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A REVIEW ON THE USE OF CARBOFURAN AND PLANT LEAF OIL AS BIOINSECTICIDE IN THE MANAGEMENT OF LEPIDOPTEROUS MAIZE STEMBORERS

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ABSTRACT

Stem borers interfere with the movement of water and metabolites through the plant's vascular system, which stunts its growth and development. Attacks during the first eight weeks after sowing result in “dead heart” and late damage (beyond eight weeks after sowing) leads to stem lodging. Both types of damage to the crop cause drastic loss in maize yield. The most important field pests of maize are lepidopterous stem and cob borers belonging to the families of *Noctuidae* and *Pyralidae*. They are: the African stalk borer (*Busseola fusca* Fuller), the spotted stem borer (*Chilo partellus* Swinhoe), the pink stem borer (*Sesamia calamistis* Hampson) and the sugar cane borer (*Eldana saccharina* Walker). Controlling these insect pests is difficult because most part of their life cycles is spent inside the plant which serves as a physical protection to insecticide application. Synthetic insecticides have been used extensively in the past by farmers for the control of stem borers, but however, they have not been effective and are not easily biodegradable besides being expensive. However, in recent times much attention has been given to biopesticides especially in controlling insect pests both in the field and in the store. The use of botanicals for the control of agricultural pests is considered to be environmentally friendly and also reduce the cost of insecticides in pest management. Carbofuran is a broad spectrum carbamate pesticide that kills insects, mites and nematodes on contact or after ingestion. It is used against soil and foliar pests of field, fruit, vegetables and forest crops. It is a pesticide that is widely used to control insects and nematodes on a variety of agricultural crops because of its wide-ranging biological activity and relatively low persistence when compared to organochlorine pesticides. It is a systemic insecticide, which means that the plants absorbs it through the roots, and from here the plant distributes it throughout its organ (mainly vessels, stems and leaves; not the fruits), where insecticidal concentrations are attained.

KEYWORDS: Biopesticide, insect, crops, stem-borers and environmental-friendly

INTRODUCTION

Maize (*Zea mays* L. Merri) is a plant in the grass family *Gramineae*, a tall annual plant with extensive fibrous root system (FAO.2002). It is the third most important cereal crop in the world after wheat and rice (FAO, 2002). In Nigeria, maize is known and called by different vernacular names like Masara (Hausa), Agbado (Yoruba), Oka (Igbo), Ibikpod (Efik).

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Maize is one of the major staple food crops widely cultivated and consumed in Africa due to its rich carbohydrate content (Rouanet, 1992).

In Nigeria, maize is grown in all agro-ecological zones mostly for its seeds either as dry grains or green maize with an estimate national production of 7.7million metric tonnes (Olaniyan, 2015). It is also called corn especially in the United State of America which is referred to as Corn Belt. It is usually stored to provide food reserve during off season and also as seed material for planting. Preparation and uses of maize alone or in combination with other food materials as staple food or snacks in Nigeria include: Ogi (in hot and cold forms), tuwo, donkumu, maasa, couscous, nakia, agbe, kokoro, elekube, abari, among others.

Maize is the most important cereal crop in sub-Saharan Africa. It is a staple food for an estimated 50% of the population (IITA, 2009). It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Africans consume maize in many forms (such as porridges, pastes and beer). Green maize fresh on the cob is eaten baked, roasted or boiled. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products (IITA, 2009). In sub-Saharan Africa, maize is mostly grown by small-scale farmers, generally for subsistence as part of mixed agricultural systems.

In Nigeria, maize crop is the first among the cereal crops grown (Romain, 2001). Cultivated throughout the ecological zones of Nigeria, maize is also demonstrated with a high yield potential in savannah regions (Mugo *et al*., 2005). It is the most cost-effective and highest yield plant resource in the world (Robert *et al.,* 2014). It serves as a material for the production of livestock forage, fodder and feed in Sub-Saharan Africa (Davies and Pedigo, 1990), as well as raw material for manufacture of many industrial products (Romain, 2001) and has also been used as biofuel and is a raw material for brewing beer and for producing starch (Romain, 2001; Misra, 2009).

