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Review

Prospects of botanical pesticides from neem, *Azadirachta indica* for routine protection of cocoa farms against the brown cocoa mirid – *Sahlbergella singularis* in Nigeria

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The brown cocoa mirids, *Sahlbergella singularis* (Haglund) is the most damaging insect pest of cocoa in Nigeria. The principal means of mirid control has been, for many years, the application of synthetic insecticides on the basis of calendar spray schedule. The use of synthetic pesticides on small-scale farms in the tropics is generally not advocated because the approach lacks sustainability and raises environmental and health concerns. Most cocoa farmers simply cannot afford the cost of pesticides, despite favourable economic returns. There is therefore the need to screen for safe and effective biodegradable pesticides with non-toxic effects on non-target organisms. In the last two decades, considerable efforts have been directed towards screening of plants, (especially neem), in order to develop new botanical insecticides from the vast store of chemical substances in them as alternatives to the existing synthetics, which are associated with phytotoxicity, vertebrate toxicity, pest resistance and resurgence, wide spread environmental hazards and high costs. This review therefore looks at the prospects and utilization of botanicals for the control of major cocoa insect pests in Nigeria taking into cognizance their formulation, dosage and mode of application.

Key words: Formulation, application, dosage, sustainability, biodegradable, toxicity, hazards.

INTRODUCTION

The brown cocoa mirids, *Sahlbergella singularis* (Haglund) is the most damaging insect pest of cocoa in Nigeria. The mirids are also very serious pests in other cocoa producing countries such as Ghana, Cote d' Ivoire and Cameroon (Lavabre, 1970; 1977; Entswitle, 1972). Their feeding activities result in cankering or bark roughening, destruction of the flower cushions and small fruits, and a severe dieback of twigs and branches. Yield losses attributed to cocoa mirids have been estimated to between 30 - 40% (Lavabre, 1977). The principal means of capsid control has been, for many years, the application of chemical insecticides on the basis of spray schedule (Lavabre, 1960; Decazy and Essono, 1979; Coulibaly et al., 1998). However, synthetic pesticides, while valued for effectiveness and convenience can pose certain problems, including phytotoxicity and toxicity to non-target organisms, environmental degradation and health hazards to farmers. They also may accelerate development of the pest biotypes resistant to specific pesticidal chemicals.

Natural pesticides are active principles derived from plants for the management of human and animal pest organisms or it can be said to be biologically active ingredients, principally derived from plants, for the manage-ent of human and animal pest organisms (Ivbijaro, 1990). With the growing global demand for environmentally sound pest management strategies; there is a need to develop alternative pesticides with minimal or non-ecological hazards. Botanical pesticides are easily biodegradable (Devlin and Zettel, 1999) and their use in crop protection is a practically sustainable alternative. It maintains biological diversity of predators (Grange and Ahmed, 1988) and reduces environmental contamination and human health hazards. The use of plant extracts to control destructive insect pests or disease vectors is not new. Rotenone (*Derris* spp), nicotine and pyrethrins have been used for a considerable time in small-scale subsistence and also in

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commercial agriculture (Hillock, D and P. Bolin, 2004). In recent times, considerable effort has been put into the development and promotion of plant-based methods and products for the control of pests (Stoll, 2000). This has resulted in the development of a science-based approach that uses a formal set of steps to discover and determine their efficacy and attempts to either produce the botanical pesticide on a commercial scale or synthesize it for broader use in commercial agriculture (Philogene and Lambert, 1993).

