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The Impact of Biofungicides on Agricultural Yields and Food Security in Africa

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Abstract Biofungicides are formulations made from naturally occurring substances that control pests (fungi) by non-toxic mechanisms in an ecological friendly manner. They are derived from animals, plants, microorganisms and include living organisms, their products or byproducts which can be used for pest management. The use of biofungicides for the control of pests started in the 17th century before the advent of synthetic pesticides. The preparation and application of botanicals for crop protection for increased food production were linked to the folklores and traditions of farmers. Biofungicides have been succinctly categorized into three major groups: Plant–Incorporated Protectants (PIP), biochemical biopesticides, and Microbial biofungicides.Bioactive compounds such as rotenone, saponin, Azadirachtin, flavonoids, Nicotine and alkaloids are found in biopesticides. These confer biological activity on them. Interest in biopesticides increased in the last decade particularly in view of the growing demand for organic and residue free foods. Biofungicides being target Pest (fungi) specific are environmentally benign, safer and cost effective alternatives to synthetic pesticides. Biofungicides are known to exert antifeedant, deterrent, toxicant, insecticidal andrepellant effects on agricultural pests. The Environmental Protection Agencies in developing countries are responsible for regulating the safety of biofungicides. Trends in the biofungicides market reveal a growing demand in the utilization of biofungicides for increased agricultural yields. This trend has led to the depletion of the reserves of pesticidal plants in the wild.

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Propagation amongst farmers is now encouraged to preserve the vanishing heritage. Conservation of novel plants and their development as biofungicides should be encouraged through the use of biotechnology.

Keywords: Biofungicides, folklore, Bioactive compound, Organic food, propagation, conservation.

Introduction

Biofungicides or biological pesticides are formulations made from naturally occurring substances that control pests by non-toxic mechanisms and in an ecologically friendly manner. They may be derived from animals, plants, microorganisms and include living organisms, their products or by-products which can be used for the pest management (Gupta and Dikshit, 2010; Kumar and Singh, 2014). In the European Union (EU), biofungicides have been defined as a form of pesticides based on microorganisms or natural products (European Commission, 2008). The Environmental Protection Agency (EPA) of the United States of America (EPA) (2012), states that biofungicides include naturally occurring substances that control fungi (biochemical fungicides), microorganisms that control fungi (microbial fungicides) and fungicidal substances produced by plants containing added genetic material (i.e plant-incorporated protectants) or PIP.

The use of biofungicides for the control of pests started in the 17th century. Anonymous (2014), reported that plant extracts were likely the earliest agricultural biofungicides, as history records that nicotine was used to control plum beetles as early as the 17th century. Experiments with mineral oils as plant protectants were also reported in the 19th century. Dhaliwal and Arora (2006) pointed out that the use of botanical or inorganic insecticides was done in USA from the end of 18th to the end of 19th century. In sub-Saharan Africa, the use of plant derivatives for pest control was said to have been common before the advent of synthetic pesticides and the preparation and application of botanicals for crop protection for increased food production were linked to the folklores and traditions of the farmers (Saxena, 1987). Many other scientists and farmers themselves have reported the use of crude or formulated plant pesticides in Asian and African countries (Anjorin *et al*, 2004; Tsado and Tanko, 2002). Farmers surveys carried out in Ghana have highlighted that many farmers do not use commercial synthetics (Belmain and Stevenson, 2001) and instead, use plant-based products.

The impact of biofungicides on agricultural yields and food security in Africa cannot be overemphasized. Biofungicides have gained lot of interest in the last decade particularly in view of the growing demands for organic foods (Kumar and Singh, 2014). Many farmers in Asia and Africa have been using plant extracts such as neem (*Azadirachta indica*), wild tobacco (*Calotropisprocera*), wood ash and dried chillies among others for controlling and repelling some insect pests (Anukwuorji, *et al.*, 2012; 2013; Ahmed *et al.*, 2005). More recently, surveys in Malawi and Zambia in 2007/2008 (Kamanula *et al.*, 2011 and Nyirenda *et al.*, 2011) reported that farmers were knowledgeable about plant materials as environmentally benign, safer and cost effective alternatives to synthetic pesticides.

This research study is aimed at reviewing the impact of biofungicides on agricultural yields and food security in Africa. The target beneficiaries of the information in this review paper include researchers at universities, governmental research stations, Non-governmental Organizations (NGOs), policy makers, small and medium scale enterprises, farmers cooperatives and rural poor farmers, who are in constant search for alternatives to chemical/synthetic pesticides. The collective knowledge of the stakeholders about the use and optimization of pesticidal plants is paramount for the adoption and promotion of biofungicides on large scale basis. The wide adoption of biofungicides will help to protect crop against pest infestation at a cost which is effective and relatively affordable. This will in turn boost agricultural yields and ensure food security.

Classification of Biofungicides

Biofungicides, according to Gupta and Dikshit (2010); McGrath *et al* (2010); the United States Environmental Protection Agency (EPA)

(2012); Kumar and Singh (2014) are classified into three (3) major groups namely;

1. Microbial fungicides
2. Plant-Incorporated Protectants (PIPs)
3. Biochemical fungicides

Microbial Fungicides

A microbial fungicides consists of microorganisms (bacteria, fungi, viruses or protozoans) as the active ingredient (Gupta and Dikshit, 2010; Kumar and Singh, 2014). Coombs (2013) noted that microbial fungicides can control many different kinds of fungi, although each separate active ingredient is relatively specific for its target pests. For example, there are fungi that control certain weeds and other fungi that kill specific insects. The most widely known microbial pesticides are varieties of the bacterium, *Bacillus thuringiensis* or Bt (Koul and Dhaliwal, 2002) which can control certain insects in cabbage potatoes and other crops (Gupta and Dikshit, 2010; Kumar and Singh, 2014). Gupta and Dikshit (2010) reported that certain other microbial fungicides act by out-competing fungi organisms. Microbial fungicides need to be continuously monitored to ensure they do not become capable of harming non-target organisms, including humans (Kilic and Akay, 2008).

Plant-Incorporated Pesticides (PIP's)

These are fungicidal substances that plants produce from genetic material that has been added to the plant (Gupta and Dikshit, 2010). Kumar and Singh, (2014), reported that Plant-Incorporated Fungicides are produced naturally on genetic modification of a crop plant, such as Bt cotton. Such transgenic plant produces biodegradable protein with no harmful effect on animals and human beings, and thus curtails the use of hazardous pesticides. Koundal and Rajendran (2003) noted that PIP's may be more effective and economical strategies in the developing countries to help produce more food, feed and forages in an environmentally safer manner.

Biochemical Fungicides

These are naturally occurring substances from plants and animals that control pests by non-toxic mechanisms (Gupta and Dikshit, 2010; Kumar and Singh, 2014). Biochemical fungicides include substances that interfere with growth or mating, such as plant growth regulators or substances that repel or attract pests, such as insect sex pheromones (Singh *et al*, 2012). Other biochemical fungicides include plant extracts and botanical oils (McGrath, 2010; Mazid *et al*, 2011 and Singh *et al*, 2012).

