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BOTANICAL CONTROL OF PLANT DISEASES IN NIGERIA: CURRENT STATUS, POTENTIAL CHALLENGES AND THE WAY FORWARD

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SUMMARY

Available literature is replete with a reasonable number of active plant chemical substances that have useful properties for crop protection, which are cheap and locally available to farmers, often harmless to humans and animals and are rarely toxic to plants when compared with synthetic pesticides. Both cultivated and wild plants supply a number of plant protection properties. The available, updated information on the production, formulation, and accessibility to farmers the formulated products of almost 100% of biocontrol products of plant origin is lacking in Nigeria. In many developed countries, pesticides of plant origin have been formulated into readily available and easy to apply products. Several researches have revealed the potentials of these botanical extracts as preservatives and having antimicrobial action against pathogenic organisms affecting crops. These findings call for the replacement of chemically synthesized preservatives with naturally derived ones. The aim of this review is to highlight, update and discuss the existing information on the antimicrobial plants of Nigeria, the limitations on their adoption and the possible suggestions on how to ensure large scale formulation and commercialization of botanical crop protection products.

Keywords: Antimicrobial, botanicals, biocontrol products, plant chemical substances

1.0 INTRODUCTION

Diseases control in plants has been a practice that existed since the prehistoric period. The use of locally accessible plants is the earliest way to control pests during ancient period. But in the 1940s, then they were alternated by synthetically made pesticides because they are easier to handle and lasted longer. Pesticides are the substances or mixture of substances used to prevent, destroy, sterilize or mitigate the pests (5,11,19).

The enthusiasm with which they were used was greeted with unforeseen problems which were not taken into consideration at the time of their introduction. The World Health Organization (WHO) estimates that 200,000 people are killed worldwide, every year, as a direct result of pesticide poisoning. The use of synthetic chemicals also has carcinogenic, teratogenic, high and acute residual toxicity effects on humans. They cause hormonal imbalance, spermatotoxicity, long degradation period and are found as residues in food (5).

Fungi, bacteria, virus and nematodes are the major disease inciting agents in crop production. There is a recent upsurge of interest in natural plant products to be used as fungicides (28**).** Many research reports affirm the efficacy of natural products of plants in controlling microbial growth and production of some harmful secondary metabolites such as mycotoxin by fungi (2,6,16). They have been found effective for the control of foliar, soil and storage diseases affecting crops of economic importance.

Several technologies have been recommended for the reduction of crop diseases and subsequent loses. These include cultural practices, biological control (biocontrol), monitoring and crop destruction, disease may still occur when a susceptible host, conducive environment and pathogenic organism occur concurrently in a crop field. The development of disease resistant crop varieties helps in crop diseases management but, the resistant genes are broken down with time. This makes it necessary for continuous need to seek disease management interventions to reduce the loss in yield and quality of crops and its produce. The use of chemically synthesized pesticides has a lot of hazards it poses to the environment, non-target organisms and to humans who both apply the pesticides and use the treated crops which may be contaminated with pesticide residues. However, the use of crop protection products from botanical origin remains a very good option in terms of environmental, human, animal and food safety as

well as cost effectiveness. This method has been in use for several decades.

Disease management by use of botanicals has been given significant research consideration for the effective management of various fungal and bacterial diseases of plants in particularly lab trials and to an extent the field trials. In this review, we briefly highlight the importance of botanical disease control, review the various methods available for use of botanicals in disease control and then concentrate on the in-depth analysis of the formulation and use of medicinal plant products as management tools for plant diseases management in Nigeria. This review therefore, is aimed at providing information about the various botanicals that have been found effective in plant disease control. Discussion on them are based on their uses, stability, mode of action, limitations and the possible ways to enhance their uses as alternatives to synthetic chemical pesticides for diseases control.