The most important field pests of maize are lepidopterous stem and cob borers belonging to the families of *Noctuidae* and *Pyralidae* (Usua, 1968). They are: the African stalk borer (*Busseola fusca* Fuller), the spotted stem borer (*Chilo partellus* Swinhoe), the pink stem borer (*Sesamia calamistis* Hampson) and the sugar cane borer (*Eldana saccharina* Walker). Stem borers interfere with the movement of water and metabolites through the plant's vascular system, which stunts its growth and development. Attacks during the first eight weeks after sowing result in “dead heart” and late damage (beyond eight weeks after sowing) leads to stem lodging. Both types of damage to the crop cause drastic loss in maize yield (Bosque-Perez, 1995; [c]Nta *et al*.,).

Therefore, feeding activities can cause fenestration, thereby reducing the photosynthetic area of the leaves that result to poor yield (Ofor *et al*., 2009; Ekpenyong *et al*.,). Generally, the yield losses due to stem borers range from 10 to 100% (Bosque-Perez and Mereck 1990). Damage resulting from stem borer infestation on maize plant can cause between 20-40% losses during cultivation, and 30-90% at post-harvest and storage (Robert *et al*., 2014). They also reported that increased damage on young maize plants is as result of the soft nature of the stems and leaves. In Nigeria, 14.0% yield loss for early maize as a result of stem borer activities was reported (Okweche *et al.,* 2013). The prevalence of *B. fusca* followed by *S. calamistis* on the early- and/or late-sown maize at Makurdi, Benue State, Calabar, Cross River State, and South-western Nigeria has been established (Balogun *et al*, 2001; Okweche, 2010; Okweche and Umoetuk, 2012).

Controlling these insect pests is difficult because most part of their life cycles is spent inside the plant which serves as a physical protection to insecticide application (Vitale, 2007). Synthetic insecticides have been used extensively in the past by farmers for the control of stem borers, but however, they have not been effective and are not easily biodegradable besides being expensive. (Clieve, 2003). However, in recent times much attention has been given to biopesticides especially in controlling insect pests both in the field and in the store (Ileke, 2015). The use of botanicals for the control of agricultural pests is considered to be environmentally friendly and also reduce the cost of insecticides in pest management (Maddonni *et al.,* 2016; [b]Nta *et al*.,).

STEMBORER SPECIES

The major species of stem borers associated with maize in Nigeria are the maize stalk borer, *Busseola fusca* Fuller (Noctuidae), the pink stalk borer, *Sesamia calamistis* Hampson (Noctuidae), the millet stemborer, *Acigona ignefusalis* Hampson (Pyralidae) and the Africa sugarcane borer, *Eldana saccharina* Walker (Pyralidae) (Polaszek, 1998; Balogun *et al*, 2001). Others of less importance are the spotted stalk borer (*Chilo partellus* Swinehoe. Pyralidae), *C. orichalcociliella, C. suppressalis,* and the ear borer (*Mussidia nigrivenella* Pyralidae) (NRI, 1996; Dike *et al.,* 1999; Khan, *et al.,* 2001).

Usua (1966) reported that *B. fusca* (Fuller) and, *S calamistis* (Hampson) were predominant in Northern and Southern Western Nigeria respectively. Polaszek, (1998) also reported that *Chilo partellus* (Lepidoptera; Pyralidae) is dominant at altitude below 1200m while *B. fusca* (Lepidoptera: Nuctuidae) is dominant at higher altitudes. Usua (1997) observed that *S. calamistis* was more abundant than both *B. fusca* in Eastern and Southern States of Nigeria. Okweche *et al.* (2010) and [a]Nta *et al*., reported that *B. fusca* is the most predominant borer species in the guinea savanna agro-ecological zone of Nigeria followed by *S.calamistis, E. saccharina, A. ignefusalis and C. partellus* in early and late maize plantings.

Obhiokhenan *et al.* (2002) reported higher stem borer populations in the Mangrove zone followed by rain forest and derived savannah zones of Cross River State.

Severity and nature of stem borer damage depends upon the borer species, the plant growth stage, the number of larvae feeding on the plant, and the plant's reaction to borer feeding. Almost all plant parts, leaves, stems, tassels and ears are attacked. Crop losses may result from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging and direct damage to the ears. The incidence of stalk and ear rots is increased by larval feeding and lodging of the plants (Bosque-Perez, 1995).