Plant products and their analogues are an important source of agrochemicals used for the control of insect pests (Cardellina, 1988). One widely studied plant in this context is the neem tree, *Azadirachta indica* (A) Juss (Meliaceae). Neem is being used to manufacture natural or bio insecticides, which are environmentaly friendly and do not have any toxic effects on plants and soil. Neem insecticides are used to protect both food as well as cash crops (GEP, 2008a). The insecticidal effect of neem has been proved on several insect groups, including Lepidoptera, Diptera, Coleoptera, Homoptera and Hemiptera species (Sadre et al., 1983). The few works conducted`on cocoa mirids with neem extracts in Ghana and Cote d' Ivoire gave promising results (Padi et al., 1999; 2000; 2003; N'Guessan et al., 2006). However, the full potential effect of neem and neem based products for the control of the brown cocoa mirids has not yet been investigated in Nigeria. The evaluation has become necessary in the wake of the new European Legislation on the Maximum Residue Levels (MRLs) allowable on cocoa beans and cocoa products, and the quest by the developed/consumer countries for organic products.

This review report gives an insight into the prospects of using botanicals (natural plant products) from neem, *A. indica* (A) for the protection of cocoa plantations and produce against the brown cocoa mirids- *S. singularis* in Nigeria.

BOTANICAL FORMULATIONS FROM NEEM

The part of the neem plant used for insecticide formulations are the stembark, rootbark, leaves, flowers, fruits, seeds and seed kernels. The formulations can either be in the form of powder (dusts), crude oil extracts, ethanol extracts, aqueous extracts or commercial formulation.

Powder formulation

The neem plant materials were either sun dried or oven dried and then pulverized into fine powder using pestle and mortar or electric mill and sieved with a fine mesh (0.25 mm diameter sieve) (Jackai and Oyediran, 1991; Jackai et al., 1992; Jackai, 1993). They can also be made into pastes or cakes (Gahukaar, 2006).

Mode of application: For field application, the neem powder, cake or granules can be spread out over the field crops by hand in a manner similar to fertilizer application, that is by broadcasting. Alternatively they are applied at planting time along with the basal NPK fertilizer application and worked into the soil or applied around the growing plants by ring method or side banding (Ahmed et al., 1984). In the case of stored products the desired quantity is measured out with a measuring scale and spread over the products (grains or nuts) and mixed properly before storage (Stoll, 1992; Yusuf et al., 1998). This can be applied to cocoa beans and grains in a situation where they will be stored for a very long time.

Dosage: The application rate of powder formulation ranges from less than 1 - 20 g/kg of grain/beans, but does not usually exceed 2% of the weight of grains/nuts/beans (Ivbijaro and Agbaje, 1986; Ogunwolu and Idowu, 1994; Yar'adua, 2007). The neem dust or paste can be used as soil amendments at 100 - 2000 kg/ha for the management of soil borne pest and diseases (Yar'adua, 2007). However, the concentrations of the commercial dust formulations tested were based on recommendations from the manufacturers.

Oil formulation

The method utilized mainly for crude extraction of oil from neem seeds is by pounding it lightly in a motar to obtain the kernel after removing the shell or outer coat. The kernel is ground into a paste, which is transferred to a pot and heated. The paste is heated alone briefly before the addition of water. The mixture is allowed to cool after boiling. The oil settles on top of the cooled mixture and is easily scooped off for use (UNIFEM, 1987; Jackai and Oyediran, 1991; Jackai et al., 1992; Jackai, 1993). The extraction is best done in an open area with good ventilation to avoid any hazard from the very strong and sometimes-offensive odour emitted during such boiling. It is better to add small amount of water to the paste while boiling rather than adding large quantity of water at once (Jackai, 1993). Commercial extraction is usually by mechanical press method, steam and high pressure method, solvent extraction or cold pressed method. The steam and high pressure method is not very reliable as most of the active ingredient and compounds are denatured at high temperature, while the cold press is a very expensive method (GEP, 2008b).