2.0 Botanical disease control in Nigeria

2.1 Botanicals and their importance in disease control

The kingdom plantae are recognized as the most efficient producer of chemical compounds that synthesizes many products which are used for protection against different pests. These plants have existed in nature for millions of years without any adversative effects on the balance of the ecosystem. Natural pesticides are also very close chemically to those plants from which they are extracted, so they are easily decomposed by many soil microbes making their use to maintain the biological diversity and hence, reduce environmental contamination as well as human and animal health hazards and are rarely toxic to plants when compared with artificial pesticides (5,8). They are cheap and locally available to farmers. They are often harmless to humans and animals (2).

Both cultivated and wild plants supply a number of plant protection products. The plant materials are broad spectrum in activity and are precise in action (2). Botanicals contain biologically active chemical substances such as saponins, tannins, essential oils, flavonoids, alkaloids and other chemical compounds which have plant protection properties. These complex chemical substances of different compositions are found as secondary plant metabolites in the medicinal plants (21).

2.2 Stability and safety of botanical pesticides

These metabolites (phytochemicals) have half-lives of 24 hours or more on surfaces, in soil and in water. There are no harvest restrictions or worker re-entry restrictions for treated crops;

they are compatible with biological control agents and indigenous natural enemies of pests. They bring about reduced risks to honeybees and other foraging pollinators (22).

They decompose quickly and provide the residue free food and a safe environment (5). They are relatively safer to the user and the environment because of their high biodegradability and easy break down into harmless compounds within a short period which ranges from few hours to days in the presence of sunlight.

2.3 Diseases and pathogens affected by botanical pesticides

Plant extracts of many higher plants are reported to exhibit antibacterial, antifungal and insecticidal properties under laboratory trials (23); as well as in many field trials. The use of sun hemp *Crotalaria* sp. (the stems and roots) chopped into pieces and mixed with infected soil in plastic bags reduced the bacterial population of *Ralstonia solanacearum* (Smith) after four weeks of incubation (4).

Neem (*Azadirachta indica* Juss) which is an ever-green glabrous tree contains substances like terpenoids, nimbin, *Azadirone* and *azadirachtin* that have been found useful in human health and crop protection activities. The azadirachtin is an insect repellant which also retards insect reproduction (13, 30).

Garlic (*Allium sativum* L.) contains a significant antibiotic compound called allicin. It is effective against a broad range of bacteria species at dilutions of 1:10. Fresh *A. sativum* extracts have been found to be effective against many fungal species. It has been effectively used for the protection plants and stored foods (25).

Ginger (*Zingiber officinale* Roscoe) contains gingerols and shogoals and has too many medicinal properties. Extracts from the rhizome are effective against many pest and diseases that affect cultivated crops (17). Aqueous and ethanol extracts of *Z. officinale* is reported to have potential inhibitory effect on all the rot causing fungi (30,32).

Also, plant species such as *Piper guineense, Xylopia aethiopica, Gongronema latifolium* Brenth, *Citrus, Bryophyllum pinnatum* (Lam.) Kurz, *Vernonia amygdalina* (Delile), pyrethrum (*Chrysanthemum coccineum*, Wild.), etc. have been reported to be promising species in crop protection (25,30).

Drumstick (*Moringa oleifera* Lam.) is a highly valued plant, distributed in many countries of the tropics and subtropics. It has an impressive range of medicinal uses. It has antibacterial and antifungal activities with high

nutritional value (10,31). The acetone extract of *M. oleifera* leaves at a concentration of 5 mg/ml showed antibacterial activities against *Escherichia coli* Migula, *Enterobacter cloace* Jordan, *Proteus vulgaris* Hauser, *Staphylococcus aureus* Rosenbach and *Micrococcus kristinae.* Phytochemical screening of *M. oleifera* revealed presence of flavonoids and saponins. *Moringa* inhibited the growth of *Mucor* spp and *Rhizopus* spp. The other target fungi reported are *Alternaria alternata*, *Colletotrichum* spp, *Diplodia* spp and *Pestalotia* spp.

