Review Article

NATURE'S CURE: THE ROLE OF BOTANICALS IN INTEGRATED DISEASE MANAGEMENT

Abstract

The excessive and haphazard use of the majority of synthetic fungicides has led to a variety of toxicological and environmental issues. Our ancestors used these (the word "these" can be used only if the list of botanicals are used before) botanicals to manage plant diseases long before the advent of conventional fungicides. Recently, attention has been focused on using higher plant products as innovative chemotherapeutics in plant protection in many parts of the world. Botanical pesticides are once more becoming more and more popular (Change the sentence frame) and some plant products are being employed as bio-pesticides on a global scale. As botanical pesticides, pyrethroids and neem products have a well-established industry due to their widespread customer acceptability and generally safe reputation. Additionally, treating seeds and applying a foliar spray of freshly prepared garlic bulb extract led to a reduction in alternaria blight by 35.6%, white rust by 50.4%, powdery mildew by 67.7% and sclerotinia rot by 80.3% in mustard. This treatment also resulted in a 27.3% increase in yield compared to the untreated control. Some volatile oils, which often contain the main aromatic and flavoring components of herbs and spices, have been recommended as plant-based antimicrobials to delay microbial contamination and reduce food spoilage. Botanical pesticides are best suited for use in organic food production in industrialized countries, but they can play a much larger role in the production and post-harvest protection of food products in developing countries.

1. INTRODUCTION

Disease-induced decreases in yield significantly impact crop disease control (please recheck the sentence and reframe it) as well as post harvest storage strategies [1]. Plant diseases lead to a range of direct and indirect losses, including diminished crop appearance, reduced production efficiency, health risks and environmental contamination. Disease producing factors jointly undermine crop productivity, disrupt natural resources and limit the viability of disease management strategies, often leaving less profitable options as the only recourse [2].

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Synthetic fungicides and pesticides have been used haphazardly, resulting in a variety of environmental and toxicological consequences for human health. Although chemical control of most fungal plant diseases is available and could dramatically reduce the impact of crop diseases, field application of synthetic fungicides is not always desirable. However, they are not only cost prohibitive, but they also have the potential to harm the environment and human health in all parts of the world, while, this can also contribute to the development of resistance in pathogenic fungi to commonly used fungicides. The widely use of synthetic fungicides had a deleterious impact on crops, beneficial organisms, predators and parasites [3].

Botanical pesticides are natural plant products that are being used to control microorganisms that cause plant and human diseases. Recently, there has been increased interest in using higher plant products as novel chemotherapeutants in plant protection in different areas of the world. Botanical pesticides are regaining popularity and some plant products are being used as bio-pesticides around the world. It is becoming increasingly important to use bio-control agents and botanicals to replace the excessive use of pesticides. Plant products are environmentally sustainable, cost effective, and easily biodegradable. In addition, botanicals are natural in origin and have little or no adverse effect on plant physiology and physiological processes of plants and can be easily converted into ecologically phytochemical compounds. As an alternative to synthetic fungicides, they are useful for plant disease management [4]. The ultimate goal should be to implement sustainable agricultural systems in order to preserve natural resources and planet earth, including all of its life forms [5].

Recent research in this area has had the ultimate goal of developing alternative control strategies to reduce reliance on synthetic fungicides. There are different plant products such as plant extract, gums, essential oils, resins, etc., that have been shown to have biological activity against phytopathogenic fungi both *in vitro* and *in vivo* and can be used as botanical pesticides [6]. Plants can make aromatic secondary metabolites such as phenols, phenolic acids, quinones, flavones, flavonoids, flavanols, tannins and coumarins [7]. Carvacrol, eugenol and thymol, which have phenolic structures, were highly active against the pathogen. These compounds have antimicrobial properties and act as plant defense mechanisms against pathogenic microorganisms [8]. Thousands of phytochemicals with inhibitory effects on all types of microorganisms *in vitro* should be tested *in vivo* to determine their efficacy in controlling disease incidence in crops, plants and humans.

2. BOTANICALS

Botanical pesticides are disease killers derived from plant extracts. These are the plant component which are toxic to various pathogens. Botanical pesticides are environment friendly, target specific, financially viable and biodegradable. These are safer for both the user and the environment because they converted into harmless molecules in the presence of sun light within hours or days.

