Chapter 10

Use of Botanicals and Safer Insecticides Designed in Controlling Insects: The African Case

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1. Introduction

Insecticides are toxic substances that are used to kill or control insects. Insects pests affect humans directly by transmitting diseases or indirectly by attacking cultivated plants in farms or in storage, thus affecting food security. It is documented that the use of insecticides by man dates as far back as 1000 B.C, or earlier when burning of stone containing sulfur (brimstone) was used as a fumigant.

Substances used to kill or control insect pests can also be referred to as pesticides, though the latter word has a wider scope of application, since other non-insect pests also exist.. Insecticides in wide use are mostly synthesized organic compounds, though there are some organic compounds of plant origin referred to as "botanicals", in addition to inorganic compounds of natural and synthetic origin. Certain insecticides of synthetic, organic or inorganic origin function as insect repellents, causing little or no harm at all to the target insects. In most situations insecticides are applied by spraying or dusting onto plants and other surfaces traversed or fed upon by insects. However insecticides/pesticides of chemical origin can affect human health directly or indirectly by disrupting ecological systems that exist in rivers, lakes, oceans, streams, wetlands, forests and fields. Release of chemicals into the environment can have global impacts and there is therefore need to use safer analogues designed with safety in mind. A review of some "safe" insecticides used in Africa is presented.

Pesticides in general are toxic chemicals which adversely affect human health when mishandled. Their effects may be direct, for example, during application or when consumed in suicide bids. Also their effects may be indirect when the environment is contaminated either due to non-specificity of the target or when higher dosages are used either accidentally or due to ignorance. Such pitfalls may be overcome by use of "smart insecticides". The latter may be designed by incorporating a delivery system so as to release an insecticide over an extended time at a controlled rate. Such insecticides, therefore, target the intended pests without adversely affecting the human health or the environment.

One of the novel techniques in recent use is to encapsulate the insecticides within a macromolecular network. Biopolymers have in recent times been used for this purpose. For example, hydrogels of natural polymers such as sodium alignate, starch, gelatin, carboxymethyl cellulose etc, have been used for encapsulation of insecticides (Anamika et al, 2008).

The future development and use of safer pesticides in Africa will need to address safety concerns using functionalized polymers as delivery systems. Such technology will increase the efficiency of insecticides by targeting the specific pests while indirectly protecting the environment by reducing pollution and safety to end users. This will impact positively on health by controlling disease causing vectors and food security as well.

2. Genetically engineered plant insecticides

The technology of 'genetically engineered insecticides' is based on the development of plants or viruses genetically engineered to produce insect-selective toxins. This involves transferring naturally occurring poison-coding genes from microorganisms into crops. Such insecticides may be referred to as biopesticides or biological pesticides. The latter are based on pathogenic microorganisms specific to a target pest and offer an ecologically sound and effective solution to pest problems. The most commonly used biopesticides are living organisms, which are pathogenic for the pest of interest. Biopesticides fall into three major categories namely: biofungicides (*Trichoderma*), bioherbicides (*Phytophthora*) and bioinsecticides (*Bacillus thuringiensis*). Biopesticides contain a microorganism such as bacterium, fungus, virus, protozoa or alga, as the active ingredient.

The most widely known microbial insecticides are based on the bacterium *Bacillus thuringiensis* (Bt.), which is incorporated into plants to produce genetically modified (GM) crops or genetically modified organisms (GMO). Bt is a soil dwelling Gram-positive bacterium, discovered in 1901 by a Japanese biologist, Shigetane Ishiwatari. Later it was rediscovered in Germany by Ernst Berliner in flour moth caterpillars. The spores and crystalline insecticidal proteins produced by Bt have been used for insect control since 1920s (Lemaux, 2008).). In 1995 potato plants, incorporating Bt, were first introduced in the USA (Romeis et al, 2008) and by 1996 Bt maize, potato and cotton were grown. GMO technology is claimed to alleviate poverty by ensuring high incomes from insect prone cash crops such as cotton, maize or rice. Some Bt-based insecticides are often applied as liquid sprays on crops, where the insecticide is expected to be ingested by pests for it to be effective. A Bt strain, *Bacillus thuringiensis serovar israelensis*, is widely used against mosquito larvae.

