International Journal of Innovative Research in Computer Science & Technology (IJIRCST)
ISSN: 2347-5552, Volume-10, Issue-2, Mar 2022
https://doi.org/10.55524/ijircst. 2022.10.2.68
Article ID CST1039, Pages 336-341
www.ijircst.org

Plant Phyto-Chemicals as Plant-Producing Fungal Agents: A Review

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ABSTRACT- Plant fungus destroys vast swaths of agriculture. Fungus has been connected to a number of plant-based illnesses, posing considerable economic challenges. Plant fungus seeks to get beyond the plant's immune system by activating PAMP-triggered immunity (PTI) and effector triggered immunity (ETI) defense. Successful infections, on the other hand, may override plant PTI and ETI, using pathogenic genes to defeat the host plant's R-resistance genes, resulting in severe plant diseases. Fungus spores tend to land on plant surfaces in order to germinate, which requires perfect conditions such as moisture, nutrients, and a suitable host. If the conditions aren't right, it may still exist even if it's dormant. Chemical fungicides have been used for many years, however there have recently been indications that they are ineffective against emerging fungal strains. Furthermore, chemical fungicides are not biodegradable, posing a threat to the environment. This review attempted to offer a concise overview of plants that have anti-plant fungal properties. Because plant extracts include a variety of possible anti-fungal agents with various modes of action, the pesticide industry may be able to produce plant-based fungicides on a large scale.

KEYWORDS- Fungicides, Fungal diseases, Plant fungi, Phytochemicals, Phytochemicals.

I. INTRODUCTION

Plant fungus creates lots of damage in agricultural fields as they have evolved methods and techniques to assault any plant seeking nutrients and entrance very forcibly for its own development & expansion. Moreover these viruses may multiply either sexually &/or asexually & can overcome plant immune defences which in return impede plant development and causes severe harm. Fungus spores tend to land on plant surfaces in order to germinate, which requires perfect conditions such as moisture, nutrients, and a suitable host. If the conditions aren't right, it may still exist even if it's dormant[1][2][3].

Plant fungal infections use pathogen associated molecular patterns (PAMP) to bypass the plant's immune system, activating PAMP-triggered immunity (PTI) and effector triggered immunity (ETI) defense. Successful infections, on the other hand, may override plant PTI and ETI, using pathogenic genes to defeat the host plant's R-resistance genes, resulting in severe plant diseases. Regarding disease producing potential of fungal spores they may have a limited or a wide host range. Interestingly a single plant may be a host for numerous fungal diseases with the fungal spores being transported by air or by birds, insects etc[4][5].

Depending upon the method of infection, the plant funguses are categorized into necrotrophs, hemibiotrophs & biotrophs. Biotrophs lives on the host's living tissues via the use of appressorium & haustoria. They have a limited host range for example, rust fungus etc. Necrotrophs kills their hosts since they need to finish their lifespan in dead tissues by generating poisons. One toxin is host specific for example generated by Cochliobolus carbonum and wide spectrum toxins produced by Botrytis cinerea, Sclerotinia sclerotiorum. Hemi-biotrophs utilizes the mechanism of biotrophs to infect and the method of necrotrophs to kill their hosts[6][7][8].

Plant funguses caused illnesses like rusts and smuts in cereals, powdery mildews in grape which not only destroys the crop-fields but also impacts the human economic situation. Plant funguses causes damages during post-harvest processing such as during shipping, storage etc. Nearly 100 fungal species infect and destroy post-harvest products for example Botrytis cinerea infects grapes, peers etc., B. allii infects onions and garlic, Penicillium italicum causes green rot in citrus, Penicillium expansum causes blue rot in peers, Penicillium glabrum & Penicillium funiculosum in onion whereas Colletotrichum destroys stored fruits. Mycotoxins are produced by moulds and while they play no role in fungal growth yet they are harmful to vertebrates. Mycotoxin associated illnesses are caused Aspergillus, Penicillium sps. and they generate toxins such as aflatoxins, trichothecenes, zearalenone, ergot alkaloids etc. In Table 1, the different fungal disease affiliating crops have been listed[9][10].

