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Review Article

Biorational Approach: An Alternative Approach to Control the Wilt Diseases of Crops

Ritwik Sahoo*

MSc, Student, Department of Plant Pathology, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India

***Corresponding Author:** Ritwik Sahoo, MSc, Student, Department of Plant Pathology, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India.

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Abstract

Wilt diseases are one of the most severe diseases which vigorously cause losses in various crops like-tomato, brinjal etc. Wilt disease is caused by fungi, bacteria and virus also and can be induced by nematode also. Therefore, wilt disease is a major problem in all over the world. The severity of fusarium wilt in brinjal is 10%-90% [27,36] and for bacterial wilt fruit yield is reduced by 20%-30% [5] in brinjal Although chemicals are broadly used to control these wilt diseases, but because of growing concerns about health and environmental safety, the use of toxic, carcinogenic, and/or environmentally damaging chemicals are being discouraged. These chemicals leave toxic residues in consumable agricultural commodities. The survey of monitoring of farm-gate samples in different parts of the country recorded pesticide residues above Maximum Residue Limit (MRL) [19,23]. So, novel strategies including biorational approaches against these wilt diseases are needed for their sustainable management. Antagonistic microorganisms, such as fungi and probiotic bacteria from diverse taxonomic genera were found to suppress wilt diseases both *in vitro* and *in vivo*. Various classes of secondary metabolites, such as alkaloids, phenolics, and terpenoids of plant and microbial origin and various plant origin substances significantly inhibit the causal organisms and are also effective in managing the wilt diseases. Besides these organic amendments are also helpful to control these wilt diseases as they are commonly soil borne in nature. Common mode of action of biocontrol agents include-induced resistance, mycoparasitism, antibiosis, antibiotic production, induced systemic resistance and competition. Mechanism of organic amendments include-modification of physico- chemical environment of soil in host favour, pathogen eradication by direct antagonism and decomposition products and microbial metabolites effects. Mode of action of botanicals include-reaction with various enzymes and complex materials in cell wall or membrane. There is proof of control of bacterial wilt by *Pseudomonas sp*. [11] as well green manure derived from medicinal plant [18] and Cinnamon oil [22]. Therefore, these biorational approaches will become very helpful if we use them more commercially than chemicals, this review updates our knowledge in this perspective.

Keywords: Wilt; Biorational; Induced Resistance; Mycoparasitism; Antibiosis; Induced Systemic Resistance

Introduction

The global agricultural production sustains annual loss of about 20 to 30% on an average due to plant diseases on various crops in different countries. Occasionally, the losses rise even to 100% in the most favourable circumstances or when no control measures are taken in case of some important diseases [16]. Wilt diseases are one of the most severe diseases which vigorously cause losses in various crops like-tomato, brinjal etc. As an example the severity of fusarium wilt in brinjal is 10%-90% [27,36] and for bacterial wilt fruit yield is reduced by 20%-30% [5] in brinjal.

There are various wilt diseases cause severe damages to the crops. It can be due to fungi, bacteria, virus and also can be induced by nematodes. The diseases show various types of symptoms by which we can identify them and go for suitable measures. In Fusarium wilt, the underground stems become dry and brown as a result of cortical decay while roots may have soft and water soaked appearance, stunted growth. One of the first signs of verticillium wilt is the yellowing of older leaves, then yellow changes to brown and then the leaves die. The disease also causes discoloration of vascular tissue, which we may see as brown streaks up the stems of the plants. This discoloration may also be patchy. In bacterial wilt wilting of the foliage is shown followed by collapse of the entire plant. The wilting is characterized by dropping and slight yellowing of leaves and vascular discolouration. Milky white bacterial oozes coming out which is the diagnostic symptom for bacterial wilt when infected stem cut and dipped in water. In case of tomato spotted wilt on approaching the plant, we may notice that the newer foliage has a bronze or purplish tinge to it or it may even die back. Sometimes the plants are stunted or look wilted. Leaf symptoms may first appear as small, light brown flecks. The fruit is usually infected also and may exhibit raised circular areas, sometimes ringed with small brown spots.

