans and *morrisoni* strains are specific for coleopterans. Other strains are not active against insects at all but are toxic towards different invertebrates such *Bt* strains containing only *Cry*5- and *Cry*6-type toxins are active against nematodes. The toxins can be described in terms of their amino acid sequences, protein structures and modes of activity. *Cry* toxins interact with specific receptors located on the surface of midgut epithelial cells and are activated by host proteases following receptor binding resulting in the formation of a pre-pore oligomeric structure that is insertion competent. In contrast, *Cyt* toxins directly interact with membrane lipids and insert into the membrane (Sanahuja *et al*., 2011).

2-6-6-Mode of Action:

Bt spores have to be ingested by the susceptible insect to cause mortality. The *Cry* toxin becomes active by proteoletic enzymes in the alkaline gut juice (pH 8–10). Most *Cry* toxins are actually pro-toxins of about 130 to 140 kDa and after activation they become 60–70 kDa. The activated toxin passes through the peritrophic membrane and binds to specific receptors on apical microvillar brush border membrane of the epithelial cells of the midgut making pores through which the toxin penetrates to such cells that become swollen. The swelling continues until the cells lyse and separate from the basement membrane of the midgut epithelium. The alkaline gut juices then leak into the hemocoel causing the hemolymph PH rises that leads to paralysis and death of the insect. In the *Bt*-moderately sensitive insects such as Spodoptera *spp*. the endospore has a considerable role in killing the insect by producing toxins during its vegetative growth in the hemolymph. The *Cyt* toxin is also a protoxin about 28 kDa and is activated by the proteolytic enzymes in the midgut juice to become 24 kDa. The toxin then penetrates from peritrophic membrane and the epithelial cells which lyse and separate causing the death of the insect (Abbas, 2018).

The active toxin consists of three distinct structural domains. Domain I (7 α -helices) determines toxicity and pore formation. Domain II (3 ß–sheets) determines receptor binding and specificity whereas Domain III (2 ß–sheets), is involved in receptor binding and protein processing. The active toxin binds to specific receptors located on the apical brush border membrane of the columnar cells in the midgut of target insect the α -helices penetrate the membrane and lead to formation of pores (ion channels). The toxicity of *Bt* lies in the organisation of α-helices derived from domain I. The toxin induced pores formed in the columnar cells of mid gut and allow rapid fluxes of ions leading to swelling of the cells and osmotic lysis. The disruption of gut integrity leads to death of the insect through starvation or septicemia (Keshavareddy and Kumar, 2018).

2-7- *Balanites aegyptiaca* (Desert Date)

The desert date (*Balanites aegyptiaca* L.Delile; Zygophyllaceae) is found in many parts of the world. It contains many secondary metabolites such as alkaloids, saponins, steroids, flavonoids, tannins, and phenolic compounds which possess different biological activity such as mosquitocidal, larvicidal, and insecticidal properties (Mokhtar *et al*. 2021).

2-7-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta (Flowering Plants)

Class: Magnoliopsida (Dicotyledons)

Order: Sapindales

Family: Zygophyllaceae

Genus: *Balanites*

Species: *aegyptiaca*

S. N: *Balanites aegyptiaca* L. Delile.

C. N. : Desert date

2-7-2- Botanical description:

The tree can grow to 6–10 meters in height and is highly resistant to stresses such as sandstorms and heat waves and can grows with minimal available moisture. The tree has thick, tough glossy leaves, spiny branches, and a double root system and produces date-like fruits. The plants grow extensively even when neglected. It can successfully grow in a marginal sand dune with saline and sewage water (Chapagain and Wiesman, 2005).

2-7-3-Geographical distribution:

The desert date is found in most arid to sub-humid areas of Africa and South Asia. The tree is widely distributed in the drylands of Africa from Mauritania to Nigeria and eastward to Ethiopia, Somalia, and East Africa (Mokhtar *et al*. 2021). It is widely distributed in the Sudan under rainfall of less than 1000mm, with higher occurrence in zones of 200 –800mm (Elamin and Satti, 2013).

2-7-4-Chemistry:

Secondary metabolites like rotenone, coumarin, bergopin, steroids yamogenin and the flavonoids isorhamntetin-3-rutinoside and 3-rhamnoglactoside were detected in different parts of the tree. It also named as an African-Asian saponin-producing plant due to its high constituent of saponin compounds (Elamin and Satti, 2013).

2-7-5-Medicinal uses:

Various parts of the *Balanites* tree have been used for folk medicines in many regions of Africa and Asia. A literature survey has revealed antidiabetic, antihelminthic, and contraceptive activities in various *Balanites* extracts (Chapagain and Wiesman, 2005).

In Sudanese folk medicine the aqueous extract of the bark is widely used as an anti-jaundice agent (Mohamed *et al*., 1999).

2-7-6- Uses in pest control:

The oils of *B. aegyptiaca* can act as an alternative agent for the control of *Callosobruchus maculates* and can affects the viability and subsequent development of eggs and larvae to develop. The oils also affects movement of the adult weevils and this might have made mating impossible thus very few eggs deposited and eventually very low productivity results. Extracts from several parts of *B. aegyptiaca* were shown to exhibit antifeedants and mollucidal activities against variety of pests and steroidal saponin is believed to be the main caused behind these activities (Nwaogu *et al*., 2013).

Elamin and Satti (2013) studied the effects of different desert date extracts on *Trogoderma granarium* larvae and they found that a significant variations in its insecticidal properties whereas the seeds hexane extract (oil) achieved significantly best larval mortality compared with the other intermediate and high polarity extracts. The oil extract also exerted significant repellent effect on the pest larvae and significant reduction in sorghum damage compared with control.

The effect of aqueous extracts of the fruit pulp, seed kernel, roots, bark, and leaves of *Balanites aegyptiaca* were also studied against the larvae of the *Culex pipens* mosquito (Chapagain and Wiesman, 2005).

2-8- *Eucalyptus camaldulensis* (Eucalyptus)

Eucalyptus camaldulensis is a tree under the genus *Eucalyptus* which contains specific compound like essential oil in tits different parts. Also it possess some phytochemicals which claimed to have a pesticidal and also medicinal activities on various ailments (Khan *et al*., 2018).

2-8-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Myrtales

Family: Myrtaceae

Genus: *Eucalyptus*

Species: *camaldulensis*

S. N: *Eucalyptus camaldulensis* Dehnh.

C.N. : Eucalyptus.

2-8-2- Botanical description:

E. camaldulensis is a single-stemmed, evergreen, perennial tree 30 m in hieghet. The leaves are grey-blue, alternate, drooping 8‑22 cm long, 1‑2 cm wide, o ten curved or sickle shaped, tapering, and short pointed at base. Fruit is very small capsules at the end of thin stalks 5‑8 mm containing minute seeds (Sabo and Knezevic, 2019). In open areas it has a short trunk, wide crown and has many branches.Its leaves are yellowish in green, and the flowers are fairly round shape which come from the end buds (Ghasemian *et al*., 2019).

2-8-3-Geographical distribution:

Eucalyptus is native to Australia and widely distributed in many countries,including Argentina, Chile, Orange and the tropical regions of Brazil, South Africa and India and is grown and multiplied in more than 70 countries (Ghasemian *et al*., 2019).

2-8-4-Chemistry:

Phytochemical constituents such as steroid and fatty acids, tannins, poly phenolics, glycosides, terpenes, alkaloids, flavonoids,Saponins, Lignins, Vitamin C, Phenolics, Triterpenoid, Flavones, Anthocyanin, Anthraquinone, Steroids, Coumarins, Cardiac glycosides reported on different solvent extract of the bark. Leaf essential oils on the other hand found out to contain flavonoids tannins, alkaloids, glycosides, terpenoids and steroids (Getahun, 2016). The essential oil of the leaves was found to contain p-cymene, _-terpinene, _-pinene, 1,8-cineole, terpinen-4-ol, terpineol, carvacrol and thymol as the major components. The major components of the essential oil of the fruits were aromadendrene, pinene, drimenol, and cubenol. A pentacyclic triterpenoid, named camaldulin along with ursolic acid lactone acetate and ursolic acid lactone were isolated from this plant. Also some flavonoid glycosides were isolated from its leaves (Singab *et al.*, 2011).

2-8-5-Medicinal uses:

Eucalyptus trees are well known for the medicinal properties of the oil contained in their leaves which was used in traditional aboriginal medicines to heal wounds and fungal infections. It works very effectively as an antibiotic that is particularly successful against some strains of bacteria. The oil also possesses anti-inflammatory properties and it can stimulate the flow of blood and works to ease muscle and joint pain and also acts as an antiseptic and works well in treating sore throats, mouth sores, gum disease and gingivitis(Sani *et al*., 2014).

*E. camaldulensis*t also used to reat sore throat, anesthetic, wound, dysentery, anti-septic, diarrhea, cold, hemorrhage,cough, fever and wide range of ailments, gas-trointestinal symptoms, bladder infections, enteric infections, asthma, oral thrush, boils, sores, asthma, bronchitis, eczema and athletes foot (Getahun, 2016).

2-8-6- Uses in pest control:

Various biological properties have been attributed to the genus *Eucaly ptus*, among them larvicidal activity on culicids, insecticidal activity against beetles, and repellent action against *Phlebotomus papatasi*. The leaf extract of *E. camal-dulensis* have the potency to consider as an effective larvicidal agent against *Cu-lex quinquefasciatus* (Khan *et al*., 2018).

The *Eucalyptus* also possess antibacterial effects against multidrug-resistant *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Candida al-bicans* and *Candida parapsilosis*, *Acinetobacter baumannii* as well as to parasitic nematodes (Ghasemian *et al*., 2019).

Fathi and Shakarami (2014) who studied the effect of essential oils extracted from five *Eculayptus* species and that all tested essential oils have larvicidal effect against *Tribolium castaneum* and *Tribolium confusum*.

2-9- *Solenostemma argel* (Argel)

Solenostemma argel (Delile) Hayne (Apocynaceae) is a desert plant found in many parts of the world. It has been used traditionally to treat various diseases, alsoprevious studies reported interesting antimicrobial, antiproliferative and anti-inflammatory activities of this species (Demmak *et al*., 2019).

2-9-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Gentianales

Family: Apocynaceae

Genus: *Solenostemma*

Species: *argel*

S. N: *Solenostemma argel* Del. Hayne.

C. N. : Argel

2-9-2- Botanical description:

The argel is an erect herbaceous perennial plant that grows up to 60-100 cm tall with several vigorous stems. The leaves are oval, leathery and covered with fine hairs. It has numerous flowers with white petals, and a strong smell (Teia, 2018). Fruits are solitary follicles, thick, ovoid, lanceolate at the apex and very hard with dark purple color. Seeds are turgid, ovoid and channel down at one face. They are minutely tuberculate bearing an apical tuft hair (Farah and Ahmed, 2016).

2-9-3-Geographical distribution:

Argel is a widely spread in Central and North parts of Sudan, Egypt, Libya, Chad, Algeria, Saudi Arabia and Palestine(Farah and Ahmed, 2016). Sudan is regarded as the richest source of this plant as it grows wild or cultivated in North Sudan, in the area extending from Dongola to Barber, particularly around Abu Hamad, where it is grown under irrigation and commonly known as Hargel (Idris *et al*., 2011).

2-9-4-Chemistry:

Phytochemical screening of *S. argel* leaves, stems and flowers revealed the presence of acylated phenolic glycosides, namely argelin and argelosid, choline, flavonoids, monoterpenes, pregane glucoside, sitosterol, and a triterpenoid saponin. Also, leaf extracts contain quercetin, rutin, flavanones, and alkaloids, flavonoids, and kaempferaol (Teia, 2018). The leaves also characterized by having a high percentage of carbohydrates (64.8), slightly low percentage of protein (15), low percentage of crude fiber (6.5), crude oil (1.6), about 7.7% as ash and 4.4% as moisture. This in addition to lower percentage of minerals, phytic acid and tannin (Osman *et al*., 2014).

2-9-5-Medicinal uses:

Argel is used to treat diabetes and jaundice, some diseases of the liver, kidneys and allergies, as an incense in the treatment of measles. It is an effective treatment for bronchitis and is used to treat nerve pain and sciatica. Its leaves are infused to treat stomach and intestinal cramps, stomach pain, colic, cold and urinary tract infections as well as to suppress childbirth pains and loss of appetite (Ali, 2020).

The aqueous extract of argel leaves was showed activity against tumor tissue and reduce the risk of tumor volume. It also posses antifungal and antibacterial properties against *Aspergillus niger, Pennicilium italicum, Escerichia coli and* Salmonella *typhi* (Teia, 2018).

2-9-6- Uses in pest control:

Sir El Khatim and Abdelbagi (2015), rported that the aqueous extract of argel shoots is the more effective against the *Bruchidius incarnates.* The farmers in Kassala State put argel shoots in porous jute sacks in the irrigation canals to be leached by water to control aphids and white flies in summer tomatoes and Egyptian bull worm in okra(Idris *et al*., 2011).

Mardi and Sulaiman (2018) how stated that a significant control of African boll worm white fly, and tomato leaf curl virus disease on tomato fields can be achieved by spraying aqueous extract of *S. argel* shoot powder. Also the plant possess nematincidal effect. Extract of Argel leaves represent high mortality rates against second-stage juveniles of *Meloidogyne incognita* after 24 hrs (Teia, 2018).Another study revealed that the chloroform leaf extract and the ethyl acetate fruit extract of *S. argel* have a larvicidal activity against *Culex pipiens* (AL-Mekhlafi *et al*., 2018).

Under the laboratory conditions the aqueous and organic extracts showed mortality, repellency and anifeedant effects against cow pea beetle *Callosobruchus maculates* as the cotton soil termite *Microtermes thoracalis*.Furthermore, spraying Argel shoot water filtrate at 1ounce/6liter of water/tree was recommended to control white scale insect (*Parlatoria Blanchardii* Targ.) and (*Asterolicanium phoenicis*) on date palm(Farah and Ahmed, 2016).