Crops are genetically modified with *Bacillus thuringiensis* (Bt) so as to develop insect resistance. *B. thuringiensis* produces a diverse group of insecticidal protein toxins with narrow

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specificity towards different insects (Santie et al, 2011). Bt bacterium contains insecticidal protein crystal that is eaten by insects. The crystal then dissolves in the midgut of the insect. The toxin mixture is released and the proteins are cleaved into active forms. The toxins bind to the midgut cells, assembling a pore that leads to disintegration of the cells, gut paralysis and death. The Bt strains are known to have toxins specific for insects such as caterpillars, beetles, flies and mosquitoes and have little or no effect on mammals. South Africa has been reported to grow more than 85% of the countries cotton and some maize and is the only African country reported so far to grow 67% of the country's total maize production for food (James, 2007) using the Bt insecticides technology. Outside of South Africa, only Burkina Faso and Egypt allow commercial cultivation of GM crops. Accessibility of these products is, however, relatively restricted, especially in developing countries such as in Africa, due to vocal opposition to GM technology and lack of regulatory mechanisms to deploy such technology (Sentie and David, 2011). South African farmers and consumers have already shown a willingness to embrace biotechnology (cotton, maize, and soybean) resulting in improved yield or reduced cost, however, the Bt potato would be the first publicly-funded bioengineered crop to be released in Africa. Some commercially available Bt varieties and target pests include: *Bacillus thuringiensis*, var. *tenebrionis*- for control of Colorado potato beetle and elm leaf beetle larvae; var. *kurstaki* - for caterpillars; var. *israelensis* – for mosquito, black fly, and fungus gnat larvae; var. *aizawai* for wax moth larvae and various caterpillars, especially the diamondback moth caterpillar.

3. Synthesis of pesticides from plant botanicals

Plant extracts are commonly referred to as plant botanicals and are the secondary plant metabolites synthesized by the plant for protective purposes. Some of these compounds are toxic to insects. These plant compounds are called botanical pesticides, plant pesticides or simply botanicals. Many of the plant botanicals are used as insecticides both in homes, in commercial as well as in subsistence agriculture by small-scale farmers (Table 1). They may be contact, respiratory or stomach poisons. Botanicals are not very selective because they target a broad range of insect pests.

Plant insecticides act in several ways: as repellents by driving the insects away due to smell or taste, as antifeedants which cause insects on the plants to reduce their food intake and hence starve them to death; as oviposition deterrents, by preventing insects from laying egg; or as inhibitors by interfering with the life cycle of the insects.

Plant insecticides have several advantages. Among them are short life spans once applied and are not poisonous to humans and livestock. Secondly, botanicals do not harm the natural enemies of the pests, such as the lady bird beetle. They are cheap, easy to prepare and in most cases readily available and have more than one active ingredient which work synergistically making it difficult for pests to develop resistance. Figures 1-5 shows some structures of some compounds from some of the plants used.

Botanical insecticides role in insect pest management and crop protection in Africa play a minor role due to continued use of effective but 'toxic' commercial pesticides. However, the regulatory environment and public health needs should create opportunities for the use of safer botanicals in since human and animal health is paramount. Botanicals may also find use in organic food production, both in the field and in controlled environments for export to developed countries where strict pesticide levels are strictly monitored in horticultural products before export. In addition the greatest benefits from botanicals might be achieved in developing countries, where human pesticide poisonings are most prevalent. In Africa extracts of locally available plants have been traditionally used as crop protectants, when used alone or in mixtures. In fact indigenous knowledge and traditional practice can make valuable contributions to domestic food production in countries where strict enforcement of pesticide regulations is not applied.

Plant	Pests/Diseases
Neem tree	Armyworms, Stemborers, Bollworms, Leaf miners, Diamond blackmoth, Caterpillars, Storage pests(moth), Aphids, whiteflies, Leaf hoppers, Psyllids, Scales, Maize tassel, Beetle, Thrips, Weevils and Flour beetle
Garlic/Onions	Caterpillars, Cabbage worms, Aphids
Stinging nettle	Caterpillars
Tithonia diversifolia	Caterpillars, aphids
Spider weed	Aphids
Aloe spp. Ash	Storage moths, Storage beetles
Chilies + Hot pepper	Diamond blackmoth, Stemborers, Bollworms, Cutworms, weevils, Aphids, Beetles
Tobacco	Stemborers, Cutworms, Caterpillars, Grain weevils
Pyrethrum + Mexican marigold	Caterpillars, Aphids, bugs, Beetles
Chilies + Mexican marigold	Armyworms, Stemborers, Bollworms, Cutworms, Leaf miner, Diamond blackmoth, caterpillars, Aphids

Table 1. Some plants traditionally used to control crop pests and diseases in Kenya (Mureithi J G, 2005).

