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Role of Antimicrobial Peptides in Plant Disease Management

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Antimicrobial peptides (AMPs) are short peptide sequences of about 50 amino acid residue which are considered as first line of defense in plants. These peptides are particularly resistant to enzymatic, thermal and chemical degradation because they contain four to twelve cysteine residues that form disulphide linkages. Antimicrobial peptides have a wide range of activities against viruses, fungi and harmful bacteria. AMPs exhibit a broad spectrum of inhibitory effects on bacteria, viruses, nematodes, and fungi. Despite their great diversity, the majority of AMPs actively combat microorganisms by causing membrane rupture and pore formation, which permits the efflux of vital nutrients and ions. Thionin, Defensin, Lipid Transfer Protein, Hevein, Knotting type peptides, Cyclopeptides, Snakins, Puroindolins, and other antimicrobial peptides are among the many that play a significant part in plant defense mechanisms. Antimicrobial peptides are advantageous for plant protection in agriculture since they are extremely effective and safe.

Keywords: Antimicrobial peptides, Plant defense, Defensin, Thionin

Introduction

Numerous pathogenic bacteria are the primary cause of plant diseases, and chemical methods are primarily employed to treat them. This leads to the emergence of pathogen isolates that are resistant to treatment, and the extensive use of chemicals has detrimental effects on the environment. Therefore, innovative methods that can replace the use of chemicals in the control of plant diseases are being adopted and put into practice. In recent years, antimicrobial peptides have drawn interest as a means of protecting plants. Plants use antimicrobial peptides, which are short peptide sequences with roughly 50 amino acid residues, as their first line of defense. Plant AMPs are thought to greatly enhance plant growth and development in addition to playing a crucial role in plant defense against infections.

What are Anti-Microbial Peptides (AMPs)

In order to defend themselves from biotic stressors, plants have evolved defense mechanisms. AMPs are one of the most prevalent and efficient chemical barriers among these defense chemicals. AMPs are part of innate immune system, which contributes greatly to the host defense against pathogens. These are small polypeptides, synthesized by ribosomes where as some AMPs can be synthesized through non ribosomal peptide synthetases. Antimicrobial peptides have a wide range of activities against viruses, fungi, and harmful bacteria. About 96% of AMPs are cationic, but there are also a small number of anionic peptides that are high in aspartic and glutamic acids. Due to the presence of arginine or lysine residues in amino acid sequences, the majority of cationic antimicrobial peptides have a net charge of + 2 at neutral pH. Microorganisms, insects, amphibians, plants, and mammals have all been found

to have AMPs. Thionin, which was discovered in *Triticum aestivum* and it was the first plant AMP to be reported.

Structures of Antimicrobial peptides: The four to twelve cysteine residues that create disulphide bonds in antimicrobial peptides can provide them remarkable stability against enzymatic, thermal, and chemical degradation.The smallest known AMP comprising 7 amino acids was isolated from *Jatropha curcas*. Key features of AMPs are high constituents of cysteine and or glycine and the presence of disulphide bridges and on this basis, the AMP structure is classified as helical(where α helix are arranged in a right handed helical structure), β sheet(2 or more polypeptide chains run alongside each other and linked in a regular manner), Hairpin or loop(presence of a single disulphide bonds and cyclization of peptide chains) and Extended (Glycine, arginine or histidine rich peptides. When AMPs bind with sodium dodecyl sulphate, the linear antimicrobial peptide takes on an extended boat-shaped structure.

Mechanisms of Anti-microbial peptides (AMPs)

AMPs exhibit a broad spectrum of inhibitory effects, mostly against bacteria, viruses, and fungi. The target microorganism determines the specific site of action of AMPs, which can include cell lysis, hyphal tip bursting, suppression of DNA, RNA, and protein synthesis, and inhibition of cell wall formation.

I) Antibacterial: When AMPs come into contact with a bacterial cell, they attach to the cell surface, causing the cytoplasmic and outer membranes of gram-negative bacteria to permeabilize. This causes cell lysis and DNA damage. Gram-negative bacteria's outer membrane structure is disrupted when the positively charged domain of cationic peptides attaches to the divalent cation Lipopolysaccharide binding sites and then pushes out the native Ca^{+2} and Mg^{+2} ions. Gram-positive bacteria have negatively charged teichoic acid in their cell walls, which is most likely where AMPs first bind. Then, when lipid composition is present, the AMPs interact with the cytoplasmic membrane. When negatively charged lipid head groups connect to positively charged cationic peptides, the peptides enter into the membrane and change their shape, creating channels or pores that allow leakage and ultimately cause cell death. AMPs target nucleic acid inhibitors as well.