African maize stem borer (*B. fusca*)

B. fusca is distributed widely throughout Sub-saharan Africa. Populations in Eastern and Southern Africa appear to be adapted to different environments from those in West Africa. In the eastern and southern parts of the continent, *B. fusca* is restricted to mid-and high elevations areas (>600m), whereas in West Africa, the same species is found at all elevations, but is most abundant in the savanna zone (Overholt *et al*., 2001). The pest thrives on wide number of other cultivated and wild host plants, mostly of the grass family (Khan *et al*., 1997).

Biology and economic importance of *B. fusca*

The female lays many eggs in batches of 30-50, inserted between the sheath and the stem. Incubation lasts about 1 week. After hatching, the larvae feed on the young blades of the leaf whorl and then, suspended from silk strands, spread to neighbouring plants. Generally, they destroy the growing points and tunnel downward. After passing through six to eight stages (30-45 days), they chew an outlet for the adult and pupate in the tunnel. Pupation lasts 10-20 days. Up to four generations are produced per year. At the end of the rainy season, larvae of the last generation enter diapause in maize and sorghum stubble or in wild grasses. They pupate a few months later, just before the start of the following rainy season. In the mid and high elevation areas of eastern and southern Africa, *B. fusca* are often the most important stem borer of maize. Yield losses have been estimated to be about 12% for every 10% of plants infested (Harris and Nwanze, 1992). In Sub-Saharan African countries, which include Nigeria, *B. fusca* is considered the most important pest of maize, yield loss as high as 40% has been attributed to *B. fusca* infestations (www.maizedoctor.com, 2010).

Sesamia calamistis

S. calamistis occurs in most of tropical Africa which include South Africa, Zimbabwe, Malawi, Uganda, Tanzania, Kenya, Zanzibar, Madagascar, Mauritius, Reunion, Angola, Nigeria, Cote d Ivoire, Cameroon, Gambia, Ghana, Mozambique (Cugala *et al*., 1999), and Ethiopia. The following plants were recorded as hosts of *Sesamia calamistis*; Maize, sorghum, millet, rice, sugarcane (Khan *et.al*., 1997).

Biology and Economic importance of *S. calamistis*

The female lays up to 350 eggs, in 3-5 days deposited in batches of 10-40. The eggs are arranged in two to four continuous rows and inserted between the lower leaf sheaths and stem. Several hours after hatching, the larvae leave the oviposition site to penetrate the stems either directly or after feeding on the leaf sheath. During the larval stage, which lasts 30-60 days, depending on the climatic conditions, and usually involves five to six moults, larvae may successively attack a number of young stems. Pupation generally takes place in the stem, rarely between the sheath and stem. The pupal period lasts 10-12 days at 25^{0}C. Under tropical conditions five to six generations are completed in a year. *S. calamistis* breeds throughout the year without diapauses. *S. calamistis* is considered to be a very damaging pest in West Africa, whereas in the Eastern and Southern Africa it is only of moderate importance (Bosque-Perez *et al* 1998).

Eldana saccharina

The African sugar cane borer *E. saccharina* is widely distributed in sub-Saharan Africa including Burundi, Chad, Ghana, Kenya, Mozambique, Nigeria, Rwanda, Sierra Leone, Somalia, South Africa, Tanzania, Uganda and Zaire (Maes, 1998). The following plants were recorded as host of *Eldana saccharina*: Sugarcane, maize, rice, sorghum. (Khan *et al*., 1997).

Biology and economic importance of *E. Saccharina*

According to Atkinson (1980), Females lay batches of 50-100 eggs on dry leaves at the base of the plants, which may partly explain the tendency of *E. saccharina* to infest mature crops. Eggs hatch after about 6 days and the young larvae feed externally on epidermal tissue before penetrating the stems. The length of larval development is variable and may take up to 2 months. Larvae pupate within the stems. Up to six generations may occur in a year and there is no larval diapause (Atkinson 1980). In West Africa, *E. saccharina* is a pest of maize and sugarcane. Bosque-Perez *et al* (1991) found that even though *E. saccharina* attacks maize plants late in the growing season damage can be as high as 20%. In Southern Africa, *E. saccharina* is considered to be a serious pest of sugarcane (Atkinson, 1980). In eastern Africa, *E. saccharina* attacks maize, but usually towards the end of the growing season, and is generally not considered a serious pest.