Studies in some Africa countries suggest that extracts of locally available plants can be effective as crop protectants (Isman, 2008). Among the botanicals used are natural pyrethrins, the neem extract, *Azadirachta indica* (A. Juss), *Khaya senegalensis* against cotton bollworm (in Benin) and extracts from marigold against bruchid beetles from cowpeas in storage in Uganda (Kawuki et al, 2005), among others. M. Mugisha-Kamatenesi et al (2008) have documented a survey of botanical extracts used as insecticides within the Victoria Basin. The study has demonstrated that usage of botanical pesticides pest management by the subsistence farmers is normal around Lake Victoria. Among the plants used are *Capsicum frutescens, Tagetes* spp, *Nicotiana tabacum*, *Cypressus spp*., *Tephrosia vogelii*, *Azadirachta indica*, *Musa spp* Eucalyp-

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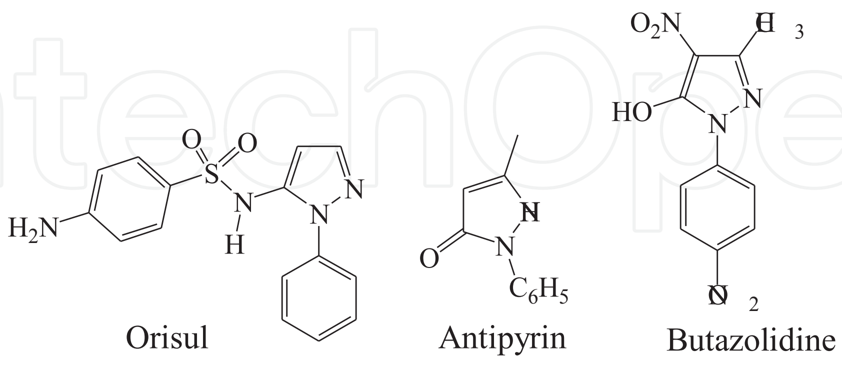
tus spp and *Carica papaya*. In Benin, West Africa, the bushmint, *Hyptis suaveolens* extract has been used for the control of pink stalk borer, *Sesamia calamistis* on maize. Also, botanical insecticides have tried for the protection of cowpeas in Ghana (Abatania et al, 2010). Ogunsina et al (2010) has also investigated plant extracts from *Lantana camara* (Verbenaceae), African nutmeg [*Monodora myristica* (Gaerth) Dunal] and Enuopiri [*Euphorbia lateriflora*, Schum and Thonner] against bean weevil *Callosobruchus maculatus* (F.) *and* maize weevil, *Sitophilus zeamais)* Motsch. The overall results showed that bean weevil was much more susceptible to all the extracts than maize weevil.

Some of the reasons for the poor market penetration of botanical insecticides in developing countries are their relatively slow action, variable efficacy, lack of persistence and inconsistent availability (Isman, 2008). But plant botanical extracts may be used as a source of lead compounds in the synthesis of effective and safe insecticides. An example is the synthesis of insecticides from nitrophenols of plant or synthetic origin (Ju and Parales, 2010), Figure 5. One of the approaches is to prospect for insecticides of plant origin. Synthesis of the botanical analogues guarantees higher yields of the insecticide that ordinarily may not be obtained when extracted from the plant parts. The chemical synthesis of botanical insecticide analogues has long been achieved (Benner, 1993). Lu et al (2007), reported synthesis of twelve 1,5-diphenyl-1-pentanone analogues similar to those derived from *Stellera chanaejasme* (Figure 6). These compounds were found to be effective against *A. gossypii* Glov.

Recent studies have resulted in synthesis of novel esters with insecticidal activity using plant lead compounds (Ji et al, 2011). Gao et al (2012) has demonstrated syntheses twenty three new fraxinellone-based hydrazone derivatives from fraxinellone. Flaxinellone (Figure 5) is a compound from *Dictamnus dasycarpus* Turcz. dried root bark.

Modification of biologically active pyrazoline derivatives of plant origin have produced 1,3,5-trisubstituted-2-pyrazoline derivatives, thought to have insecticidal activity (Kareru and Rotich, 2012). Some of these compounds have the structures below.



