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Induction of Systemic Resistance in Plant Using Non-Conventional Chemicals

Ramesh Nath Gupta[1], Shivnath Das[*2], Anil Kumar[3], Shanti Bhusan[4], Shyam Babu Sah[5], Srinivasaraghavan A[1], Kishor Chand Kumhar[6] and Ram Niwas[1]

[1]Department of Plant Pathology, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
[2] Betelvine Research Centre, Islampur, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
[3] Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
[4] Department of Plant Breeding and Genetics, VKSCoA, Dumraon, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
[5] Department of Entomology, MBAC, Agwanpur, Sahrsa, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India
[6] Deen DayalUpadhyay CoE for Organic farming, Choudhary Charan Singh Hariyana Agricultural University, Hisar, Haryana, India

ABSTRACT

Non-conventional chemical acts as elicitor, disease control agent and reducing the negative effect of chemical pesticide. It reduces environmental pollution, economics of farmers and having long lasting effect. The result of plant and pathogen interactions is significantly influenced by endogenous small molecules which coordinate plant defence responses. Exogenous application of non-conventional chemicals activates plant defences and helps in protection from pathogen infection. It induces resistance in plant and is aptly known as plant defence activators or plant activators. Non-conventional chemicals like salicylic acid, acetyl salicylic acid, indole acetic acid, indole butyric acid, riboflavin, thiamine, ascorbic acid, benzothiadiazole and bion are more common. These are an alternative and safe method for developing systemic resistance against various pathogens. Seed treatment is the most convenient and effective way of these elicitors application than soil drenching and foliar sprays because it protects the plants during its susceptible stage of growth. Treatment with these compound increases the quantities of defence related biochemical activities like total phenolics and enzymes including peroxidase, polyphenol oxidase and phenylalanine ammonia lyase and confirmed induced systemic resistance.

Keywords: *Systemic resistance, Non-conventional chemicals, BTH, Salicylic acid*

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CORRESPONDING AUTHOR:
Shivnath Das

E-MAIL ID:
Shivnath.das@rediffmail.com

INTRODUCTION

A safe and eco-friendly approach for disease management can be through resistance induction by using potential non-conventional chemicals. Plants have an innate resistance response to protect from invading pathogens. The manipulation of natural defence mechanisms is a potent method to protect crop plants [1]. Induction of systemic resistance with non-conventional chemical confers resistance in plants, without exerting pressure on pathogen population unlike fungicides. Induction of phenolics and defence enzyme phenylalanine ammonium lyase increased in salicylic acid treated sesame after inoculation of *M. phaseolina* [2]. The positive effect of inducer chemicals *viz.*, salicylic acid, ascorbic acid, benzothiadiazole and bion on systemic resistance showed against charcoal rot and enhanced growth and yield of okra [3]. [4] observed riboflavin as a resistance elicitor to protect plants against various pathogens and elucidate the signalling pathways and induced transient expression of PR1 gene for disease resistance. [5] reported that chemical elicitor benzothiadiazole increased the activities of defence related biochemical like total phenolics and enzymes including peroxidase, polyphenol oxidase and phenylalanine ammonia lyase which confirmed the induced systemic resistance against charcoal rot of cotton. Non-conventional chemicals can be used to trigger defence, since they also known to change the activity of important biochemical constituents for disease defence.

Salicylic Acid

Salicylic acid (SA) ($C_7H_6O_{3,}$ 2-Hydroxybenzoic acid) plays an important role in systemic acquired resistance (SAR) signalling and disease resistance in plants. Plant development is also frequently affected by plant defence inducers that imitate the actions of the plant immune hormone SA. In physiological studies, SA can enhance plant resistance by modulating the expression of genes encoding for ROS-scavenging players, altering the activity of resistance-related enzymes, and inducing the expression of pathogenesis-related genes to produce systemic acquired resistance by increasing the activity of defence related enzymes, PR-Proteins (chitinase and ß-1, 3 glucanase). SA is involved in the induction of resistance to biotic and abiotic stresses in higher plants. [6] reported that SA treated tobacco significantly reduced the infection caused by tobacco mosaic virus (TMV). [7] observed the leve1 of SA increased several-fold in tobacco after viral infection and correlated with SAR. [8] found the exogenous application of SA induces SAR and SAR gene expression. [9] reported that SA signalling provides resistance against biotrophic pathogens, whereas necrotrophic resistance is controlled by Jasmonic acid and Ethylene-signalling pathways. Salicylic acid is a key regulator of plant defence that primarily mediates responses to biotrophic pathogens [10]; [11]. Exogenous application of SA has induced resistance against alternaria blight of mustard [12]. SA is considered as an important signalling molecule and involved in local and systemic disease resistance to plants against various pathogenic attacks [13]. Salicylic acid acts as a potential non- enzymative antioxidant, plant growth regulator play important role in many plant physiological processes. It has been identified as a signalling component in numerous plant responses against pathogen attack and induced responses on growth and biochemical constituents in *Vigna mungo* [14].