Mode of application: The oil formulation can be applied in the field by the use of conventional knapsack, trombone, ULV or hand sprayers (Passerini and Hill, 1993; Yar'adua, 2007), but this is only feasible for those who can afford the spray equipments. Alternatively the broom sprinkling method is resorted to, which involves the dipping of a long broom or leaf branch into desired concentration of the extract and sprinkling it on the crops (Bottenberg and Singh, 1996). In this case the desired concentration of the extract is poured into a bucket and a long broom or leaf branch is dipped into it and sprinkled on the trees. The application is usually repeated at 10 days intervals or every fortnight. Oils are more conveniently applied on a volumetric basis and application rates are usually given in ml/kg of grain, with effective rates ranging from 1 - 10 ml/kg of grain (Lale, 2001; Yar'adua, 2007). It is usually the practice to add and mix teepol with the extracts before application to improve its sticking properties. The desired concentrations were usually prepared by shaking 1 - 2 ml of teepol in a small quantity of distilled water and adding the resulting solution to the desired quantity of the oil. The mixture should be thoroughly shaken, added to a measured quantity of distilled water and shaken again to obtain a well-mixed solution (Padi et al., 2000; Yar'adua, 2007).

Dosage: The oil extract is usually applied at the rate of 0.25 - 3% (high volume spray) or about 3 L/ha (low volume spray), while stored products (grains/beans) can be treated at the rate of 2.5 - 5ml/kg seeds (Yar'adua, 2007).

Alcoholic or ethanolic extracts

The selected neem plant part was chopped into small pieces and ground in a motar. The resulting paste is mixed with known quantity of absolute ethyl alcohol. The solution is allowed to stand for 72 h, after which the alcohol was evaporated off (recovered) using a rotary evaporator. The paste was then mixed with a measured quantity of distilled water and sieved through a fine nylon mesh to obtain the alcoholic extract solution (Padi et al., 2000).

Mode of application: The application methods of this formulation both in the field and storage are same as for the oil formulation above.

Dosage: The concentrations of the crude ethanolic plant extracts tested were same as for the oil formulation above.

Aqueous formulation

In this case, the pulverised neem plant materials are extracted by using water as the solvent. The aqueous neem solution was obtained by pressing out fresh juice and diluting in water or through maceration (that is steeping in water for prolonged periods). It can also be got by infusion (the immersion of plants in already boiled water for prolonged periods) (Jackai and Oyediran, 1991; Jackai et al., 1992; Lale, 1995; Jackai, 1993; N'Guessan et al., 2006). Steeping or immersion of the plant extracts in water for longer period improves the toxicity of the neem aqueous extracts against cocoa mirids (N'Guessan et al., 2006).

Mode of application: The application methods of this formulation both in the field and storage are same as for the oil formulation above.

Dosage: The concentrations of the crude aqueous plant extracts tested were same as that of oil formulation above.

Commercial formulation

The bioactive components in neem tree are normally extracted in organic solvents particularly methanol, ethanol, acetone, hexane, petroleum ether, diethyl ether, chloroform or methyl chloride (Ofuya et al., 1992; Egwunyenga et al., 1998; Anonymous, 2006). The resulting extracts are further purified by solvent partitioning in hexane to remove fatty esters. Extraction of pesticidal components in neem kernels is done after first extracting the oil components using hexane (Gahukaar, 2006). However, extraction of the azadirachtin and other terpenoidal and non-terpenoidal compounds is best done in 95% ethanol, using chromatographic techniques, which include open column chromatography, flash chromatography, thin layer or vacuum liquid chromatography on silca gel and liquid chromatography (Schmutterer, 2002). The extraction can be done in standard laboratories or in a small-scale industry. Some examples of commercial formulations of neem based insecticides (NBIs) products are: Neemol, Super Neemol, Neem Azal and Potenised Neem Systemic Oil (Padi *et al.*, 2000). In some countries, especially India, NBIs are available in the open market (eg Repelin®, Wellgro®, Nimbosol®, and Neemark® (Saxena, 1989; Schmutterer, 1990; Gahukaar, 2006). *A. indica* (neem tree) has also been commercialized in the U.S.A where it is registered as "Margosan O" and "Azatin E.C." (Larson, 1989).

Mode of application: The application methods of this formulation both in the field and storage are same as for the oil formulation above.

