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Antipathic Compounds in Plant Disease Management

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ABSTRACT

Antipathic compounds are the non fungitoxic chemicals. They do not act directly on the pathogen but control the disease by inducing the host defence system. These compounds show little effect on the rate of growth of the pathogen in vitro but show more effect in vivo. These compounds are less likely to encounter problem of development of resistant strains than conventional systemic fungicides because they act by inducing general defense mechanism of host through production of phenols, peroxidases and phenylalanineammonia-lyases. Non-conventional chemicals, viz., Salicylic Acid (SA), Acetyl Salicylic Acid (ASA), DL-β - amino-n-butyric acid (BABA), gamma-amino-n-butyric acid (GABA), Amino-iso-butyric acid (AIBA), Indole-3–pyruvic acid (IPA), Indole-3–acetic acid (IAA), Nicotinic acid (NA), Isonicotinic Acid (INA), DL-Norvaline, Benzoic Acid and Cycloheximide, when applied as foliar sprays prior to Fusarium inoculations, mortality was reduced in chickpea. Soaking of soybean seeds in benzothiadiazole (BTH) @ 0.25g/l a.i. humic acid (HA) @4g/l a.i and their combination induced systemic resistance against Fusarium oxysporum under greenhouse conditions and protected soybean plants against damping-off and wilt diseases. 2, 6 dichloro isonicotinic acid (INA) @ 100mg/l and β-Amino butyric acid (BABA) @ 0.5g/l reduced the incidence and severity of purple blotch disease in onion and increased the bulb yield significantly over control. Similarly, application of silicon compounds protected cucumber against damping off, bell pepper from Phytophthora blight and rice from blast. However, these chemicals do not have broad spectrum activity and cause phytotoxicity at higher concentrations. They have to be applied prior to fungal infections for better control of diseases. They need to be evaluated against similar fungi in other crops and may be included in integrated disease management along with fungicides.

Key words: *Antipathic compounds, Plant pathogens, Disease control, Host defence*

INTRODUCTION

Plant diseases are one of the major factors limiting the productivity of agro-ecosystems. Lack of reliable chemical controls, occurrence of fungicide resistance in pathogens and breakdown of host resistance by pathogen populations are some of the reasons to develop new disease control measures. There are some chemicals which are not fungitoxic and do not act directly on the pathohgen. These are called Antipathic compounds.

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Antipathic compounds:

The group of chemicals which exhibit very poor or no antifungal activity *in vitro* condition, but provide protection to the plants against the disease by inducing the host defense system are called Antipathic compounds. The Antipathic compounds include Salicylic acid (SA), Jasmonic acid (JA), Probenazole, Fosetyl-Al, 2,2-dichloro-3,3-dimethyl cyclopropane-1- carboxylic acid (DDCC), Phenylthiourea (PTU), β-Aminobutyric acid (BABA), Benzothiadiazole (BTH), SiO_2.

Uses of Antipathic compounds:

- Low selection pressure.
- The compounds are effective at low concentration.
- Less development of resistant strains than conventional systemic fungicides.
- No environmental hazard.
- Side effects on microbial population in the environment are less.

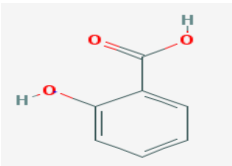
The list of Antipathic compounds and plant pathogens controlled by these compounds are given below[6].

ANTIPATHIC COMPOUNDS	PLANT PATHOGENS CONTROLLED
Salicylic acid	*Albugo candida, Alternaria brassicae, A. parasitica, A. solani, Cladosporium cucumerium, Perinospora parasitica, Venturia inaequalis .*
Jasmonic acid	*Alternaria parasitica, Erysiphhae graminis f. sp. hordei, Phytophthora parasitica, P. infestans, Verticillium dahliae*
Isonicotinic acid	*Colletitrichium lindemuthianum, Cercospora beticola, C. lagenarium,, E. graminis, Erwinia amylovora*
DDCC	*Magnapotyha grisea*
Beta amino butyric acid (BABA)	*E. graminis f. sp. tritici, Fusarium oxysporum f. sp. lycopersici , F. oxysporum f. sp. melonis, P. parasitica, Alternaria brasssicola*
Benzothiadiazole	*A. candida, A. brassicae, Cercospora nicotianae, Cladosporium cucumerinum, Erwinia caratovora, Rhizoctonia solani*
Fosetyl – Al	*Plasmopara viticola, P. capsici, P. cinnamomi*
Sio_2	*Pythium spp. M. grisea*
Probenazole	*M. grisea, Xanthomonas oryzae*