Chilo partellus

The spotted stalk borer *C. partellus* is native to Asia where it is considered to be a pest of maize and sorghum. It was reported in Africa in 1930 in Malawi, and has since spread to most countries in Eastern and Southern Africa, including Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Africa, Sudan, Tanzania, Uganda, Botswana, Swaziland, Zimbabwe Comoro Islands, Madagascar, (Sithole, 1990). The following plants were recorded as hosts of *C. partellus*: Maize, sorghum, rice, sugarcane. (Khan *et al*, 1997).

Biology and Economic importance of *Chilo partellus*

Adults emerge from the pupae in the late afternoon and early evening and are active at night. During the day they rest on plant debris. Females mate soon after emergence and oviposit for two to three subsequent nights, in batches of 10-80 overlapping eggs, on the upper and undersides of leaves, mainly near the midribs. Some eggs are also laid on the stem. Adults live for about 2-5 days and do not normally disperse far from emergence sites. Eggs hatch early in the morning (06:00-08:00 h), 4-8 days after being laid, and young larvae ascend plants to enter the leaf whorls, where they start to feed. Older larvae tunnel into stem tissue, and after feeding for 2- 3 weeks, pupate in the stem for 5-12 days. Under favourable condition, the life cycle is completed in 25-50 days, and five or more successive generation may develop during a single maize growing season. In cold and/or dry conditions, larvae may enter a resting stage (diapause) in stems, stubble and other crop residues, where they spend up to 6 months before pupating.

However, part of the stem borer population may remain active in wild grasses during the season (Overholt *et al*., 2001). *C. partellus* is considered to be the most important stem-borer in most low to medium elevation areas of eastern and southern Africa.

BIO-PESTICIDAL PLANTS

Andrographis paniculata

Andrographis paniculata (Burm.F.) is an annual, herbaceous plant 1-3 feet high, of the family *Acanthaceae*. It is widely grown in south eastern Asia, where it is used to treat infections and diseases. It is called Creat in English and is known as the “King of bitters”. Traditionally, the leaves are the most important part used externally for wounds. Research has indicated that they possess antifungal, cytotoxic, insecticidal, hepatoprotective, anti-inflammatory, anti-pyretic, antioxidant, immunoodulatory, anti-platelet aggregation and anti-viral potential (Awan and Aslam, 2014; Kumar *et al* 2004). The major active constituent, andrographolide exhibits a broad range of biological activities, such as anti-inflammatory, antibacterial, antitumor, antidiabetic, antimalarial, and hepatoprotective (Jarakamjorn and Nemoto, 2008; Singha *et al* 2003). Phytochemical reports on the family *Acanthaceae* are glycosides, benzonoids, flavonoids, triterpenoids, phenolic compounds and naphtoquinone (Awan and Aslam, 2014)

The result of qualitative phytochemical studies on *Andrographis paniculata* reported by Obodofin *et al*., (2014) indicated the presence of flavonoids, glycosides, reducing sugar, and terpenoids as the major active principle of the plant. The presence of these active principles is suggested to give the bitter taste to the plant and this is evident that the presence of toxic substances will serve as a protector to grains (Sukesh *et al.,* 2011; [c]Nta *et al*.,).

The results obtained from (Obadofin *et al*, 2014) study showed that aqueous extracts of *A. paniculata* from all the test plant concentrations caused high mortality of adult *C. maculatus*. The cowpea seeds treated with extracts from 37.5% and 50% of the aqueous extracts were the most toxic of all the extracts tested, followed by that of 25% and 12.5% evoking 100% mortality, respectively at 96 h of exposure.

The mode of action of the extract of *A. paniculata* showed contact and systemic effects, as it caused high rates of mortality. High concentrations of *A. paniculata* is thought to reduce the reproductive capacity and feeding of *C. maculatus* because once ingested, their effects prevent food utilization by susceptible insects and therefore mortality results from starvation.