2.1 Sources and Study of Different Botanicals Against Plant Pathogens

2.1.1 Ash of different plant part

A field study conducted on evaluation of ash from some tropical plants of Nigeria for the control of *Sclerotium rolfsii* Sacc. on wheat (*Triticum aestivum* L.) [9]. Eleven ash samples from nine tropical plants were tested for their ability to inhibit mycelial growth and sclerotial germination of a Nigerian isolate of *S. rolfsii* on agar and in the soil. *In vitro*, ten ash samples inhibited the mycelial growth of *S. rolfsii* and concluded that the ash samples from *Delonix regia* stem wood, *Mangifera indica* and *Vernonia amygdalina* leaf were the most effective, completely inhibiting *S. rolfsii* mycelial growth *in vitro* (The sentence, start and end with the same words- Using it one time might be better). The germination of sclerotia on agar was suppressed by the ash from *Ocimum gratissimum* leaves, *Delonix regia* wood and *Musa paradisiaca* flower bracts. Nine ash samples shielded seeds from pre-emergence rot. *M. indica* leafash, *V. amygdalina* leaf ash and *Azadirachta indica* leaf ash all protected seedlings from post-emergence infection.

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2.1.2 Dust of *A. indica*

According to Prasad *et al.* [10], the cauliflower collar rot pathogen was tested using a dual culture technique, and the effect of four botanicals, namely eucalyptus leaf, neem leaf (dried), achook 0.3 percent (per cent) (azadiradione, nimbocinol and apinimbocinol) and neem dust 1, 2 and 3 per cent, on the growth of *Trichoderma harztanum*, (44.1%) isolate outperformed *T. viride* (39.1%) isolate in reducing *S. rolfsii* colony diameter. Neem dust, eucalyptus, and neem leaf extracts might be utilized in conjunction with *T. harzianum* in IDM of certain pathogens. Of the botanicals studied, achook strongly suppressed the growth of *T. harzianum*.

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2.2 Other Source of Botanicals Helps to Control Plant Disease

Table 1: Botanicals source with host

Plant sp.	Photos	Part used	Preparation	Effective against	References

Datura/thorn apple (*Datura stamonium),* *Calotropis procera* (Ait.) R. Br. and *Oscimum* spp.	 	Root, stem, leaf and flowers	Crude extract	*Curvularia lunata*	Manoharachary and Gourinath [11]
Turmeric (*Curcuma longa* Linn.) and Ginger (*Zingiber officinale* Rosc.)	 	Rhizome	Crude extract	*Phytopthora infestance, Fusarium solani*, and *Pyricularia oryzae*	Bandara *et al.*[12]
Purslane (*Portulaca oleracea* Linn.)		Leaf	Crude extract	*Helminthosporium maydis*	Noriel and Robles [13]
Neem/Margosa (*Azadirachta indica* A. *Juss*. (No Italics)), Sugar apple (*Annona squamosa* Linn.) and Holybasil (*Oscimum*	  	Leaf, stem, bark and root	Crude extract	Anthracnose of pepper	Nduagu *et al.* [14]

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sanctum Linn.)					
Hena (*Lawsonia inermis* Linn.)		Leaf	Crude extract	*Dreshslera oryzae*	Natarajan and Lalithakumari [15]
Garlic (*Allium sativum* Linn.) and Datura (*D. stramonium* Linn.)	 	Bulb and leaf	Ethanol extract	*Curvularia lunata*	Upadhyay and Gupta [16]
Spearmint (*Mentha spicata* Linn.), Greek Sage (*Salvia fruticosa* Mill.) and *Thymbra* spp.	  	Leaf	Essential oil	*Rhizoctonia solani*, *Sclerotium sclerotiorum*	Yegen *et al.* [17]
Spanish flag (*Lantana camara* Linn.)		Leaf	Crude Extracts	Castor grey rot (*Botrytis ricini*)	Bhattiprolu and Bhattiprolu [18]

