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Laboratory Evaluation of Insecticidal Activities of Some Botanicals against Four Insect Pests of Honey Bees *(Apis mellifera* L.*)*

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Abstract

The study evaluated the effectiveness of methanol, n-hexane and aqueous leaf extracts of Ocimum gratissimum, Carica papaya, Tithonia diversifolia, Ageratum conyzoides and Azadirachta indica in the management of four insect pests of honeybees namely; acrobat ant (Crematogaster lineolata), small hive beetle (Aethina tumida), lesser wax moth (Achroia grisella) and greater wax moth (Galleria mellonella) in the laboratory. Test of contact toxicity of the extracts was conducted by topical application of 2 ml of treatments at 10% w/v on five insects using standard method. Repellency study of the extracts was conducted using an area of preference test. N-hexane extracts of all the plants caused 100% mortality of all the insects within 6 hour. Methanol extract caused between 90% and 100% mortality of all the insects except A. tumida. Aqueous extract of all the plants cause 100% mortality of C. lineolata, but induce no mortality of A. tumida. Mortality of other insects treated with aqueous extracts of the plants varied between 15% and 100%. The % repellence of A. grisella by plant extracts and cypermethrin varied between 45% and 90% and were not significantly (p>0.05) different from each other, while that of A. tumida varied between 35% and 78%. The n-hexane and methanol extracts of the five plants had repellence and insecticidal effects on the four insect pests of bees and could be considered as bioactive candidate for management of the insects.

Key words: *Apis mellifera,* synthetic insecticide, leaf extracts, mortality, repellence

Introduction

Honey bees (*Apis mellifera* L.) are the single most important and efficient insect pollinators of food plants on earth (Kevin and Lorna, 2003). They maintain flower constancy and are directly responsible for 80% insect pollinating activities in plants (Ojeleye, 1999; Chittka *et al*., 1999; Olagunju, 2000). Placement of bee colonies around plants during flowering has been reported to give higher yield and improve quality of fruit (Ojeleye, 1999). There are three castes in a bee colony and these are queen, workers and drones (Clive, 1997). The queen is the only sexually productive female in the colony; she is the mother of workers, drones and virgin queen. The worker bees are the smallest bee and they perform most of the activities in bee colony. The drone is the male bee of the colony that developed from an unfertilized egg.

Honey is one of the products from bee-keeping, it is a complex biological mixture that consists of mostly primarily glucose and fructose. Honey is made from nectar and sweet deposits from plants and stored in the honey comb by honey bees. It has antibacterial and antifungal properties and will not rot or ferment when stored under normal condition (Beismeijer, 2003). Other useful products from beekeeping are propolis, venom and beewax. Propolis is a resinous mixture of bee wax and resin collected by the honeybees from plant buds, leaves and exudes (Chittka *et al.*, 1999). In the hive, it reduces vibration of hives and makes the hive more defensible by sealing alternate entrance to prevent hive against disease and parasites (Krell, 1996). Bee wax is mainly esters of fatty acids and various long chain alcohols used by the bees to building honey combs cells in which their young are raised and pollens are stored (Chittka *et al.*, 1999). Honey bee and its colony are however, infested by many diseases and pest worldwide (FAO, 2006). The most serious arthropod pests of honey bees that cause major decline in honey bee colonies are wax moth *Galleria mellonella* and *Achroia grisella*, ant - *Crematogaster lineolata,* varroa mites - *Varroa destructor*, small hive beetles - *Aethina tumida*, tracheal mite - *Acarapis woodi* and others (Kraus and Page, 1995; Finley *et al.*, 1996; Wilson *et al*., 1997; Gatton *et al*., 2006; Akinwande *et al.*, 2013). Infestation of bee colony by these insects have been reported to result in total colony loss and absconding of honey bees in Europe, USA, South America, Australia, Asian and African (Monheim *et al.*, 2010). In Nigeria, a decline of 15% in bee colony establishment due to infestation of pests has been reported (Oyerinde and Ande, 2009). *Aethina tumida* has been reported to weaken bee colony, damage wax comb, reduce quality of honey by defeacating within the food cells and may cause bees to abandon the hive (MAAREC, 2007). *Galleria mellonella* and *A. grisella* are serious pests of wax combs and cause over 5 million dollars in damage within the United States annually (May, 1969; Apiculture Factsheet, 2004). These Lepidopteran pests suck honey and could cause colony absconding in weak colonies (Apiculture Factsheet, 2004). Varroa mites are the most serious parasite of honey bee globally; it kills a colony in two-four years if preventive measures are not taken. Intense parasitism of the mite leads to pupal death, malformed wings, legs, abdomens and shortened life span due to tissue damage. Varroa mites also vector numerous viral diseases such as deformed Wing Virus (DWV), Kashmir Bee Virus (KBV), Chronic Bee Paralysis Virus (CBPV) and Acute Bee Paralysis Virus (ABPV) (MAAREC, 2007).