Vernonia amygdalina

Vernonia amygdalina (Delile) belongs to the family *Asteraceae* which are herbs, shrubs, or trees. (Ologunde *et al,* 1992) *Vernonia* is a genus of about 1,000 species of herbs and shrubs of which *V. amygdalina* is the most prominent species. (Johri and Singh, 1997) It grows predominantly in tropical Africa especially in Nigeria, Zimbabwe and South Africa (Erasto *et al,* 2006; [b]Nta *et al*.,). It is popularly called bitter leaves because of its bitter taste and is used as vegetables in soups. The bitter taste of *V armygdalina* is as a result of its anti-nutritional components such as alkaloids, saponins, glycosides and tannins (Ologunde *et al.*, 1992). In Nigeria, it is known by several local names such as “Ewuro” in Yoruba language, “Onugbu” in Igbo language, “Oriwo” in Bini language, “Ityuna” in Tiv language, “Chusar doki or fatefate” in Hausa language and “Etidot” in Ibibio (Igile *et al*, 1995). The roots and leaves decoction of *V. armygdalina* are commonly used in ethno medicine to treat fevers, hiccups, kidney problems and stomach discomfort, among others.

It is also used in the treatment of diarrhea, dysentery, hepatitis and cough and as a laxative and fertility inducer (Harmowia and Safren, 1994). In addition, extracts of the plants have been reported to be used in Nigerian herbal homes as tonic, in the control of tick and treatment of hypertension (Amira and Okubadejo, 2007). The aqueous and alcoholic crude extracts of the leaves, bark, stem and roots are reported to be widely used as anti-malarial, treatment of eczema and as a purgative (Masaba, 2000). The wood, particularly those from the root is a tooth cleaner, an appetizer, fertility inducer and also for gastrointestinal upset (Challand and Willcox, 2009). Other documented medicinal uses include the treatment of schistosomiasis, amoebic dysentery, treatment of malaria, wound healing, veneral diseases, hepatitis and diabetes (Akah & Ekekwe, 1995).

Phytochemicals derived from plant sources can act as larvicides, insect growth regulators, repellents and ovipositor attractants, and these different activities have been observed by many researchers (Musa *et al*., 2009; Ntonifor and Mueller-Harvey, 2010; Ekpenyong *et al*.,). Plants are considered rich sources of bioactive chemicals and may be an alternative source of insect control agents so as to ensure food security in developing countries like Nigeria.

Moses and Dorathy, (2011) reported that bitter leaf gave the best protection against cowpea weevil when compared with garlic and ginger. Musa *et al*. (2009) also reported on efficacy of Mixed Leaf Powders of *Vernonia amygdalina* and *Ocimum gratissimum* against *C. maculatus*. Akunne *et al*, (2013) reported on efficacy of mixed application of leaf powders of *V. amygdalina* and *Azadirachta indica* against adult *C. maculatus*. They observed mortality and lower adult emergence could result from death of immature stages as a result of treatment, an effect that has been reported by many researchers (Adedire, 2002; Maina *et al*, 2004; Adedire *et al.,* 2011a; Ileke *et al*, 2012). This is in agreement with the finding of Musa *et al* (2009) who reported the efficacy of *V. amygdalina* in the management of *C. maculatus*. Enobakhare and Law-Ogbono (2002) reported the effectiveness of *V. amygdalina* plant powder in the control of *S. zeamais* causing 100% mortality. The insecticidal effects of this plant powders on the weevil could be linked to the presence of some chemical compounds like sesquiterpene lactones containing vernodalin, vernodalol and 11, 13-dihydrovernodalin, these have insecticidal properties which act as an insect feeding deterrent (Pascual *et al*., 2001). The effect of the plant powder on oviposition could be due to respiratory impairment which probably affects the process of metabolism of the weevil (Adedire *et al*., 2011b; Ileke *et al*., 2012). Plant product has been reported to inhibit locomotion (Adedire *et al*., 2011); hence, the weevils were unable to move freely thereby affecting mating activities (Ileke *et al*. 2012).

Abdullahi *et al.,* (2011) worked on the efficacy of lime peel oil in protecting stored maize against adult maize weevil (*Sitophilus zeamais*) and reported that the mortality of the insects was dose dependent where the higher concentration used recorded the highest mortality (100%) after 72 hours of treatment which was significantly higher than untreated control (0%). Umoetuk, *et al* (2013) also reported that efficacy of bio pesticides was also shown to increase with increased rate of application and time of exposure to the target pests.