Table 1: Some examples of plant fungal diseases, the crops they affect and the part that is affected by them. Such diseases prove to be a great burden for the food security of a nation[11][12][13].

Crop produce	Part that is affected	Fungal disease
Fruits	Leaf, fruit, stem	anthracnose
Mango	Leaf, fruit, stem	anthracnose
Grape	Leaf, fruit, stem	Powdery mildew
Pomegranete	Leaf, fruit, stem	Downey mildew
Vegetables		
Beans	Leaf	anthracnose
Bengal gram	Leaf	Powdery mildew
Soybean	Leaf	Downey mildew
Sunflower	Leaf	Rust
Tomato	Leaf	Late blight
Cash crops		
Chilli	Leaf, fruit, stem	anthracnose
Cotton	Leaf, fruit, stem	Powdery mildew
Sugarcane	Leaf, fruit, stem	Downey mildew
Cereals		
Jowar	Leaf	Leaf blight
Wheat		Leaf spot
Maize		Powdery mildew

II. LITERATURE REVIEW

M. Zaker in his study discloses about the chemical pesticides that continue to be used to manage different plant diseases. While plant diseases may be managed with the use of chemical fungicides, the dangerous effects on human health and the environment of such chemicals are well recognised. In addition, pest resistance may be present with their excess treatments. Natural plant compounds are proven helpful in the treatment of plant diseases and may be safely integrated into synthetic fungicides as appropriate alternatives[14][15][16].

In another research, Mehdi Behdani studied the antifungal efficacy of 13 medicinal plant essential oils against apple gray mold using a pour plate approach and the formation of volatile compounds. The data demonstrated that essential oils of Anise, Cumin, Caraway, Ammin, Pennyroyal, Thyme, and Cinnamon had a significant influence against Botrytis cinerea on PDA culture in pour plate method at all concentrations of 250, 500, and 750 microliters per liter. Cumin, Ammin, Pennyroyal, Dill, Cinnamon, Anise, and Caraway essences had the greatest inhibitory influence, while the others had a little fungistatic effect, according to the volatile compounds creation approach. The findings also revealed that the antifungal activity against B. cinerea increases in lockstep with increasing plant essential oil concentrations[17][18].

The usefulness of eight plant extracts (garlic, clove, garden quinine, Brazilian pepper, anthi mandhaari, black cumin, white cedar, and neem) in treating wheat leaf rust disease was examined in vitro and in vivo, according to Yasser M.Shabana. All treatments decreased spore germination by over 93 percent in vitro. Neem extract suppressed spore germination by 98.99 percent, with no discernible difference from the fungicide Sumi-8 (100 percent). (A hundred percent) Seed soaking in neem extract (at a dosage of 2 ml/L) resulted in a 36.82 percent reduction in the number of pustules/leaf under greenhouse conditions as compared to untreated controls[19][20].

III. DISCUSSION

A. Control of plant pathogen

Various fungicides are used to prevent plant fungal invasion, however they are harmful to humans and have detrimental effects on soil organisms and plant pollinators. Natural origin fungicides are becoming more popular as a result of these characteristics[21][22].

B. Inducing resistance against fungi

The use of plant defense compounds to generate resistance to plant funguses is known as natural resistance. Salicylic acid and its analogs, for example, are employed to create systemic acquired resistance in sick crops. Wheat crops are protected from fungal infection with 40 g of benzo (1, 2, 3) thiadiazole-7-carbothioic acid S-methyl ester (BTH). Jasmonic acid and its derivatives enhance resistance in diseased plants while also promoting the manufacture of compounds that have health benefits. Methyl jasmonates prevent B. cinerea from infesting strawberries and P. digitatum from infesting 'Marsh Seedless' grapefruit after harvest. Furthermore, natural compounds such as propolis, chitosan, and others give resistance to plant funguses[23].

C. Fungicides

Since 1800s when the first chemical fungicides were employed, the chemical fungicides have been been used to prevent plant fungal infection. Though successful for many years nevertheless fungal resistances have developed and they are harmful to soil health and to the organisms helpful to the crops. Moreover since these fungicides are not bio-degradable thus they stay the soil or in water bodies giving geno-toxicity to everyone[24].