Neem/Margosa (*A. indica*)		Seed and leaf	Crude Extracts	Early blight of tomato	Patil *et al.* [19]
Madar (*Calotropis procera* (Ait.) R.Br.		Leaf	Crude Extracts	Tikka leaf spot disease of groundnut	Srinivas *et. al.* [20]
Neem/margosa (*A. indica*)		Seed	NSKE	Powdery mildew of pea	Surwase *et al.* [21]
Neem/margosa (*A. indica*)		Leaf	Achook formulations	Sheath blight of rice	Kandhari [22]
Neem/Margosa (*A. indica*)		Seed kernel	Neem oil	Rice tungro virus	Muthamilan and Revathi [23]
Neem/Margosa (*A. indica*)		Leaf and seed	Achook, Neemazal	Bacterial blight of rice	Sunder *et al.* [24]
Oregano (*Origanum heracleoticum* (weed species)		Leaf	Essential oils	*Fusarium oxysporum* and *Phoma tracheiphila*	Salomone *et al.* [25]
Indian aloe (*Aloe barbadensis* Mill.) Neem/Margosa (*A. indica*)	 	Leaf	Crude extracts	Dry rot of yam *F. oxysporum*	Taiga [26]

and Tobacco (*Nicotiana tabacum* Linn.)					
Lemon grass (*Cymbopogon* spp.) and Thyme (*Thymus vulgaris* Linn.)	 	Leaf and root	Volatile compound	Black mould disease on onion bulbs (*Aspergillus niger*)	Abd-Alla [27]
Brassica napus and Tomato (*Lycopersicon esculentum* Mill.)	 	Leaf and stem	Water extract	Bacterial disease on onions	Kowalska and Smolinska [28]
Malabar nut (*Adhatoda vasica* L.)		Leaf, Root, Bark, Fruit and Flower	Aqueous, Ethanolic, Methanolic extraction	Bacterial blight of rice	Madhiazhagan *et al.* [29]
Onion (*Allium cepa* Linn)		Seed	Steam distillation	Early and late blight of tomato and potato	Ponnanna and Adiver [30] and Abd-El-Khair and Haggag [31]

3. MODE OF ACTION OF DIFFERENT BOTANICALS

Studies on the mechanisms of disease suppression by plant products have suggested that active principles in them may either act directly on the pathogen [32] or induce systemic resistance in host plants, resulting in reduced disease development [33, 34]. On the other hand, Jorgensen *et al.* [35] discovered that extracts from some plant species appear to act very differently, as they do not inhibit spore germination (*Venturia inaequalis*) on glass slides but reduce symptoms when applied to apple seedlings. Such plant extracts may act as resistance inducers in apple seedlings by activating natural defense systems.

Table 2: Mode of action of botanicals

Plant source	Photos	Active Compounds	Target Site	Mechanism ofAction	References
Haloxylon salicornicum		Nicotine	Nervous system	It competes with the neurotransmitter by attaching to acetylcholine receptors (nAChRs) at neuronsynapses, producing unregulated nerve firing. The disturbance of normal nerve impulse performance caused physiological systemmal functions of the neurons	Akaike *et al.* [36]; Blotnick-Rubin and Anglister [37]
N. tabacum					
Stemona japonicum					
Lonchocarpus spp.		Rotenone	Mitochondria	Cell respiratory enzyme inhibitor disrupts cellular metabolism, reduces ATP output. Nerve and muscle cell malfunctions lead to low feeding rates	Casida and Durkin [38]; Ware and Whitacre [39]
Derris spp.					
Cedrus spp.,		Essential oils	Octopaminergic system	Increase the level of intracellular messenger and effectively inhibitcyclic AMP of abdominal epidermal tissue	Rattan [40]; Kostyukovsky *et al.* [41]
Pinus spp.					

Citronella spp.,					
Eucalyptus spp.,					
A. indica		Azadirachtin, Nimbin, Salannin, Melandriol	Endocrine System	Inhibit Prothoracicotropic hormone (PTTH); distort phagostimulant disruptor by cholinergic transmission	Nisbet [42]; Laxmishree and Singh [43]
S. officinale		Cevadine, Veratridine	Mitochondria	Interrupt nerve cell membrane process, induced nerve cell membrane, paralysis, and mortality	Pavela [44]
A. squamosa		Squamocin (annonin), Debitterizedannona oil	Mitochondria	Dunnione acts as insecticide and fungicide, disrupting mitochondrial complex III	Pavela [44]