2-10-*Acacia nilotica* (Gum Arabic)

Acacia is a genus of shrubs and trees belonging to the family Fabaceae or Leguminosae pod-bearing, with sap and leaves typically contain a large amounts of tannins (Verma, 2017). It is naturally wide spread in drier area of Africa. In Sudan, the species is familiar by local names, "Sunt" for the tree and "Garad" for the fruit pods. Different products of this tree are known to have many traditional uses in the country since earlier times (Edriss *et al*., 2012).

2-10-1-Taxonomy:

Kingdom : Plantae

Division: Magnoliophyta (Flowering Plants)

Class: Magnoliopsida (Dicotyledons)

Order: Fabales

Family: Fabaceae

Genus: *Acacia*

Species: *nilotica*

S. N: Acacia nilotica L.

C. N. : Gum Arabic

2-10-2- Botanical description:

A. nilotica is a medium-sized, thorny evergreen tree with a short trunk and having round spreading crown with feathery foliage. It can grows to 15- 18 m in height and 2-3 m in diameter. The leaves are fine and densely hairy with 3-6 pairs of pinnate consisting of 10-20 pairs of leaflets that are narrow with parallel margins and are rounded at the apex with a central midrib closely crowded. Thorns are thin, straight, light grey exist in axillary pairs 5-7.5 cm long in young trees. Flowers are globular heads, 1.2-1.5 cm in diameter of a bright golden yellow colour (Verma, 2016).

The fruits are linear and narrow, flattened pods about 4-22 cm in length and 1-2 cm in diameter, contains 8-15 elliptical bean-shaped and dark brown to gray in color seeds (Abdallah, 2016).

2-10-3-Geographical distribution:

Acacia nilotica is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia from Arabia eastward to India, Burma and Sri Lanka (Verma, 2017). In Sudan, it is a widely spread tree in the central and northern parts of the country (Abdallah, 2016).

2-10-4-Chemistry:

Phytochemical investigations have revealed that stem bark of *A. nilotica* contains terpenoids, alkaloids, saponins, cardiac glycosides and tannins (Vasudev *et al*., 2015). Seeds and leaves of *A. nilotica* contain various compounds such as crude proteins, saponins, tannins, galactose, sulphides, pentosan, arabienose, catechol, galacton, silica, phosphorous and calcium. Moreover, the ethanol extract of *A. nilotica* aerial part was isolated and a compound structure determined by spectral methods showed D-pinitol (=3-0 methyl-D-chiro-inositol) with lipophilic nature (Edriss *et al*., 2012).

2-10-5-Medicinal uses:

A number of medicinal properties have been assigned to various parts of this plant has been found to exhibit antioxidant, antimalarial , anticancer, antiplasmodial, antimolluscicidal, antifungal, anti-microbial activity and also inhibitory activity against HCV and HIV-I (Vasudev *et al*., 2015). The bark, gum, leaves and pods of the tree also have many medicinal uses in Africa for treating cancer, colds, cough, fever, tumors, hemorrhage, typhoid, convalescence, nerve stimulant, intestinal pain and diarrhea (Edriss *et al*., 2012).

Pulp of leaves, decoction of bark and the gum are prescribed in diarrhoea, dysentery and diabetes. A paste made of the burnt leaves with coconut oil makes a very efficacious ointment in cases of itch. The leaves and the gum are used for gargling for relaxing sore throat and spongy gums (Verma, 2017).

2-10-6- Uses in pest control:

Leaves and fruits extracts of *A. nilotica* have proved to be effective as fungicides, bactericides, molluscicides and insecticides (Edriss *et al*., 2012). Also, methanol and acetone bark extracts from *Acacia nilotica* adversely affected the larval period and total developmental period of *Bactrocera cucurbitae* (Vasudev *et al*., 2015). Elkhidr *et al*. (2020) who noted that the fruits aqueous extract of *Acacia nilotica* can be used as an alternative method of mosquito and can cause 75% and 100% mortality of Culex species larvae.

Abdallah (2016) also reported that the pod methanolic extract of *Acacia nilotica* represented effective bacteriostatic activity against all tested bacteria, even at low concentration (12.5 mg/ml) against the gram-positive bacteria

CHAPTER THREE

MATERIALS AND METHODS

3-1- Study location:

The experiments were conducted in the Research Laboratory, College of Agricultural Studies (Shambat), Sudan University of Science and Technology (SUST). where the temperature ranged between 25-30°C.

3-2- Insect collection and rearing:

Larval instars of *H. armigera* were collected from unsprayed tomato plants grown in Gamouaia Agricultural Irrigated Scheme and brought to the laboratory for mass rearing. Early larval instars were reared in groups of 100 larvae in plastic cages 19 cm in diameter covered with muslin cloth and fed on okra fruits.The 4^{th} larval instars were reared separately in plastic cups 5 cm in diameter and 7 cm in height to avoid cannibalism. The bottom of each cup was filled with sand for pupations.

Upon emergence, the adults were transferred to plastic cages 31x20x19 cm covered with muslin cloth and fed on 10% sugar solution(Jallow *et al*., 2001). Cotton stripes were hung on the margins of the cages for eggs laying and were replaced daily with new stripes. Newly hatching larvae were transferred to the larval rearing cages. The rearing process continued until a sufficient number of homogenous populations of larvae was collected for the experiments.

3-3- Plant materials and extraction methods:

3-3-1- Ethanol Extracts:

Seeds of *C. occidentalis*, *D. stramonium* and *R. communis* were collected from river bank, Omdurman area. Tubers of *C. rotundus* were collected from Arashkool scheme in the White Nile State and brought to the laboratory for shade-drying.

After complete dryness the plant samples were crushed into powder by an electronic blender. 120g of the prepared powder of each plant sample were extracted with absolute ethanol using a Soxhlet apparatus for six hours, and a rotary evaporator was used to remove the solvent (Elnour, 2014). Five concentrations (4%, 6%, 8%, 10% and 12%) were prepared for each extract by serial dilution and tested against the 2nd larval instar of *H. armigera*. Mortality percentage was recorded after 24, 48, 72 and 96 hrs. The effect of each ethanolic extract was tested alone and co-adminstered with sesame oil at the same five concentrations.

3-3-2- Aqueous Extracts:

The leaves of *Balanites eagyptiaca* and *Eucalyptus camaldulensis* were collected from trees grown in Shambat area whereas the shoots of *Solenostemma argel* and pods of *Acacia nilotica* were brought from the market of Omdurman. Then the plant materials were brought to the laboratory for shade- drying. After complete dryness the plant samples were crushed into powder by an electronic blender. 300g of the prepared powder of each plant material were soaked in one Liter of water and left to dissolves overnight. After 24 hrs the extracts were filtered using a muslin cloth. Five concentrations (1.8%, 3.75%, 7.5%, 15% and 30 %) were prepared from each extract by serial dilution.

3-3-3- *Bacillus thuringiensis*:

Biotect® 9.4 % WP commercial formulation containing *Bacillus thuringiensis kurstaki* from(Organic Biotechnology Co., First industrial zone , El Noubareya, El Beheira, Egypt) were used in 5 concentrations (0.62, 1.25, 2.5, 5, and 10 mg/ml).

3-3-4- Nimbecidine®:

Nimbecidine® EC (0.03% Azadirachtin) a commercial Neem based insecticide from T. Stanes and Company Limited, 8/23-24, Race Course Road, Coimbatore – 641018, Tamil Nadu, India.) was used in the treatments. Five concentrations (1.25, 2.5, 5, 10 and 20 ml/ L) were used in this study.

3-4- Bioassay procedures:

3-4-1- Toxicity of plant extracts:

The second larval instar of the African bollworm *H. armigera* was used in this study. Fruits dipping method (Visnupriya and Muthukrishnan, 2017) was followed, where small pieces of fresh okra fruits were dipped for 30 seconds in different concentrations and left to dry under room conditions for 10 minutes. Ten pre starved larvae (one hour) were used for each treatment and each treatment was replicated three times. Three replicates were also used as a control set. All treated larvae were kept in Petri-dishes 9 cm in diameter at temperature of 25±1 °c. Treated larvae were provided with fresh okra pieces till the end of experiment. The mortality % was recorded 24, 48, 72 and 96 hrs after application.

In order to evaluate the synergistic effect of sesame oil, sesamee oil was added to each plant extract at a ratio of 1:1 in five concentration levels along with a control treated only with sesame oil.

3-4-2- Mixture toxicity:

To evaluate the joint action of tested plant extracts and *Bt* the method of Mansour *et al*.(2012) adopted from Sun and Johnson (1960) was followed with some modifications. Paired mixtures of plant extracts were prepared at concentration levels of their respective LC_{25} values at 1:1 ratio. Each mixture was tested in three replicates along with controls. Mortality percentages were determined after 24 and 48 hrs and the combined action of the different mixtures was expressed as a Co-toxicity factor. The following formula was used to determine potentiation, antagonism and additive effect:

Co - toxicity factor = (O – E) x 100/E; where:

O : is observed mortality percentage and **E**: is expected mortality percentage. The co-toxicity factor differentiates the results into three categories. A positive factor of ≥20 indicates potentiation, a negative factor of ≤-20 indicates antagonism, and the intermediate values of >-20 to<20 indicates an additive effect (Mansour *et al*.,2012)

The LC_{25} values of each extract and *Bt* were tested again against 2nd larval instar in order to determine the accurate and expected mortality. The expected mortality of the combined pair is the sum of the mortalities of single compound at recorded LC_{25} and the observed mortality is the recorded mortality obtained after 24 – 48 hrs of exposure to the mixture.

3-5- Statistical analysis:

The obtained data were statistically analyzed according to analysis of variance (ANOVA); Duncan's Multiple Range Test was used for means separation using GenStat version 12.1. Also the data were subjected to Probit analysis using SPSS 16.0 software.

CHAPTER FOUR

RESULTS

4.1: Lethal effect of the tuber ethanolic extract of *C. rotundus* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera*:-

The obtained results in (Table 4.1 and Fig. 4.1) showed that all concentrations of the tubers ethanolic extract of *C. rotundus* scored a significantly higher mortality percentage than that of the control throughout the experimental period. It should be noted that the mortality percentage increases with the increase of both concentration and exposure period. Each concentration of tubers ethanolic extract of *C. rotundus* when mixed with sesame oil gave a significantly higher mortality percentage than its counterpart alone. In fact, 8% concentration of the extract mixed with sesame oil caused 96.7% mortality percentage which was higher than that the highest concentration (12%) alone.

It is worth to mention that there were no significant differences in the mortality percentage among the highest concentrations (8% ,10% and 12%) of the tuber ethanolic extract mixed with sesame oil throughout the experimental period as indicated in (Table 4.1). It was observed that the tubers ethanolic extract of *C. rotundus* induced an abnormal larval development that failed to reach the pupal stage and finally die as shown in Plate (1).

Table. 4. 1: Lethal effect of the tubers ethanolic extract of *C. rotundus* against 2nd larval instar of *H. armigera.*

Treatments	Conc. (%)	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
C. rotundus	4	36.7 (6.0)e	43.3 (6.6)f	46.7 (6.9)g	50.0(7.1)g
	6	43.3 (6.6)e	53.3 (7.3)e	60.0 (7.8)f	60.0 (7.8)fg
	8	56.7 (7.6)d	70.0 (9.4)cd	73.3 (8.6)de	73.3 (8.6)de
	10	60.0 (7.8)d	73.3 (8.6)cd	76.7 (8.8)cde	80.0 (8.9)cd
	12	76.7 (8.8)bc	86.7 (9.3)ab	90.0 (9.5)abc	90.0 (9.5)abc
C. rotundus + Sesame oil	4	56.7 (7.6)d	63.3 (7.9)de	66.7 (8.2)f	66.7 (8.2)ef
	6	66.7 (8.2)cd	76.7 (8.8)bc	83.3 (9.2)bcd	83.3 (9.2)bcd
	8	83.3 (9.2)ab	90.0 (9.5)ab	93.3 (9.7)ab	96.7 (9.6)ab
	10	96.7 (9.8)a	100.0 (10.0)a	100.0 (10.0)a	100.0 (10.0)a
	12	100.0 (10.0)a	100.0 (10.0)a	100.0 (10.0)a	100.0 (10.0)a
Sesame oil	-	16.7 (4.0)f	20.0 (4.4)g	23.3 (4.8)h	23.3 (4.8)h
Control	-	0.0(0.7)g	0.0 (0.7)h	0.0(0.7)i	0.0(0.7)i
C. V. %		7.3	5.5	5.8	5.4

* Means followed by the same letter (s) are not significantly different at (p< .001).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

*C. V. = Coefficient of Variation.