Efficacy of Antipathic Compounds in Plant Disease Management

Salicylic acid (SA):

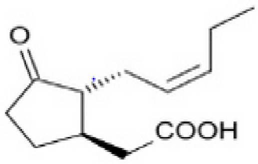
SA is obtained from the bark and leaves of the white willow plant (*Salix alba).* It has bacteriostatic, fungicidal, and keratolytic actions. Salicylic acid may function as plant growth regulator[2]. The application of salicylic acid (SA), acetylsalicylic acid (ASA) or other analogues of SA, to the leaves of corn and soybean accelerated their leaf area and dry mass production but plant height and root length remained unaffected[14]. It controls white rust of mustard, chickpea wilt, Alternaria leaf spot of cabbage, early blight of tomato, scab of cucurbits, downy mildew of mustard and apple scab. It regulates the activities of various enzymes such as peroxidase (POD), polyphenol oxidase PPO), superoxide dismutase (SOD), phenylalanine ammonia lyase (PAL) etc., which are the major components of induced plant defence against biotic and abiotic stresses.



Jasmonic acid:

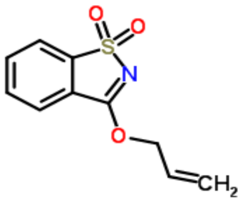
Novel plant immune hormone derived from α-linolenic acid. It is produced by certain fungi *(Lasiodiplodia theobromae).* It translocates through both xylem and phloem. Exogenous applications of JA and jasmonates not only act as important elicitors of grapevine immunity but also enhance grape and wine quality[20]. Jasmonic acid and Ethylene enhance Induced Systemic Resistance (ISR) in plants.

It controls Alternaria leaf spot of mustard, powdery mildew on barley, downy mildew of mustard, late blight of potato, Verticillium wilt of cotton.



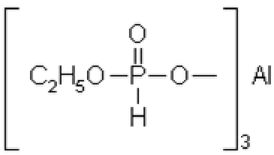
Probenazole:

It controls diseases like blast and bacterial leaf blight of rice. After application to rice plants, probenazole is absorbed by the roots and then systemically transferred to the whole plant, almost completely controlling leaf blast for 40 – 70 days after application. Pretreatment of probenazole increases the accumulation of SA& PR proteins in leaves of adult plants. It also increases the accumulation of peroxidase, phenylalanine ammonia lyase and catechol - o – methyltransferase in treated plants which acts as a lignoid barrier around invaded cells [23]. Despite extensive use over many years, development of resistance in the target fungus was not reported.



Fosetyl- Al:

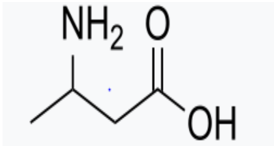
It controls Grapevine downy mildew and Phytophthora blight of Tomato. It translocates in both upward and downward movement inside the plant. Fosetyl-Al treatment enhances phenol accumulation and produces necrotic blocking (defense) reactions around infection sites on tomato leaves infected with *Phytophthora capsici*[4,8]. Fosetyi-Al also enhances production of antifungal stilbenes and flavanoids and reduces disease symptoms in grape leaves inoculated with *Plasmopara viticola* [17] **.** It inhibits spore germination and penetration of pathogen into the plant by blocking its mycelial growth and spore production. Also enhances the plant's own natural defense system against diseases.