Scheme 1. Chemical Structures of Biologically Active Pyrazoline Derivatives

Synthesis and biological activities of various 1,3,5-trisubstituted-2-pyrazoline derivatives have been reported in literature. According to Deng *et al.* (2012), among the existing various pyrazoline type derivatives, 2-pyrazoline has been identified as one of the most promising scaffolds. In the area of medicinal chemistry, 2-pyrazoline derivatives have been found to display anti-cancer and anti-inflammatory activity. 2-Pyrazoline type derivatives such as (code: PH 60-42) shown in Figure 1.(a) have also been known to possess insecticidal activity since 1970s though it was not commercially exploited due to their environmental properties (Deng *et al.,* 2012). Figure 1.(b) and (c) shows some of the examples of biologically active 2-pyrazoline derivatives used in the field of medicine in the treatment of cancer and Alzheimer disease respectively (Gokhan-Kelekci *et al.,* 2007).

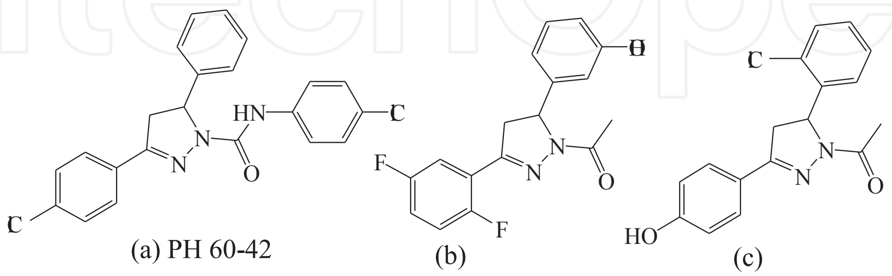


Figure 1. Examples of biologically active 2-pyrazoline derivatives used in the field of medicine

Synthesis of biologically active compounds from the botanicals lead compounds have advantages of being produced in large amounts unlike the yields obtained by from plant parts using the solvent. Synthesis of insecticides using plant lead compounds is an ongoing research in our laboratories. Toxicity of synthesized compounds will be determined to assess efficacy and safety.

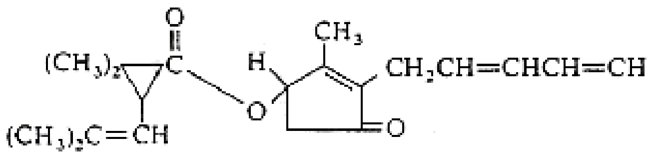


Figure 2. Pyrethrin I structure from Pyrethrum

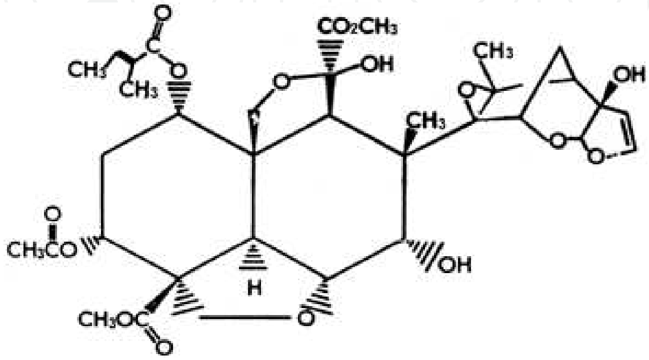


Figure 3. Azadirachtin from Neem tree

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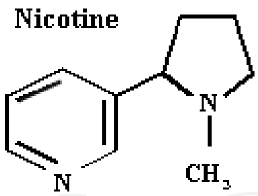

Figure 4. Nicotine structure (from Tobacco)