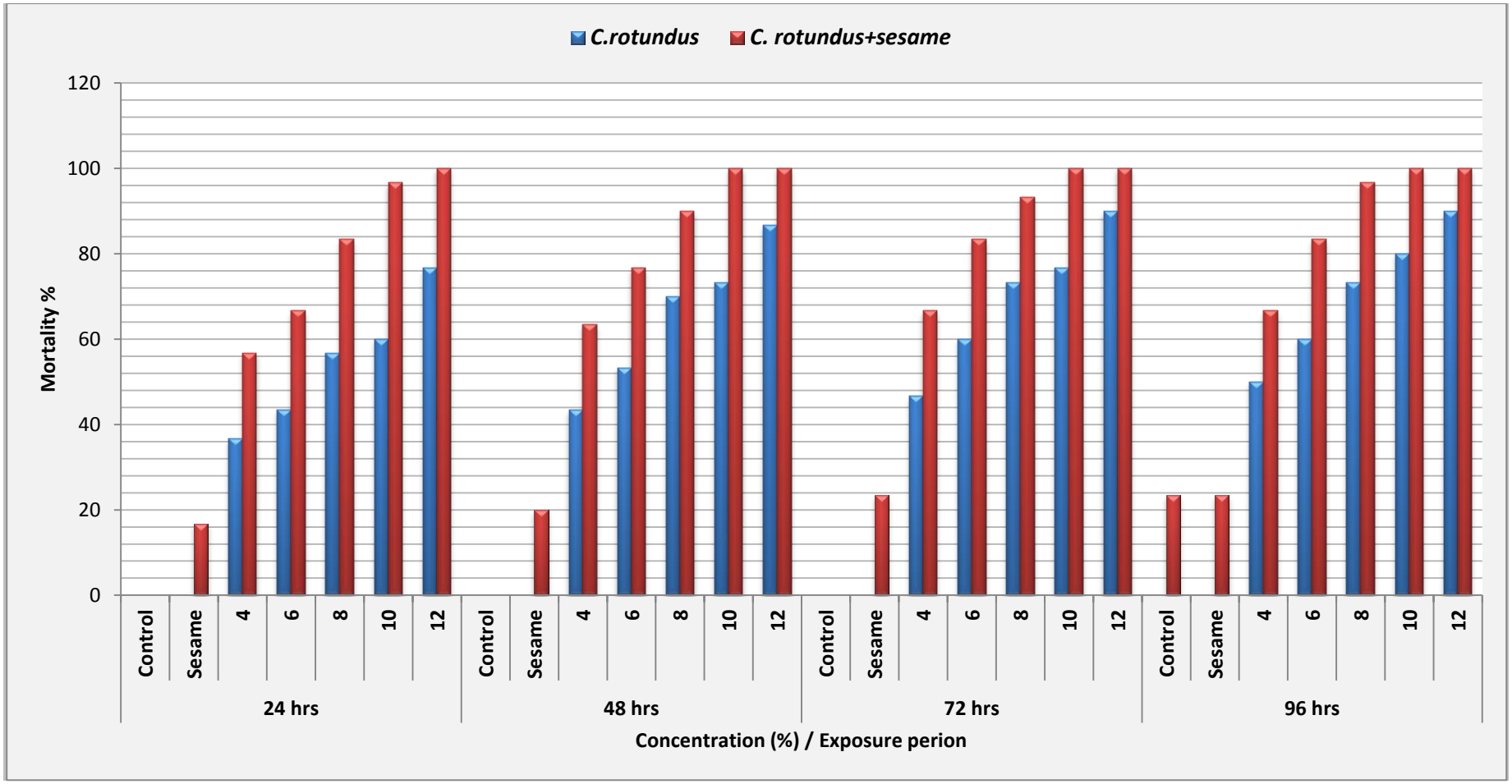

Figure. 4. 1: Letahal effect of the tuber ethanolic extract of *C. rotundus* alone and co-administered with sesame oil on 2nd larval instar of *H. armigera*

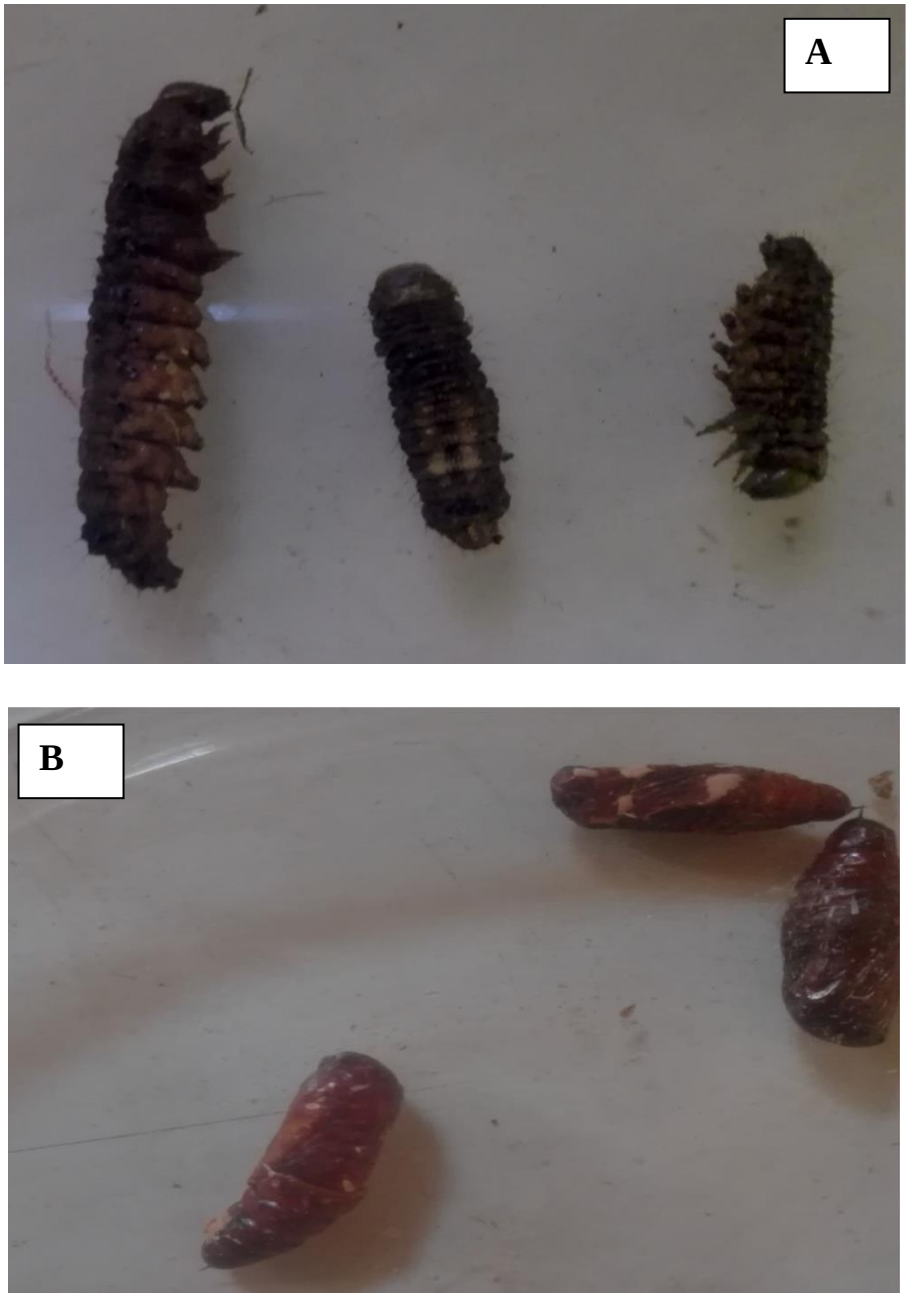

Plate. 1: Malformation in Pupal instar induced by sub lethal concentrations of *C. rotundus* A) Larvae and B) Pupae.

4.2: Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera*:-

As shown (Table, 4.2 and Figure 4.2) all concentrations of seeds ethanolic extract of *D. stramoniu*m generated a significantly higher mortality percentage than that of the control throughout the experimental period. Additionally all increments in the concentrations were accompanied with increase of mortality percentage. When the different concentrations of the seeds ethanolic extract of *D. stramoniu*m were mixed with sesame oil they scored a significantly higher mortality percentage than their counterpart alone. In fact there was no significant difference in mortality percentage between the highest concentration (12%) alone and the lowest concentration (4 %) mixed with sesame oil after 24, 72 and 96 hrs of exposure.

It should be noted that there were no significant differences in mortality percentage among the highest concentrations (8% ,10% and 12%) of the seeds ethanolic extract of *D. stramonium* mixed with sesame oil throughout the experimental period as shown in (Table 4.2).Also an abnormal larval development in terms of reduction in size of the 5th instar was observed as in (Plate 2).

Table. 4. 2: Lethal effect of the seeds ethanolic extract of *D. stramonium* against 2nd larval instar of *H. armigera.*

Treatments	Conc. (%)	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
D. stramonium	4	23.3 (4.9)de	30.0(5.5)e	40.0(6.4)e	40.0(6.4)f
	6	26.7 (5.2)d	33.3(5.8)de	43.3(6.6)e	43.3(6.6)ef
	8	30.0 (5.5)cd	46.7(6.9)c	50.0(7.0)de	53.3(7.3)de
	10	33.3(5.8)bcd	50.0(7.0)bc	53.3(7.3)de	56.7(7.6)d
	12	46.7 (6.9)ab	63.3(7.9)a	70.0(8.4)bc	76.7(8.8)abc
D. stramonium + Sesame oil	4	33.3(5.8)bcd	43.3(6.6)cd	60.0(7.8)cd	63.3(7.9)cd
	6	43.3(6.6)abc	60.0(7.8)ab	70.0(8.4)bc	73.3(8.6)bc
	8	50.0 (7.0)a	66.7(8.2)a	76.7(8.8)ab	90.0(9.5)ab
	10	56.7 (7.6)a	70.0(8.4)a	83.3(9.2)ab	93.3(9.7)a
	12	60.0 (7.8)a	73.3(8.6)a	93.3(9.7)a	93.3(9.7)a
Sesame oil	-	16.7 (4.0)e	20.0 (4.4)f	23.3(4.8)f	23.3(4.8)g
Control	-	0.0(0.7)f	0.0 (0.7)g	0.0(0.7)g	0.0(0.7)h
C.V. %		11.6	7.4	7.8	7.2

* Means followed by the same letter (s) are not significantly different at ($p < .001$).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

*C. V. = Coefficient of Variation.

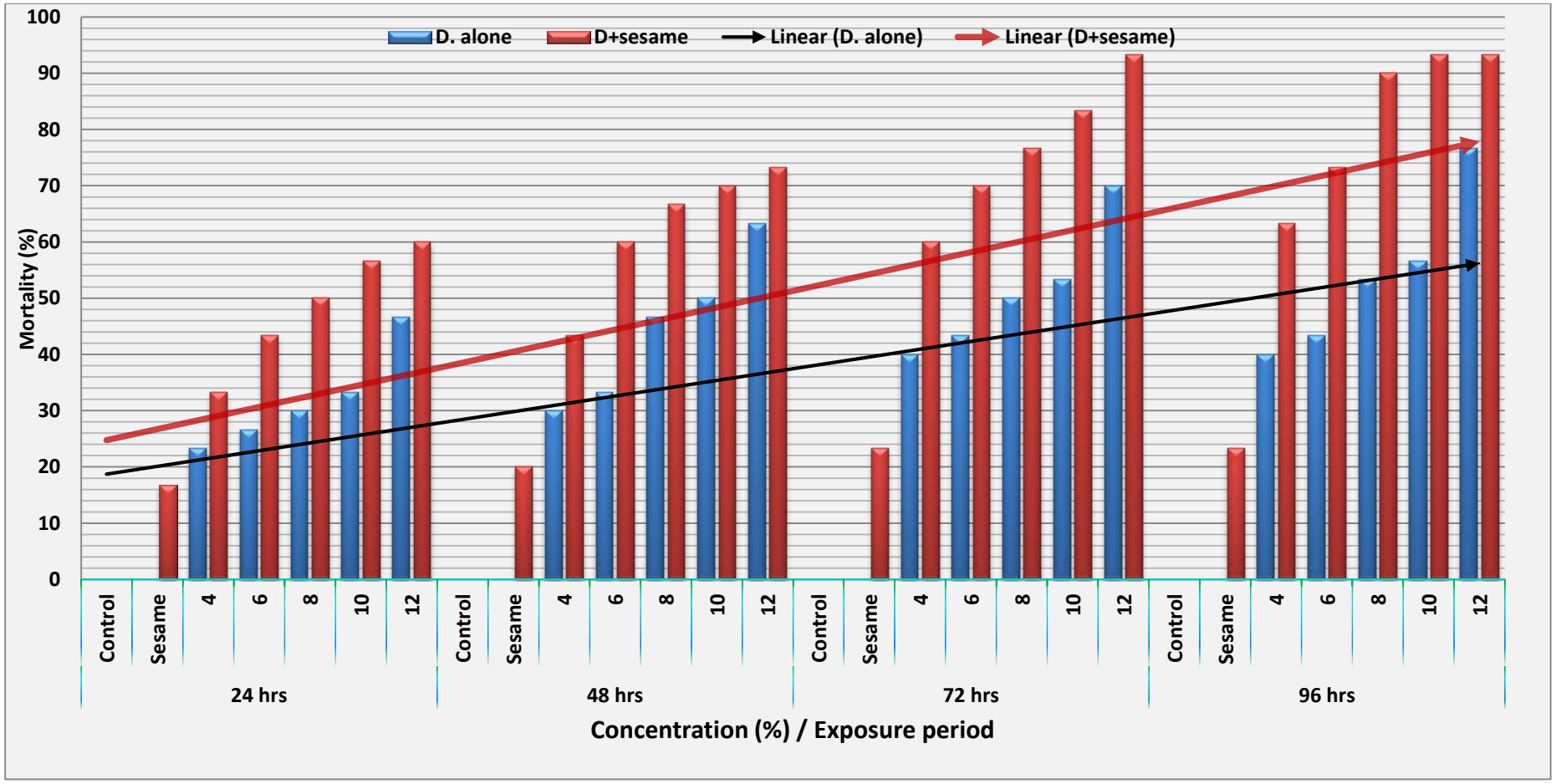

Figure. 4. 2: Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil on 2nd larval instar of *H. armigera* .

Plate. 2: Malformation in Larval instar induced by sub lethal concentrations of *D. stramonium*.

4.3: Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera*:-

The obtained results in (Table 4.3 and Fig. 4.3) show that all concentrations of the seeds ethanolic extract of *C. occidentalis* induced a significantly higher mortality percentage than that of the control throughout the experimental period. The results also demonstrate the mortality percentage increases with the increase of both concentration and exposure period.