Bioactive Component of Biofungicides

Plants are known to produce a diverse range of secondary metabolites such as terpenoids, alkaloids, polyacetylenes, flavonoids, universal amino acids, sugars, tannis, saponin, etc. The structures of more than 600 alkaloids, 3000 terpenoids, several thousands of phenylpropanoids, 1000 flavonoids, 500 quinones, 650 polyacetylenes, and 4000 amino acids have already been elucidated (Metcalf and Metcalf, 1992). According to Harborne (1973); Sofawara (1993); Okigbo *et al.* (2009a), these secondary metabolites which are biologically active substances are called phytochemicals. Koul and Dhaliwal (2000); Koul (2005) described in detail numerous examples of phytochemical biopesticides and their role in Integrated Pest Management (IPM). Tyler (1999) reported that plants also contain other compounds that moderate the effects of the active ingredients. Dhaliwal *et al.* (1996) opined that many of these chemicals protect the plants from pests and pathogens. Dhaliwal and Arora (2006) asserted that plants are biochemists par excellence and during their long evolution have synthesized a diverse array of chemicals to prevent their colonization by insects and other herbivores. These chemicals repel approaching insects, deter feeding and oviposition on the plants, disrupt behaviour and physiology of insects in various ways and even prove toxic to different developmental stages of many insects.

Sofowora (1993); Sarasan *et al.* (2011), reported that the chemistry of some plants varies according to the season, the plant age and location. They suggested that chemical analysis is essential to determine the best time to harvest or for identifying elite material for propagation.

Singh (2000) noted that pesticidal plants reported so far are distributed in 189 plant families and there are more than 2400 plant species as pesticidal in these families. Singh *et al.* (1999) described the ten (10) most important plant families. These include Asteraceae, Apocyanaceae, Fabaceae, Euphorbiaceae, Leguminosae, Meliaceae, Myrtaceae, Rosaceae, Ranunclaceae and Rutaceae. Most of the pesticidal plants occur in Meliaceae, which has more than 500 specie.

Table 1 summarizes some biopesticides along with their bioactive components and the types of effects produced in target pests.

Importance of Biofungicide in Agriculture

The benefits of biofungicides in boosting agricultural yields and ensuring food safety and security in Africa have been reported. Kumar (2012) reported that the potential benefits of using biofungicides in agriculture and public health programmes are considerable. Kumar and Singh (2014) reported that organic farmers turn towards biofungicides to ensure and enhance quality of their organic products. According to Kumar (2012); Kumar and Singh (2014), biofungicides do not have residual effects which is a matter of significant concern for consumers, particularly in case of fruits and vegetables. When used as a component of Integrated Pest Management (IPM), efficacy of biofungicides can be equal to the conventional pesticides, especially for crops like fruits, vegetables, nuts and flowers. By combining performance and environmental safety, biofungicides perform efficaciously with the flexibility of minimum application restrictions and superior resistance management potential (Kumar, 2012; Kumar and Singh, 2014).

Table 1. Selected Biopesticides (or Pesticidal Plant Species) with Fungicidal Properties

S/No	Plant	Family	Biologically Active Components	Target Pests	Types of Activity/Effect
1.	*Ageratum conyzoides* Linn.	Asteraceae	Phenolic Chromene, hydroxyl ethyl Chromene,	*Oncopettus fasciatus* (Dallas)	Anti-JH Activity Suppressed egg laying
2.	*Alluim sativum* L.	Amaryllidaceae	Diallyl sulfide, diallyl trisulfide	*Culex pipiens* Linnaeus, *Spodoptera litura* (Fabricius)	Repellent, antifeedant, toxicant
3.	*Azadirachta indica* A. Juss (Neem)	Meliaceae	Limonoideae azadirachtin	*Helicoverpa armigera* (Hubner); *Plutella Xylostella* (Linnaeus)	Antifeedant, Oviposition, deterent, behaviour and physiological disturbance, toxicant.
4.	*Citrus limon* (L) Burm.(Lemon)	Rutaceae	Limonin, nomilin, obacubone	*Helicoverpa zea* (Boddie)	Antifeedant, toxicant
5.	*Ginkgo biloba* (L)	Ginkgoaceae	Salicylic acid derivatives, bilobalide	*Popillia japonica* Newman; *Pieris rapae* (Linnaeus)	Feeding determent
6.	*Hedera helix* (English ivy)	Araliaceae	Saponin	*Reticulitermes flavipes* (Kollar).	Antifeedant, toxicant
7.	*Medicago Sativa* L. (Alfalfa)	Fabaceae	Butyric acid, succinic acid, Xanthophyll, coumarins	*Bruchophagus rodi* (Gussakovsky), *Hypera postica* (Gyllenhal)	Repellant, toxicant
8.	*Mentha spicata* L. (Spearmint)	Labiatae	Carvone pulegone, Menthol	*Microcerotermes crassus*	Antifeedant, toxicant
9.	*Nicotiana tabacum* L.	Solanaceae	Nicotine	Soft bodied insects	Contact toxicant, fumigant
10.	*Piper nigrum* L. (Black pepper)	Piperaceae	Piperine, other amides	*H. zea*; *Anthonomus grandis* Boheman	Toxicant, Oviposition deterrent
11.	*Plumbago capensis*Thunb.	Plubaginaceae	Plumbagin	*Helicoverpa Spp; Pectinophora gossypiella* (Saunders)	Antifeedant, chitin synthesis inhibitor
12.	*Ricinus communis* L. (Castor bean)	Euphorbiaceae	Ricinine	*Cydia pomonella* (Linnaeus)	Toxicant, Oviposition deterrent
13.	*Tephrosia vogelii* Hook F.	Fabaceae	Rotebone, tephrosin	*Spodoptera exempta* (walker)	Feeding deterrent
14.	*Vitex negundo* L.	Verbenaceae		Stored grain pest	Insecticidal, repellant, fumigant.
15	*Zanthoxylum monophyllum*Lam.	Rutaceae	Zanthophylline	*H. postica*	Feeding deterrent

SOURCE: JACOBSON (1990); DHALIWAL *et al* (1996); DHALIWAL AND ARORA (2006).

Kumar (2012); Kumar and Singh (2014); reported that the interest in biofungicides is based on advantages associated with the product such as;

1. They are usually inherently less toxic than conventional pesticides.
2. Biofungicides generally affect only the target insect and closely related organisms in contrast to broad spectrum, conventional pesticides that may affect organisms as different birds, insects and mammals.
3. Biofungicides often are effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
4. When used as a component of Integrated Pest Management (IPM) programmes, biofungicides can greatly decrease the use of conventional insecticides, while crop yields remains high.
5. Biofungicides (or fungicidal plants) are low cost compared to synthetic products and some have multiple uses which can help promote their use.

Demerits

1. High specificity which may require an exact identification of the pest/pathogen and the use of multiple products to be used; although this can also be an advantage in that the biofungicides is less likely to harm species other than the target.
2. Often slow speed of action. Biofungicides are used primarily as preventive measures, so they may not perform as quickly as some synthetic chemical pesticides do (Kumar and Singh, 2014). Thus, making them unsuitable if a pest outbreak is an immediate threat to crop.
3. Often variable efficacy due to the influence of various biotic and abiotic factors (since biofungicides are usually living organisms, which bring about pest/pathogen control by multiplying within the target insect pest/pathogen).