The use of synthetic pesticides for management of insect pests has been restricted because of their carcinogenicity, teratogenicity, high and acute residual toxicity, creation of hormonal imbalance, spermatotoxicity, extensive ground water contamination, evolution of resistance and resurgence of treated populations, outbreaks of secondary pests, long degradation period and deposition of toxic residues in food (Pretty, 2009; Khater, 2011; Dulbey *et al.*, 2011). However, botanical pesticides are easily decomposed by a variety of microbes common in most soils; they reduce environmental contamination and maintain the biological diversity of predators that are often killed by broad-spectrum synthetic pesticides (Grange and Ahmed, 1998). In the last 15-20 years, new extracts of some tropical plants have been reported to have antibacterial, insecticidal, repelling and or ovicidal effects (Schmutterer 1995; Adoyo *et al.*, 1997; Peter, 2011; Koche *et al*., 2012). This study therefore evaluated the effectiveness of methanol, n-hexane and aqueous leaf extracts from five commonly available plants for the management of four major insect pests of honeybees.

Materials and Methods

Source of insects

Four insect pests of honey bee used for this study: acrobat ant *Crematogaster lineolata* (Hymenoptera: Formicidae), small hive beetle *Aethina tumida* (Coleoptera: Nitidulidae), greater wax moth *Galleria mellonella* (Lepidoptera: Pyralidae) and lesser wax moth *Achroia grisella* (Lepidoptera: Pyralidae) were sourced from bee colonies in four Kenya Top Bar Hives located in four apiaries in Ogbomosho (Latitude 8° 8′ N and Longitude 4°16'E), Oyo State, Nigeria.

Collection of plants and preparation of extracts

Young leaves of scent leaf (*Ocimum gratissimum*), pawpaw (*Carica papaya),* sunflower (*Tithonia diversifolia*), goat weed (*Ageratum conyzoides*) and neem *(Azardirachta indica)* were collected from Federal University of Agriculture, Abeokuta (Latitude 7°30'N and Longitude 4°32'E), Ogun State, Nigeria. The leaves were rinsed with distilled water and air-dried on work-tables in the laboratory at room temperature (27± 2ºC) until they are crispy dried. The dried leaves were mechanically ground with a grinding machine into powder and passed through a sieve with fine mesh (0.841 mm) to obtain fine powder.

One hundred gram (100 g) of each powder was poured into 1000 ml of water (10% w/v) and left for 48hrs in a plastic bottle of 2 litre size. The mixture was shaken thoroughly, allowed to settle and was decanted. The decanted solution was filtered using Whatman No 1 filter paper and used as aqueous extraction. Extraction of treatments from the test plants with methanol and n-hexane was done at the central Laboratory of FUNAAB using soxhlet extractor. Forty gram each of the plant samples were separately extracted twice with 400 ml of the solvents in the apparatus for at least 8 h. The extracts were concentrated on rotary evaporator by removing excess solvent under vacuum desiccators and stored in a small reagent bottle at 4º C in a refrigerator. The synthetic insecticide, Cypermethrin, was sourced from a chemical store in Abeokuta was used as a check.

Contact toxicity of plant extract by topical application

Test of contact toxicity of the extracts to *C. lineolata*, *A. tumida*, *A. grisella* and *G. mellonella* was conducted by topical application of the extracts on them using standard method described by McDonald *et al.* (1970). Five insects pests of same genus and species of unknown age and sex were placed in a plastic petri dish**.** Two ml of plant extract and synthetic insecticide (1% Cypermethrin) were applied to the dorsal surface of thorax of each insect individually with a micro applicator (Ebenezer, 2000). Each of the treatments were replicated four times and arranged on a work table in the laboratory using complete randomized design. The mortality of the treated insects was assessed at 6 h, 12 h, 24 h, 36 h 48 h, 60 h and 72 h after treatment by probing them with a blunt object. Insects that did not move or respond to the three probings were considered dead (Obeng-Ofori *et al*., 1998). Percentage insect mortality was calculated according to Baba-Tierto Niber (1994) using the formula:

$$\text{Mortality (\%)} = \frac{\text{No. of dead insects}}{\text{Total No. of insects}} \times 100$$