The mortality percentage scored by the lowest concentration (4%) was only 16.7% after 24 hrs ; however when sesame oil was added it increased significantly to 50 percent. On the other hand the mortality percentage generated by highest concentration (12%) of the extract alone was not significantlyincreased when sesame oil was added. An abnormal development in terms of larval, pupal and adults malformation was also observed as shownin (Plate. 3).

Table. 4. 3: Lethal effect of the seeds ethanolic extract of *C. occidental* against 2nd larval instar of *H. armigera.*

Treatments	Conc. (%)	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
C. occiden-talis	4	16.7 (4.1)f	26.7(5.2)fg	26.7(5.2)ef	30.0 (5.5)ef
	6	23.3 (4.9)ef	33.3(5.8)ef	36.7(6.1)de	36.7(6.1)de
	8	30.0 (5.5)de	36.7 (6.1)ef	40.0(6.3)d	46.7(6.9)cd
	10	36.7 (6.1)d	40.0 (6.3)de	46.7(6.9)cd	53.3(7.3)c
	12	60.0(7.8)abc	66.7 (8.2)abc	66.7(8.2)ab	70.0(8.4)ab
C. occiden-talis + Sesame oil	4	50.0(7.1)c	53.3(7.3)cd	56.7(7.6)bc	56.7(7.6)bc
	6	56.7(7.6)bc	60.0(7.8)bc	70.0(8.4)ab	73.3(8.6)a
	8	66.7(8.2)ab	73.3(8.6)ab	76.7(8.8)a	76.7(8.8)a
	10	70.0(8.4)ab	76.7(8.8)ab	80.0(8.90a	80.0(8.9)a
	12	73.3(8.6)a	83.3(9.2)a	83.3(9.2)a	86.7(9.3)a
Sesame oil	-	16.7(4.0)f	20.0(4.4)g	23.3(4.8)f	23.3(4.8)f
Control	-	0.0(0.7)g	0.0 (0.7)h	0.0(0.7)g	0.0(0.7)g
SE±		8.6	9.1	8.5	7.3

* Means followed by the same letter (s) are not significantly different at (p< .001).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

*C. V. = Coefficient of Variation.

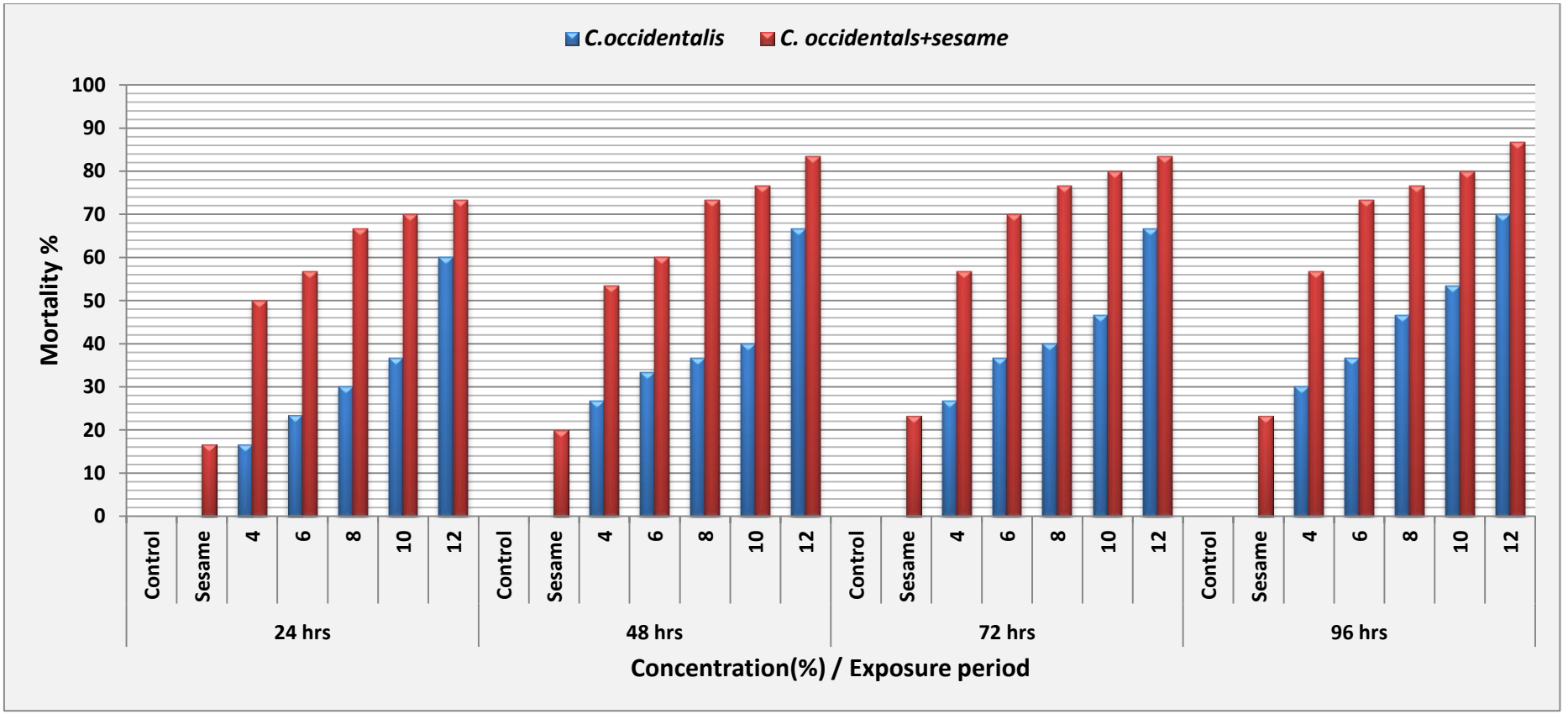

Figure. 4. 3: Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil on 2nd larval instar of *H. armigera*.

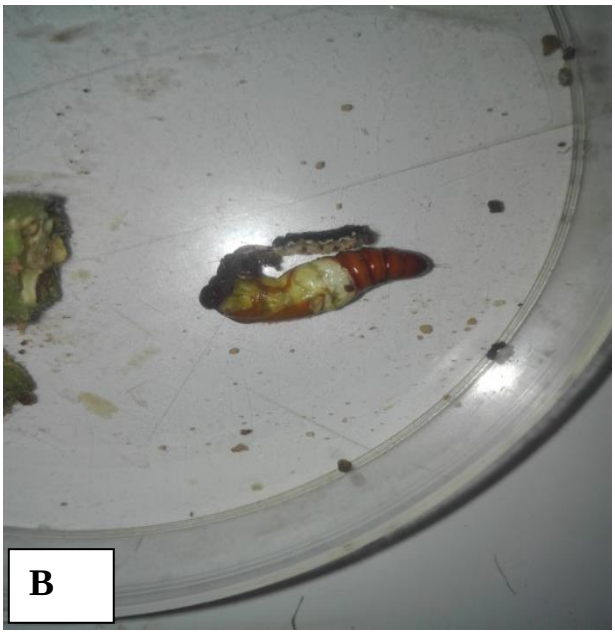

Plate. 3: Malformation in developmental stages of *H. armigera* induced by sub lethal concentrations of seeds ethanolic extracts of *C. occidentalis* A) Larval instar, B) Pubal instar, C) Adult stage .

4.4: Lethal effect of the seeds ethanolic extract of *R. communis* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera*:-

As shown in (Table, 4.4 and Figure 4.4) all concentrations of the seeds ethanolic extract of *R. communis* recorded a significantly higher mortality percentage than that of the control throughout the experimental period. Additionally all increments in the concentrations were accompanied with an increase of the mortality percentage. The results illustrated that the mortality percentage were dose and time dependent. On the other hand when sesame oil was added to each concentration of the seeds ethanolic extract of *R.communis* it increased the mortality percentage significantly than its counterpart alone throughout the experimental period. An abnormal larval developmental in terms of reduction in size of the 5th was as in Plate (4).

As shown in (Fig. 4.5) all tested plant extracts posses an insecticidal activity against the African bollworm, with different degrees of lethality. In fact the tuber ethanolic extract of *C. rotundus* gave the highest mortality percentage among all tested extracts, followed by *R. communis*, *D. stramonium* and *C. occidentalis*.

It is worth to mention that the sesame oil exhibited a synergistic effect when incorporated with all ethanolic extracts. However there were no significant differences among the mortality percentages caused by the highest concentrations (8% ,10% and 12%) of the ethanolic extracts of *C. rotundus, R. communis* and *D. stramonium*.

Table. 4. 4: Lethal effect of the seeds ethanolic extract of *R. communis* against 2nd larval instar of *H. armigera*.

Treatments	Conc. (%)	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
R. communis	4	26.7 (5.2)c	36.7(6.1)f	36.7(6.1)e	43.3(6.6)f
	6	30.0(5.5)c	40.0(6.3)ef	40.0(6.3)e	46.7(6.9)f
	8	43.3(6.6)b	46.7(6.9)def	53.3(7.3)d	53.3(7.3)ef
	10	50.0(7.1)b	50.0(7.1)de	56.7(7.6)d	60.0(7.8)de
	12	56.7(7.6)b	56.7(7.6)d	73.3(8.6)bc	80.0(8.9)bc
R. communis + Sesame oil	4	43.3(6.6)b	60.0(7.8)cd	63.3(7.9)cd	66.7(8.2)cd
	6	56.7(7.6)b	73.3(8.6)bc	73.3(8.6)bc	73.3(8.6)cd
	8	76.7(8.8)a	86.7(9.3)ab	90.0(9.5)ab	90.0 (9.5)ab
	10	83.3 (9.2)a	93.3(9.7)a	96.7(9.9)a	100.0(10.0)
	12	93.3(9.7)a	96.7(9.9)a	100.0(10.0)a	100.0(10.0)
Sesame oil	-	16.7(4.0)d	20.0(4.4)g	23.3 (4.8)f	23.3(4.8)g
Control	-	0.0(0.7)e	0.0 (0.7)h	0.0(0.7)g	0.0(0.7)h
C. V.%		9.2	7.6	7.5	6.5

* Means followed by the same letter (s) are not significantly different at ($p < .001$).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

*C. V. = Coefficient of Variation.

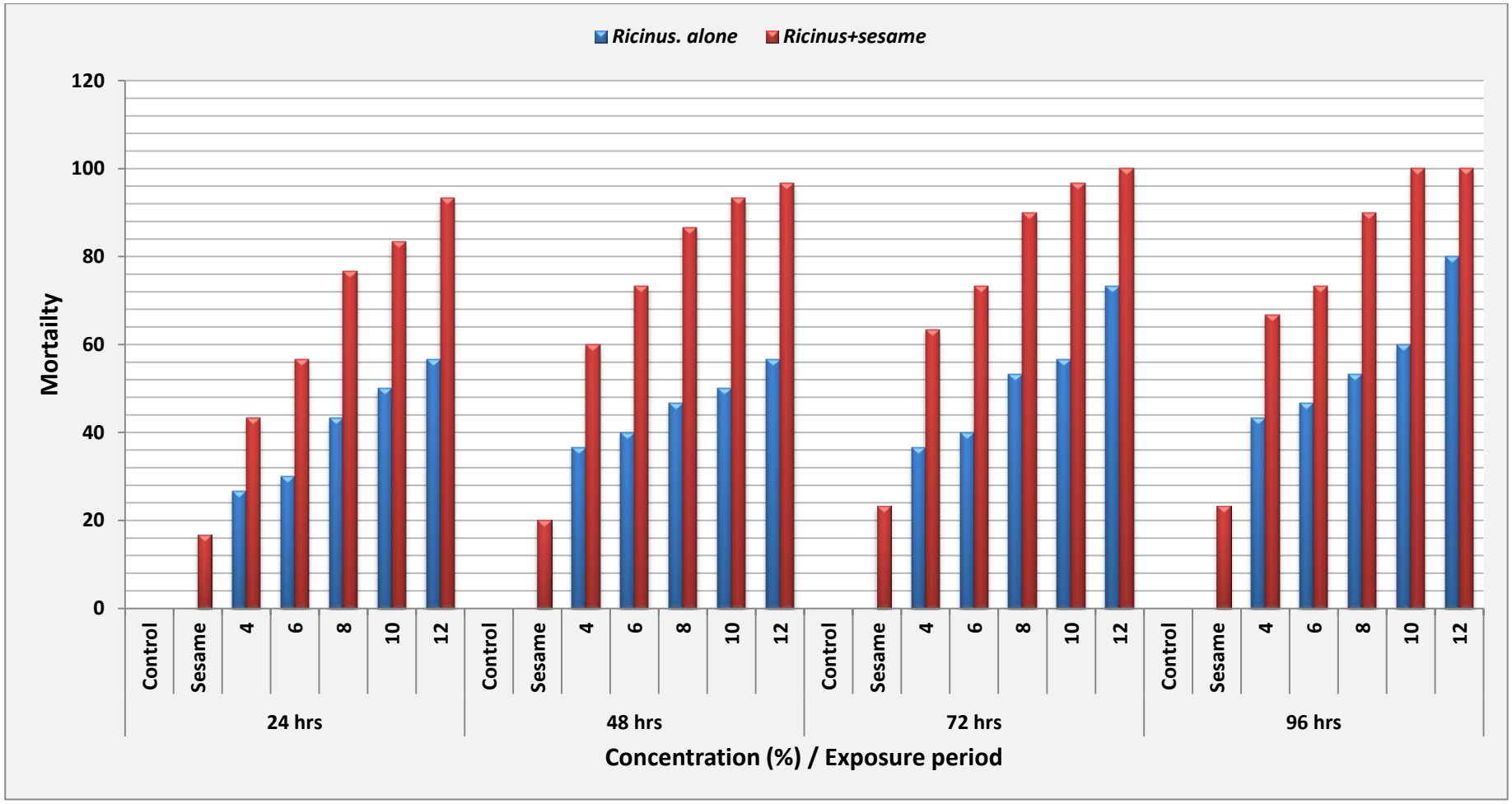

Figure. 4. 4: Lethal effect of the seeds ethanolic extract of *R. communis* alone and co-administered with sesame oil on 2nd larval instar of *H. armigera*