Dosage: The concentrations of the commercial neem oil formulations tested were based on recommendations from the manufacturers.

BENEFITS OF NEEM PESTICIDE

Some of the important advantages of neem based pesticides, which differs it from its synthetic counterparts are as follows:

- They are environmental friendly and do not contaminate terrestrial and aquatic environment.
- They are non toxic.
- They can be used in combination with other pesticide and oil for more effectiveness.
- They posess anti feedant properties, which helps to protect the plants.
- Pests generally do not develop resistance to them.
- They are generally water soluble and help in the growth of the plants.
- They act as pest reproductive controller.
- They help to nourish and condition the soil.
- They are relatively less expensive.

NEEM MORTALITY AGAINST MIRIDS

The efficacy of the neem seed aqueous crude extracts has already been demonstrated in several insects, including Lepidoptera, Diptera, Coleoptera, Homoptera and Hemiptera species (Sadre et al., 1983). A high mortality rate of 88.2, 96.6 and 98.5% was recorded against cocoa mirids with a neem seed aqueous crude extracts at 10, 20 and 30% respectively at 96 h after treatment (N'Guessan et al., 2006). This was a confirmation of an earlier report by Padi et al., 2000, 2003, which obtained a field mirid efficacy of 54 and 80% with neem seed aqueous crude extracts.

The neem Azal was the best of the commercial formulations, having effected 88.5% and 95.2% capsid mortality at 3 and 5% w/v respectively, in the laboratory. The 3% solution caused 81.5 and 50% - 84.9% mortality in the "cage spray" and small-scale field trials respectively (Padi et al., 2000). In addition, Neem Azal, Neemol and Potensised Neem Systemic Oil exhibited anti-feedant effects in the "cage spray" tests with 23 - 48 lesions/10 capsids recorded on treated cocoa pods 30 h after treatment, compared to 157 lesions/10 capsids on the untreated control pods. The number of trees having fresh capsid damage on neem-treated plots ranged between 0 and 5 compared to 6 - 18 on the untreated control plots. The mealybug vector of cocoa swollen shoot disease, *Planococcoides njalensis* (Dist.), and its attendant ants, *Pheidole megcephala* and *Camponotus* spp. and some minor pests, including the mirid *Helopeltis* sp. and the psyllid *Tyora tessmanni* (Aulm.), were also adversely affected by the crude neem extract and the commercial neem formulations, especially Neem Azal (Padi et al., 2000). In another report, Adu-Acheampong et al. (2000) recorded 80.3% mean mirid mortality with neem crude extracts.

The overall efficacies of the neem-based products were higher in the laboratory bioassays than in field trials for the same neem concentration. This has been observed with synthetic insecticides and was attributed to the experimental conditions such as heterogeneous tree heights, some of which are higher than the reach of the spray equipment during normal insecticide applications (Coulibaly et al., 1998). Also, the efficacies of insecticides have been shown to be affected by the architecture of the cocoa trees (N'Guessan et al., 1999). Some mirids may remain hidden between the pods and the trunks and escape from a lethal dose of the insecticide applied. In a situation of blanket spraying of cocoa farms, it has been found that pods located at the base of the trees receive very small amount of insecticide, which does not reach all the mirids.

Although mirid mortality caused by Neem Azal and crude neem extracts in the field was below the acceptable level of 95% established for conventional insecticides, the formulations might be effective miricides based on their antifeedant effects, since the effectiveness of neem-based compounds is known to rely more on their ability to repel and inhibit feeding, growth and reproduction, rather than on direct insect kill (Padi *et al*., 2000). The pesticidal properties of neem have been attributed to a group of chemically related compounds called the terpenoids (or limonoids) and some non-terpenoidal bioactive compounds (Schmutterer, 2002). These compounds are found all over the tree, in the fruits, seeds, seed kernels, twigs, stem bark, root barks and flowers. These vast arrays of bioactive compounds in neem act in concert and in several ways inimical to the pests, thereby giving no room for development of resistance. *Azadirachtin* is the best known and most important limonoid in neem, and its concentration in seed kernels is said to be about 2 - 4% by weight (NRC, 1992; Rembold et al., 1987).