Repellency study of the insects by treated paper method

The study to assess insect repellence by the plant extracts was conducted using 'Area of Preference Test' described by McDonald *et al.* (1970) and Landani *et al*. (1995). Test area was number 1 Whatman filter paper (11cm diameter) that was cut into equal halves that have no contact with each other to prevent exchange of content. One half was dipped into the treatment with forceps and allowed to drain before placement into the plastic petri dish. The other half was placed into distilled water (control), allowed to drain and was placed side way with the first half. Four insect pests of same genus and species of unknown age and sex were released separately into the centre of each filter paper in the petri dish. Each treatment was replicated four times and arranged on a work table in the laboratory using complete randomized design. The number of insects presents on control (NC) and treatments (NT) half were recorded after 1 h exposure. Percent repellence (PR) values were computed using the method of Hossanah *et al*. (1990) as follows:

$$PR = \frac{NC\text{-}NT \times 100}{NC + NT}$$

Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) and means separation was done using Duncan Multiple Range Test (P<0.05).

Results

Mortality effects of the plant extracts on the pests

The % mortality of *C. lineolata* treated with the plant extracts is depicted on Table 1. All the insects treated with methanol, n-hexane and aqueous plant extract died at 6 h after application. The mortality effects of the plant extracts on the insects was not significantly (P>0.05) different from the effect of cypermethrin**.** The synthetic insecticide (Cypermethrin) and n-hexane extract of all the plants caused 100% mortality of *A. tumida* 6 h after treatment. *Aethina tumida* was not killed by aqueous extract of all the plants at all the exposure periods. No insect died in the untreated petri dishes of *A. tumida* (Table 2).

Table 1: Mean percent mortality of acrobat ant (*Crematogaster lineolata)* treated with plant extract and cypermetrin

Treatment	Time (H)						
	6	12	24	36	48	60	72
Methanol							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
N-Hexane							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Aqueous							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Cypermethrin	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Control	0.00[b]	0.00[b]	0.00[b]	0.00[b]	0.00[b]	0.00[b]	0.00[b]

Means with the same alphabet along the column are not significantly different from each other using Duncan Multiple Range Test at ≤ 0.05.

Table 2: Mean percent mortality of small hive beetle (*Aethina tumida*)

Treatment	Time (H)						
	6	12	24	36	48	60	72
Methanol							
Carica papaya	0.00[c]	0.00[c]	0.00[c]	0.00[c]	5.00[bc]	5.00[bc]	5.00[bc]
Tithonia diversifolia	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Ocimum gratissimum	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	5.00[bc]	5.00[bc]
Azardirachta indica	0.00[c]	0.00[c]	0.00[c]	0.00[c]	10.00[b]	10.00[b]	10.00[b]
Ageratum conyzoides	10.00[b]	10.00[b]	10.00[b]	10.00[b]	10.00[b]	10.00[b]	10.00[b]
N-Hexane							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Aqueous							
Carica papaya	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Tithonia diversifolia	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Ocimum gratissimum	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Azardirachta indica	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Ageratum conyzoides	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]
Cypermethrin	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Control	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]	0.00[c]

Means with the same alphabet along the column are not significantly different from each other using Duncan Multiple Range Test at ≤ 0.05.

Cypermetrin, methanol, n-hexane extract of all the plants caused 100% mortality of *A. grisella* 6 h after exposure to the treatments. Aqueous extract of *A. indica* and *A. conyzoides* caused mortality of between 85% and 100% in *A. grisella* treated with the extract (Table 3). Methanol extract of *Ocimum gratissimum* caused 90% mortality of *G. mellonella* as from 6 h after exposure till 72 h. Methanol extract of other plants caused 100% mortality of *G. mellonella* 6 h after exposure to treatment. Cypermetrin and n-hexane extract of all the plants caused 100% mortality of *G. mellonella* 6 h after exposure to the treatments (Table 4).

Repellency effects of the plant extracts on bee pests

Repellence of *A. tumida* by methanol, n-hexane and aqueous extract of all the plants varied between 32.03% and 89.15% and they were not significantly (P>0.05) different from each other. Cypermethrin caused 80.19% repellence of *A. tumida*. The % repellence of the *A. tumida* by cypermethrin was not significantly (P>0.05) different from the % repellence of the insect by plant extracts (Table 5). Cypermethrin caused the highest (90.0%) repellence of *C. lineolata*. The repellence effects were however, not significantly (P>0.05) different from the repellence effects of the insect by methanol extract of all plants except *O. gratissimum*, n-hexane extract of *O. gratissimum*, *A. indica*, *A. conyzoides* and aqueous extract of *C. papaya* (Table 5).