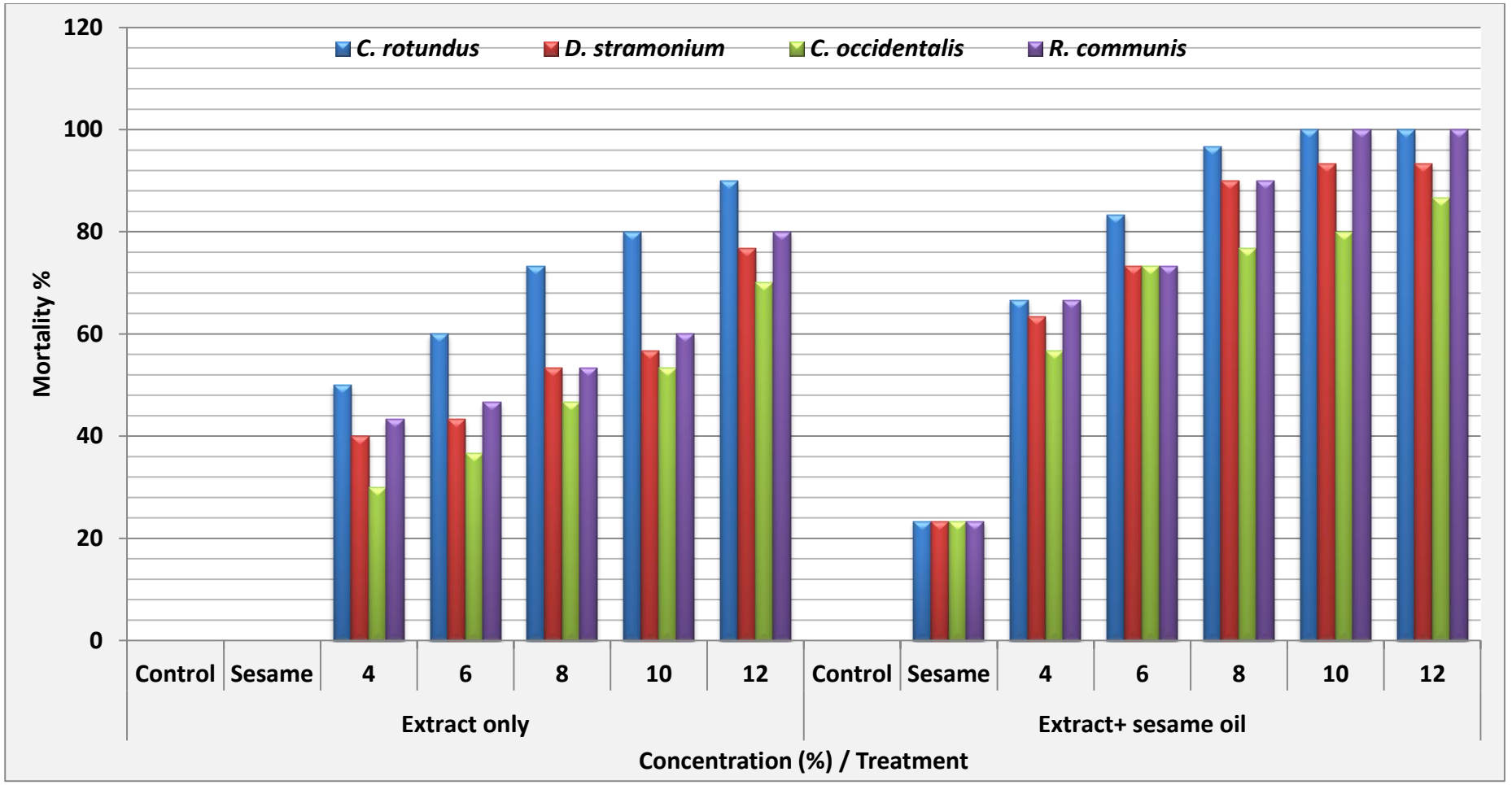

Figure. 4. 5: Lethal ffect of ethanolic extracts of tested plants with and without sesame oil on 2nd larval instar of *H. armigera* after 96 hrs of exposure .

Plate. 4: Malformation in developmental stages of *H. armigera* induced by sub lethal concentrations of seeds ethanolic extracts of *R. communis* A) Larval instar and B) Adult stage.

4.5: Lethal effect of ethanolic extracts of tested plants:-

The data presented in (Table 4.5 and Fig. 4.6) provide a clear evidence that the ethanolic extracts of all tested plant have a lethal effect against the 2nd larval instars of the African bollworm. Probit analysis of the mortality data showed that the lethal concentrations of the extracts vary from one plant to another whether it is used alone or mixed with sesame oil.The lowest LC_{50} value for ethanolic extract alone was recorded by *C.rotundus* followed by *R.communis*, *D. stramonium* and *C.occidentalis*. was generate by *C. rotundus*.

The LC_{50} value of each of the ethanolic plant extract was reduced when sesame oil was added. It should also be noted that there was no significant difference in the mortality percentage generated by LC_{50} of the mixture of the sesame oil and *D. stramonium* and that of the mixture of sesame oil and *C.occidentalis*.

Table. 4. 5 : LC values for ethanolic plant extracts with and without sesame oil against 2nd larva l instar of *H. armigera* after 96 hrs of exposure.

Plant extract	LC* values and 95% Confidence limits (Lower – Upper)			
	LC_{50}	LC_{90}	Slope± SE*	Chi-square $\chi 2$
C. rotundus	4.2 (0.5 -5.8)	12.4 (10.4 – 18.1)	2.0±0.7	1.2
C. rotundus + Sesame oil	2.9 (0.5 - 4.1)	6.5 (5.6 – 8.2)	4.9± 1.1	1.4
D. stramonium	7.1 (3.8 – 9.0)	18.4 (14.0 – 38.4)	1.8 ±0.64	2.1
D. stramonium + Sesame oil	3.1 (1.3 – 4.3)	9.1 (7.3 – 14.7)	2.8±0.75	0.9
C.occidentalis	8.6 (6.8 – 10.9)	18.7 (14.6 – 34.2)	2.0±0.64	1.11
C.occidentalis + Sesame oil	3.1(0.3 – 4.6)	15.8 (10.5- 143.6)	1.8 ±0.66	0.3
R. communis	6.4 (2.6 – 8.3)	17.7 (13.6 – 35.9)	1.8±0.62	2.6
R. communis + Sesame oil	3.5 (2.2 – 4.3)	7.2 (6.2 – 9.3)	4.1±0.9	4.4

* LC = Lethal Concentration * SE = Standard Error.

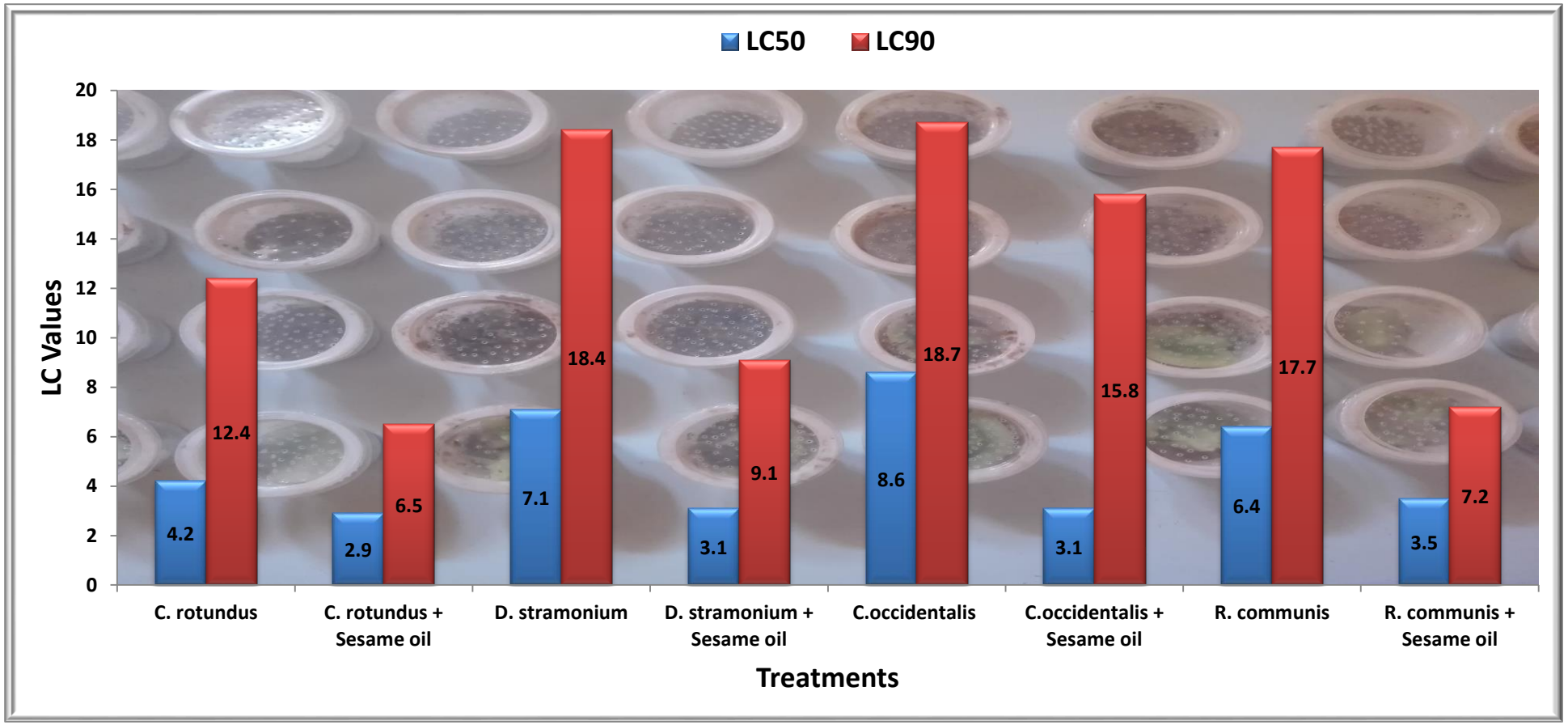

Figure. 4. 6 : LC values for plant extracts with and without sesame oil against 2nd larva l instar of *H. armigera* after 96 hrs of exposure.

4.6: Combination Activity (Joint Action) of Plant extracts:-

Paired mixtures of plant extracts were tested against 2nd larval instar of *H. armigera* as described in materials and methods section. The results shown in (Table. 4.6) illustrated that the binary mixture of *R. communis* and *D.stramonium* caused a potentiation effect throughout the experimental period. On the other hand *R. communis* and *C. occidental* mixture generated an additive effect after 24 hrs of exposure but a potentiation effect was recorded after 48 hrs of application (CTF = +23.5). It should also be noted that the binary mixture of *C. rotundus* and *D.stramonium, C. occidentalis* and *R. communis* extracts induced an additive effect throughout the whole experimental period.

4.7: Lethal effect of *B. thuringiensis* and Nimbecidine:-

The results shown in (Table, 4.7) showed that all *Bt* and Nimbicidene concentrations generated a significantly ($p < .001$) higher mortality percentage than that of the control throughout the experimental period. It should also be noted that the mortality percentage increased with the increase of both concentration and exposure period.

It was also observed that the Nimbicidene have strong sub-lethal effect on *H. armigera*. In fact it exhibited a severe malformation in the developmental stages of African bollworm (larvae, pupae and adults) as in (Plate, 5).

Table. 4. 6: Joint action of tested ethanolic plant extracts on 2nd larval instar of *H. armigera.*

Extract Mixture	Mortality %		CTF	Action type
	Expected	Observed		
		24 hrs		
Cyperus + *Ricinus*	50.0	46.7	-6.7	Ad.
Cyperus + *Datura*	46.6	40.0	-14.2	Ad.
Cyperus + *Cassia*	50.0	50.0	0.0	Ad.
Ricinus + *Datura*	50.0	70.0	+40.0	Po.
Ricinus + *Cassia*	53.4	56.7	+6.2	Ad.
Datura + *Cassia*	50.0	63.3	+26.6	Po.
		48 hrs		
Cyperus + *Ricinus*	53.4	50.0	-6.37	Ad.
Cyperus + *Datura*	53.4	50	-6.37	Ad.
Cyperus + *Cassia*	56.7	53.33	-5.94	Ad.
Ricinus + *Datura*	53.4	73.3	+37.33	Po.
Ricinus + *Cassia*	56.7	70	+23.46	Po.
Datura + *Cassia*	56.7	70	+23.46	Po.

*Ad. = Additive, Po. = Potentiation , CTF = Co-toxicity coefficient.

Table. 4. 7: Lethal effect of *Bt* and Nimbecidine against 2nd larval instar of *H. armigera.*

Treatments	Conc.	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
Bt (mg/ml)	0.625	16.7 (4.1)ef	43.3(6.6)e	56.7(7.6)cde	66.7 (8.2)c
	1.25	26.7(5.2)cd	46.7(6.9)de	66.7(8.2)cd	80.0 (8.9)b
	2.5	46.7(6.8)b	60.0(7.8)bcd	86.7(9.3)ab	90.0(9.50ab
	5	53.3(7.3)b	70.0(8.4)b	93.3(9.7)a	100.0(10.0)a
	10	76.7(8.8)a	93.3(9.7)a	100.0(10.0)a	100.0(10.0)a
Nimbecidine (ml/L)	1.25	10.0(3.2)f	16.7(4.1)f	20.0 (4.4)f	23.3(4.9)e
	2.5	23.3(4.9)de	36.7(6.1)e	43.3 (6.6)e	43.3(6.6)d
	5	33.3(5.8)c	46.7(6.8)de	50.0 9(7.1)e	50.0(7.1)d
	10	46.7(6.9)b	50.0(7.1)cde	53.3(7.3)de	63.3 (7.9)c
	20	60.0(7.8)b	63.3(7.9)bc	70.0 (8.4)bc	80.0 (8.9)b
Control	-	0.0(0.7)g	0.0 (0.7)g	0.0(0.7)g	0.0(0.7)f
C. V.%		9.3	8.4	7.8	5.5

* Means followed by the same letter (s) are not significantly different at ($p < .001$).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

* C. V. = Coefficient of Variation.