Scent leaf (*Ocimum gratissimum L.)* has been reported to be used against human fungal infections. It is an established fact that the various extracts of *Ocimum gratissimum* tested *in vitro* were active against some bacterial and fungal isolates. Aqueous and ethanol extracts of *O. gratissimum* have possible inhibitory effect on rot-causing fungi (32).

Pawpaw (*Carica papaya* L.) has fungicidal properties. *Carica papaya* roots and seeds were reported *in vitro* to contain antimicrobial compounds that strongly affected the germination of *Colletotrichum destructivum* (O'Gara) spores. In addition, the leaves exhibit fungicidal activities against *Fusarium* oxysporum **(**Schlecht. emend. Snyder and Hansen)**,** mycelium (9, 15). Leaf mould, leaf spot, early blight, frog-eye leaf spot, fruit and stem rots have been controlled by *C. papaya* (9).

West African pepper *(Piper guineense* Schumach and Thonn.) seeds contain significant proportion of myristicin, elemicin, safrole and dillapoil. Elemicin and myristicin are reported to exhibit significant fungicidal properties (http://martinslibrary.blogspot.com). Safrol reduced the growth rates of *Rhizoctonia solani* Kühn, *Ceratocystis pilifera,* Moreau, and *Fusarium oxysporum by* up to 50% (23). The powder spread around stored grains was reported to be effective against cotton stainer, diamond back moth, common cutworms and weevils.

Negro pepper *Xylopia aethiopica* (Dunal) is a slim, tall, evergreen tree crop, which produces fruits with a dense cluster, twisted bean-like dark brown pods. In a recent review, *X. aethiopica* was shown to have a wide range of biological activities including insecticidal and antimicrobial which were attributed to the wide variety of secondary metabolites in the plant (1, 3).

2.4 Existing technologies by which plant antimicrobials can be delivered

There are various methods by which plant antimicrobials could be formulated for disease management both at pre-harvest and post-harvest stages. Recent technology incorporates antimicrobials into food packaging materials instead of the food itself. This technology gives the advantage of concentrating the antimicrobial at the surface of the food product where potential pathogens grow, and reduces obstruction from food particles (27). This application changes the condition of the food package to better preserve the sensory attributes, safety, and shelf-life of the product since microbial contact primarily occurs on the surface of a packaged (24).

Plant Antimicrobials have also been formulated into micro capsules in many advanced countries. Microencapsulated antimicrobial agents incorporated in food packaging have been proven to successfully destroy a range of microorganisms, offering a controlled release preservation technique (24,27).

Plant antimicrobials can also be delivered via plant extracts or consumed whole. The literature generally cites that spice extracts are less antimicrobial than the whole spice (27).

3.0 Botanical disease management approaches

3.1 Pre harvest and post-harvest uses of plant antimicrobial compounds

Plant antimicrobial disease control is mostly used for control purposes. Biochar, the ash of various plant materials is recently being used as soil amendment/treatment for management of many plant diseases. Also, foliar sprays of many plant extracts have been effectively used in pre-harvest disease management.

The controls of pathogenic organisms in foods by the botanicals reveal the potentials of these extracts as preservatives as well at post-harvest stage. They are the most appropriate for use in organic food production that can play a great role in developing countries as a new class of environment friendly products for controlling diseases in stored crops. The findings add impetus to the clarion call by consumers and authorities in food industries for the replacement of chemically synthesized preservatives with "naturally derived" ones (5). The medicinal plant powders can be produced and used as Seed dusts for crop storage. Biologically active products of plant origin such as flavonoid compounds, glucosinolates, chitosan, essential

oils and plant extracts have been exploited for the management of fungal rotting of fruits and vegetables. Botanical fungi-toxicants are used for the protection of stored food commodities from fungal infection (7, 18).