D. Biological control

As a result, in order to combat the bad effects of chemical fungicides, the world is now focused on the use of biological agents, which are made up of substances derived from natural biological sources. GiloGard (Gliocladium virens – seedling diseases of ornamentals and bedding plants), F-Stop (Trichoderma harzianum – numerous soilborne diseases), and other biological products are available[14].

E. Using plant extracts

Though many papers have been published regarding the in vitro anti-plant-fungal role of plant extracts using agar diffusion assay but many antifungal phyto-chemicals are mostly non-polar that do not permeate efficiently in the agar medium therefore it becomes difficult for it to be applied on croplands. The tetrazolium violet test that was utilized for evaluating the antibacterial function of plant extracts has been used for plant fungal inhibition as well. By this technique, the plant extract's minimum inhibitory concentration (MIC) against plant fungus are being determined. Moreover, the amount of anti-plant-fungal phytomolecules may be determined by Bio-autography. When acetone was employed as a solvent for extraction the yield of phytochemicals and their antifungal effectiveness was significantly greater as compared to water[25].

Many essential oils from plant origin inhibit post-harvest plant fungal infections & mycotoxin formation thus extending the shelf-life of stored crops. Some plants generate a range of antimicrobials (e.g. phytoanticipins & phytoalexins) (e.g. phytoanticipins & phytoalexins). The benefit of plant extract being used as an anti-plant-fungal agent is it is rich in chemicals which not only works on various fungi but also has diverse mode of actions thus avoiding the development of fungal resistance. For example 7-geranoxy coumarin extracted from Citrus paradis has shown antifungal function against P. italicum & P. digitatum. Phenolic substances like phenol, chlorogenic acid etc. suppresses the causative agent of sweet potato's Java black rot; Botryodiplodia theobroma. Similarly, Kaempferol extracted from Acacia nilotica inhibits P. italicum.

Nearly seven invasive plant species from South Africa have been shown to be effective against Aspergillus niger, Colletotrichum gloeosporioides, and other fungi. The leaf extract of Campuloclinium macrocephalum suppressed Colletotricum gloeosporioides. In Table 2 & 3, the anti-fungal property of plants has been listed. The chemical structure of different families of phytochemicals with their members have been shown in Figure 1 and the chemical structure of certain additional anti-plant fungal metabolites has been presented in Figure 2.

The primary aim of this study is to give a short summary of the phytomolecules that were reported to have anti-plant fungal activity with the idea that such plants and their components may be utilized for the commercial manufacture of plant based plant fungicides[17].

Table 2: Anti-plant fungal properties of some plants. Such plants may itself be resistant to the action of the tabulated fungus & thereby may become a source for anti-plant fungus by itself[23]

Plant fungi	**Plant(compound)**
Aspergillus candidus	Acacia, datura
Alternaria alternata	Extracts of Lavender & Eucalyptus
Aspergillus niger	Clove bud, extract of garlic
Fusarium oxysporum	Extracts of Neem, garlic
Fusarium solani	Artemisia extract
Alternaria solani	Extract of turmeric
Rhizopus stolonifer	Kolkum extract
Botrytis cinerea	Grape seed
Alternaria alternata	Anise
Phytophtora nicotiane	Pepper
Fusarium moniliforme	Citral
Botrytis cinerea	Carvacrol, menthol

Table 3: Mode of action of anti-fungal phytochemicals. These phytochemicals can be exploited further use by the pesticide industry[6]

Mechanism of anti-fungal activity	**Compound**
Membrane disruption	Simple phenols
Adhesin binding	Phenolic acids
Membrane disruption	Terpenoids
Membrane disruption	Essential oils
Cell wall intercalation	Alkaloid
Protein binding	Tannins
Adhesin binding	Flavonoids
DNA interaction	Coumarins
Disulphide bridge formation	Lectins
Disulphide bridge formation	Polypeptides