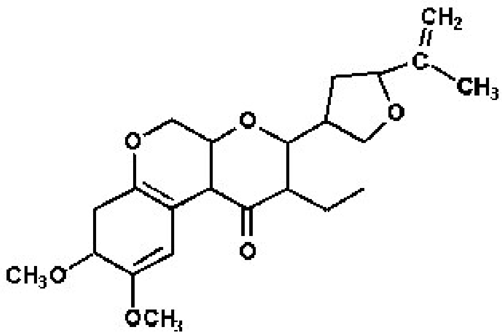

Figure 5. Rotenone molecular structure

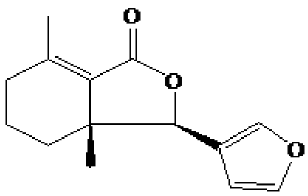

Figure 6. Fraxinellone from *Dictamnus dasycarpus* Turcz. dried root bark

4. Stabilization of pyrethrin insecticides with botanical oils

Pyrethrins are the six esters produced in the Chrysanthemum plant, *Chrysanthemum cinerariaefolium*. The esters are found in high concentration within flower structures known as achenes which are located in the flower head of the Chrysanthemum plant. Pyrethrins have a toxic effect in insects when they penetrate the cuticle and reach the nervous system. Pyrethrins bind to sodium channels that occur along the length of nerve cells and are responsible for nerve signal transmission along the length of the nerve cell. When pyrethrins bind to sodium channels, a loss of function of the nerve cell most often leads to death after pyrethrins exposure. Since insects have evolved detoxification mechanisms to pyrethrins, synergists are added to circumvent the detoxification mechanism of insects. Synergists are chemicals which directly increase the toxicity of insecticides. Usually, the synergist, piperonyl butoxide, is added and a lower concentration of pyrethrins is required to achieve insect control.

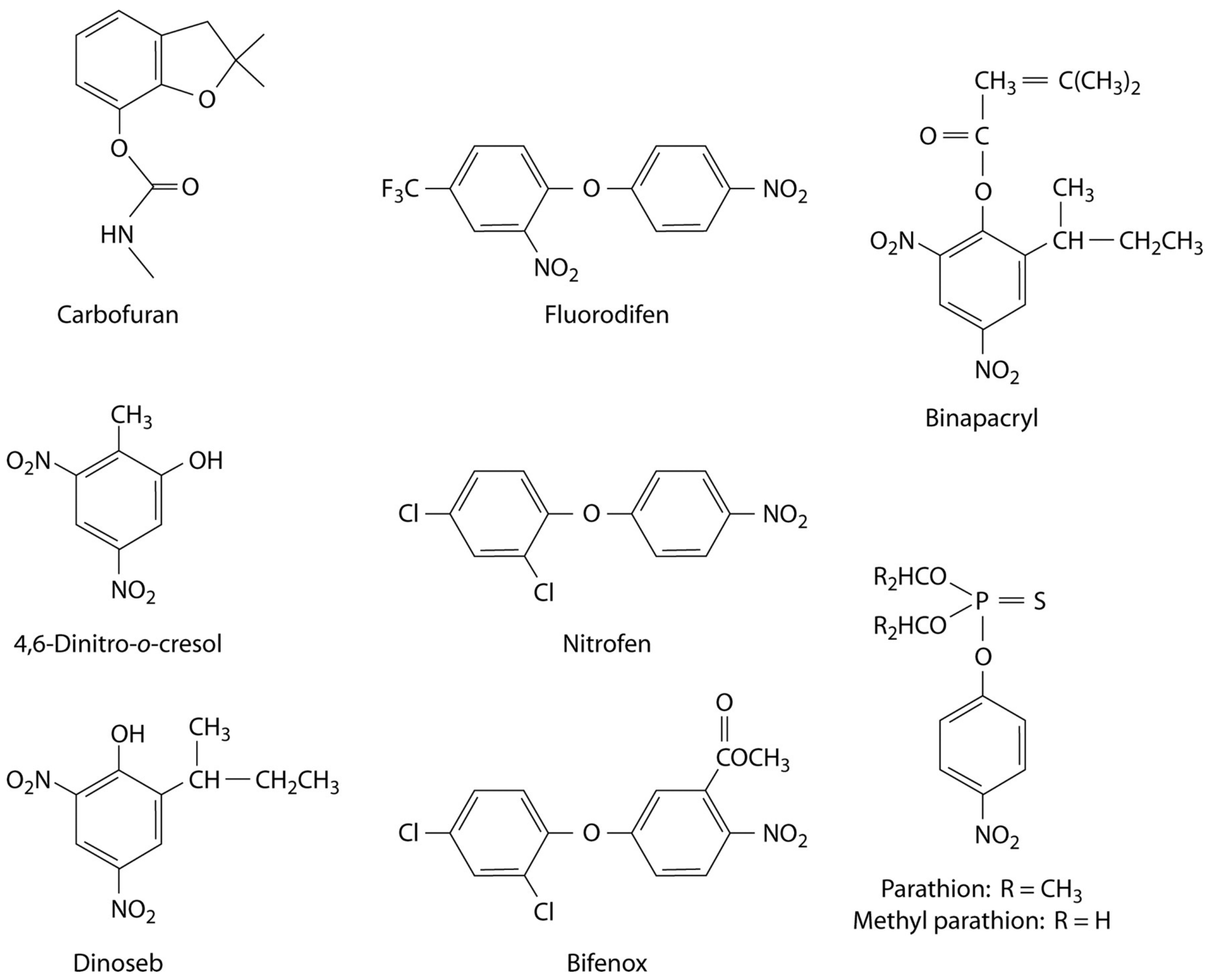

Figure 7. Pesticides synthesized from nitrophenols (Ju et al, 2010)