Plant materials have been shown to possess potentials for development as new fumigants and they may be more advantageous than conventional fumigants in terms of low mammalian toxicity, rapid degradation and local availability (Isman 2008).

ESSENTIAL OILS OF PLANTS

Essential oils are volatile natural complex secondary metabolites characterized by a strong odour and have a generally lower density than that of water (Bakkali *et al*., 2008). There are 17,500 aromatic plant species among higher plants and approximately 3,000 essential oils are known out of which 300 are commercially important for pharmaceuticals, cosmetics and perfume industries (Bakkali *et al*., 2008) apart from pesticidal potential (Chang and Cheng, 2002). They are lipophilic in nature and interfere with basic metabolic, biochemical and physiological and behavioural functions of insects. Genera capable of elaborating the compounds that constitute essential oils are distributed in a limited number of families, such as Myrtaceae, Lauraceae, Rutaceae, Lamiaceae, Asteraceae, Apiaceae, Cupressaceae, Poaceae, Zingiberaceae and Piperaceae.

Essential oil compounds and their derivatives are considered to be an alternative means of controlling many harmful insects and their rapid degradation in the environment have increased specificity that favours beneficial insects (Pillmoor *et al*., 1993). Further research has demonstrated their larvicidal and antifeedant activity (Gbolade, 2001; Adebayo *et al*., 1999), capacity to delay development, adult emergence and fertility (Marimuth *et al.,* 1997), deterrent effects on oviposition (Oyedele *et al*., 2000), and arrest ant and repellent action (Landolt *et al*., 1999).

Essential oil chemistry

The volatile components of essential oils can be classified into four main groups: terpenes, benzene derivatives, hydrocarbons and other miscellaneous compounds (Ngoh *et al.*, 1998). Mono-terpenoids are the most representative molecules constituting 90% of the essential oils and allow a great variety of structures with diverse functions. There are ten carbon hydrocarbons or their related compounds such as acyclic alcohols (e.g. linalool, geraniol, citronellol), cyclic alcohols (e.g. menthol, isopulegol, terpeniol), bicyclic alcohols (e.g. borneol, verbenol), phenols (e.g. thymol, carvacrol), ketones (carvone, menthone, thujone), aldehydes (citronellal, citral), acids (e.g. chrysanthemic acid) and oxides (cineole). The main group is composed of terpenes and terpenoids and the other of aromatic and alliphatic constituents all characterized by low molecular weight terpenes mainly the monoterpenes (C10) and sesquiterpenes (C15), but hemiterpenes (C5), diterpenes (C20), triterpenes (C30) and tetraterpenes (C40) also exist. Aromatic compounds occur less frequently than the terpenes and are derived from phenylpropane e.g. Aldehyde: cinnamaldehyde; Alcohol: cinnamic alcohol; Phenols: chavicol, eugenol; Methoxy derivatives: anethole, elemicine, estragole, methyl eugenols; Methylene dioxy compounds: apiole, myristicine, safrole. (Arun *et al*., 2009)

Essential oil extraction

Composition of oil varies to a large extent depending on the isolation method used. The chemical profile of the essential oil products differs not only in the number of molecules but also in the stereo chemical types of molecules extracted. Steam distillation is the procedure most frequently used to isolate essential oils by Clevenger-type apparatus. However, distillation may influence the composition of the oil isolated, because isomerization, saponification and other reaction may occur under distillation conditions.

The other methods of isolation of essential oils are solvent extraction, simultaneous distillation extraction, supercritical carbon dioxide and microwave ovens. The extraction product can vary in quality, quantity and in composition according to climate, soil composition, plant organ, age and vegetative cycle stage (Masotti et *al.*, 2003; Angioni *et al*., 2006).