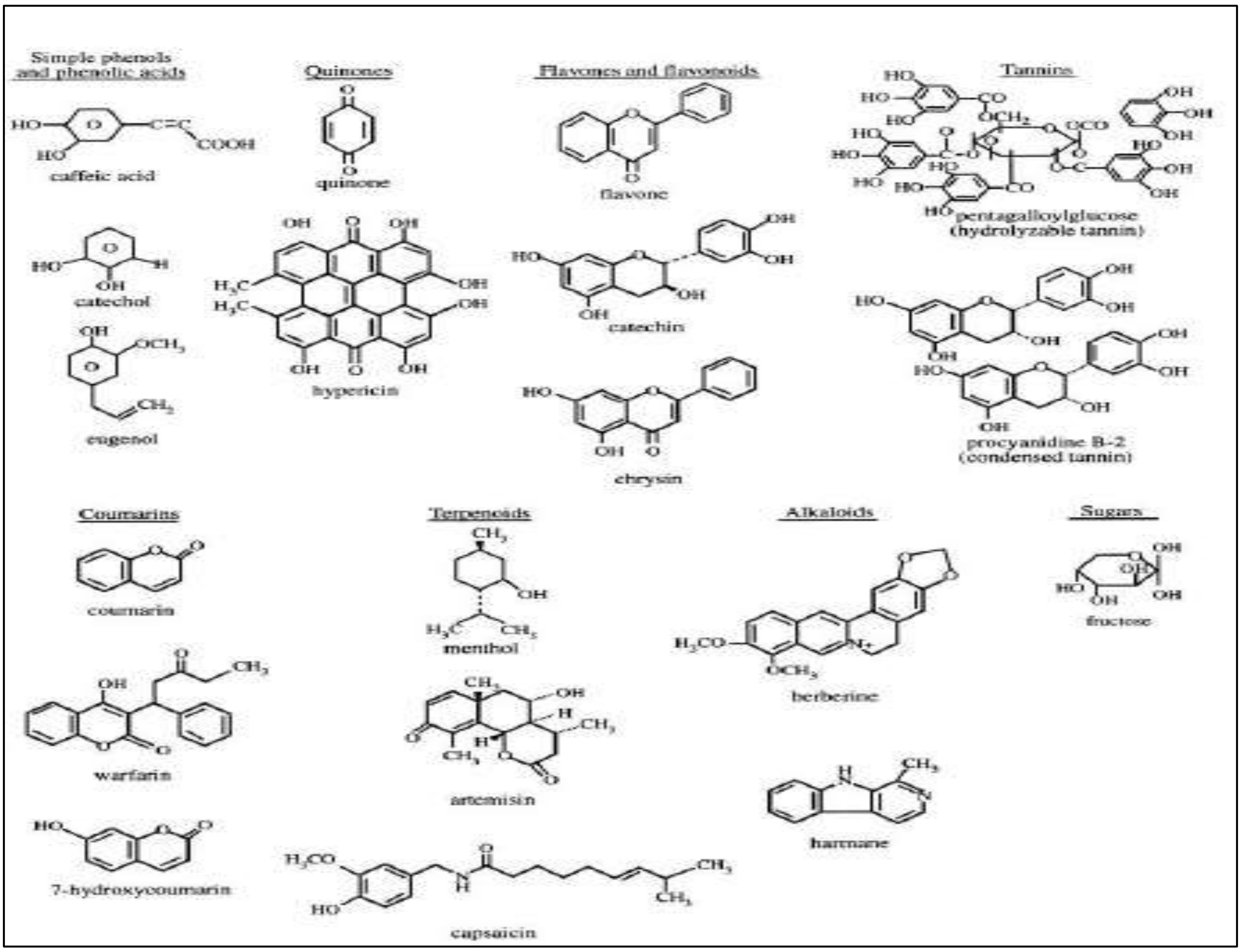

Figure 1: Chemical structures of main group of phytochemicals. They are divided into: Simple phenols & phenolic acids like Caffeic acid, catechol, eugenol. Quinones like quinone, hypericin, Flavones & flavonoids like flavone, catechin, chrysin, Tannins like pentagalloylglucose, Coumarins like coumarine, warfarin, 7-hydroxycoumarine, Terpenoids like menthol, artemisin, capsaicin, Alkaloids like berberine, harmane & Sugars like fructose Figure courtesy[17]