Table 3 Mean percent mortality of lesser wax moth (*Achroia grisella*)

Treatment	**Time (H)**						
	6	12	24	36	48	60	72
Methanol							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
N-Hexane							
Carica papaya	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Tithonia diversifolia	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ocimum gratissimum	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Azardirachta indica	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Ageratum conyzoides	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Aqueous							
Carica papaya	35.00[b]	65.00[b]	75.00[bc]	80.00[bc]	80.00[bc]	85.00[b]	85.00[b]
Tithonia diversifolia	30.00[b]	65.00[b]	65.00[c]	70.00[c]	75.00[c]	85.00[b]	85.00[b]
Ocimum gratissimum	25.00[b]	30.00[c]	30.00[d]	30.00[d]	35.00[d]	35.00[c]	40.00[c]
Azardirachta indica	85.00[a]	90.00 [a]	90.00[ab]	90.00[ab]	90.00[ab]	90.00[ab]	90.00[ab]
Ageratum conyzoides	90.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Cypermethrin	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Control	0.00[c]	0.00[d]	0.00[e]	0.00[e]	0.00[e]	0.00[d]	0.00[d]

Means with the same alphabet along the column are not significantly different from each other using Duncan Multiple Range Test at $\leq$ 0.05.

Table 4: Mean percent mortality of greater wax moth (*Galleria mellonella*)

Treatment	Time (H)						
	6	12	24	36	48	60	72
Methanol							
Carica papaya	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Tithonia diversifolia	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Ocimum gratissimum	90.00^{a}	90.00^{a}	90.00^{a}	90.00^{a}	90.00^{a}	90.00^{a}	90.00^{a}
Azardirachta indica	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Ageratum conyzoides	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
N-Hexane							
Carica papaya	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Tithonia diversifolia	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Ocimum gratissimum	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Azardirachta indica	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Ageratum conyzoides	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Aqueous							
Carica papaya	30.00c	60.00b	70.00b	90.00a	90.00ab	90.00ab	90.00ab
Tithonia diversifolia	15.00d	50.00b	55.00b	60.00b	60.00c	60.00c	60.00c
Ocimum gratissimum	15.00d	20.00c	25.00c	25.00c	25.00d	25.00d	25.00d
Azardirachta indica	55.00b	60.00b	65.00b	70.00b	75.00b	80.00b	80.00b
Ageratum conyzoides	90.00a	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
Cypermethrin	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
Control	0.00e	0.00d	0.00d	0.00d	0.00e	0.00e	0.00e

Means with the same alphabet along the column are not significantly different from each other using Duncan Multiple Range Test at $\leq$ 0.05.

Repellence (80.19%) of *G. mellonella* by cypermethrin was not significantly (P>0.05) different from repellence of the insect by extract of all plants except aqueous extract of *O.gratisimmum*, *A. indica* and *C. papaya* and methanol extract of *C. papaya* (Table 5). Aqueous extract of *A. conyzoides* had the highest (90.0%) repellence of *A. grisella*. The repellence was however, not significantly (P>0.05) higher than the repellence (80.19) caused by cypermethrin and extracts of other plants except aqueous extract of *C. papaya* and *O. gratissimum* that caused 44.72 repellence each (Table 5).

Table 5: Percent repellence of *Aethina tumida, Crematogaster lineolata, Galleria mellonella* and *Achroia grisella*