3.1 Direct Actions of Botanicals

The majority of plant extracts that have an effect in the plant assay also have a moderate to strong effect on conidium germination in the glass slide test, indicating that their primary modes of action are fungistatic or fungicidal. Chauhan and Singh [45] discovered a fungistatic effect of achook (neem product) against mycelial growth of *Phytophthora drechsleri* f. sp. *cajani* (Phytophthora blight of pigeonpea) at a concentration of 24 µg/ml, while achook and reptlin were fungicidal at a concentration of 48 µg/ml. Similarly, Sharma and Tripathi [46] revealed that treating *A. niger* with essential oil extracted from the epicarp of *Citrus sinensis* causes distortion and thinning of the hyphal wall, as well as a reduction in hyphal diameter and the absence of conidiophores, using scanning electron microscopy.

3.2 Induce Systemic Resistance Through Botanicals

Plant products contain biologically active compounds that act as elicitors, inducing resistance in host plants and reducing disease development [47]. There have been several reports of plant extracts inducing resistance in plants [48]. Aqueous extract of healthy barley leaves induced the formation of papillae, which provides resistance to powdery mildew in barley seedlings [49]. Similarly, Doubrara *et al.* [50] discovered that treating cucumber first leaves with spinach extracts induces resistance to *Colletotrichum orbiculare*. According to Chakraboty *et al.* [51], foliar application of *Cathranthus roseus* aqueous extract induced a high level of three defense enzymes (â - 1, 3-glucanase, chitinase and phenylalanine ammonia lyase) in tea plants, as well as rapid and distinct accumulation of phenolics, which leads to a reduction in disease incidence (foliar blight of tea). Similarly, barley treated with *A. indica* leaf extract resulted in the induction of protection against the pathogen *Drechslera graminea*, which involves the accumulation of proteins in the intercellular spaces and the treated leaf exhibited significantly high activity of enzymes PAL, TAL, as well as rapid accumulation of fungitoxic phenols [52]. Following application of *Datura metel* leaf extract and challenge inoculation with either *Rhizoctonia solani* or *Xanthomonas oryzae pv. oryzae*, rice plants showed induction of peroxidase, PAL, chitinaseand â-1,3-glucanase [53]. There is a link between the improved activities of chitinase, â-1,3-glucanase, PO, polyphenol oxidase (PPO), PAL and lysozyme in cucumber and tobacco leaf after treatment with *Reynoutria sachalinensis* leaf extract and resistance induction [54]. According to Singh and Prithviraj [55], neemazal, a neem product (5% azadiractin solution), induced resistance in pea (*Pisum sativum*) against *Erysiphe pisi* and disease development was associated with increased PAL activity in pea leaf following neemazal treatment. These enzymes induce apoptosis pathogens and may also cause the development of a toxic barrier against subsequent fungal attack [56].

4. CONCLUSION

Crop protection is a complex process for suppressing of disease causing organisms, for that necessitates to understanding of (change wordings) the interactions between the environment, farming methods and the dominant cultivation system. As a result, crop protection cannot consist of a single measure, but rather of a suitable combination of methods (IDM approach) based on crop, climate and region. The use of botanical pesticides is one such method that fits well in IDM strategies to achieve and maintain good crop health and has become increasingly important in modern agriculture. Plants contain thousands of constituents that could be a rich source of novel and biologically active antimicrobial compounds. According to research on disease suppression by plant products, the active principles found in them may either act directly on the pathogen or induce systemic resistance in host plants. More research in this area has the potential to increase the utility of natural plant products or botanical pesticides in crop production systems. Recent advances in the

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development of botanical pesticides provide opportunities for the worldwide use of botanicals as alternatives to more hazardous and environmentally unacceptable chemical insecticides, as well as for inclusion in integrated disease management programs. Botanical pesticides combined with other plant disease management practices can reduce health risks and costs due to chemical poisoning and environmental damage, improve export earnings by lowering chemical residue levels on export commodities and provide additional benefits by preserving natural enemies in crop systems and indigenous bio-diversity. Scientific efforts should be made to document the plants that contain antimicrobial compounds and to investigate the biocontrol efficacy of plant diseases in plant products. Field trials are required to assess the practical applicability of botanical pesticides, which should be combined with other plant disease management strategies. To determine their toxicity to humans, animals and crop plants, biosafety studies should be conducted.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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