4. Living organisms evolve and increase their resistance to biological, chemical, physical or any other form of control. If the target population is not exterminated or rendered incapable of reproduction, the surviving population can acquire a tolerance of whatever pressures are brought to bear, resulting in an evolutionary arm race.

Some Biopesticides (Biofungicides) Currently in Use to Boost Agricultural Yields And Ensure Food Security In Africa

Plants are a rich source of bioactive organic chemicals (Dhaliwal and Arora, 2006). According to Benner (1993), it is estimated that there are about 250,000 to 500,000 different plant species in the world today. Only 10 percent of these have been examined chemically indicating that there is enormous scope for further work. Fungicidal plants (or biofungicides) reported so far are distributed in 189 plant families and there are more than 2400 plant species as fungicidal in these families (Singh, 2000). Most of the fungicidal plants occur in Meliaceae, which has more than 500 species. Table 2 summarizes the ten (10) most important plant families and their relative numbers.

Table 2. Important Plant Families having Fungicidal Plants

Family	**Number of Plants**
Asteraceae	39
Asteraceae	70
Euphorbiaceae	63
Fabaceae	57
Leguminosae	60
Meliaceae	>500
Myrtaceae	72
Ranunculaceae	55
Rosaceae	27
Rutaceae	39

Source: Singh *et al* (1999); Dhaliwal and Arora (2006).

Many farmers in Asia and Africa have been using plant extracts such as Neem (*Azadirachta india*), wild tobacco (*Calotropis procera*), Woodash and dried Chillies among others for controlling and some insect pests/fungi (Ahmed *et al.*, 2005). Tsado and Tanko (2002); Tang'an *et al.* (2002); Anjorin *et al* (2004), elucidated that many other scientists and farmers themselves have reported the use of crude or formulated plant pesticides in Asian and African countries. In sub-Saharan Africa, the use of plant derivatives for pest control was said to have been common before the advent of synthetic pesticides, and the preparation and application of botanicals for crop protection for increased food production were linked to the folklores and tradition of the farmers (Saxena, 1987). Some of the biopesticides used since time immemorial and which are still currently in use for boosting agricultural yields and ensuring food security in Africa are described below.

1. Azadirachta indica A. Juss (Family: Meliaceae)

Azadirachta indica, commonly known as Neem is indigenous to India from where it has spread to many Asian and African countries. For centuries, the tree has been held in esteem by Indian folk because of medicinal and insecticidal value. A breakthrough in the insecticidal application of neem was made by Pradhan *et al* (1962), who successfully protected the standing crops at Indian Agriculture Research Institute, New Delhi, by spraying them with 0.001 percent neem seed kernel suspension during a locust invasion. Due to its legendry insect-repellent and medicinal properties, it has been identified as the most promising of all plants by the National research council, Washington, USA (NRC, 1992).

All parts of the neem tree possess insecticidal activity but seed kernel is the most active (Anukwuorji, *et al.*, 2012; Dhaliwal and Arora, 2006). Stevenson *et al.* (2012) reported that the seeds produce the greatest quantities and diversity of pesticidal and deterrent compounds). Neem bark, leaf, fruit and oil as well as extracts with various solvents especially ethanol have been found to exhibit activity against insect pests. Neem products exhibit a wide range of activity against insects such as antifeedant, deterrent, repellent, insect growth inhibitor, among others (Dhaliwal and Arora, 2006). The repellent and antifeedant effects of neem have been reported against a wide range of insect pests including desert locust, *Schistocerca gregaria* (Forskal); migratory locust, *Locusta migratoria* (Linnaeus), ear cutting caterpillar, *Mythimma separata* (walker) etc.

Nearly 100 protolimonoids, limonoids or tetranor-triterpenoids, pentanortri-terpenoids, hexanortriterpenoids and some non- terpenoids have been isolated from various parts of the neem tree and still more are being isolated (Dhaliwal and Arora, 2006). Azadirachtin, the most important biologically active component of neem shows phagorepellent and toxic effect at 0.1 to 1000ppm when incorporated into diets of different insect species (Saxena, 1993). Azadirachtin, according to Anonymous (2014), is an insect growth regulator and feeding deterrent. Gupta and Dikshit (2010) reported that Azadirachtin affects the reproductive and digestive process of a number of important pests.

The neem extracts have been reported to be broad-spectrum in activity, degrade rapidly to harmless metabolites and therefore, leave no residues in the environment where they are applied (Schmutterer, 1990, Deka and Singh, 2001). Obeng- ofori and Ankrah (2002); Okigbo *et al.* (2010) Anukwuorji *et al.*, (2012, 2013, 2016), reported that the use of neem extracts and other medicinal plants can from an important component of pest management strategies, especially in developing countries. According to the report of a survey of crop seed protection with botanicals, carried out in Nigeria by Anjorin (2008), the benefits of neem plant as source of fungicide include but not limited to the following, it is relatively cheap and easily available, its possession of complex mixture of active ingredients which function differently on various parts of the insects life cycle that makes it difficult for pests to develop resistance to it. It is systematic, thereby protecting the plant from within. Neem has also been shown to be effective in controlling pathogens, *Meloidogyne*, root-knot nematolde, *Rhizoctonia*, fungus and rice stunt virus (Anonymous, 1992). The post-harvest deterioration of cassava and its control using extracts of *Azadirachtaindica* and *Aframomum meleguetawas* evaluated by Okigbo *et al.* (2009). *A. indica* proved to be more fungitoxic than *A.melegueta*both in water and ethanol extractions.

2. Securidaca longepedunculata **(Family: Polygalaceae)**

This is a small tree often referred to as the African violet tree and is found throughout Sub-Saharan Africa (Stevenson *et al.* 2012). Belmain *et al.* (2001) showed that *Securidaca Iongependunculata* was the most toxic to other species reported in the northern region of Ghana to be used traditionally for pest control in stores. When evaluating thirty three (33) West African Species for Toxicity to *Callosobruchus maculatus*, Boeke *et al.* (2004a, b), showed *S.longependunculata*along with *Nicotinia tabacum* and *Tephrosia vogelii* to reduce F1 progeny, indicating a level of toxicity to the beetles or oviposition deterrence.

Methyl salicylate is the principal volatile component in the root of *S. Iongependunculata*(Jayasekera *et al*., 2002) and it is this compound that causes at least some of the toxic effect (Jayasekera *et al*., 2005). However, toxicity is also attributable to the saponins that are found in abundance in the root extract. These compounds might then explain the toxicity of*S. Iongependunculata*non-polar extracts to the mosquito, *Ochlerotatus triseriatus*and to a lesser extent the whitefly,*Bemisia tabaci*reported by Georges *et al* (2008). Stevenson *et al* (2012) suggested that the saponins would be conducive to use as spray by making a water extract since saponins are water soluble.