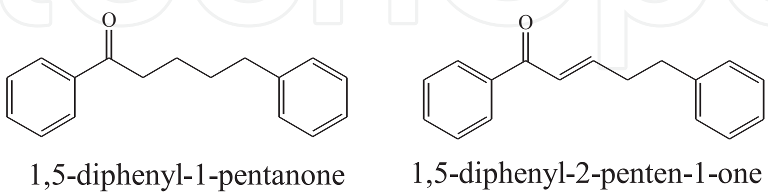

Figure 8. Lead Compounds from *Stellera chamaejasme* L

Mostly pyrethrins may be used as a contact insecticide for household insects such as flies, mosquitoes or applied as aerosols or space sprays. Some formulations can be applied to agricultural crops and due to their safety, pyrethrum extracts are used extensively in areas such as in households, industrial sanitation and in warehouses to protect stored food. They have little or no hazard to birds and mammals, are relatively nonhazardous to honey bees but toxic to fish. Synthetic analogues are referred to as pyrothroids and have similar insecticidal properties. Both types have minimal residual period in the environment. Pyrethrum pyrethrins and synthetic pyrethroids are stable for a limited time period because they are subject to photochemical degradation by Ultraviolet light. To counteract photochemical degradation chemical additives are added to increase their potency and enhance the mode of action. The addition of synergists causes these insecticides to be more toxic to insects, mammals and humans as well (Berger-Preiss et al, 1997).

Recent studies demonstrated that stabilized natural pyrethrins have shown contact toxicity against adult maize weevils (*Sitophilus zeamais*) in a time dependent manner. Natural pyrethrum extract was stabilized against ultraviolet (UV) light by blending with fixed oils extracted from *Azadirachta indica* A. Juss (neem tree), *Thevetia peruviana* (yellow oleander) and *Gossypium hirsutum* L. (cotton) seeds. In the study, the fixed seed oils enhanced the stabilization of the natural pyrethrum insecticide (Wanyika et al, 2009). The results indicated that natural pyrethrum extract blended with cottonseed oil exhibited the highest mean mortality against the maize weevils. This implied that cottonseed oil had the highest stabilization effect on natural pyrethrum among the botanical oils used. On the other hand the UV stabilization due to neem oil generally increased with the concentration in the insecticide blend. Oleander oil was found to have moderate stabilization effect which decreased with the amount of oil added to the insecticide. It was noted, however, that synergism contributed by vegetable oils in bio-pesticide formulations might have contributed to the enhanced activity of the pyrethrum blends investigated. Pyrethrum extracts stabilized with cotton and neem oils showed a marked increase in bio-efficacy against the maize weevils while the yellow oleander seed oil had a moderate stabilizing effect on the pyrethrum insecticide. Cotton seed oil, however, had the highest stabilizing effect on the pyrethrum extract exposed to UV light at 366 nm compared to the other botanical oils used and the control.

5. Acaricidal effect of bee propolis extracts

Propolis (bee glue) is a strongly adhesive resinous bee-hive product collected by honeybees *(Apis mellifera* Linnaeus) from leaf buds and cracks in the bark of various plants and is used in the hives to exclude draughts, to protect against external invaders and to mummify their carcasses. It typically consists of waxes, resins, water, inorganics, phenolics and essential oils. Chemical analysis of bee propolis from Europe is reported to contain various phytochemicals: phenolic acids and esters, flavanones, flavones and flavonols, cinnamic acids, phenylated p-coumaic acids and furofuran lignans, among others (Bankova V, 2005; Bankova et al, 2002).

A number of researchers have reported insecticidal effect of bee propolis. Solvent extracts of propolis samples from Brazil and Bulgaria exhibited leishmanicidal activity against different species of *Leishmania* (Gerzia et al, 2007). In Nigeria, Osipitan et al (2010) tested propolis ethanolic extracts against the larger grain borer, *Prostephanus truncates* (Horn) in maize grains. A reduction of the borer population in maize was observed. Interestingly, pesticides commonly used in agriculture were detected in honey and propolis samples (Lucia et al, 2011) in Uruguay.