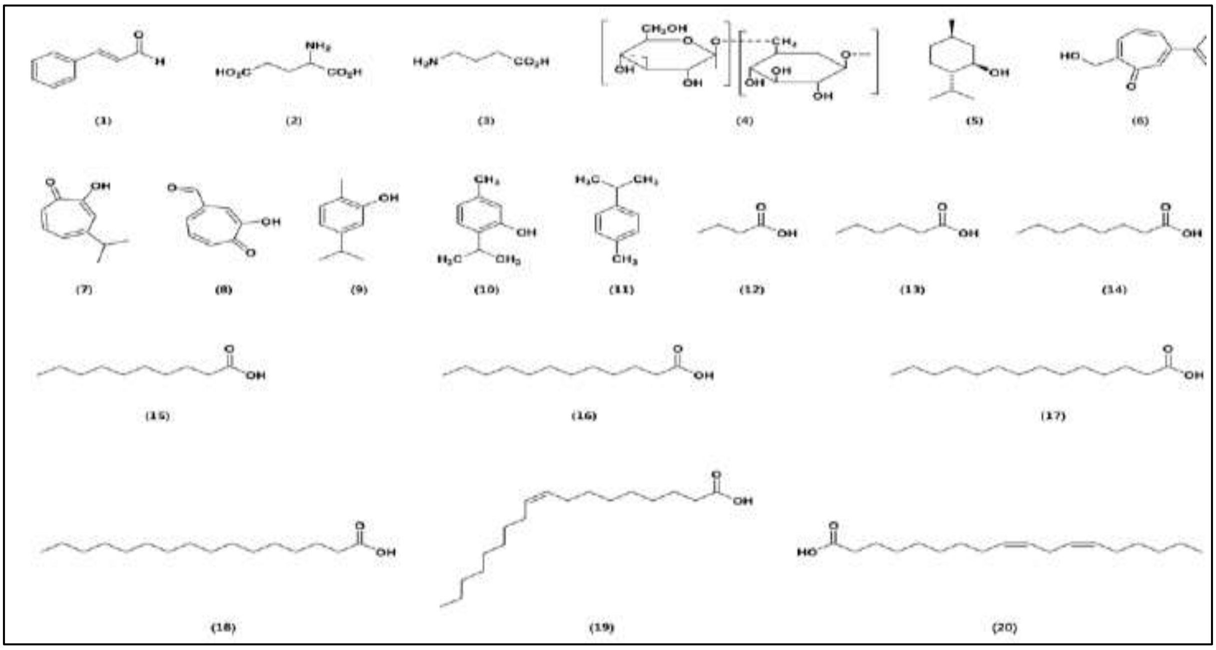

Figure 2: Chemical structures of some anti-plant fungal metabolites isolated from plants. The various numerical are indicative of the name of the compound whose chemical structure is represented here. (1) Cinnamaldehyde, (2) Gamma-aminobutyric acid (GABA) (3) Jojoba oil (4) Laminarin (5) Menthol (6) β-dolabrin (7) γ-thujaplicin (8) 4-acetyltropolone (9) carvacrol (10) thymol (11) p-cymene (12) butyric acid (13) caproic acid (14) caprylic acid (15) capric acid (16) lauric acid (17) myristic acid (18) palmitic acid (19) oleic acid (20) linoleic acid Figure courtesy[23]