3.1.1 Possible uses of botanicals for disease prevention

Essential oils extracted from medicinal plants play an important role in the protection of the plants as antibacterial, antivirals, antifungals, insecticides and also against herbivores by reducing their appetite/feeding rate for such plants (5). Plant Defensins which are structurally related to insect and mammalian are able to inhibit bacteria and fungi. Lipid transfer proteins isolated from barley, maize, spinach, *Arabidopsis*, broccoli, and radish have demonstrated some antimicrobial activities (24).

3.2 Compositions and mode of action botanicals

The plant products used for plant disease management are essential oils and extracts which have many similarities but also differ in some characteristics (33). Phenols, flavonoids, quinones, terpenens, tannins, alkaloids, lectins, polypeptides, saponins and sterols are the most common compounds investigated for disease management (13, 14). They affect mostly only target pest and closely related organisms and are effective in very small quantities (5). The effects of these products may have fungicidal or fungistatic activities on plant pathogens and/or create conditions unfavourable for establishment and multiplication of pathogenic microorganisms on host plants (14).

The mode of action for most plant antimicrobials against bacteria involves cell membranes of targeted organisms and is determined by net positive charge, flexibility, and hydrophobicity to enable interaction with bacterial membranes (19). Research suggests there may be alternative modes of action as against the originally thought that the sole mode of action was permeabilization of the bacterial cell membrane. The antifungal mode of action was initially thought to only involve cell lysis or interference with the synthesis of the fungal cell wall but research reports additional modes of action such as permeabilization, binding to ergosterol/cholesterol in the membrane, depolymerization of the actin cytoskeleton, and targeting intracellular organelles, such as mitochondria (20).

Antiviral activity is often related to a direct effect on the viral envelope or related to the viral adsorption and entry process (20). Table 1 below

shows more compounds from plants and their modes of action.

Table1: Compounds of plants origin and their modes of action.

Name of compound	Mode of action
Simple Phenols	Membrane disruption, substrate deprivation
Phenolic acids	Bind to adhesins, complex with cell wall, inactivate enzymes
Terpenoids	Membrane disruption
Essential oils	Membrane disruption
Alkaloids	Intercalate into cell wall
Tannins	Bind to proteins, enzyme inhibition, substrate deprivation
Flavonoids	Bind to adhesins, complex with cell wall, Inactivate enzymes
Coumarins	Interaction with eucaryotic DNA
Lectins	Form disulfide bridges
Polypeptides	Form disulfide bridges

Source: Zaker (33).

4.0 Limitations of use of Botanicals in Disease Control

4.1 Non large-scale production

One major factor that has limited the use of botanical disease control in Nigeria is large scale production of plant-based pesticides of the identified potential medicinal plants. This makes the farmers to be reluctant in the acceptance and adoption of botanical pesticides and always rely on the readily available synthetic pesticides in required quantities for their disease control activities

4.2 Exact field doses and application time

To determine the disease controlling ability of a plant species, it is important to determine the exact and certain field doses that can be applied at any given disease control activity for a particular disease. This is another crucial factor that should be determined for a plant-based botanical to receive the desired acceptance level from the farmers. Where these are not accurately determined, poor acceptance and adoption is bound to restrict the use of such natural pesticide even though found effective. Also, botanicals found effective under laboratory and screen house trials should be tried on the field at different application periods to validate its effectiveness before recommendation for general farmers' use.

4.3 Short lived effectiveness and poor acceptance by farmers

Plant based pesticides are mostly not long lasting in their disease suppression duration because they are easily degraded in the environment where they are applied compared with the conventional synthetic pesticides. For this reason, an average Nigerian farmer will prefer the use of the later to that of the plant-based pesticides (14). Many identified medicinal plants for disease control have received very low acceptance by the majority of Nigerian farmers. This could be attributed to short-lived effectiveness of the botanicals when compared to the chemically synthesized pesticides readily available in the market.

4.4 Variation in medicinal plants essential oil and organic constituent composition

The phytochemicals and essential oil content of most botanicals often vary even within same plant species as well as according to the part of the plant being used for extraction. More so, the plant phenological state, season, climate, soil type etc. cause variation in the organic constituent composition of most medicinal plants (5). Purified genetic variants of thionins exhibited differences in activity and some differences in specificity (24).