Synthetic chemicals may be used in plant protection programs to limit crop damage by pests and pathogens. But because of growing concerns about health and environmental safety, the use of toxic, carcinogenic, and/or environmentally damaging chemicals are being discouraged. These chemicals leave toxic residues in consumable agricultural commodities. The survey of monitoring of farm-gate samples in different parts of the country recorded pesticide residues above Maximum Residue Limit (MRL) [19,23]. That's we should focus on biorational approaches for management of plant diseases. In this review we focus on various biorational approaches to control the wilt diseases of crops.

Relevance

Wilt diseases of different crops commonly fusarium wilt and bacterial wilt are now a global concern as they severly effect the various crops. Biorational measures can be the alternative measures of it. Though it is a subject of research for decades but has not yet been adequately commercialized. Hence, mechanism and their efficiency should be highlighted as a control measures of wilt diseases. Due to the development of fungicide resistance to pathogens as well as ecological and public health considerations, the number of available fungicides is reduced day by day. In addition, the industry is facing rising costs of development and the sale of new disease control products. For these reasons, there is a growing need for the development of another disease management products, which can provide a friendly environment and possible economic control of important plant diseases.

Biorational approach

Biorational agents are designating or relating to pest, disease and weed control agents used because of their specific effects upon the organisms they are intended to control, rather than because of their toxicity or other general effects; employing or involving such agents. These Approaches includes various techniques and agents which are involved in pest and disease control without effecting the other organisms, environment as they are less toxic. As now a days the toxicity of chemicals largely affect the environment, as well as other organisms that are not harmful therefore, we should focus on these approaches.

The advantages of this approach include

- Biorational products can be used to reduce the environmental impact of farming.
- They are less toxic.
- They work in synergy with the plant's microbiome by feeding and/or not killing beneficial microbes.
- They can control the diseases effectively.
- They not only control the pests and diseases but also help the crop to get better nutrient and helps them for better growth [8].

Various biorational approaches to control the wilt theses are- Bio-Control Agents, Organic Amendments, Plant Origin Substances [1,4,9].

Bio-control agents

Biological Control Agent (BCA) can be defined as the use of natural efficient strains of any microorganisms or modified organisms that reduce the incidence or severity of diseases caused by plant pathogens. It exhibits an antagonistic activity toward a particular phytopathogen [6]. Microbial biocontrol agents (BCAs) for plant diseases are usually fungal or bacterial strains

isolated from the phyllosphere, endosphere or rhizosphere. They are commonly host specific, environment friendly and labor intensive [12].

Various fungal strains for biocontrol are-*Trichoderma sp., Gliocladium sp., Aspergillus sp., Fusarium sp., Beauveria sp.* Various bacterial strains are-*Pseudomonas sp., Serratia sp., Streptomyces sp., Rhizobium sp., Bacillus sp., Enterobacter sp.* [2,15,20,26,32,37].

Mechanism of biocontrol

- **Induced Resistance:** Biocontrol agents release various effectors, metabolites, enzymes like callose synthetase which activate the defense reaction of the host by different way like reactive oxygen species, PR proteins-PR1(anti oomycetes, antifungal), PR2(beta-1,3 glucanase), PR3(chitinase), PR4(antifungal), PR6(Proteinase inhibitor). Many compounds are secreted by the *Trichoderma sp.* into the zone of interaction and induce resistance in plants. Fungal proteins such as xylanase, cellulases and swollenins are released by *Trichoderma sp.* [25]. Another group of proteins that induce this mechanism in plants are avirulence-like (Avr) genes [38]. These are produced by a variety of fungal and bacterial plant pathogens. They usually function as race- or pathovar-specific elicitors of hypersensitive and other protection-related responses in plant species that contain the respective resistance (R) gene.
- **Mycoparasitism:** Hyper-parasitism is the maximum taken into consideration and the maximum direct form of antagonism. Hyper-parasitism involves tropic increase parasitism of bio manipulate agent toward the goal organism, coiling, very last attack and dissolution of target pathogens cellular wall or membrane with the aid of the activity of enzymes. Harman (2000) reported the involvement of chitinase and β-1,3 glucanase inside the *Trichoderma* mediated biocontrol management. Considering that enzymes are the merchandise of genes, slight alternate in the structure of gene can cause the manufacturing of various enzyme.
- **Antibiosis:** by antimicrobial proteins, metabolites like *Trichoderma sp.* produces unique peptaibols, which are peptide antibiotics which can produce pore in the cell membrane and cause programmed cell death. Many microorganisms produce and launch lytic enzymes that may hydrolyze a wide form of polymeric compounds, consisting of chitin, proteins, cellulose, hemicellulose, and DNA. Expression and secretion of these enzymes by way of specific microbes can now and again result in the suppression of plant pathogen activities immediately. Selvakumar and Srivastava, (2000) reported another antibiosis mechanism is by growth promoting activity. *Aspergillus niger* strain AN-27 was reported to produce growth promoting compounds, 2-carboxy-methyl- 3 -hexyl-maleic anhydride and 2 methyl ene-3- hexyl-butanedioic acid (hexylitaconic acid) that have been immediately answerable for extended root and shoot length and biomass of crop vegetation.
- **Competition:** From the microbial perspective, soils and residing plant surfaces are regularly nutrient confined surroundings. So, to colonize the phytosphere, a microbe ought to efficiently compete for the available vitamins [28]. Both the bio control agents and the pathogens compete with one another for the nutrients and space to get established inside the surroundings. Lorito., *et al.* (1994) reported this technique of opposition is taken into consideration to be an oblique interaction among the pathogen and the bio control agent, wherein the pathogens are excluded through the depletion of food base and through physical occupation of the site. Bio controls agents additionally compete with the pathogen for physical occupation of the sites and thereby lessen or postpone the foundation of the pathogen [21].