Pesticidal properties of essential oils

The toxic effect of essential oils, apart from the variability of phytochemical patterns, involves several other factors. The point of entry of the toxin is one of them. Commonly, essential oils can be inhaled, ingested or skin absorbed by insects (Ekpenyong *et al*., [a]Nta *et al*., ; Prajapati *et al*., 2005). Survey of the literature on bio-pesticidal potential of essential oils from the year 2000 onwards indicates that the plants of families Myrtaceae, Lamiaceae, Asteraceae, Apiaceae and Rutaceae are highly targeted for anti-insect activities against specific insect orders like Lepidoptera, Coleoptera, Diptera, Isoptera and Hemiptera. Essential oils have been explored for repellent, fumigant, larvicidal and adulticidal activities against the insects of the above orders.

Essential oils of *Artemisia* species have been reported for vapour toxicity and repellent activity against coleopteran beetles (*Sitophilus spp.*, *Tribolium castaneum* and *Callosobruchus maculatus*) (Kordali *et al*., 2006; Negahban *et al*., 2007). Similarly, essential oils of *Cinnamomum camphora*, *C. cassia* and *C. zeylanicum* have been found to have repellent action against mosquitoes (Prajapati *et al*., 2005; Kim *et al*., 2003). Chaiyasit *et al;* 2006 determined toxic effect of essential oil of *Curcuma zedoaria* with LC_{50} ranging from 5.44 - 8.52g/mg for mosquito adults. Ocimene is repellent to the leaf cutter ant, *Attacephalotis* in both field and laboratory experiments (Harborne, 1987). Experiments with the aphid *Carvariella aegopodii*, which feeds on umbelliferae species, indicate that the aphid can be captured in traps baited with carvone, but is repelled by linalool (Harborne, 1987). Carvone occurs in the essential oils of several plants of the Apiaceae.

A number of monoterpenes and methyl esters of fatty acids were evaluated for their repellent and attractant properties towards *Denroctonus* species. Although activity was observed in the laboratory, none of the compounds tested were active in field tests. Cineole, geraniol and piperidine found in Bay leaves (*Laurus nobilis*, Lauraceae) possess repellent properties towards cockroaches. Female carribean fruit flies, *Anastrepha suspense*, lay their eggs readily in ripe grape fruit but do not oviposit in immature grape fruit because of the presence of linalool, which is toxic to the eggs and larvae of insects. Limonene found in sour oranges (*Citrus aurantium*) is toxic to adult bean weevils (*Callosobruchus phasecoli*), but highly attractive to male mediterranian fruit flies (Jacobson, 1982).

Mode of action of essential oils

Most monoterpenes are cytotoxic to plants and animal tissue, causing a drastic reduction in the number of intact mitochondria and golgi bodies, impairing respiration and photosynthesis and decreasing cell membrane permeability. At the same time they are volatile and many serve as chemical messengers for insects and other animals. Furthermore, most monoterpenes serve as a signal of relatively short duration, making them especially useful for synomones and alarm pheromones. The doses of essential oils needed to kill insect pests and their mechanism of action, are potentially important for the safety of humans and other vertebrates. The target sites and mode of action have not been well elucidated for the monoterpenoids and only a few studies have examined this question (Watanabe *et al.,* 1990; Rice and Coats, 1994; Lee *et al*., 1997).

Essential oils as insecticide

Little is known about the physiological actions of essential oils on insects, but treatments with various essential oils or their constituents cause symptoms that suggest a neurotoxic mode of action (Kostyukovsky *et al*., 2002). A monoterpenoid, linalool has been demonstrated to act on the nervous system, affecting ion transport and the release of acetylcholineesterase in insects (Re *et al*., 2000). Octopamine has a broad spectrum of biological roles in insects, acting as a neurotransmitter, neurohormone and circulating neurohormone - neuromodulator (Hollingworth *et al*., 1984). Octopamine exerts its effects through interaction with at least two classes of receptors which, on the basis of pharmacological criteria, have been designated octopamine-1 and octopamine-2 (Evans, 1981). Interrupting the functioning of octopamine results in total breakdown of nervous system in insects. Therefore, octopaminergic system of insects represents a biorational target for insect control. A number of essential oil compounds have been demonstrated to act on octopaminergic system of insects. Enan (2005) showed that eugenol mimicked octopamine in increasing intracellular calcium levels in cloned cells from the brain of *Periplaneta americanus* and *Drosophila melanogaster* and this was also found to be mediated via octopamine receptors. Furthermore, the toxicity of eugenol was increased in mutant *D. melanogaster* that were deficient in octopamine synthesis, suggesting that the toxicity is mediated through the octopaminergic system, though this was not the case for geraniol. It was suggested that these cellular changes induced by eugenol are responsible for its insecticidal properties (Price and Berry, 2006). Kostyukovsky *et al.,* 2002 reached a similar conclusion, suggesting possible competitive activation of octopaminergic receptors by essential oil constituents; they found significant effects at low concentrations in abdominal epidermal tissue of *Helicoverpa armigera.*