5.0 The Way Forward

5.1 Formulation into ready to apply products

In many developed countries such as United States of America and European Union, botanicals have been exploited greatly for diseases control by having them in ready to use formulations. In developing countries, medicinal plants offer distinctive and interesting opportunities for exploration, and exploitation for each country to develop formulated products own botanicals.

5.2 Commercialization of the synthetic pesticides

Focusing on identified potent antimicrobial plants, identifying the actual active ingredient (s), their best extraction method, and their formulation in commercial quantities will be a step towards encouraging the acceptance and adoption of botanical pesticides by the general Nigerian farmers. Available literature and information are replete with several botanical pesticides existing in many developed countries. In the developing world like Nigeria, the formulated products will constitute an affordable tool for crop protection to farmers (22).

5.3 Identification of suitable carriers/ dispersants for active plant antimicrobial chemicals

Owing to their volatility, environmental non persistent and easy degradation of pesticides of plant origin; there is short lived activity of most plant-based pesticides. This could be a discouraging factor in the use of phytochemicals; which can be overcome by finding slow and controlled release strategies of the active toxic agent of the medicinal plants. According to Ćosić *et al.* (5), creams, polymer mixtures, or microcapsules-based formulations will enhance controlled release and an increase in duration of bio pesticide activity. Also, regular and repeated application is encouraged to enhance adequate treatment that will achieve the best disease control results with botanical pesticides.

5.4 Registration of the formulated products

A literature review and a search of the web pages of the governmental agencies yield no result of known approved plant antimicrobial pesticides in Nigeria for food application (24). Researchers should focus botanical disease control efforts on the formulation and commercialization. Prior to full commercialization, permission should be sought from governmental agencies that will evaluate the safety of the products for targeted use and provision should also be made for guidance and regulation on their use. There is a strict protocol in place in order for food additives to be approved for human consumption. Thus, when applying for authorization of a product, an applicant should submit a formal request to the appropriate agency/commission and include information on the substance, scientific data concerning safety. Upon acceptance of the application, the agency/commission will certify the safety of the substance for its intended uses. In addition to carrying out safety evaluations of product before they can be authorized for use in the country, regular reviews of scientific information and/or changing conditions should be carried out. A clue needs to be borrowed from India where botanical pesticides applicants are allowed to market their new products for up to a period of five (5) years before final registration (26, 29).

5.5 Consideration of synergistic uses

Most botanical antimicrobials are highly variable in stability and efficacy. For this reason, it is critical that plant-derived antimicrobials be selected and delivered in such a way that they are active against potential pathogens in particular and are stable throughout the crops production

period/ food's shelf life. Therefore, the effects of these compounds in combination with other compounds or techniques must be more thoroughly investigated before use in synergy (24). Importantly, the registration of botanicals made up of a single active ingredient should be discouraged as there may be attendant risk of pest resistance as obtained in the synthetics which are in most cases made up of a single active ingredient (29).

6.0 CONCLUSION

This review has cited many of the benefits and lists some of the current limitations of implementing plant-derived antimicrobials in disease management. Most significantly, despite extensive research of plant-derived antimicrobials, there are limited little or no formulated products in Nigeria. Because of their minimal costs and ecological side effects, botanical pesticides study in Nigeria needs to receive more research attention and more importantly scaling up than it has received so far. The disease control effects of botanicals over broad-spectrum conventional pesticide are encouraging enough to consider commercial production of the numerous identified pesticides of plant origin. The antimicrobial activities of many wild and cultivated plants cannot be over emphasized, having identified ample plants that are useful in protection against diseases affecting crops; research efforts should be centered towards formulating finished products for crop protection of plant origin that will be ready to use by the farmers and always available at the periods of crop production when they will be needed by farmers to apply in their fields. This will enhance a greater acceptance and use of the identified medicinal plants by farmers in their crop disease management activities.

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