3. Bobgunnia madagacariensis **(Family: Leguminosae)**

Bogbunniamadagacariensis (Syn. *Swartzia madagacariensis*), is reportedly used for protection of stored products from beetles in Zambia and other parts of Southern Africa. There is surprisingly little scientific evidence to substantiate activity for this reported application. However, considerably more reports of medicinal and molluscicidal activity have been recorded. Minjas *et al.* (1986) reported that the extracts of *Bobgunnia madagascariensis* were shown to be active against mosquito larvae and repellent to termites (Crombie *et al.*, 1971). There are some reports of activity against mosquitoes and whitefly. For example, ethyl acetate extract of *B. madagascariensis* caused 80% mortality in one report with other plants (Georges *et al.*, 2008); whereas other plants in the same bioassays exhibited only 30-50% mortality. In the report, antifeedant assays against *Helicoverpa zea*and*Heliothis virescens*, showed that the methanol extracts of *B.madagascariensis*,*C.nigricans* and*S.hispiduc* were effective against *H.zea* causing a reduced weight gain of test insects.

The active components are likely to be saponins which occur in the pods and bark (Stevenson *et al.*, 2010). Stevenson *et al.*, (2010), reported that the only other components found in the pods are highly glycosylated flavonoids which are not biologically active to insects. The presence of these saponins, however vary between locations, thus the selection of appropriate progeny for propagation or simply as a source bioactive material is critical and should be based on chemical analysis (Sarasan *et al.*, 2011).

4. Tephrosia vogelii (Leguminosae) Hook f

*Tephrosia vogelii*is possibly the best known and widely used pesticidal plant in Africa, particularly in southern and Eastern Africa (Nyirenda *et al.*, 2011; Kamanula *et al.*, 2011) but is widespread across the continent. *Tephrosia vogelii*is a well-studied pest control species (Koona *et al.*, 2005).*Tephrosia vogelii* is also widely cultivated for soil improvement as well as for its pesticidal use and fish poisoning properties (Neuwinger, 2004) although the latter application is now prohibited in virtually all regions of the continent.

Leaves and seeds of *Tephrosia vogelii*,contain rotenone (Dhaliwal and Arora, 2006). Also leaves of *T. vogelii* contain at least four rotenoids wityh deguelin and tephrosin the major Isoflavonoid components and rotenone and dehydrorotenone as minor components. Stevenson *et al.* (2012) reported that the highest concentration of the active compounds is found in the leaf which makes it ideal for use since the foliage is the most abundant and sustainably harvested plant part.

5. *Tithonia diversifolia* (Asteraceae)

*Tithonia diversifolia*commonly known as Mexican marigold or Tree marigold is a noxious exotic weed of southern and eastern Africa growing from South Africa to Uganda and from sea level to at least 1500m. It is reported by farmers to be one of the pesticidal plant options available and used by them in Southeastern Africa (Nyirenda *et al.*, 2011).

Adedire and Akinneye (2004), showed that the leaf powder and the leaf extract reduced oviposition, adult emergence and increased mortality of *C. maculates* although this effect was greatest for the leaf extracts. One hundred percent mortality was reported for adults after 48hours at all concentrations tested indicating a potent effect of compounds in the leaves. This effect could be associated with the sesquiterpene lactones that are reported to exude from the leaf hairs, particularly on the abaxial leaf face. They are considered to be responsible for the deterrent effect of the leaves against bordered patch larvae,*Chlosyne lacinia*. *Tithonia diversifolia* along with*Montanoa hibiscifolia*was also known to be a deterrent to *Bemisia tabaci* (Bagnarello *et al.*, 2009).

6. Vernonia amygdalina (Asteraceae)

Vernonia amygdalina belonging to the family Asteraceae, is well known for its healthy properties as a food supplement and perhaps best known as a choice supplement of chimpanzees who use it to deparasite themselves (Yeap *et al.*, 2010). However, the species is reported to be a pesticidal plant by some farmers and appears to have some evidence supporting this potential use (Stevenson *et al*, 2012). Adeniyi *et al* (2010), reported that organic extracts of *V. amygdalina*were more toxic to the bean weevil *Acanthoscelides obtectus* than *Sida acuta, Ocimmum gratissimum* and *Telfaria occidentalis,* while the combined essential oil of *V. amydalina*was toxic against *S. oryzae* (Asawalam *et al.,* 2008). Okigbo and Mmeka (2006), evaluated the antibacterial activity of*Vernonia amygdalina*and *Afromumum melegueta*.

7. *Nicotiana tabacum*Linnaeus (Family: Solanaceae)

Nicotiana tabacum commonly known as tobacco has been cultivated by the American Indians for at least 1000 years and it remained a part of their religious ceremonies (Dhaliwal and Arora, 2006). The bioactive component of tobacco is the nicotine alkaloid, which has been reportedly used as a dust or water extract to control phytophagous insects. Nicotine sulphate is effective against a wide range of pests. Its efficacy against soft bodied insects like aphids is well known, but it has also been found effective against whitefly, thrips and bollworms in cotton, brown plant hopper and green leaf hopper in rice. Recently nicotine sulphate (0.2 and 0.4%) has been found highly toxic to eggs and neonate larvae of*Helicoverpa armigera*(Hubner) and *Spodoptera litura* (Fabricius). It was also found highly effective against *Bemisia tabaci*(Gennadius) under field conditions (Dhaliwal and Arora, 2006).

8. Annona squamosa Linnaeus (Family: Annonaceae)

Annona squamosa commonly known custard apple, contain a number of mono or sesquiterpenes like α-pine, β-pinene, germacrene-D, etc. Powdered seeds applied to wheat and rice grains act as a protectant against *Sitophilus oryzae* (Linnaeus) and *C. chinensis*. The plant extracts act as a feeding deterrent against *A. moorei, Oncopeltusfasiatus* (Dallas), etc (Dhaliwal and Arora, 2006). As with other botanical insecticides, disruption of growth, reduced oviposition, reduced adult emergence and moderate toxicity has also been observed in different species (Arora and Dhaliwal, 1994).

Annonine, an alkaloid found in the stems and leaves of custard apple has been found effective in checking the infestation by termites, root grubs etc. Other compounds isolated recently which may prove to be biologically active are annonacin and annonidines (Jacobson, 1990).

9. Bacillus thuringiensis (Bt)

Bacillus thuringiensis is the most commonly used biospesticide globally. It is primarily a pathogen of legidopterous pests like American bollworm in cotton and stem borers in rice. When ingested by pest larvae, Bt releases toxins which damage the mid gut of the pest, eventually killing it. Main sources for the production of Bt preparations are the strains of the subspecies *kurstaki, galeriae*and *dendrolimus* (Gupta and Dikshit, 2010).

***10. Trichoderma spp* Per ex S.F Gary**

Trichoderma spp is another biospesticide technology developed in the 1990's that has been widely commercialized in recent years (Anonymous, 2014). According to Gupta and Dikshit (2010), *Trichoderma* is a fungicide effective against soil borne diseases such as rot. It is particularly relevant for dry land crops such as groundnut, black gram, green gram and chickpea, which are susceptible to these diseases. Anonymous (2014), reported that*Trichoderma*help to control plant disease by stimulating plant host defenses and growth and under certain conditions, parasitizing harmful fungi within the plant root zone. Okigbo and Ikediugwu (2000), conducted studies on Biological control of Postharvest Rot in yams (*Dioscorea* spp) using *Trichodermaviride*. Interestingly, the result obtained in the inhibition of *Trichoderma viride*against the postharvest pathogen of yam, suggest that this organism is strongly antagonist to*A. niger*and *P. oxalicum*as well as *B. theobromae*and has potential in post-harvest control of yam rot.