Acetyl Salicylic Acid

Acetyl salicylic acid (ASA) ($C_9H_8O_4$, 2-Acetoxybenzoic acid) is derivative of salicylic acid.ASA interacts with key components of a complex network regulating both basal and induced resistance in different pathosystems. In plants, ASA is one of the most prevalent antioxidant compounds. ASA protects plant cells from various environmental conditions that cause oxidative stress, such as wounding, ozone, excessive salinity, and pathogen infections, by acting as a first line of defence against harmful reactive oxygen species (ROS). [15] evaluated acetyl salicylic acid *in vitro* and *in vivo* conditions against *Sclerotinia sclerotiorum*, significantly reducing the mycelial growth, sclerotial formation and carpogenic germination of the pathogen. They observed enzymatic activity of peroxidase, polyphenol oxidase and phenylalanine ammonia lyase were increased in the inoculated carrots three days and four hours after application of ASA. [16] reported that ASA is an important plant hormone which involved in many processes including root initiation, seed germination, stomata closure, floral induction, thermo-genesis and response to biotic and abiotic stresses. [17] found that application of ASA (15mM) reduced the incidence of root rot of lupine and enhanced the growth parameters, yield parameters and seeds quality.

Indole Acetic Acid

Indole acetic acid/Indole-3-acetic acid (IAA) ($C_{10}H_9NO_2$, 2-(1H-indol-3-yl) acetic acid) is a basic natural occurring auxin and having property to induce resistance in plants. [18] observed the regulation of the enzymatic activity of the glutathione S- transferase in potato by IAA and regulated the induction of plant defence mechanisms. IAA plays an important role in numerous plant pathogen interactions [19]. [20] showed exogenous application of IAA regulates b-1, 3-glucanase and chitinase accumulation in potato leaves inoculated with *Phytophthora infestans*. [21] observed IAA acts as an activator of plant resistance and enhanced enzymatic activity of peroxidase and phenylalanine ammonia-lyase in barley. [22] evaluated different non-conventional chemicals *viz.*, IAA, Cycocel, $ZnSO_4$, $ZnCl_2$, $BaSO_4$ and $BaCl_2$ at 10^{-4} and 10^{-5} M concentrations for 24 hours to determine its bio-efficacy against stem rot of ground nut and found lowest disease incidence (25.7 %) and highest significant yield (486.8g / m^2) by the treatment of IAA at 10^{-5} M concentration.

Indole Butyric Acid

Indole butyric acid (IBA) ($C_{12}H_{13}NO_2$, 1H-indole-3-butanoic acid) is a plant hormone of auxin family performing similar role of indole acetic acid and regarded as synthetic auxin.[23] found that pre-soaking sesame seed in IBA was found effective treatments for reducing charcoal rot incidence. They also observed significant induction of total phenols, total sugars and defence enzyme activities like peroxidase, polyphenol oxidase and catalase as compared to check.

Riboflavin

Riboflavin ($C_{17}H_{20}N_4O_6$,-7,8-dimethyl-10-[(2S,3S,4R)-2,3,4,5-tetra hydroxyl pentyl] benzo [g] pteridine-2,4-dione) is an activator of signalling process and elicitor of systemic resistance in plants. It induces expression of pathogenesis-related (PR) genes in the plants and has ability to trigger a signal transduction pathway of systemic resistance. It influences the outcome of plant and pathogen interactions. [24] reported that treatment of leaves of pepper, tomato and eggplant with riboflavin prior to inoculation of roots with *Verticillium dahliae* and found significant reduction of fungal load and overall disease symptoms of the plants. [25] observed that riboflavin induced systemic resistance in chickpea against charcoal rot and Fusarium wilt of chickpea. Riboflavin (1.00 mM) treated chickpea inoculated with pathogens showed induction of resistance two days after treatment and reached at highest level between 5 to 7 days and then decreased. It induced higher accumulation of phenols, POX and PAL activities after challenged inoculation with pathogens in riboflavin pre-treated plants. [26] found that riboflavin helps in protection of various hosts from bacterial, viral and fungal pathogens without phytotoxicity. [27] observed the defence responses elicited by riboflavin in tobacco cells inducing an oxidative burst, expression of defence-related genes, accumulation of phenolics compounds and lignin. Riboflavin treated plant inoculated with *Phytophthora parasitica* and *Ralstonia solanacearum* showed 47.9% and 48.0% protection, respectively. [28] tested riboflavin for induction of resistance against virulent *Pseudomonas syringae* in Arabidopsis. Results showed that riboflavin induced disease resistance based on MAPK-dependent priming for the expression of PR1gene.