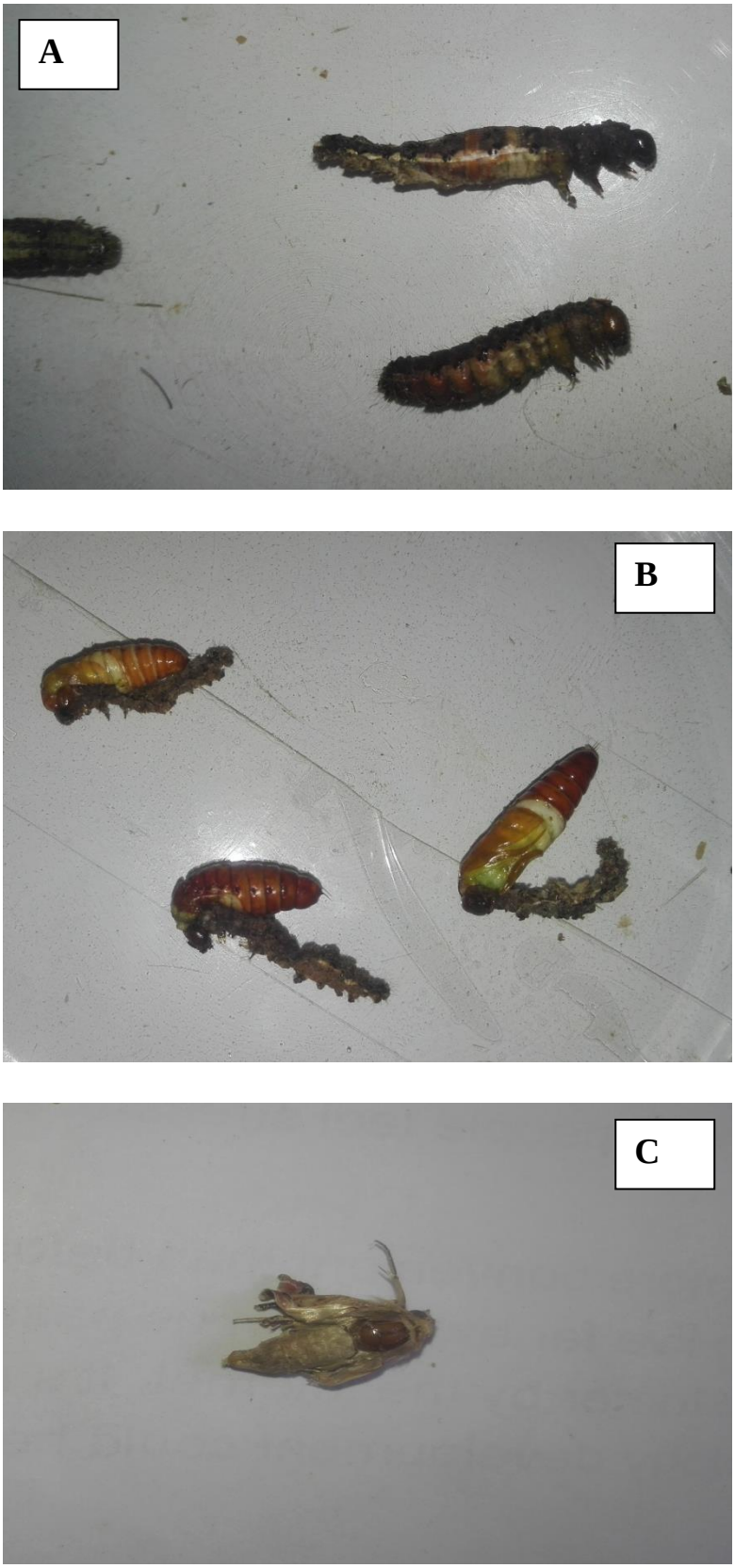

Plate. 5: Malformation in developmental stages of *H. armigera* induced by sub lethal concentrations of Nimbecidine® A) Larval instar, B) Pubal instar, C) Adult stage.

4.8: Combination Activity (Joint Action) of tested ethanolic Plant extracts, Nimbecidine® & *Bt*:-

Paired mixtures of plant extracts and *Bt* were tested against 2nd larval instar of *H. armigera* as described in materials and methods section. As shown in (Table, 4.8) the binary mixture of *Bt* and *R. communis* as well as *Bt* and Nimbecidine induced a potentaition effect throughout the experimental period. On the other hand the binary mixture of Bt and the ethanolic extract of the other tested plants (*D.stramonium*, *C. occidentalis*) induced an additive effect throughout the experimental period.

4.9: Lethal effect of aqueous extracts of tested plants:

The data presented in (Table 4.9 and Fig. 4.7) showed that the aqueous extracts of all tested plants generated a significantly ($p < .001$) higher mortality percentage than that of the control throughout the experimental period and that percentage mortality increased with the increase of both concentration and exposure period.

The results also showed that there was no significant difference in mortality percentages induced by the hieghest concentration (30%) of *Balanites eagyptiaca*, *Solenostemma argel* and *Eucalyptus camaldulensis* after 48 hrs of application. As shown in (Table, 4. 10) the aqueous extract of *Balanites eagyptiaca* was most toxic among all tested aqueous plant extracts. In fact, the LC_{50} values were 12.3%, 15.4%, 24.5% 27.9% for *Balanites eagyptiaca*, *Solenostemma argel*, *Eucalyptus camaldulensis* and *Acacia nilotica* respectively after 96 hrs of exposure.

Table. 4. 8: Joint action of tested extracts & *Bt* on 2nd larval instar of *H. armigera* .

Extract Mixture	Mortality %		CTF	Action type
	Expected	Observed		
		24 hrs		
Cyperus + *Btk*	46.6	50.0	+7.3	Ad.
Ricinus + *Btk*	50.0	63.3	+26.7	Po.
Datura + *Btk*	46.6	50.0	+7.3	Ad.
Cassia + *Btk*	50.0	53.3	+6.7	Ad.
Btk + Nimbecidine	43.3	53.3	+23.1	Po
		48 hrs		
Cyperus + *Btk*	63.4	66.7	+5.2	Ad.
Ricinus + *Btk*	63.4	76.7	+21.0	Po.
Datura + *Btk*	63.4	70.0	+10.4	Ad.
Cassia + *Btk*	66.7	76.7	+14.9	Ad.
Btk + Nimbecidine	63.4	80.0	+26.2	Po.

*Ad. = Additive, Po. = Potentiation , CTF = Co-toxicity coefficient.

Table. 4. 9: Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm.

Plant extract/ Used parts	Conc .(%)	Means mortality (%)			
		Exposure time (hrs.)			
		24	48	72	96
Balanites ea-gyptiaca (leaves)	1.8	16.7(4.1) ef	23.3 (4.9) de	30.0(5.5) fghij	33.3(5.8) hij
	3.75	23.3(4.9) cdef	33.3(5.8) bcd	40.0(6.4)	43.3(6.6) efg
	7.5	26.7(5.2) bcde	36.7(6.1) abc	43.3(6.6) bcde	50.0(7.1) cde
	15	36.7(6.1) abc	40.0(6.4) ab	50.0(7.1) bc	56.7(7.6) bc
	30	43.3(6.6)a	46.7(6.9)a	53.3(7.3) ab	63.3(7.9) ab
Solenostemma argel (shoot)	1.8	6.7(2.7)g	16.7(4.1) ef	26.7(5.2) ijk	26.7(5.2)j
	3.75	20.0(4.5) def	23.3(4.9) de	33.3(5.8)	36.7(6.1) ghi
	7.5	26.7(5.2) bcde	26.7(5.2) cd	40.0(6.4)	43.3(6.6) efg
	15	36.7(6.1) abc	36.7(6.1) abc	46.7(6.9) bcd	46.7(6.9) def
	30	40.0(6.4) ab	46.7(6.9)a	63.3(7.9) a	70.0(8.4)a
Eucalyptus camaldulensis (leaves)	1.8	13.3(3.7)f	23.3(4.9)de	23.3(4.9) jk	30.0(5.5)ij
	3.75	20.0(4.5) def	26.7(5.2)cd	30.0(5.5) fghij	33.3(5.8) hij
	7.5	23.3(4.9) cdef	30.0(5.5) bcd	36.7(6.1)	40.0(6.4) fgh
	15	33.3(5.8) abcd	36.7(6.1) abc	43.3(6.6) bcde	43.3(6.6) efg
	30	43.3(6.6)a	46.7(6.9)a	50.0(7.1) bc	53.3(7.3) cd
Acacia nilotica (pods)	1.8	3.3(1.9) gh	10.0(3.2)f	13.3(3.7)i	20.0(4.5)k
	3.75	6.7(2.7)g	16.7(4.1)ef	20.0(4.5)k	33.3(5.8) hij
	7.5	20.0(4.5) def	26.7(5.2)cd	30.0(5.5)fhij	36.7(6.1) ghi
	15	23.3(4.9) cdef	26.7(5.2)cd	36.7(6.1)defgh	40.0(6.4) fgh
	30	26.7(5.2) bcde	30.0(5.5) bcd	40.0(6.4)cdef	50.0(7.1) cde
Control	-	0.0(0.7)h	0.0(0.7)g	0.0(0.7)m	0.0(0.7)i
C.V. (%)	-	15.5	10.0	8.0	5.7

* Means followed by the same letter (s) are not significantly different at ($p < .001$).

* Means between brackets are transformed according to $\sqrt{X + 0.5}$

* C. V. = Coefficient of Variation.

Table. 4. 10: LC values for aqueous extracts of tested plants against 2nd larva l instar of *H. armigera* after 96 hrs of exposure.

Plant extract	LC* values and 95% Confidence limits (Lower – Upper)			
	LC_{50}	LC_{90}	Slope± SE*	Chi- square χ^2
Balanites ea-gyptiaca	12.3 (-2.2 – 30.8)	66.7 (40.5 – 378.6)	0.6±0.2	0.5
Solenostem-ma argel	15.4 (9.5 – 25.1)	51.4 (36.1 – 105.8)	0.8±0.2	1.3
Eucalyptus camaldulen-	24.5(14.0 – 1873)	88.6 (49.7 – 11306)	0.5±0.2	0.2
Acacia nilot-ica	27.9(17.5 – 158.6)	84.9 (49.9 – 673.5)	0.6±0.2	0.5

* LC = Lethal Concentration * SE = Standard Error

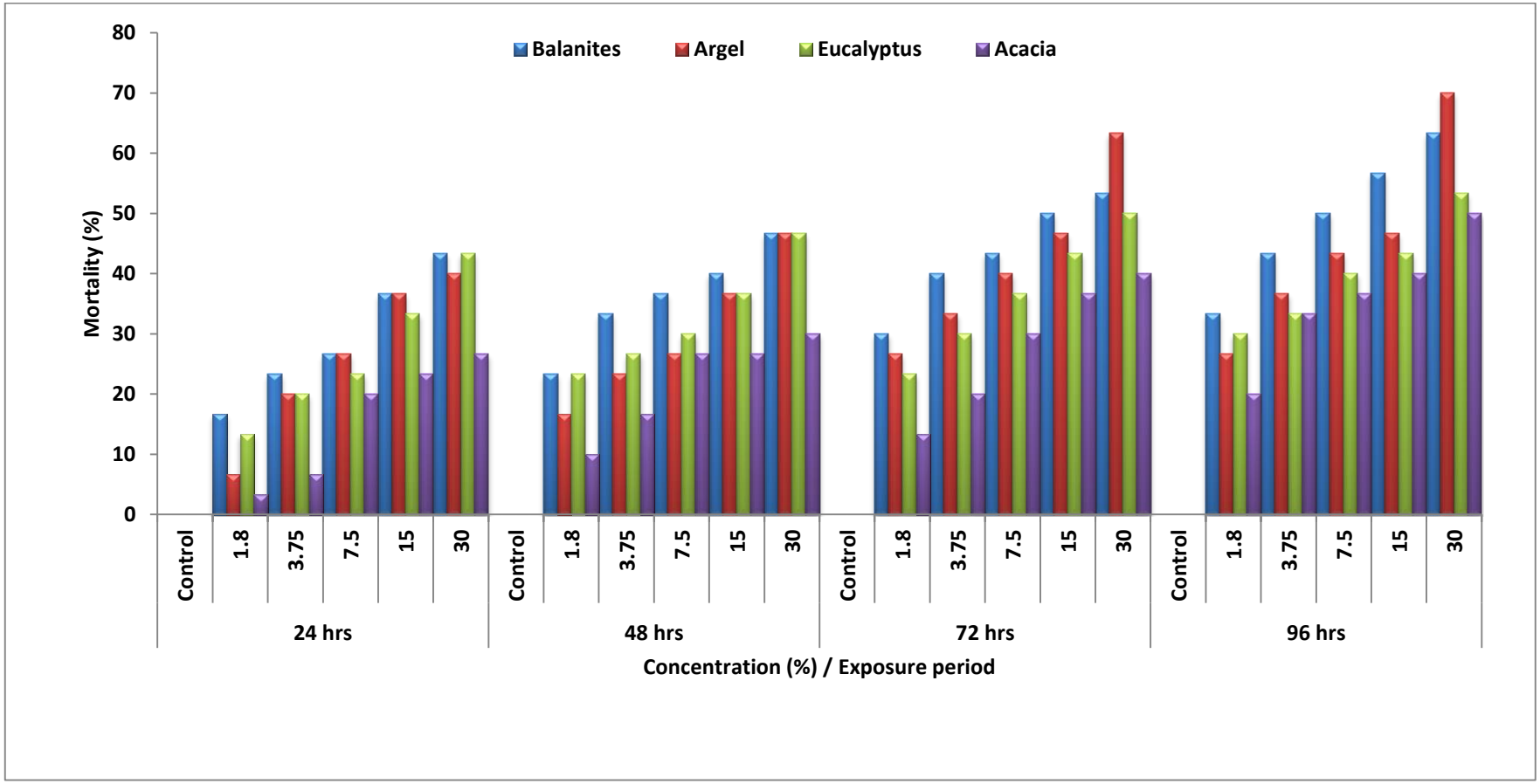

Figure. 4. 7: Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm.