Table 3 summarizes some of the selected biopesticides used in boosting agricultural yield and ensuring food security.

Table 3. Selected Biopesticides and their Impact in Boosting Agricultural Yields and Ensuring Food Security

S/No	Plant	Family	Bioactive Component	Parts Used	Effect	References
1.	*Azadirachta indica* A. Juss (Neem)	Meliaceae	Azadirachtin protolinionoids Limonoids,	Seed, bark, leaf, fruit	Insect-repellent antifeedant, deterrent, insect-growth inhibitor	Dhaliwal and Arora (2006); Anukwuorji *et al.*, (2012); Anonymous (2014); Stevenson *et al* (2010).
2.	*Securidaca longependunculata* (African violet tree)	Polygalaceae	Saponin, Methyl Salicylate	Root	Oviposition deterrence, antifeedant	Belmain *et al* (2001); Boeke *et al* (2004a, b).
3.	*Bogbunnia madagascariensis*	Leguninosae	Saponin	Pods, bark	Molluscidal activity, repellant, antifeedant	Stevenson *et al* (2010); Kone *et al* (2004)
4.	*Tephrosia vogelii* Hookf	Leguninosae	Rotenone, deguelin, tephrosin	Leaves, seeds, roots,	Antifeedant, insecticidal, ovvicidal, acaricidal	Koona *et al* (2005); Gaskins *et al* (1972)
5.	*Tithonia diversifolia* (Mexican marigold)	Asteraceae	Sesquterpene lactones	Leaves	oviposition deterrence,	Bagnarello *et al* (2009); Adedire and Akinneye (2004)
6.	*Annona squamosa* L. (custard apple)	Annonaceae	Anonine (alkaloids) anonacin, annonidines	Stems, leaves	Antifeedant, oviposition deterrence, insect growth inhibitor,	Jacobson (1990); Arora and Dhaliwal (1994) Dhaliwal and Arora (2006).
7.	*Nicotiana tabacum* L. (Tobacco)	Solanaceae	Nicotine (alkaloids)	Dust or water extract	Deterrent	Dhaliwal and Arora (2006)
8.	*Vernonia amygdalina*	Asteraceae	Essential oil	Organic extract	Antifeedant	Okigbo *et al.*, (2012; 2014); Adeniyi *et al* (2010). Okigbo and Mmeka (2006),

Safety and Regulation of Biofungicides

It is invariably assumed that natural is safe and this received wisdom applies particularly to pesticidal plants. There are clear economic benefits for the use of biofungicides The greatest benefit from their use may be in terms of human health. Research studies by Gupta and Dikshit (2010); Stevenson *et al.* (2012); Kumar and Singh (2014), shows that biofungicides are generally less toxic than chemical pesticides, often target specific pests, have little or no residual effects, hence pose less risks to human health, the environment and have acceptability for use in the organic farming.

Plant compounds such as rotenone, azadirachtin and pyrethrum, break down particularly in sunlight into environmentally benign products leaving no dangerous residues behind as often occurs with synthetics. From a resource poor farmer's perspective, pesticidal plants are appealing because they cannot be adulterated and are cost effective (Stevenson *et al.*, 2012). More recently, surveys in Malawi and Zambia in 2007/2008 (Kamanula *et al.*, 2011; Nyirenda *et al*, 2011), reported that farmers were knowledgeable about plant materials as environmental benign, safer and cost effective alternatives to synthetic pesticides.

The challenge is to develop a regulatory system able to balance the broadly defined costs and benefits of biofungicides compared with synthetic pesticides (Kumar and Singh, 2014). In the European Union, a greater emphasis on IPM as part of agricultural policy has led to innovations in the way that biofungicides are regulated (Chandler *et al.*, 2008). The U.S. Environmental Protection Agency (EPA) report showed that EPA is responsible for ensuring that the American public is protected from potential health risks posed by eating foods that have been treated with pesticides (EPA, 2007). According to the United States Environmental Protection Agency (USEPA, 2013), EPA tests biofungicides for safety but not for efficacy, as efficacy testing any result in higher cost of biofungicides than chemical pesticides.

In the US, the Environmental Protection Agency (EPA) is responsible for the registration of Plant Incorporated Protection (PIP) i.e. genetically modified crops. Identification of the new PIP character added to the plant generally follows guidance developed by the EPA, Canadian Food Inspection Agency (CFIA) and the USDA's Animal and Plant Health Inspection Service (APHIS). Guidelines have been produced by the EPA giving the requirements for registration (USEPA, 2012). Koundal and Rajendran (2003) reported that application of PIPs may be more useful and economical in the developing countries of the world to help enhance safe food, feed and forage production.

In the European Union, Genetically modified (GM) food and feed, i.e. crops producing pesticidal substances from genetic material that has been added to the plant, can only be authorized for placing on the market after a scientific assessment of any risks which they might present for human and animal health and as the case maybe, for the environment (according to Regulation (EC) 1829/2003). In India, Farmer Field Schools (FFSs) have been organized for a number of crops and especially with the aim of reducing the massive use of pesticides in cotton production (Amacini *et al.*, 2007). Women farmers in a selected sample of the cotton Integrated Pest Management Farmer Field Schools (IPMFFSs) were trained to identify the signs and symptoms of acute poisoning and to analyze the consequences of unsafe pest management behaviours (Mancini *et al.*, 2005).

Eze and Echezona (2012), opined that “food quality” refers not only to external appeal, taste and freshness; food safety is now the priority. As environmental safety is of global concern (Kumar and Singh, 2014), awareness need to be created among farmers, manufacturers, government agencies, policy makers and the common men to switch over to biopesticide for pest management requirements.

Trends in the Biofungicides Market

Biofungicides are used globally for controlling insect pests and diseases. Increasing demand for residue free crop produce is one of the key drivers of the biopesticide market. Growing organic food market and easier registration than chemical pesticides are other important driving factors for the growing biofungicides market (Kumar, 2012). In India, Gupta and Dikshit (2010), reported that the demand for organic food as a result of increasing health consciousness among the people indicates that there is huge scope for growth of the biofungicides sector in India. Stevenson *et al.* (2012), opined that the demand for fungicidal plants will continue to grow which can only realistically be met through their cultivation and marketing.

The growth of total world production of biofungicides is rising and therefore demands and use is also increasing (Gupta and Dikshit, 2010). Kumar (2012) reported that North America dominated the global biofungicides market and accounted for about 40% of the global biofungicides demand in 2011. The US biofungicides market is valued at around $205 million and expected to increase to approximately $300 million by 2020. European market is estimated nearing $200 million and due to the stringent pesticide regulations and increasing demand from organic producers, it is expected to be the fastest growing market. Asian market presents a good opportunity for biofungicides as China and India adopts more biofungicides.