Recently bee propolis extracts have been reported to have acaricidal effect on red spider mites (*Tetranychus spp*.), which attack tomatoes, (Kareru and Wamaitha, 2012, unpublished work).

Figure 9. The four stages of a red spider mite life cycle (egg, larva, nymph and adult). Source: http://www.bio-bee.com

Tomato is a vegetable crop grown worldwide and its selection and preference as a crop is due to its nutritional value and economic importance. Crop production losses to pests are estimated to exceed 35% annually. Red spider mites (*Tetranychus* species) are polyphagous, parenchyma cell feeding pests and have a serious economic impact on many crops, especially tomatoes. Synthetic pesticides used for control of red spider mites end up in the environment where they may affect non-target species, have adverse effects on wildlife, pollute soil and water and in addition are usually very expensive and beyond the reach of resource of poor African farmers.

Compounds present in propolis can provide potential alternative in the place of currently used insect pest control agents because they constitute a rich source of bioactive chemicals and may act in many way on various types of pest complex. They also have no or little harmful effects on non target organisms such as pollinators, natural enemies and are biodegradable.

Both ethanolic and ethyl acetate extracts of bee propolis acted on red spider mites in a concentration and time dependent manner. The activity of ethanolic extracts at concentrations of 75 and 100 mg/ml was not significantly different with that of the positive control used. Ethanolic and ethyl acetate extracts acted on tomato red spider mites in a concentration and time dependent manner, and had no significant differences in activity.

Bee propolis extracts could thus be used as a safe insecticide in the control of red spider mites. However, further research need to be done on its potential on other life stages of red spider mites and other common tomato pests. The insecticidal activity was thought to be due to bioactive phytochemicals of plant origin ingested by the bees during pollination.

6. Conclusion

While development of safer insecticides is a noble idea in Africa, safety concerns are paramount. Widespread misuse of pesticides, some of which are banned, affects farmers' health with fatal consequences. Due to ignorance on their part, farmers may keep pesticides near food stores where seepage of food is inevitable; over-spray food crops, inhalation and skin contact while in use, have adverse effects to their health. And although an alternative to pesticides use could be achieved through organic farming and integrated pest management practices, the future lies in investing in technology which will afford safe application of insecticides.

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References

[1] Abatania L N, KO Gyasi, AB Salifu, ON Coulibaly, A Razak (2012). Factors affecting the adoption of botanical extracts as pesticides in cowpea production in northern Ghana, Ghana journal of agricultural Science, 43(1): 9-15

[2] Anamika R, J Bajpai and A K Bajpai, (2008). Development of calcium alignate-gelatin based microspheres for controlled release of endosulfan as a model pesticide, Indian J. of Chem. Technology, 16:388-395

[3] Adda C, Atachi P, Hell K, Tamò M., 2011. Potential use of the bushmint, *Hyptis suaveolens,* for the control of infestation by the pink stalk borer, *Sesamia calamistis* on maize in southern Benin, West Africa. *Journal of Insect Science* 11:33

[4] Bankova V, Popova M, Bogdanov S and Anna-Gloria S, 2002. Chemical composition of European propolis: Expected and unexpected results, Z. Naturforsch. 57c: 530-533

[5] Bankova Vassya, 2005. Chemical diversity of propolis and the problem of standardization, Journal of ethanopharmacology, 100:114-117.

[6] Berger-Preiss, E., et. al., 1997 The Behavior of Pyrethroids Indoors: A Model Study, Indoor Air., 7: 248-261,

[7] Benner JP 1993. Pesticidal compounds from higher plants, Pestic. Sci. 39: 95-102

[8] Deng, H., Zhi-Yi, Y., Guan-Ying, S., Ming-Jing, C., Ke, T. and Tai-Ping, H. (2012). Synthesis and *in Vitro* Antifungal Evaluation of 1,3,5-Trisubstituted-2-pyrazoline Derivatives, *Chemical Biology Drug Design*, 79: 279-289.