β-Aminobutyric acid:

β-Aminobutyric acid (BABA) is an isomer of the amino acid aminobutyric acid with the chemical formula $C_4H_9NO_2$. It has two isomers, alpha-aminobutyric acid and gamma aminobutyric acid (GABA), a neurotransmitter in animals that is also found in plants, where it may play a role in signalling.

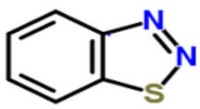
It controls diseases including powdery mildew of wheat, Fusarium wilt of Tomato and of melons, black shank of tobacco, Alternaria leaf spot of brassica. It enhances callose and lignin deposition around the point of infection, which act as a physical barrier in preventing the disease. Accumulation of pathogenesis-related proteins (PR proteins) involved in prevention of diseases was also observed in some BABA treated plants. Foliar application of BABA resulted in the accumulation of salicylic acid (SA) and systemic acquired resistance (SAR)[6].



Benzothiadiazole (BTH):

BTH is a novel type of plant protection compound that works by inducing the plant's inherent disease resistance mechanisms. It is a safe, reliable and non phytotoxic plant protection agent[22]. It acts as a functional analogue of the endogenous defence signalling molecule, salicylic acid.

It controls white rust of mustard, Alternaria leaf spot of Brassica, frog eye spot of tobacco, scab of cucumber. Exogenous application of BTH to tobacco, wheat and Arabidopsis leaves activated a number of SAR associated genes, leading to enhanced plant protection against various pathogens[11]. Application of BTH to cucumber leaves prior to challenge inoculation with the root pathogen *Pythium ultimum* triggered a set of plant defense reactions resulted in fungitoxic environment and protected the roots by restricting pathogen growth to the outermost tissues[3].

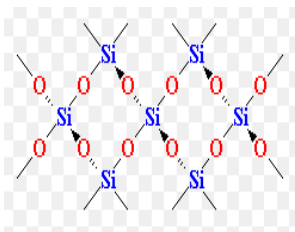


SiO_2:

Si alleviates the toxic effects caused by abiotic stresses, e.g., salt stress, drought, heavy metals. It also ameliorates the vigour of plants and improves their resistance to exogenous stresses. The protective role of Si was initially attributed to a physical barrier fortifying the cell wall (e.g., against fungal hyphae penetration)[19].

It is effective against damping off disease in cucumber and rice blast disease. Silicon is absorbed in roots, in the form of monosilicic acid and is transported passively through transpiration stream and deposited beneath the cuticle, forming a cuticle-silica double layer[9]. This double layer delayed the penetration of *Pyricularia grisea* in rice leaves[15].

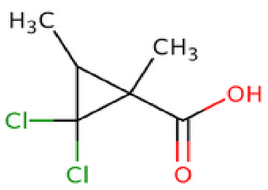
Biochemically, Si also increases the production of phenolic compounds, phytoalexins and lignin; increase the activity of enzymes like chitinases and β-1,3-glucanases, which are related to the defense as well as increased expression of genes associated with plant resistance to diseases[7].



DDCC:

It specifically controls rice blast disease caused by *P. oryzae*[16]. It results in the accumulation of the fungitoxic substances, momilactones A and B which suppress the hyphal development. The accumulation of these phytoalexins is more rapid and far greater in magnitude in leaves of DDCC treated plants than in leaves of untreated plants.

Rapid development of intracellular hyphae in cells of untreated plants was observed, while hyphal development was halted soon after penetration in cells of treated plants due to accumulation of fungitoxic substances, momilactones A and B, in the tissue surrounding the invasion site[5]. Accumulation of these phytoalexins was more rapid and far greater in magnitude in leaves of DDCC treated plants than in leaves of untreated plants. DDCC is most effective when applied via the roots and before infection[18].