India has a vast potential for biofungicides. Biofungicides consumption in India has shown its increased use overtime. However, Gupta and Dikshit (2010), reported that its adoption by farmers in India needs education for maximizing gains. Biofungicides represents only 2.8% (as on 2005) of the overall pesticide market in India as is expected to exhibit an annual growth rate of about 2.3% in the coming years (Thakore, 2006). Recent report (Kumar, 2012), revealed that in India, biofungicides represents only 4.2% of the overall pesticide market and is expected to exhibit an impressive annual growth rate of about 10% in the coming years. Kumar and Singh (2014), reported that data on microbial biofungicides agents from Agriculture and Agri-Food Canada and the US Environmental Protection Agency (EPA) indicates that more than 200 products are being sold in the US, compared to only 60 comparable products in the European Union. According to Anukwuorji *et al.* (2016), analysts believe that there would be a greater development in the biofungicides sector.

Globally, there are 175 registered biofungicides active-ingredients and 700 products available in the market. The global market for biofungicides was valued at US $1.3 billion in 2011, and it is expected to reach US $3.2 billion by 2017 (Kumar, 2012). As of early 2013, there were approximately 400 registered biofungicides active ingredients and more than 1250 registered biofungicides products (USEPA, 2013). Gupta and Dikshit (2010) reported that in India, so far, only twelve (12) types of biofungicides have been registered under the Insecticide Act, 1968 (as on 2007). Table 4 summarizes the biofungicides thus;

Table 4. Biopesticides registered under insecticide act, 1968

S/N	Name of Biofungicides
1	*Bacillus thuringiensis* var isrealensis
2	*Bacillus thuringiensis* var kurstaki
3	*Bacillus thuringiensis* var gallerine
4	*Bacillus sphaericus*
5	*Trichoderma viride*
6	*Trichoderma harzianum*
7	*Pseudomonas fluoresens*
8	*Beauveria bassiana*
9	NPV of *Helicoverpa armigera*
10	NPV of *Spodoptera litura*
11	Neem based pesticides
12	*Cymbopogon*

Source: www.ncipm.org.in/biopesticides/registered.htm
Gupta and Dikshit (2010).

Conclusion

Biofungicides use in Africa has been an important part of traditional pest management practices by farmers. Biofungicides have continued to exert major impacts on agricultural yields and food security by boosting the livelihoods of farmers. Biofungicides has curbed the menace caused by arthropod pests and other agricultural pests.

Demand for biofungicides use in agriculture as alternatives to synthetic pesticides increased in the last decade. This increase is attributed to increasing environmental consciousness and food safety. Industrial scale use of biofungicides has contributed immensely to the economics of developing countries through improved export earnings, employment creation and poverty alleviation. However, this has also resulted to the indiscriminate felling of trees with promising potentials of biological activity.

The increasing demand for biofungicides should propel research scientists, research institutes, biotechnologists and major stakeholders to engage in tissue culture as an alternative method to provide large amounts of fungicidal plants and other biofungicides compounds. Policies should also be directed at developing biotechnology capabilities through funding of projects, training of researchers and creation of specialized research institute

Suggestions for Further Studies

The following are the suggestions made for further studies on the impact of biofungicides on agricultural yields and food security in Africa.

1. Policy makers, researchers, government, stakeholders and individuals should be actively involved to tackle issues concerning conservation and proportion of novel plants and their development as biofungicides.
2. Regulatory agencies, policy makers and government should develop models that will be used as a reference for the registration of biofungicides.
3. Emphasis should be placed on developing biotechnology capabilities and the adoption of tissues culture techniques for the improvement of biofungicides.
4. Basic safety information data that is relatively accessible should be provided to the general public. This will enhance the greater acceptability of biofungicides.

References

Adedire, C. O. and Akinneye, J. O. (2004). Biological activity of tree marigold, *Tithonia diversifolia*, on cowpea seed bruchid, *Callosobruchus maculatus* (Coleoptera: Bruchidae). Annual Applied BiologyJournal 144:185-189.

Adeniyi, S. A., Orjiekwe, C. L., Ehiagbonare, J. E and Arimah, B. D. (2010). Preliminary phytochemical analysis and insecticidal activity of ethanolic extracts of four tropical plants (*Vernonia amygdalina, Sida acuta, Ocimum gratissimum* and *Telfaria occidentalis*) against beans weevil (*Acanthscelides obtectus*). International Journal of Physical Science 5:753-762.

Ahmed, S., Naseer, A. and Fiaz, S. (2005). Comparative efficacy of botanical and insecticides on termites in sugarcane of Faisalabad. Parkistan Entomology Journal 27:23-25.

Amacini, F. H., Ariena, C. and Bruggen, V. (2007). Evaluating cotton Integrated Pest Managemnet (IPM) farmer field school using the sustainable livelihoods approach in India. Experimental Agricultural Journal 43:97-112.

Anjorin, S. T. (2008). A Survey of crop seed protection with botanicals in the FCT-Abuja, Nigeria. Journal of Sustainable Tropical Agricultural Resources 24:076-082

Anjorin, S. T., Salako, E. A. and Ndana, R. W. (2004). In vitro assessment of some plant leaf extracts for the control of *Meloidogyne* spp. and *Rhizoctonia solani* Zuma. Journal of Pure and Applied Sciences 7:23-29.

Anonymous (1992). Neem: A tree for solving global problems. Report of an Ad-hoc panel of the Board of Science and Technology for International Development, National Research Council. Washington D.C.: National Agency Press.

Anonymous (2014). History of Biopesticides. Biopesticide Industry Alliance. University of Arkansas, the Ohio State University, U.S. EPA. Retrieved from http://www.biopesticideindustryalliance.org/history-of-biopesticide

Anukwuorji, C. A., Anuagasi, C. L. and Okigbo, R. N. (2013). Occurrence and control of fungal pathogens of potato (*Ipomoea batatas* L. Lam) with plant extracts. PharmTechMedica 2:278-289

Anukwuorji, C. A., Obianuju, C. M., Ezebo, R. O. and Anuagasi, C. L. (2016). Antimicrobial effects of four plant extracts against post harvest spoilage fungi of yam (*Dioscorea rotundata* Poir). International Journal of Plant and Soil Science 12:1-10.

Anukwuorji, C. A., Putheti, R. R. and Okigbo, R. N. (2012). Isolation of fungi causing rot of cocoyam (*Colocasia esculenta* (L.) Schott) and control with plant extracts: *Allium sativum*, L., *Garcinia kola*, heckle., *Azadirachta indica*, L. and *Carica papaya*, L.). Global Advanced Research Journal of Agricultural Science 1:33-47.

Arora, R. and Dhaliwal, G. S. (1994). Botanical Pesticides in insect pest management. In Dhaliwal, G. S. and Kansal, B. D. (Eds.), Management of Agricultural Pollution in India. Commonwealth publishers, New Dehli, India. pp. 213-245.

Asawalam, E. F., Emosairue, S. O. and Hassanali, A. (2008). Contributions of different constituents to the toxicity of the essential oil constituents of *Vernonia amygdalina* (compositae) and *Xylopia aetiopica* (Annonaceae) on maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). African Journal of Biotechnology 7:2957-2962.

Bagnarello, G., Hilje, L., Bagnarello, V., Cartin, V. and Calvo, M. (2009). Phagodeterrent activity of the plants *Tithonia diversifolia* and *Montanoa hibiscifolia* (Asteraceae) on adults of the pest insect *Bemisia tabaci* (Homoptera: Aleyrodidae). Revista De Biology Tropical 57:1201-1215.