[9] Gerzia M C M, Leonor L L, Solange L D C, 2007. Activity of Brazilian and Bulgarian propolis against different species of Leishmania, Memorias do Institute oswaldo Cruz, 10291): 73-7

[10] Genetically Altered Potato Ok'd For Crops, Lawrence Journal-World - 6 May 1995

[11] Gokhan-Kelekci, N., Yabanoglu, S., Kupeli, E., Salgin U., Ozgen, O., Ucar, G., Yesilada, E., Kendi, E., Yesilada, A. and Bilgin, A. A. (2007). A new Therapeutic Approach in Alzheimer Disease: Some Novel Pyrazole Derivatives as Dual MAO-B Inhibitors and Anti-inflammatory analgesics, *Bioorganic Medicinal Chemistry,* 15: 5775-5786.

[12] Guo Y, Yan Y Y, Yang C, Yu X, Zhi X Y, Xu H, 2012. Regioselective synthesis of fraxinellone-based hydrazone derivatives as insecticidal agents, Bioorg Med Chem Lett., [Epub ahead of print]

[13] Isman B Murray, (2008). Perspective Botanical insecticides: for richer, for poorer, Pest Management Sci 64:8–11

[14] International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines

[15] James C (2007). Global Status of Commercialized Biotech/GM Crops: ISAAA Brief, Vol. 37. ISAAA, Ithaca, NY.

[16] Ju K S, Parales R E, 2010. Nitroaromatic compounds, from synthesis to biodegradation, Microbiology and Molecular Biology Reviews, 74:250-272

[17] Kareru P G, Rotich K, 2012. Synthesis of biologically active compounds using plant lead compounds (unpublished work)

[18] Kareru P G, Esther W. Maina, 2012. Acaricidal effects of bee propolis extracts on tomato red spider mite (*Tetranychus* species) (unpublished work)

[19] Kawuki RS, Agona A, Nampala P and Adipala E, (2005). A comparison of effectiveness of plant-based and synthetic insecticides in the field management of pod and storage pests of cowpea. *Crop Prot* 24:473–478

[20] Lawrence Journal-World (1995): Genetically Altered Potato Ok'd For Crops

[21] Lemaux, Peggy (2008)."Genetically Engineered Plants and Foods: A Scientist's Analysis of the Issues (Part I)".*Annual Review of Plant Biology* 59: 771–812. doi:10.1146

[22] Lucia P, Marios C, Andres P-P, Silvina N, Leonidas C-L, Natalia B, Maria V C and Horacio H, 2011. Detection of pesticides in active and depopulated beehives in Uruguay, Int. J. Environ. Res. Public Health, 8:3844-3858.

[23] Lu Tao, Chen Lin, and Hou Taiping, 2007. Synthesis and structure-activity study of botanical aphicides 1,5-diphenyl-1-pentanone analogues, Pestc. Biochem. And Physiology, 89:60-64

[24] Mureithi, J G, (2008). Use plant pesticides to control crop pests, Kenya Agricultural Research Institute, Kenya, http://www.kari.org

[25] M. Mugisha-Kamatenesi , A. L. Deng , J.O.Ogendo, E. O.Omolo , M. J.Mihale , M. Otim, J.Buyungo and P K Bett Buyungo 2008. Indigenous knowledge of field insect pests and their management around lake Victoria basin in Uganda, African Journal of Environmental Science and Technology, 2 (8): 342-348

[26] Osipitan A A, Ogunbanwo I A, Adeleye I G and Adekanmbi D I, 2010. Propolis production by honeybee *Apis mellifera* (Hymenoptera: Apidae) and its potential for the management of the larger grain borer *Prostephanus truncates* (Horn) (Coleoptera: Bostrichidae) on maize grains, J. of plant protection Research, 50(1):61-66

[27] O. O. Ogunsina, M. O. Oladimeji and L. Lajide, 2010. Insecticidal action of hexane extracts of three plants against bean weevil, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus Zeamais* Motsch.

[28] Romeis J, Shelton A M, Kennedy G G (eds.), (2008). Integration of insect-resistant genetically modified crops within IPM programs, Springer Science + Business Media B.V, pp 195-221.

[29] Santie M. DeVilliers and David A. Hoisington (2011). The trends and future of biotechnology crops for insect pest control. African Journal of Biotechnology, 10(23): 4677-4681

[30] Wanyika H N, P G Kareru, J M Keriko, A N Gachanja, G M Kenji and N J Mukiira (2009). Contact toxicity of some fixed plant oils and stabilized natural pyrethrum extracts against adult maize weevils (*Sitophilus zeamais* Motschulsky), African Journal of Pharmacy and Pharmacology , 3(1):066-069