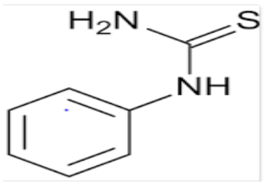


Phenylthiourea (PTU):

It controls scab of cucurbits (*Cladosporuim cucumerinum*) and rice blast disease. It enhances lignification in PTU treated plants around sites of penetration of *C. cucumerinum* and this is believed to be the basis of protection. PTU is a potent inhibitor of polyphenol oxidase (tyrosinase) activity in the plant tissue as well as in the invading pathogen.

As a consequence phenolic precursors of lignin accumulate and are rapidly converted to lignin by the elevated levels of peroxidase found in the PTU treated tissue. It moves from roots to the upper portions of the plant[13].

PTU @ 100-200 μg / ml controlled rice blast disease by inhibiting penetration of both appressoria and hyphae indicating direct action on the pathogen as an antipenetrant[1].



Case Studies on the use of Antipathic Compounds

1. Salicylic acid:

When chickpea plants are treated with salicylic acid at concentrations (1, 1.5 and 2 mM), methanol and water are used as control. It was observed that plants responded very quickly to SA at 1.5 mM and showed higher induction of peroxidase (POD) and polyphenol oxidase (PPO), besides the higher accumulation of phenols, h_2O_2 and proteins, where as plants treated with SA at 2 mM showed phytotoxic symptoms. It indicates that Sa at 1.5 mM is safe to these plants and could be utilized for the induction of plant defence. No significant difference was observed in POD activity in plants sprayed with SA 1.0 and 2.0 mM, methanol and water ($p > 0.05$). Significant elevation of the PPO activity was observed in plants sprayed with SA (1.5 mM) ($F = 54.8$, $p < 0.01$) followed by the plants sprayed with SA 1.0 Mm[25].

2. Isonicotinic Acid and BetaAmino Butyric acid

When onion plants were treated with 2, 6 dichloro isonicotinic acid (INA) @ 100mg/l and β-Amino butyric acid (BABA) @ 0.5g/l reduced the incidence and severity of purple blotch disease and increased the bulb yield significantly over control. In Arka Kalyan variety, disease incidence was lowest in BABA 0.5 g / L treatment which ranged between 5.0 -18.13 per cent from 35 to 95 days after transplanting and was highest in untreated control which ranged between 7.86 - 31.3 per cent from 35 to 95 days after transplanting.

With respect to severity of disease, BABA treatment @ 0.5 g / L recorded least disease index which ranged between 1.13 - 13.96 per cent as against untreated control recording highest disease index of 2.36 – 20.86 per cent. BABA 1.0 g / L, BABA 0.5 g / L, INA 100 mg/L, INA 150 mg / L were better or on par with standard check (mancozeb 2.5 g/L) in reducing severity of disease indicating their effectiveness against the purple blotch disease.

In Arka Kalyan variety, highest collar thickness was observed in (INA 100 mg / L), whereas, in Bellary Red variety, highest collar thickness was observed in (INA 100 mg/L), (0.5 g / L BABA) and (1.0 g /L BABA)[12].

3. Benzothiadiazole and Humic Acid

Soaking of soybean seeds in benzothiadiazole (BTH) @ 0.25g/l a.i. humic acid (HA) @4g/l a.i and their combination induced systemic resistance against *Fusarium oxysporum* under greenhouse conditions. These results were confirmed under field conditions in two different locations. The tested treatments significantly reduced damping-off and wilt diseases and increased growth parameters, except number of branches plant, and seed yield.

Soybean seed soaking in BTH + HA recorded the highest activities of the testes of oxidative enzymes followed by BTH in the four soybean cultivars. Whereas, HA treatment was recorded the lowest increased of these oxidative enzymes. Also, similar results were obtained in case of total phenol but HA increased the total phenol more than BTH in all tested cultivars. Soy bean seed treated with HA at 2 g/l recorded the lowest reduction of damping-off for all the tested cultivars, while seed treated with BTH at 0.25 g/l recorded the lowest wilt for the all tested cultivars.