CHAPTER FIVE

DISCUSSION

Botanicals have long been proposed as smart alternatives to synthetic insecticides for pest management because they are safe to the environment and human health. Thousands species of plants have been reported to have chemicals with insecticidal propertiesin their various parts. However, a few of them were used for insect control on a commercial scale (Mardi and Sulaiman, 2018).

In the last four decades many botanical formulations have proven to be potent and effective as many as conventional synthetic pesticides even at low concentrations. In fact, botanical insecticides have drawn great attention as major control agents in organic farming. Higher plants are extremely abundant and contain biologically active secondary metabolites. In fact, over 80% of all known alkaloids, phenols and other secondary metabolites were produced by higher plants(Elsiddig, 2007). Stoll (2000) reported that the use of plant extracts to control destructive insects is not a new approach as Rotenone, Nicotine and Pyrethrin have been used for a long time in subsistence and commercial agriculture.

In the present study, the obtained results revealed that all concentrations of the tubers ethanolic extract of *C. rotundus* generated significantly higher mortality percentage than control throughout the experimental period. This clearly demonstrates that tubers ethanolic extract of *C. rotundus* has a lethal effect against the *H. armigera* larvae. Similar results were obtained by Imam, *et al*. (2013); they found that the rhizomes of *C. rotundus* exhibited larvicidal activity against *Aedes aegypti* larvae. Sharma and Gupta (2007) found out that methanolic extract of *C. rotundus* tubers strongly inhibits the activity of acetylcholinesterases (AChE).

Aacetone leaves extracts of *C. rotundus* at 50% exhibited significant mortality percentage of 46.6% and 51.6% repellency against Rice grains weevils *Sitophilus Oryzae* (El Monairy and Kamel, 2011).

The data also showed that the seeds ethanolic extract of *D. stramonium* scored a significantly higher mortality percentage than that of the control after 24 hrs of exposure. Similar results were obtained by Karimzadeh and Rabiei (2020), they found out that flower, seed and root extracts of *D. stramonium* were highly toxic against diamondback moth *Plutella xylostella* larvae. Abbasipour *et al*. (2011) also found that the *D. stramonium* extract had strong contact toxicity against *Callosobruchus maculatus* adults and that the mortality increases with increase in the concentration and exposure period.

The findings of this study showed that the *R. communis* extract generated a low efficacy against 2nd larval instar o *H. armigera*. In fact even the highest concentration (12%) gave only 56.7% mortality percentage after 48 hrs of exposure. On the other hand Kodjo *et al*. (2011) found that 5% oil emulsion of *R. communis* caused 89.5% mortality of the diamondback moth *Plutella xylostella* in ingestion toxicity test. Parajapati *et al*.(2018) also recorded that the seed extracts of *R. communis* showed better insecticidal activity than the leaf extracts against *S. frugiper* due to the active compounds such as castor oil and ricinine.

The second highest concentration (10%) of *C. occidentalis* generated only 46.7 mortaliy percentage after 72 hours of exposure; however when sesame oil was added the lowest concentration (4%) generated 50% mortalty percentage after only 24 hrs of exposure. Similar results were recorded by Elnour (2014) who found that the percentage mortality caused by various concentrations of seeds ethanolic extract of *C. occidentalis* against African melon ladybird *Henosepilachna elaterii* increased significantly when sesame oil was added.

The results also revealed that all *Bt* concentrations caused a significantly higher mortality percentage ($p < .001$) than that of the control throughout the experimental period and. LC_{50} value of *Bt* generate in this study was 0.41 mg/ml. Whereas Plata-Rueda *et al*. (2020) found that LC_{50} of *Btk* on nettle caterpillar *Euprosterna elaeasa* was 1.25 mg/ ml.

When sesame oil was added to each concentration of ethanolic extract of all tested plants it exhibited a synergistic effect. This may indicate that detoxification mechanisms in this insect involve mixed function oxidases which are known to be inhibited by sesame oil (Matsumura, 1976).

Similar results were obtained by Elnour (2014) who indicated that sesame oil has a synergistic effect when mixed with *Cassia occidentalis* and *Conocarpus lancifolius* upon testing against African melon lady bird beetle *Henosepilachna elaterii* (Rossi). Visetson *et al*., (2003) reported that sesame oil playes a simillar role to that of Piperonyl butoxide (PBO) as a ynergist with cypermethrin against diamondback moth *Plutella xylostella*

The use of plant extract mixtures may increase the spectrum of their activity against various target pests. The use of synergistic extract mixtures might help delay the development of insecticide resistance, minimize the risk to non-target organisms, reduce the cost of production, reduce the ferquancy of application and hence reduces the environmental pollution (Prijono *et al*., 2021).

The present study findings illustrated that, the binary mixture of *R. communis* and *C. occidentalis* have an additive effect after 24 hrs, whereas after 48 hrs of application a potentiation effect (CTF = +23.5) was recorded. Regarding the binary mixture of *Bt* and plant extracts, the results revealed that the *R. communis* and *Bt* mixture induced a potentiation effect (CTF = +26.7). Meanwhile; *C. occidentalis* and *Bt* mixture generated an additive effect.

Reddy and Chowdary (2021) noted that the compatibility of a plant extract for combination with microbial insecticides depends on qualitative and quantitative variations of secondary metabolites, which may affect the microbes. Many plants extract such as *Annona squamosa* L., *Datura stramonium* L., *Eucalyptus globules Labile, Ipomea carnea* Jacq., *Lantana camara* L., *Nicotiana tabacum* L., and *Pongamia pinnata* L. showed a synergistic effect when mixed with *Btk*.

As for aqueous extracts, the data obtained in the present study clearly proved the efficacy of tsted plants againt the 2nd larval instar of the African bollworm. In fact all concentrations of *Balanites eagyptiaca* caused a significantly higher mortality percentage than that of the control. This finding agrees with Chapagain and Wiesman (2005) who stated that the aqueous extracts of the fruit pulp, seed kernel, roots, bark, and leaves of *Balanites aegyptiaca* demonstrate potency in the control of *Culex pipens* mosquito larvae. Also extracts from several parts of *B. aegyptiaca* were shown to exhibit antifeedants and molluscidal activities against variety of pests where the steroidal saponin is believed to be the main factor behind these activities (Nwaogu *et al*., 2013).

The shoots aqueous extract of *Solenostemma argel* applied in the present study exhibited a lethal effect on the 2nd larval instar of *H. armigera* and the mortality was both dose and time dependent. Simillar results were recorded by Mardi and Sulaiman (2018) who stated that a significant control of African boll worm, white fly, and tomato leaf curl virus disease on tomato fields can be achieved by spraying aqueous extract of *S. argel* shoot powder.

The recent finding of this study also clearly showed that the leaves aqueous extract of *Eucalyptus camaldulensis* induced a significantly higher mortality percentage than that of the control. This agreed with Fathi and Shakarami (2014) who studied the effect of essential oils extracted from five *Eculayptus* species and found that all tested essential oils have larvicidal effect against *Tribolium castaneum* and *Triboli-*

um confusum. They also found that *T. confusum* was more susceptible than *T. castaneum*.

The obtained results also revealed that the aqueous extract of *Acacia nilotica* pods has insecticidal effect against the 2nd larval instar of the African boll worm and it scored the lowest mortality percentage among all tested aqueous extracts. In fact its highest concentration scored only 50 % mortality after 96 hrs of exposure. On the other hand, Elkhidr *et al*. (2020) found that the aqueous extract of *Acacia nilotica* fruits caused a high mortality percentage ranging between 75% and 100% against *Culex* species larvae.

Vasudev *et al*., (2015).Stated that, the methanol and acetone bark extracts from *Acacia nilotica* adversely affected the larval period and total developmental period of *Bactrocera cucurbitae*

CONCLUSION

The obtained results clearly proved that all all tested plant extract, *Bt* and Nimbecidine® exhibited insecticidal activity against 2nd instar larvae of *H. armigera*. However, tubers ethanolic extract of *C. rotundus* gave the highest mortality percentage among the tested plant extracts. The study revealed that the sesame oil has as a synergistic effect when added to all tested ethanolic plant extracts.

It is observed form this study that, the efficacy of tested ethanolic plant extracts can be enhanced by mixing them together or in a combination with *Bt*. This would lead to a significant reduction in the amount of insecticides required for application and hence reduce the environmental pollution and reduce costs of production. Also the obtained results showed that, there is no significant difference in the mortality percentages induced by the highest concentration (30%) of leaves aqueous extract of *Balanites eagyptiaca* and shoot aqueous extract of *Solenostemma argel* throughout the experimental period.

RECOMMENDATIONS

Based on the above mentioned results, organic extracts of the tested plants mixed with sesame oil and/or *Bt* can be recommended to be used as a control agent for *H. armigera*. However, further comparative studies should be conducted to evaluate the effects of these plant extracts with other organic solvents on other insect pests. Finally, a comprehensive study should be conducted to specify the active ingredients of the tested plants.

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APPENDICES

Appendix (1) Lethal effect of the tuber ethanolic extract of *C. rotundus* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 24 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. rotundus	4	30	40	40	36.7
	6	50	40	40	43.3
	8	50	60	60	56.7

	10	60	50	70	60.0
	12	80	80	70	76.7
C. rotundus + sesame oil	4	60	50	60	56.7
	6	70	70	60	66.7
	8	80	90	80	83.3
	10	90	100	100	96.7
	12	100	100	100	100.0
Sesame oil	-	30	10	10	16.7
Control	-	0	0	0	0.0

Appendix (2) Lethal effect of the tuber ethanolic extract of *C. rotundus* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 48hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. rotundus	4	50	40	40	43.3
	6	60	50	50	53.3
	8	70	70	70	70
	10	80	70	70	73.3
	12	90	80	90	86.7
C. rotundus + sesame oil	4	60	60	70	63.3
	6	80	70	80	76.7
	8	90	90	90	90.0
	10	100	100	100	100.0
	12	100	100	100	100.0
Sesame oil	-	30	10	20	20.0
Control	-	0	0	0	0.0

Appendix (3) Lethal effect of the tuber ethanolic extract of *C. rotundus* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 72 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. rotundus	4	50	40	50	46.7
	6	60	60	60	60.0
	8	80	70	70	73.3
	10	80	80	70	76.7
	12	90	90	90	90.0

C. rotundus + sesame oil	4	60	70	70	66.7
	6	80	80	90	83.3
	8	100	90	90	93.3
	10	100	100	100	100.0
	12	100	100	100	100.0
Sesame oil	-	30	10	30	23.3
Control	-	0	0	0	0.0

Appendix (4) Lethal effect of the tuber ethanolic extract of *C. rotundus* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 96 hrs.

Treatment	**Conc. %**	**R1**	**R2**	**R3**	**Mean**
C. rotundus	4	50	50	50	50.0
	6	60	60	60	60.0
	8	80	70	70	73.3
	10	80	80	80	80.0
	12	90	90	90	90.0
C. rotundus + sesame oil	4	60	70	70	66.7
	6	80	80	90	83.3
	8	100	90	100	96.7
	10	100	100	100	100.0
	12	100	100	100	100.0
Sesame oil	-	30	10	30	23.3
Control	-	0	0	0	0.0

Appendix (5) Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 24 hrs.