Treatments	*Aethina tumida*	*Crematogaster lineolata*	*Galleria mellonella*	*Achroia grisella*
Methanol				
Carica papaya	41.83^{ab}	64.33^{ab}	25.97^{c}	64.33^{ab}
Tithonia diversifolia	41.83^{ab}	64.33^{ab}	48.47^{bc}	64.33^{ab}
Ocimum gratissimum	32.03^{ab}	42.42^{bc}	44.72^{abc}	54.53^{ab}
Azardirachta indica	54.53^{ab}	64.33^{ab}	70.38^{ab}	80.19^{ab}
Ageratum conyzoides	80.19^{a}	74.14^{ab}	60.58^{abc}	80.19^{ab}
n-hexane				
Carica papaya	57.69^{ab}	38.67^{bc}	48.47^{abc}	54.33^{ab}
Tithonia diversifolia	89.19^{a}	38.67^{bc}	48.47^{abc}	64.33^{ab}
Ocimum gratissimum	58.28^{ab}	54.53^{abc}	54.53^{abc}	60.58^{ab}
Azardirachta indica	67.50^{ab}	58.28^{abc}	64.33^{ab}	80.19^{ab}
Ageratum conyzoides	80.19^{a}	70.38^{ab}	80.19^{a}	80.19^{ab}
Aqueous				
Carica papaya	25.97^{b}	90.00^{a}	38.67^{bc}	44.72^{b}
Tithonia diversifolia	44.72^{ab}	50.77^{bc}	44.72^{abc}	54.53^{ab}
Ocimum gratissimum	57.69^{ab}	26.57^{c}	38.67^{bc}	44.72^{b}
Azardirachta indica	54.53^{ab}	50.77^{bc}	38.67^{bc}	70.38^{ab}
Ageratum conyzoides	64.33^{ab}	50.77^{bc}	80.19^{a}	90.00^{a}
Cypermethrin	80.19^{a}	90.00^{a}	80.19^{a}	80.19^{ab}

Means with the same alphabet along the column are not significantly different from each other using Duncan Multiple Range Test at ≤ 0.05

Discussion

The results of the studies showed the ability of *O. gratissimum, C. papaya, T. diversifolia, A. conyzoides* and *A. indica* to repel and induce mortality in *C. lineolata*, A. *tumida*, G. *mellonella* and *A. grisella*. The insecticidal activities of plant extracts have been reported by many authors (Subapriya and Nagini 2005; Hossanah *et al.*, 1990; Dubey *et al.*, 2011). Messina and Renwish (1983) and Lale (1993) reported that plant products act as *de facto* contact insecticide against both adults and immature stages of insects. Pedigo (2002) and Modue (2004) reported that compounds from botanical insecticides could be toxic, regulate growth, repel, and deter feeding, growth and development of insects. Aiyelaagbe and Osamudiamen (2009) posited that botanical insecticides contain chemically active compounds such as alkaloids, tannins, flavonoids and phenolic compounds. Adoyo *et al.* (1997) reported extracts from *Tithonia diversifolia* have insecticidal activities against termite. Awasthi (2007) reported the effectiveness of chopped leaves of *A. indica* in the control of *Sitotroga cerealella* in stored rice. Bomford and Isman (1996) and Pedigo (2002) reported that the major biologically active constituents of *A. indica* that makes it to be efficient are Azadirachtin and Salannin.

Dutta *et al.* (1993) and Adoyo *et al.* (1997) reported that *T. diversifolia* contains biologically active compounds that control termite and other insects.

In this study, aqueous extract of *A. conyzoides* had a higher repellence of *Achroia grisella* relative to cypermethrin, the synthetic insecticide. This is similar to earlier finding of Sighamony *et al.* (1986) who compared the effectiveness of Karanja oil (*Pongamia glabra*), *P. pinnata* and cedar-wood oil (*Juniperus virginiana*) with that of dimethyl phthalate, a standard synthetic repellent against *Tribolium casteneum* and reported that these products were more potent than the synthetic repellent. Sighamony *et al*. (1984), Malik and Naqvi (1984) and Su (1985) reported that several floral species act as repellents and antifeedants against a number of stored products Coleoptera.

Aqueous extract of all the plants cause 100% mortality of *C. lineolata*, but induce no mortality of *A. tumida*. Mortality of other insects treated with aqueous extracts of the plants varied between 15% and 100%. N-hexane and methanol extracts caused a significantly ($p<0.05$) higher mortalities and repellence of between 90% and 100% to all the insect pests The higher effectiveness of methanol and n-hexane extract of the plants compared to aqueous extract could be attributed to variation in the polarity of the solvent media. Methanol and n-hexane are less polar than water and this makes many organic compounds to dissolve more in methanol and n-hexane than water (Christian, 2003). N-hexane extracts of all the plants caused 100% mortality of all the insects within 6 h. This portrays rapid action of the plant extracts and positions it to compete with synthetic insecticides that are highly favoured due to their swift action among others. This study indicated that *O. gratissimum*, *C. papaya*, *T. diversifolia*, *A. conyzoides* and *A. indica* repelled and caused mortality of *C. lineolata*, *A. tumida*, *G. mellonella* and *A. grisella* in the laboratory. The activities of these botanicals should be tested on the field to determine their effectiveness on the field and insecticidal effect on honey bees.

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