CARBOFURAN PESTICIDE

Carbofuran is a broad spectrum carbamate pesticide that kills insects, mites and nematodes on contact or after ingestion. It is used against soil and foliar pests of field, fruit, vegetables and forest crops. Carbofuran is available in liquid and granular formulations (Adegbite and Agbaje, 2007; Howard 1989; Adegbite and Adesiyan, 2001; Adekunle *et al.,* 2003). It is a pesticide that is widely used to control insects and nematodes on a variety of agricultural crops because of its wide-ranging biological activity and relatively low persistence when compared to organochlorine pesticides (Ajayi *et al*., 1993). It is a systemic insecticide, which means that the plants absorbs it through the roots, and from here the plant distributes it throughout its organ (mainly vessels, stems and leaves; not the fruits), where insecticidal concentrations are attained. (Ogunwolu, 1987).

Carbofuran also has contact activity against pests. Stem borer species on maize are effectively controlled by applying carbofuran as seed treatment, whorl leaf treatment, single or split dose soil treatment (Egwuatu and Ita, 1982). The choice of carbofuran is because it is nonpersistent and rapidly metabolizable and does not pass along the food chain. Like other carbamates, it is metabolized rapidly in animals into less toxic and finally nontoxic metabolites. Carbofuran and its metabolite, 3-hydroxycarbofuran, exert their toxicity by reversibly inhibiting acetylcholinesterase (AChE) (Egwuatu *et al*, 1982) leading to the persistent action of the otherwise hydrolyzed neurotransmitter, acetylcholine, on its postsynaptic receptors.

CONCLUSION

The most important field pests of maize are lepidopterous stem and cob borers belonging to the families of *Noctuidae* and *Pyralidae*. They are: the African stalk borer (*Busseola fusca* Fuller), the spotted stem borer (*Chilo partellus* Swinhoe), the pink stem borer (*Sesamia calamistis* Hampson) and the sugar cane borer (*Eldana saccharina* Walker). Stem borers interfere with the movement of water and metabolites through the plant's vascular system, which stunts its growth and development. Attacks during the first eight weeks after sowing result in “dead heart” and late damage (beyond eight weeks after sowing) leads to stem lodging. Both types of damage to the crop cause drastic loss in maize yield.

Controlling these insect pests is difficult because most part of their life cycles is spent inside the plant which serves as a physical protection to insecticide application. Synthetic insecticides have been used extensively in the past by farmers for the control of stem borers, but however, they have not been effective and are not easily biodegradable besides being expensive. However, in recent times much attention has been given to biopesticides especially in controlling insect pests both in the field and in the store. The use of botanicals for the control of agricultural pests is considered to be environmentally friendly and also reduce the cost of insecticides in pest management.

Carbofuran is a broad spectrum carbamate pesticide that kills insects, mites and nematodes on contact or after ingestion. It is used against soil and foliar pests of field, fruit, vegetables and forest crops. It is a pesticide that is widely used to control insects and nematodes on a variety of agricultural crops because of its wide-ranging biological activity and relatively low persistence when compared to organo-chlorine pesticides. It is a systemic insecticide, which means that the plants absorbs it through the roots, and from here the plant distributes it throughout its organ (mainly vessels, stems and leaves; not the fruits), where insecticidal concentrations are attained. The choice of carbofuran is because it is non-persistent and rapidly metabolizable and does not pass along the food chain. Like other carbamates, it is metabolized rapidly in animals into less toxic and finally nontoxic metabolites. Carbofuran and its metabolite, 3-hydroxycarbofuran, exert their toxicity by reversibly inhibiting acetylcholinesterase (AChE) leading to the persistent action of the otherwise hydrolysed neurotransmitter, acetylcholine, on its postsynaptic receptors.

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