Treatment	**Conc. %**	**R1**	**R2**	**R3**	**Mean**
D. stramonium	4	20	30	20	23.3
	6	30	20	30	26.7
	8	30	20	40	30.0
	10	40	30	30	33.3
	12	50	50	40	46.7

D. stramonium + sesame oil	4	30	30	40	33.3
	6	40	50	40	43.3
	8	50	60	40	50.0
	10	60	60	50	56.7
	12	60	50	70	60.0
Sesame oil	-	30	10	10	16.7
Control	-	0	0	0	0.0

Appendix (6) Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 48 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
D. stramonium	4	30	30	30	30.0
	6	30	30	40	33.3
	8	50	40	50	46.7
	10	60	40	50	50.0
	12	70	60	60	63.3
D. stramonium + sesame oil	4	40	50	40	43.3
	6	60	60	60	60.0
	8	70	70	60	66.7
	10	70	70	70	70.0
	12	70	70	80	73.3
Sesame oil	-	30	10	20	20.0
Control	-	0	0	0	0.0

Appendix (7) Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 72 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
D. stramonium	4	40	40	40	40.0
	6	40	40	50	43.3
	8	60	40	50	50.0
	10	60	50	50	53.3
	12	70	70	70	70.0

D. stramonium + sesame oil	4	50	60	70	60.0
	6	80	60	70	70.0
	8	80	70	80	76.7
	10	80	90	80	83.3
	12	90	90	100	93.3
Sesame oil	-	30	10	30	23.3
Control	-	0	0	0	0.0

Appendix (8) Lethal effect of the seeds ethanolic extract of *D. stramonium* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 96 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
D. stramonium	4	40	40	40	40.0
	6	40	40	50	43.3
	8	60	50	50	53.3
	10	60	60	50	56.7
	12	70	80	80	76.7
D. stramonium + sesame oil	4	60	60	70	63.3
	6	80	70	70	73.3
	8	80	100	90	90.0
	10	80	100	100	93.3
	12	90	90	100	93.3
Sesame oil	-	30	10	30	23.3
Control	-	0	0	0	0.0

Appendix (9) Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 24 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. occidentalis	4	20	10	20	16.7
	6	20	20	30	23.3
	8	30	30	30	30.0
	10	40	40	30	36.7
	12	60	60	60	60.0

C. occidentalis + sesame oil	4	50	50	50	50
	6	60	50	60	56.7
	8	60	70	70	66.7
	10	70	70	70	70.0
	12	70	80	70	73.3
Sesame oil	-	30	10	10	16.7
Control	-	0	0	0	0 .0

Appendix (10) Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 48 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. occidentalis	4	30	20	30	26.7
	6	40	20	40	33.3
	8	30	40	40	36.7
	10	40	50	30	40.0
	12	70	60	70	66.7
C. occidentalis + sesame oil	4	50	50	60	53.3
	6	60	60	60	60
	8	70	80	70	73.3
	10	70	80	80	76.7
	12	80	90	80	83.3
Sesame oil	-	30	10	20	20.0
Control	-	0	0	0	0 .0

Appendix (11) Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 72 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
C. occidentalis	4	30	20	30	26.7
	6	40	30	40	36.7
	8	30	50	40	40.0
	10	50	50	40	46.7
	12	70	60	70	66.7

C. occidentalis + sesame oil	4	60	50	60	56.7
	6	70	70	70	70
	8	70	80	80	76.7
	10	70	80	90	80.0
	12	80	90	80	83.3
Sesame oil	-	30	10	30	23.3
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (12) Lethal effect of the seeds ethanolic extract of *C. occidentalis* alone and co-administered with sesame oil against 2nd larval instar of *H. armigera* after 96 hrs.

Treatments	**Conc. %**	**R1**	**R2**	**R3**	**Mean**
C. occidentalis	4	30	30	30	30.0
	6	40	30	40	36.7
	8	40	50	50	46.7
	10	50	60	50	53.3
	12	70	70	70	70.0
C. occidentalis + sesame oil	4	60	50	60	56.7
	6	70	70	80	73.3
	8	70	80	80	76.7
	10	70	80	90	80.0
	12	80	90	90	86.7
Sesame oil	-	30	10	30	23.3
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (13) Lethal effect of the seeds ethanolic extract of *R .communis* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 24 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
R .communis	4	20	30	30	26.7
	6	30	20	40	30.0
	8	40	50	40	43.3
	10	40	50	60	50.0
	12	60	60	50	56.7

R .communis + sesame oil	4	40	50	40	43.3
	6	50	60	60	56.7
	8	80	70	80	76.7
	10	90	80	80	83.3
	12	90	100	90	93.3
Sesame oil	-	30	10	10	16.7
Control	-	0	0	0	0.0

Appendix (14) Lethal effect of the seeds ethanolic extract of *R .communis* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 48 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
R .communis	4	40	30	40	36.7
	6	30	40	50	40.0
	8	40	50	50	46.7
	10	40	50	60	50.0
	12	60	60	50	56.7
R .communis + sesame oil	4	60	60	60	60.0
	6	80	70	70	73.3
	8	90	90	80	86.7
	10	100	90	90	93.3
	12	100	100	90	96.7
Sesame oil	-	30	10	20	20.0
Control	-	0	0	0	0.0

Appendix (15) Lethal effect of the seeds ethanolic extract of *R .communis* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 72 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
R .communis	4	40	30	40	36.7
	6	30	40	50	40.0
	8	60	50	50	53.3
	10	60	50	60	56.7
	12	70	70	80	73.3

R .communis + sesame oil	4	60	70	60	63.3
	6	80	70	70	73.3
	8	100	90	80	90.0
	10	100	90	100	96.7
	12	100	100	100	100.0
Sesame oil	-	30	10	30	23.3
Control	-	0	0	0	0.0

Appendix (16) Lethal effect of the seeds ethanolic extract of *R .communis* alone and co- administered with sesame oil against 2nd larval instar of *H. armigera* after 96 hrs.

Treatment	Conc. %	R1	R2	R3	Mean
R .communis	4	40	50	40	43.3
	6	40	50	50	46.7
	8	60	50	50	53.3
	10	60	60	60	60.0
	12	80	80	80	80.0
R .communis + sesame oil	4	70	70	60	66.7
	6	80	70	70	73.3
	8	100	90	80	90.0
	10	100	100	100	100.0
	12	100	100	100	100.0
Sesame oil		30	10	30	23.3
Control		0	0	0	0.0

Appendix (17) Lethal effect of *Bt* and Nimbecidine against 2nd larval instar of *H. armigera* after 24 hrs.

Treatment	Conc.	R1	R2	R3	Mean
Bt (mg/ml)	0.625	10	20	20	16.7
	1.25	30	30	20	26.7
	2.5	40	60	40	46.7
	5	50	50	60	53.3
	10	80	80	70	76.7
Nimbecidine	1.25	10	10	10	10

(ml/L)	2.5	30	20	20	23.3
	5	40	30	30	33.3
	10	40	50	50	46.7
	20	50	70	60	60.0
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (18) Lethal effect of *Bt* and Nimbecidine against 2nd larval instar of *H. armigera* after 48 hrs.

Treatment	**Conc.**	**R1**	**R2**	**R3**	**Mean**
Bt (mg/ml)	0.625	50	40	40	43.3
	1.25	40	50	50	46.7
	2.5	50	70	60	60.0
	5	60	70	80	70.0
	10	90	100	90	93.3
Nimbecidine (ml/L)	1.25	10	20	20	16.7
	2.5	40	40	30	36.7
	5	60	40	40	46.7
	10	40	50	60	50
	20	60	70	60	63.3
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (19) Lethal effect of *Bt* and Nimbecidine against 2nd larval instar of *H. armigera* after 72 hrs.

Treatment	**Conc.**	**R1**	**R2**	**R3**	**Mean**
Bt (mg/ml)	0.625	60	50	60	56.7
	1.25	60	70	70	66.7
	2.5	80	90	90	86.7
	5	90	90	100	93.3
	10	100	100	100	100.0
Nimbecidine	1.25	10	20	30	20.0

(ml/L)	2.5	50	40	40	43.3
	5	60	50	40	50.0
	10	40	60	60	53.3
	20	60	80	70	70.0
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (20) Lethal effect of *Bt* and Nimbecidine against 2nd larval instar of *H. armigera* after 96 hrs.

Treatment	**Conc.**	**R1**	**R2**	**R3**	**Mean**
Bt (mg/ml)	0.625	70	60	70	66.7
	1.25	70	90	80	80.0
	2.5	90	90	90	90.0
	5	100	100	100	100.0
	10	100	100	100	100.0
Nimbecidine (ml/L)	1.25	20	20	30	23.3
	2.5	50	40	40	43.3
	5	60	50	40	50.0
	10	60	60	70	63.3
	20	80	90	70	80.0
Control	-	0 (0.7)	0 (0.7)	0 (0.7)	0 (0.7)

Appendix (21) Mortality percentage induced by LC25 of the tested ethanolic plant extracts, Nimbicidine and *Btk* on 2nd larval instar of *H. armigera* after 24 hrs.

Extract	**R1**	**R2**	**R3**	**Mean**
Cyperus	30	20	20	23.3
Ricinus	30	30	20	26.7
Datura	30	20	20	23.3
Cassia	20	40	20	26.7
Bt	20	20	30	23.3
Nimbicidine	20	20	20	20.0

Appendix (22) Mortality percentage induced by LC25 of the tested ethanolic plant extracts, Nimbicidine and *Btk* on 2nd larval instar of *H. armigera* after 48 hrs.

Extract	R1	R2	R3	Mean
Cyperus	30	20	30	26.7
Ricinus	30	30	20	26.7
Datura	30	20	30	26.7
Cassia	30	40	20	30.0
Bt	40	40	30	36.7
Nimbicidine	20	30	30	26.7

* The expected mortality of the combined pair is the sum of the mortalities of single compound at recorded $LC_{25.}$

Appendix (23) Joint action of tested ethanolic plant extracts on 2nd larval instar of *H. armigera* after 24 hrs (observed mortality).

Mixture	R1	R2	R3	Total	Mean
Cyperus + *Btk*	50	30	70	150	50.0
Ricinus + *Btk*	60	60	70	190	63.3
Datura + *Btk*	50	60	40	150	50.0
Cassia + *Btk*	50	40	70	160	53.3
Nimbecidine + *Btk*	60	60	40	160	53.3

Appendix (24) Joint action of tested ethanolic plant extracts on 2nd larval instar of *H. armigera* after 48 hrs. (observed mortality).

Mixture	R1	R2	R3	Total	Mean
Cyperus + *Btk*	70	60	70	200	66.7
Ricinus + *Btk*	70	80	80	230	76.7
Datura + *Btk*	60	80	70	210	70.0
Cassia + *Btk*	80	70	80	230	76.7
Nimbecidine + *Btk*	80	80	80	240	80.0

Appendix (25) Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm after 24 hrs.

Plantextract/ used part	Conc. %	R1	R2	R3	Mean
Balanites ea-gyptiaca (Leaves)	1.8	20	20	10	16.7
	3.75	30	20	20	23.3
	7.5	20	30	30	26.7
	15	30	40	40	36.7
	30	50	40	40	43.3
Solenostemma argel (Shoot)	1.8	0	10	10	6.7
	3.75	20	20	20	20.0
	7.5	30	30	20	26.7
	15	40	30	40	36.7
	30	40	40	40	40.0
Eucalyptus camaldulensis (Leaves)	1.8	10	10	20	13.3
	3.75	20	20	20	20.0
	7.5	30	20	20	23.3
	15	40	30	30	33.3
	30	40	50	40	43.3
Acacia nilot-ica (Pods)	1.8	0	0	10	3.3
	3.75	10	0	10	6.7
	7.5	20	20	20	20.0
	15	20	20	30	23.3
	30	20	30	30	26.7
Control		0	0	0	0.0

Appendix (26) Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm after 48 hrs.

Plantextract/ used part	Conc. %	R1	R2	R3	Mean
Balanites ea-gyptiaca (Leaves)	1.8	30	20	20	23.3
	3.75	30	40	30	33.3
	7.5	40	40	30	36.7
	15	40	40	40	40.0
	30	50	40	50	46.7

Solenostemma argel (Shoot)	1.8	10	20	20	16.7
	3.75	20	20	30	23.3
	7.5	30	30	20	26.7
	15	40	30	40	36.7
	30	40	50	50	46.7
Eucalyptus camaldulensis (Leaves)	1.8	20	30	20	23.3
	3.75	30	20	30	26.7
	7.5	30	30	30	30.0
	15	40	40	30	36.7
	30	50	50	40	46.7
Acacia nilot-ica (Pods)	1.8	10	10	10	10.0
	3.75	10	20	20	16.7
	7.5	20	40	20	26.7
	15	20	30	30	26.7
	30	30	30	30	30.0
Control		0	0	0	0.0

Appendix (27) Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm after 72 hrs.

Plantextract/ used part	Conc. %	R1	R2	R3	Mean
Balanites ea-gyptiaca (Leaves)	1.8	30	30	30	30.0
	3.75	40	40	40	40.0
	7.5	40	50	40	43.3
	15	50	60	40	50.0
	30	60	50	50	53.3
Solenostemma	1.8	20	30	30	26.7

argel (Shoot)	3.75	30	30	40	33.3
	7.5	40	40	40	40.0
	15	50	50	40	46.7
	30	60	70	60	63.3
Eucalyptus camaldulensis (Leaves)	1.8	20	30	20	23.3
	3.75	30	30	30	30.0
	7.5	40	40	30	36.7
	15	40	40	50	43.3
	30	50	60	40	50.0
Acacia nilot-ica (Pods)	1.8	10	20	10	13.3
	3.75	20	20	20	20.0
	7.5	20	40	30	30.0
	15	30	40	40	36.7
	30	40	40	40	40.0
Control		0	0	0	0.0

Appendix (28) Lethal effect of aqueous extracts of tested plants on the mortality of second larval instars of the African bollworm after 96 hrs.

Plantextract/ used part	Conc. %	R1	R2	R3	Mean
Balanites ea-gyptiaca (Leaves)	1.8	40	30	30	33.3
	3.75	40	50	40	43.3
	7.5	50	50	50	50.0
	15	50	60	60	56.7
	30	70	60	60	63.3
Solenostemma	1.8	20	30	30	26.7

argel (Shoot)	3.75	30	40	40	36.7
	7.5	40	40	50	43.3
	15	50	50	40	46.7
	30	70	70	70	70.0
Eucalyptus camaldulensis (Leaves)	1.8	30	30	30	30.0
	3.75	30	30	40	33.3
	7.5	40	40	40	40.0
	15	40	40	50	43.3
	30	50	60	50	53.3
Acacia nilot-ica (Pods)	1.8	20	20	20	20.0
	3.75	30	40	30	33.3
	7.5	40	40	30	36.7
	15	40	40	40	40.0
	30	50	50	50	50
Control		0	0	0	0.0

Appendix (29) *Cyperus rotundus* plant.

Appendix (30) *Datura stramonium* plant.

Appendix (31) *Cassia occidentalis* plant.

Appendix (32) *Ricinus communis* plant.

Appendix (33) *Balanites eagyptiaca* plant.

Appendix (34) *Solenostemma argel* plant.

Appendix (35) *Eucalyptus camaldulensis* plant.

Eucalyptus camaldulensis

Appendix (36) *Acacia nilotica* plant.

Acacia nilotica