Figure 1: [21].

Besides these Induced resistance (Production of phytoalexin, PR proteins, lignification), Loon., *et al*. (2000) and Duiiff., *et al*. (1998) reported antibiotic production and competition are also the mechanisms of biocontrol.

Various fungal Strains with their targeted wilt diseases (Research Achievements)

Fungal Strains			
Bio-Control Agents	**Targeted wilt diseases**	**Host**	**References**
Trichoderma sp.	Bacterial wilt	Cotton	41
	Fungal wilt	Tomato	20
Gliocladium sp.	Fungal wilt	Tomato	20
Fusarium sp.	Fungal wilt	Tomato	20
Beauveria sp.	Fungal wilt	Capsicum	10

Table 1

Various bacterial Strains with their targeted wilt diseases (Research Achievements)

Bacterial Strains			
Bio-Control Agents	**Targeted wilt diseases**	**Host**	**References**
Pseudomonas sp.	Bacterial wilt	Tomato	11
	Fungal wilt	Tomato	32
	Spotted Wilt	Tomato	17
Serratia sp.	Verticillium wilt	Oilseed rape	26
Bacillus sp.	Fungal wilt	Tomato	15
Streptomyces sp	Fungal wilt	Tomato	3
	Fungal wilt	Tomato	42
	Bacterial Wilt	Tomato	42
Rhizobium sp.	Fungal wilt	Chickpea	31
Enterobacter sp.	Bacterial wilt	Tomato	39

Table 2

Various Commercial Products of Bioagents

Commercial Products		
Bio-Control Agents	**Product**	**Diseases**
Trichoderma sp.	Rootshield	Fungal wilt
Gliocladium sp.	Primastop	Fungal wilt
Fusarium sp.	Fusaclean, Biofox C	Fungal wilt
Bacillus sp.	Biostart	Root affecting Pathogen

Table 3

Organic amendments

According to Himanshu., *et al.* 2014) these are the composition of organic moieties usually derived from nature (residues, peat moss from peat bogs), or are the by-products of processing plants or mills (sawdust, cedar chips, bark, bagasse, rice hulls) or waste disposal plants (compost, processed sewage sludge, biosolids etc.). Organic Amendments include-Compost, Green Manure, Peat Moss, Fish Meal, Blood Meal, Feather Meal, Oilcakes (Neem, Castor etc.), Wood Chips and Shavings.

Sources

According to Nin., *et al.* (2016) and Larney., *et al*. (2012) there are various sources of organic amendments

- **On Farm Sources:** Bedding materials, Compost, Crop residue, Green manure, Silage juice, Weed biomass, Living mulch.
- **Off Farm Sources:** Sphagnum Peat Moss, Wood waste, Non-agricultural wastes (municipal biosolids, food and kitchen waste etc).