Soybean treated with combination between BTH and HA at concentration 0.25 + 4g/l caused the highest protection against to infection with damping-off. Also, the wilt symptoms were reduced from 21.41, 10.67, 27.67 and 10.20% in control to 3, 2.67, 7.33 and 2.15%. Soy bean treated with HA at 2 g/l recorded the least redaction and not significant of damping-off disease compared with control[10].

4. Silicon

The application of silicon (Si) reduces the intensity of diseases in several economically important crops. It protects cucumber against damping off, bell pepper from *Phytophthora* blight and rice from blast. When bell pepper plants were grown in substrate amended with calcium silicate (+Si), the concentration of Si in the roots, but not in the stems, was greater than when plants were supplied with calcium carbonate (- Si) regardless of the inoculation status of the plants.

In general, there was 40% increase in concentration of Si in the roots when plants were amended with calcium silicate in comparison to calcium carbonate treatment. There was also an increase of 92.8% in the concentration of Si in the roots of inoculated versus non-inoculated plants. In the absence of Si, roots were severely damaged by the pathogen causing intense necrosis in the root system followed by necrosis in the crown and main stem as disease progressed. In contrast, the roots were less damaged and necrosis on crown and stems was greatly reduced in Si treated plants[21].

Determination and compartmentalization of Si in the roots of bitter gourd revealed that symplastic Si, rather than apoplastic Si, was associated with the ability of the plant to reduce the spread of the pathogen in roots[21].

5. Non-convectional Chemicals

Non-conventional chemicals, *viz.*, Salicylic Acid (SA), Acetyl Salicylic Acid (ASA), DL-β - amino-n-butyric acid (BABA), gamma-amino-n-butyric acid (GABA), Amino-iso-butyric acid (AIBA), Indole-3–pyruvic acid (IPA), Indole-3–acetic acid (IAA), Nicotinic acid (NA), Isonicotinic Acid (INA), DL-Norvaline, Benzoic Acid and Cycloheximide, when applied as foliar sprays prior to *Fusarium* inoculations, mortality was reduced in chickpea.

Among them, Salicylic acid was significantly superior and reduced the wilt incidence followed by DL- β -amino- n -butyric acid (BABA) and Nicotinic acid (NA) also increased germination of chickpea seed and reduced percent mortality compared to control. Individual treatment of the chemicals showed better results than their combinations as plant mortality was reduced and accumulation of SA, BABA and NA increased in their individual treatments.

All the chemicals showed non-fungi toxic response against *Fusarium oxysporum* f.sp. *ciceri* when tested *in vitro* by poisoned food technique. Maximum germination (95%) was observed in pots where in the seeds were treated with salicylic acid followed by NA (90.6%) and BABA (90.3%). Maximum wilt incidence was recorded in isonicotinic acid (INA), which results 47.8% disease control, over check. The germination percentage of chickpea seeds were increases 49.9% through salicylic acid followed by NA (42.3%), whereas cycloheximide treated seeds also exhibited 20.6% increased in germination[24].

6. Probenazole

The activities of enzymes were increased evidently in the treated-inoculated rice leaves with probenazole and rice blast fungus conidia than in the leaves of treated-noninoculated, nontreated inoculated or nontreated-noninoculated one. The activity of phenylalanine ammonia-lyase, tyrosine ammonia-lyase and catechol-O-methyltransferase was expressed as cinnamic acid, coumaric acid and ferulic acid µM/hr/g fresh leaves, respectively, when rice leaves were inoculated by spraying method[26].

CONCLUSION

Antipathic compounds have several advantages over conventional fungicides. These compounds are active at low concentration and ecofriendly. These are less likely to encounter fungal resistance than many conventional systemic fungicides. These compounds are potentially very valuable since the side effects on microbial population in the environment are less severe than those produced by conventional fungicides. These are called as ‘green chemicals’ because of their environmental friendliness. Along with advantages there are some difficulties with these compounds. These are concentration specific with high concentration these chemicals become phytotoxic to the plants. These are not effective against all the fungi, no broad spectrum of activity. We cannot apply these chemicals after the penetration of the fungi. So these chemicals show only preventive action but not curative.

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