Thiamine

Thiamine ($C_{12}H_{17}N_4OS$, 2-[3-[(4-amino-2-methylpyrimidin-5-yl) methyl]-4-methyl-1, 3-thiazol-3-ium-5-yl] ethanol) is an important factor for primary metabolism for all living organisms. It also plays role in the processes of protection of plants against biotic and abiotic stresses. [29] observed the effects of thiamine on disease resistance and defence-related gene expression. They observed that activity of peroxidase, polyphenol oxidase and phenylalanine ammonia lyase were increased in the inoculated and non-inoculated plants treated with the thiamine and riboflavin than control. Treatment with riboflavin (2.5mM) and thiamine (5mM) showed maximum induction of systemic resistance against charcoal rot of soybean at six days after inoculation with *Macrophomina phaseolina* of soybean. It also increased number and fresh and dry weight of nodules per plant than untreated control [30]. Application of thiamine loaded chitosan nanoparticle increased seed germination and seedling vigour and decreased cell death in roots of chickpea [31].

Ascorbic Acid

Ascorbic acid (AsA) is one of the most abundant antioxidants in the cell, and most of it in the chloroplast exists in de-oxidation form under normal physiological conditions [32]. The AsA in plants is oxidized to mono dehydro ascorbic acid (MDHA) under the action of APX (at the same time, the H2O2 is catalytic and then deoxygenized to H2O). MDHA is not very stable, and can be converted to DHA without the action of any enzyme, while in the role of mono dihydro ascorbate reductase (MDAR), MDHA again transformed into AsA. Accumulation of AsA metabolites is not always associated with the expression of their biosynthetic genes; most of these genes expression tend to be positively correlated with total AsA and DHA, negatively correlated with AsA [33] ; [34].

All eukaryotes, including animals and plants, have ascorbic acid (AA), while prokaryotes, with the exception of cyanobacteria, have a minimal amount. Due to its characteristics (antioxidant and cellular reductant, for example), and multifunctional functions in plant growth, development, and control of a remarkable range of plant cellular processes against environmental stresses, AA has now taken an important place in plant research. Plant stress responses may be thought of as being managed by a network that connects signalling pathways defined by the synthesis of ET, JA, SA, ABA, and GA3. In higher plants, cross tolerance, or the induced tolerance to additional biotic and abiotic challenges following exposure to a single oxidative stress, is a common defensive mechanism. Stress is mediated by one MAPK2, whereas ABA is mediated by an antagonistically reacting MAPK2 [35].

Benzothiadiazole

Benzothiadiazole (BTH), a synthetic analog of SA, has been widely used to protect crops from diseases by inducing plant defense responses. [36] demonstrated that BTH confers resistance against *Rhizoctonia solani*, the causal agent of sheath blight disease in *Brachypodium distachyon*. BTH compromised the resistance of Bd3-1 and Gaz4, the two sheath blight-resistant accessions of B. distachyon, which activate SA-dependent signaling following challenge by R. solani. The susceptibility of Bd21 to *R. solani* was increased after treatment with JA. Surprisingly, therapy with BTH had no effect on Bd21's degree of R. solani resistance. Although the corresponding effects on gene expression in *Arabidopsis* following treatment with either SA or BTH were very similar, our comparative transcriptome analysis of Bd21 leaves after treatment with SA or BTH revealed that their transcriptional changes involved a number of common genes but also included very large differences [37]. SA stimulated the expression of 89 genes in *B. distachyon* that were not activated by BTH, including a number of genes involved in secondary cell wall (SCW) production. To explored this same expression of genes encoding allene oxide synthase (AOS) and the small subunit of ribulose-1, 5-bisphosphate carboxylase/oxygenase (rbcS) in response to BTH, SA, or JA to confirm our findings from the transcriptome analysis that BTH can induce the expression of chloroplast- and JA-related genes in *B. distachyon*. The rbcS proteins are found in the chloroplast and serve an important role in photosynthesis in plants [38].

The functional enrichment analysis of the BTH-specific up regulated genes revealed that BTH has an impact on a wide variety of phytohormone signalling pathways in *B. distachyon*, especially those linked to SA and JA. BTH treatment substantially upregulated BdAOS, a JA response marker gene in both susceptible and resistant accessions Bd21 and Bd3-1[39]. [40] reported that BTH has been found to trigger JA signalling in rice.

Bion

Bion causes systemic acquired resistance since it mimics the role of salicylic acid. Ethylic oils are another component that can make plants resistant to fire blight [41]. [42] evaluated in vivo and in vitro against E. amylovora. *In vitro*, Bion and BioZell-2000 B had no impact on the pathogen, which was the first hint that such chemicals and bacteria may be used to produce acquired resistance in plants. [43] found similar findings by the treatment of Bion and BioZell-2000 B which significantly reduced apple blossom infection.

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