Balmain, S. and Stevenson, P. (2001). Ethnobotanicals in Ghana: reviving and modernizing age-old farmer practice. Pesticide outlook 12:233-238.

Belmain, S. R., Neal, G. E., Ray, D. E. and Golob, P. (2001). Insecticidal and vertebrate toxicity associated with Ethnobotanicals used as post-harvest protectants in Ghana. Food and Chemical Toxicology Journal 39:287-291.

Benner, J. P. (1993). Pesticidal compounds from higher plants. Pesticide Science Journal 39:95-102

Boeke, S. J., Barnaud, I. R., Van Loon, J. J. A., Kossou, D. K., Van Huis, A. and Dicke, M. (2004a). Efficacy of plant extracts against the cowpea bettle, *Callosobruchus maculatus*. International Journal of Pest Management 50:251-258.

Boeke, S. J., Baumgart, I. R., Van Loon, J. J. A., Van Huis, A., Dicke, M., Kossou, D. K. (2004b). Toxicity and repellence of African plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus*. Journal of stored product Research 40:423-438.

Chandler, D., Davidson, G., Grant, W. P., Greaves, J., Tatchell, G. M. (2008). Microbial biopesticides for integrated crop management: An Assessment of environmental and regulatory sustainability. Trends in Food Science Technology 19:275-283.

Coombs, A. (2013). Fighting Microbes with Microbes. The scientist Exploring Life, inspiring innovation. Retrieved from http://www.the-scientist.com.articles.view

Crombie, L., Ham, P. J. and Whiting, D. A. (1971). Sapogenin of termite-repellent fruit of *Swartzia madagascariensis*. Chemical Industry Research Journal 6:176-180.

Deka, M. K. and Singh, S. N (2001). Neem Formulation in the Management of Sugarcane insects and pests. Proceedings of the 63rd Annual Conference of Sugar Technology Association, 27-29 August 2001. Jailpur, India. pp. 33-38.

Dhaliwal, G. S. and Arora, R. (2006). Integrated Pest Management Second edition. New Delhi India: Kalyani Publishers.

Dhaliwal, G. S., Arora, R. and Dilawari, V. K. (1996). Botanical Pesticides in insect pest management: Emerging trends and strategies. In Narwal, S. S. and Tauro, P. (Eds.), Allelopathy in pest management for sustainable Agriculture. Jodhpur, India: Scientific publishers. pp. 93-119.

Environmental Protection Agency of the USA (2007). The EPA and Food Security. Retrieved from http://www.epa.gov/pesticides/food/ipm.htm.

Environmental Protection Agency of the USA (2012). Regulating Biopesticides. Retrieved from http://www.epa.gov.oppoooo1/biopesticides.

Eze, S. C., and Echezona, B. C. (2012). Agricultural pest control programmes, food security and safety. African Journal of Food, Agriculture, Nutrition and Development 12:6583-6592.

Gaskins, M. H., White, G. A., Martins, F. W., Delfel, N. E., Rupel, E. G. and Barnes, D. K. (1972). *Tephrosia vogelii*: A source of Rotenoids for Insecticidal and Piscidal use. Agricultural research service, united states department of agriculture. Technical Bulletin No. 1445. Washington, D.C: Government Printing Office. pp. 1-40.

Gupta, S. and Dikshit, A. K. (2010). Biopesticides: An Ecofriendly approach for pest control. Journal of Biopesticides 3:186-188.

Harbone, J. B. (1973). Phytochemical method: A guide to modern techniques of plant analysis. London: Chapman and Hall Ltd.

Jacobson, M. (1990). Glossary of plant derived insect deterrents. Boca Raton, Florida, USA: CRC press.

Jayasekera, T., Stevenson, P. C., Belmain, S. R. and Hall, D. R. (2002). Methylsalicylate isomers in the roots of *Securidaca longepedunculata*. Journal of Mass Spectrum 37:577-580.

Jayasekera, T., Stevenson, P. C., Hall, D. R. and Belmain, S. R., (2005). Effects of volatile constituents from *Securidaca longepedunculata* on stored grain insects pests. Journal of Chemical Ecology 31:303-313.

Kamanula, J., Sileshi, G. W., Belmain S. R. Sola., Mvumi, B. M., Nyirenda, S. P. and Stevenson, P. C. (2011). Farmers' insect pest management practices and pesticidal plant use in the protection of stored maize and beans in southern Africa. International Journal of Pest Management 57:41-49.

Kilic, A. and Akay, M. T. (2008). A three generation study with genetically modified Bt corn in rats: Biochemical and histopathological investigation. Food Chemical Toxicology 46:1164-1170.

Kone, W. M., Atindehou, K. K., Terreaux, C., Hostettmann, K., Traore, D. and Dosso, M. (2004). Traditional medicine in North Cote-d'Ivoire screening of 50 medicinal plants for antibacterial activity. Journal Ethnopharmacol 93:43-49.

Koona, P. and Dorn, S. (2005). Extracts from *Tephrosia vogelii* for the protection of stored legume seeds against damage by three bruchid species. Annual Journal of Applied Biology 147:43-48.

Koona, P., Malaa, D. and Koona, O. E. S. (2007). Hexane extracts from *Tephrosia vogelii* Hook. f. protect stored maize against the weevil *Sitophilus zeamais* Motschulsky (Coleoptera: curculionidae). Entomological Science Journal 10:107-111.

Koul, O. (2005). Insect Antifeedants. Boca Raton, Florida: CRC Press.

Koul, O. and Dhaliwal, G. S. (2001). Phytochemical Biopesticides. Amsterdam, the Netherlands: Harwood Academic publisher.

Koul, O. and Dhaliwal, G. S. (2000). Phytochemical Biopesticides (Advances in Biopesticides Research). Boca Raton, Florida: CRC Press.

Koundal, K. R. and Rajendran, P. (2003). Plant insecticidal proteins and their potential for developing transgenic resistant to insect pests. Indian Journal of Biotechnology 2:110-120.

Kumar, A., Prasad, M., Mishra, D., Srivastav, S. K. and Srivastav, A. K. (2010). Toxicity of aqueous extract of *Euphorbia tirucalli*latex on catfish, *Heteropnestes fossilis*. Ecotoxicology, Environmentand Safety Journal 73:1671-1673.

Kumar, S. (2012). Biopesticides: A Need for food and environmental safety. Journal of Biofertilizer and Biopesticide 3:107-113.

Kumar, S. (2013). The role of biopesticides in sustainably feeding the nine billion global populations. Journal of Biofertilizer and Biopesticide 4:114-119.

Kumar, S. and Singh, A., (2014). Biopesticides for integrated crop management: Environmental and regulatory aspects. Journal of Biofertilizer and Biopesticide 5:121-129.

Kumar, S., Chandra, A., and Pandey, K. C. (2008): *Bacillus thuringiensis* (Bt) transgenic crop: an environment friendly insect – pest management strategy. Journal of Environmental Biology 29:641-653.