DISCUSSION

Neem is known for its "bitter taste" derived from limonoids, a group of tetranortripterpinoids of which *azidrachtin* is the most active. Neem products have shown activity on a wide range of insect pests of many crops worldwide, and its derivatives are known to have distinct antifeedant and growth inhibitory effects (Schmutterer et al., 1980; Schmutterer and Ascher, 1984; 1987; Schmutterer, 1985; 1990; 2002; Jacobson, 1986; Saxena, 1989; NRC, 1992; Kleeberg and Zebitz, 2000). In Africa, there have been more investigations with neem on postharvest pests than on any other group, but there are a few exeptions. Field pests of arable crops have been researched more recently, especially in the tropics where the tree grows naturally (Schmutterer, 1985; Saxena, 1987a; 1987b). Botanical pesticides from neem tree (*A. indica*) have good potential for widespread application and can be applied either as a farmers' recipe (crude extract) or as a standardized industrial formulation (Bruan, 2000). They are toxicologically safe, environment friendly, easy to use and have a wide range of insecticidal activity. Moreover, recent studies have shown that neem seeds in Ghana are of high quality, having an *Azadirachtin c*ontent of 6.2 - 6.9%, second only to those in Kenya where the *Azadirachtin* content ranged from 6.81 - 8.80% (Foerster, 2000).

Neem tree grows widely in the Nigeria savanna and elsewhere in the tropics. Presently, widespread use of neem as antimaleria drug; so farmers and other likely users are already quite conversant with the plant as a source of medication. Crude preparations of neem pesticides can easily be prepared by farmers for pest management, and for the treatment of malaria and other disorders, for which reasons the tree is widely referred to as "Village Pharmacy" (NRC, 1992). Additionally, some farmers already use it to control grasshopper damage on cowpea farms during the dry season in a number of the northern states in Nigeria (Jackai and Oyediran, 1991; Jackai et al., 1992; Jackai, 1993). The procedure for the crude oil extraction (UNIFEM, 1987) is simple and inexpensive, and requires no sophisticated equipments or skills. Every farmer can be taught to do it. Application can be done with local broom or similar implements, for those farmers who cannot afford the cost of sprayers.

Botanical insecticides have long been touted as attractive alternatives to synthetic chemical insecticides for pest management because botanicals reputably pose little threat to the environment and human health. The body of scientific literature documenting bioactivity of plant derivatives to arthropod pests continues to expand, yet only a handful of botanicals are currently used in agriculture in the industrialized world, and there are prospects for commercial development of new botanical products. It is estimated that only about 10% of the over 250,000 different plant species in the world today have been examined chemically (Farnsworth, 1990). Therefore, potential sources of plant chemicals still exist in the tropical forest which needs exploitation.

Several factors appear to limit the success of botanicals, most notable regulatory barriers and the availability of competing products (newer synthetics, fermentation products, microbials) that are cost-effective and relatively safe compared with their predecessors. In the context of agricultural pest management, botanical insecticides are best suited for use in organic food production in industrialized countries but can play a much greater role in the production and post harvest protection of food in developing countries (Isman, 2006).

Finally the Government, Private Sector and Non-Governmental organizations should be encouraged by the abundant diverse flora in the forests and savannahs of Nigeria to fund research on botanicals. Periodic update of research and development on natural pesticides through workshops and conferences should be funded by Government in collaboration with Industries and Non-Governmental Organizations to ensure an increased food production in a world friendly environment. The crude aqueous plant extracts and commercial formulations should be tested on farmers' farms, as small-scale researcher-managed trials continue to yield encouraging results, including improved yield and anticipated favourable results from taint and residue analysis.

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