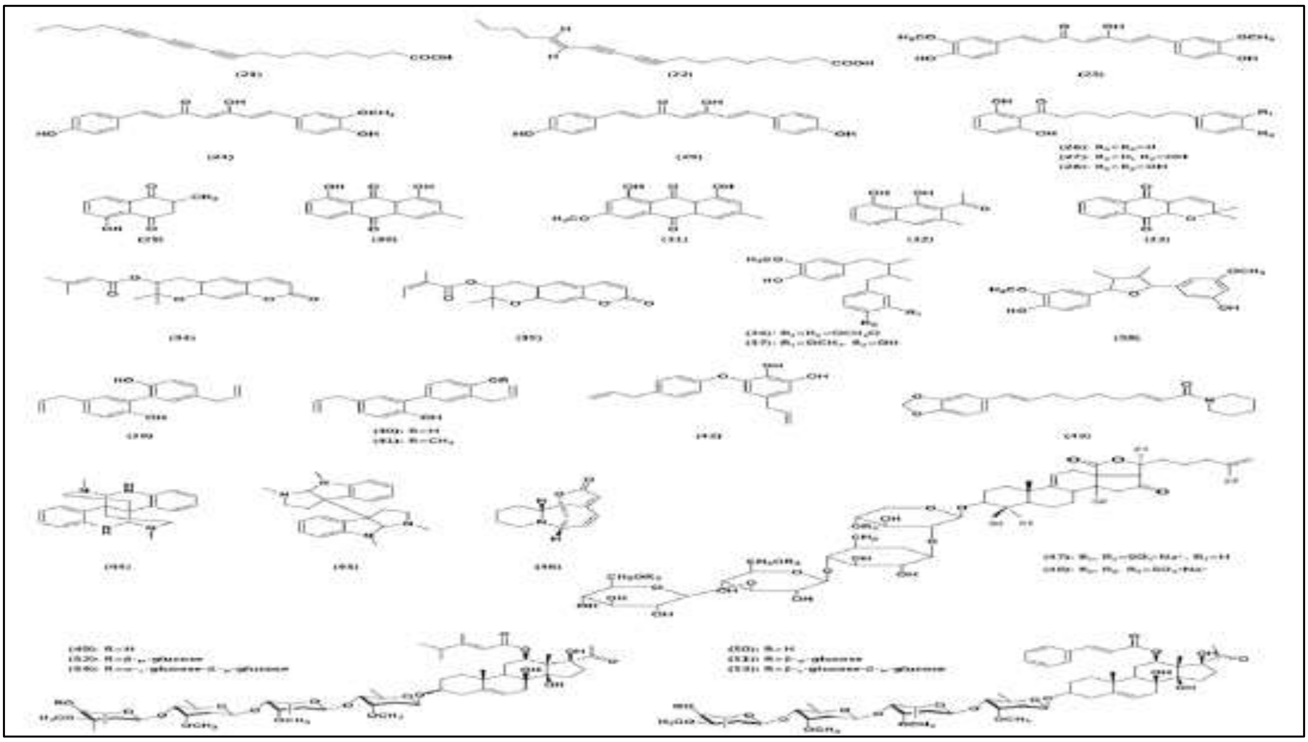

Figure 3: (continuation): Chemical structures of some anti-plant fungal metabolites isolated from plants. (21) octadeca-9, 11, 13-triynoic acid (22) trans-octadec-13-ene-9, 11-diynoic acid (23) curcumin (24) demethoxycurcumin (25) bisdemethoxycurcumin (26) malabaricones A (27) malabaricones B (28) malabaricones C (29) plumbagin (30) Chrysophanol (31) parietin (32) nepodin (33) Dehydro-α-lapachone (34) Decursin (35) decursinol angelate (36) erythroaustrobailignan-6 (37) meso-dihydroguaiaretic acid (38) nectandrin-B (39) magnolol (40) honokiol (41) 4-methoxyhonokiol (42) obovatol Figure courtesy[17]

IV. CONCLUSION

Plant fungus destroy enormous swaths of agriculture. Many plant-based epidemics have been linked to fungus, resulting in significant economic losses. Plant fungus that are successful employ their genes to fight the host plant's R-resistance genes, producing severe plant diseases. Chemical fungicides have been used for a long time, however they are no longer effective against new fungal strains. Furthermore, chemical fungicides are hazardous to the environment since they are non-biodegradable. This review attempts to provide a quick summary of plants that have anti-fungal properties.

Plants create a large number of phyto-molecules with biological functions. These plants resemble either plants that are resistant to a certain fungal type or plants that are invasive. Plant extracts have a wide range of possible antifungal properties, and the pesticide industry might create plant-based fungicides on a large scale.

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