Other sources are

- **Agriculture Sources:** Livestock manure (fresh, composted), Crop residues, Spent mushroom compost
- **Forestry Sources:** Deinking sludges, Wood chips and Shavings, Wood ash
- **Urban Sources:** Municipal biosolids (sewage sludge, municipal sludge), By-products of food processing industry.

Mechanism of action

According to Sharma and Gupta, (2014) various mechanisms include

- **Disease Avoidance:** By modification of physico- chemical environment of soil in host favour
- **Pathogen eradication:** By decomposition products and microbial metabolites effects and through direct antagonism.

Figure 2: Possible Pathways of action of organic amendments against pathogen

Source: Chaube and Pundir, 2005.

Research achievements

Pathogen	Crop	Organic Amendment	Reference
Fusarium sp.	Several hosts	Vegetal Compost	40
Verticillium Dahliae	Brinjal	Horse manure, Municipal green waste, wood shavings	24
Ralstonia solanacearum	Tomato	Green Manure of the medicinal plant *Adhatoda vasica* (L.) Nees	18
Tomato Spotted Wilt Virus	Tomato	Alfa alfa straw	7

Table 4

Plant origin substances

Plant origin substances like-higher plants contain essential oils and a wide spectrum of secondary metabolites such as phenols, flavonoids, quinones, tannins, alkaloids, saponins and sterols. Such plant-derived chemicals may be exploited for their different biological properties. Because of their natural/ plant origin, they are biodegradable and do not usually leave toxic residues or by-products. Commonly used plant substances are get from-Neem (*Azadirachta indica* A. Juss), garlic (*Allium sativum* Linn.), eucalyptus (*Eucalyptus globulus* Labill.), turmeric (*Curcuma longa* Linn.), tobacco (*Nicotiana tabacum* Linn.) and ginger (*Zingiber officinale* Rosc.) [29].

Types

According to Gurjar., *et al.* (2012) there are various types of botanicals -

- **Plant Extracts:** Neem (*Azadirachta indica* A. Juss), garlic (*Allium sativum* Linn.), eucalyptus (*Eucalyptus globulus* Labill.), turmeric (*Curcuma longa* Linn.), tobacco (*Nicotiana tabacum* Linn.) and ginger (*Zingiber offi cinale* Rosc.).
- **Essential Oils:** Nettle oil (Urtica spp.), thyme oil (Thymus vulgaris Linn.), eucalyptus oil (Eucalyptus globulus Labill.), rue oil (Ruta graveolens Linn.), lemongrass oil [(*Cymbopogon flexuosus* (Steud.) Wats] and tea tree oil (*Melaleuca alternifolia*).
- **Gel and Latex:** *Aloe vera* (Tourn. Ex Linn.)

Some examples with their mode of action

Flavonoids-inactivate enzymes, form complex with cell wall, Phenolic acids-bind to adhesions, form complex with cell wall, inactivate enzymes, Phenolics-membrane disruption, substrate deprivation, Terpenoids, essential oils-membrane disruption, Alkaloids-intercalate with cell wall, Tannins-bind to proteins, inhibit enzymes, non-availability of substrate, Coumarins-interaction with eukaryotic DNA, Lectins and polypeptides-form disulphide bridges [29].

Research achievements

Pathogen	Botanicals	References
Fusarium sp.	Clove oil, Neem oil, Essential oil of mustard	[8]
Ralstonia solanacearum	Cinnamon oil from *Cinnamomum sp.*	[22]
Tomato Spotted Wilt Virus	Azadirachtin from Neem Plant	[30]

Table 5

Future prospects

As additional insights are gained regarding biorational approaches and the mechanisms, there is every reason to believe that the use of biorational approaches will likely control the wilt

diseases of plants and that can also increase food production without imposing any health hazard, and at the same time conserve the environment. It is essential that researchers continue to learn more about biorational approaches and, immediately, translate this knowledge into a form that can readily be used by farmers.

Conclusion

As chemicals for controlling diseases are toxic to environment, causes health hazards, adversely affect the beneficial microorganisms and if overused it losses its effectivity and as it is not easily degradable so their residues can also affect the same. So now we should focus on various biorational approaches. As we discuss here the effectivity, their mode of action and how they are advantageous than the chemicals. Therefore, we can come to conclusion that we should start the use of these approaches commercially as it will be beneficial for us, our environment and soil ecology. These approaches also indirectly or directly help in plant growth as well as increase the crop yield.

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