Mancini, F., Bruggen, V., Jiggins, A. H. C., Ambatipudi, L. S. J. and Murphy, H. (2005). Acute Pesticide poisoning of cotton growers in Andhra Pradesh. International Journal of Occupational and Environmental Health 11:221-232.

Mazid, S., Kalida, J. C. and Rajkhowa, R. C (2011). A review on the use of biopesticides in insect pest management. International Journal of Science and Advanced Technology 1:169-178.

McGrath, M., Vallad, G. and Gardener, B. M. (2010). Biopesticides for Plant Disease Management in Organic Farming. Retrieved from http://www.extension.org/pages/29380/biopesticidesfor-plant-disease-management-in-organic-farming

Metcalf, R. L and Metcalf, E. R. (1992). Plant Kairomones in Insect Ecology and Control. New York, USA: Chapman and Hall.

Minjas, J. N. and Sarda, R. K. (1986). Laboratory Observations on the Toxicity of *Swartzia madagascariensis* (Leguminosae) extract to mosquito larvae. Transitional Royal, Social and Tropical Medicine Hygiene 80:460-461.

Neuwinger, H. D. (2004). Plants Used for fish poisoning in tropical Africa. Toxicology Journal 44:417-430.

NRC (1992). Neem: A Tree for solving Global problems. Report of Adhoc Panel of the Board on Science and Technology for International Development, National Research council. Washington, D.C, USA: National Academy Press. 347 pp.

Nyirenda, S. P. N., Sileshi, G., Belman, S. R., Kamanula, J. F., Mvumi, B., Sola, P., Nyirenda, G. K. C. and Stevenson, P. C. (2011). Farmers' ethno-ecological knowledge of vegetable pests and their management using pesticidal plants in Northern Malawi and Eastern Zambia. African Journal of Agricultural Resource 6:1525-1537.

Okigbo, R. N. and Ikedigwu, F. E. O. (2000). Studies on biological control of postharvest rot in yams (*Dioscorea* spp.) using *Trichoderma viride*. Journal of phytopathology 148:351-355.

Okigbo, R. N. and Mmeka, E. C. (2006). An appraisal of phytomedicine in Africa. KMITL Science and Technology Journal 6:83-93.2

Okigbo, R. N., Anuagasi, C. L. and Amadi, J. E. (2009a). Advances in selected medicinal and aromatic plants indigenous to Africa. Journal of Medicinal Plants Research 3:086-095.

Okigbo, R. N., Anukwuorji, C. A. and Eguae, C. T. (2012). Control of microorganisms causing the deterioration of yam chips with *Vernonia amygdalina* and *Zingiber officinale*. Nigerian Journal of Mycology 4:45-56.

Okigbo, R. N., Anukwuorji, C. A. and Igweonu, M. Z. (2014). Fungitoxic effect of *Azadirachta indica* and *Vernonia amygdalina* extracts on *Aspergillus niger* and *Fusarium oxysporium* the casual organisms of yam (*Dioscorea rotundata*) rot. The Bioscientist 2:70-86

Okigbo, R. N, Putheti, R. and Achusi, C. T. (2009b). Post-harvest Deterioration of cassava and its control using Extracts of *Azadirachta indica* and *Aframomum melegueta*. E-Journal of Chemistry 6:1247-1280.

Pradham, S., Jotwani, M. G. and Rai, B. K (1962). The Neem seed deterrent to locusts. Indian Fumigation Journal 12:7-11.

Sankoh, O. A. (1999). Environmental assessment and management. African Journal of Environmental Management 1:3–10.

Sarasan, V, Kite, G. C., Sileshi, G. W. and Stevenson, P. C. (2011). The application of phytochemistry and in vitro tools to the sustainable utilization of medicinal and pesticidal plants for income generation and poverty alleviation. Plant Cell Reports 30:1163-1172.

Saxena, K. (1987). Indigenous crop protection practices Sub-Saharan East Africa. In Database of Natural Crop Protectant Chemicals (DNCPC). Retrieved from http://www.impafrica.htm.

Saxena, R. C. (1993). Scope of Neem for developing countries. Paper presented at the Souvenir World Neem Conference, Bengalore, India, 24-28 February 1993. pp. 30-36.

Schmutterer, H. (1990). Properties and potentials of natural pesticides from the Neem tree. Annual Review of Entomology 35:371-298.

Singh, R. P. (2000). Botanicals in pest management: An Ecological prospective. In Dhaliwal, G. S. and Singh, B. (Eds.), Pesticides and environment. New Delhi: Commonwealth Publishers. pp. 279- 343.

Singh, R. P., Singh, S. and Wahab, S (1999). Biodiversity and importance of botanical pesticides. In Dhaliwal, G. S., Arora, R. and Dhawan, A. K. (Eds.), Emerging trends in sustainable agriculture. New Delhi: Commonwealth Publishers. pp. 282-299.

Singh, A., Khare, A. and Singh, A. P. (2012). Use of vegetable oils as biopesticides in grain protection- A review. Journal of Biofertilizer and biopesticides 3:114-117.

Sofowora, A. E. (1993). Medicinal plants and traditional medicines in Africa 2nd edition. Ibadan, Nigeria: Spectrum Books. 289 pp.

Stevenson, P. C., Nyirenda, S. P., Mvumi, B., Sola, P., Kamanula, J. F., Sileshi, G. W. and Belmain, S. R. (2012). Pesticidal plants: A Viable alternative insect pest management approach for resource-poor farming in Africa. In Biopesticides in Environment and Food Security. India: Scientific Publishers.

Stevenson, P. C., Nyirenda, S. P. and Veitch, N. C. (2010). Highly glycosylated flavonoids glycosides from *Bobgunnia madagascariensis*. Tetrahedron Letters 51:4727-4730.

Tang'an, B. N. S., Adebitan, S. A., Adbul, S. D. and Ogidi, S. D. and Ogidi, J. A. (2002). Fungicide activity of some plant extracts on *Cercosporea sojina* Hara: The causal agent of frogeye leaf spot of soya beans. Proceedings of the 30th Annual Conference of the Nigerian Society for Plant Protection, University of Agriculture, Abeokuta. 1-4 September 2002.

Thakore, Y. (2006). The Biopesticide market for global agricultural use. Industrial Biotechnology, Fall 2006:194-208.

Tsado, E. K. and Tanko, M. A. (2002). Evaluation of three local plants for the control of storage insect pests of maize and cowpea. Proceedings of the 30th Annual Conference of the Nigerian Society for Plant Protection, University of Agriculture, Abeokuta. 1-4 September 2002.

Tyler, V. E. (1999). Phytomedicines: Back to the future. Journal of Natural Products Research 62:1589-1592.

USEPA (United States Environmental Protection Agency) (2013). Regulating Biopesticides.

Yeap, S. K., Ho, W. Y., Beh, B. K., Liang, W. S., Ky, H., Yousr, A. H. H. and Alitheen, N. B. (2010). *Vernonia amygdalina*, an ethnoveterinary and ethnomedical used green vegetable with multiple bio-activities. Journal of Medicinal Plants Research 4:2787-2812.

Youdeowei, A. (1995). Pest and vector management in the Tropics. Longman Nigeria Plc. 52 Oba Akran Avenue, Ikeja Lagos, Nigeria.

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