II) Antifungal: Both the cell wall and the nucleic acid may be the primary targets of AMPs in fungal cells. Additionally, these disturb mitochondria and create reactive oxygen species, which results in osmotic stress. Additionally, in some fungal genera like *Rhizopus* and *Fusarium*, AMPs prevent spore germination and the production of germ tubes.

AMP targeting cell wall: The main polysaccharide of the fungal cell wall, B glucan, is targeted by AMPs because it contains β 1,3 glycosidic bonds that give the cell wall strength. A small number of AMPs trigger an immune response by identifying fungal infections through a particular β 1,3 glucan receptor. Additionally, AMPs suppress chitin. A small number of AMPs are mannan binding peptides that cause cell death by recognizing D-mannose.

Nucleic acid inhibitors: AMPs also target the metabolism and production of nucleic acids. They impact repair mechanisms by binding to DNA and blocking the actions of enzymes that process DNA.

III) Antiviral: The AMPs interact with the membranes of the enveloped viruses because their membrane are made of anionic phospholipids and cause structural disruption. These impact the stability of the nucleocapsid in addition to lysing the viral envelope. In the instance of TMV, AMP Melittin inhibits the expression of the viral gene. When AMP and TMV bind, RNA undergoes structural changes that impact the degree of gene expression. Antiviral peptides compete with viruses for cellular binding sites by interacting with the aminoglycan found on the cell surface. These AMPs attach themselves to the viral receptor needed to gain access.

Types of Antimicrobial peptides (AMPs): So far, 3425 AMPs have been reported. Microorganisms, plants, and animals all produce natural AMPs. Based on their structures and

sequences, plant antimicrobial peptides are commonly categorized as thionins, defensins, hevein-like peptides, knottins, lipid transfer proteins, snakins, and cyclotides.

Defensins: Mendez *et al*. discovered Defensin, a small, cystine-rich antimicrobial peptide of 45–54 amino acids and three–five disulfide linkages, from barley and wheat in 1990. Defensins are expressed in developing seeds to resist fungal invasion of the newly developed radicle tissues. Defensin enhances ion permeability through interactions with the cell membrane. The interaction between the serine residue and the glycosyl portion of the fungal cell membrane causes membrane permeability and ion leakage from the membrane. Defensin interaction also speeds up ROS production, which triggers programmed cell death.

Thionin: Thionins are composed of three or four disulfide bonds, six or eight cysteines, and 45–48 amino acids.Cambrin, viscotoxin are thionin peptides with six cysteine -β/αresidue and three disulphide bridgeswhereas -hordothionin are peptides with β/α purothionins, eight cysteine residue and four disulphide bridges. When γ thionin peptide interacts with glucosylceramide molecules found in the cell membrane, γ thionin is repelled within the cell membrane, causing membrane rupture and ion efflux.

Lipid Transfer Protein (LTP): Tiny, cysteine-rich peptides with molecular weights under 10 kDa. There are 70–100 amino acids in it.Cationic peptides with a conserved pattern of four to five disulfidebridges having eight to ten cys-cys bonds. TPs and thionins work together to *combat Clavibacter* spp. When cutinase activity of pathogens breaks down the plant cell wall, LTP combines with the cutin monomer to form a complex that starts the manufacture of cutin and restores the plant cell wall.

Hevein like peptides: Heveins are tiny, antimicrobial proteins that include conserved glycine and aromatic acid residues. They are 42–45 amino acids in size and 4.7 Kda in size. These proteins have three to five disulfide links and are cationic. In order to combat fungal infections, plants generate chitinases. Fungal chitinases are broken down by fungalysin, which is secreted by fungi. Hevein-like WAMPs, on the other hand, prevent chitinase cleavage and suppress fungalysin activity.

Table 1: Classification of major antimicrobial peptides (AMPs)

Peptides	Classification	Target organism /Functions	References
Cp-thionin ii	Thionin	Antifungal	Schmidt *et al*.,2019
WRKY	Thionin	Capsicum chlorosis virus	Naito et al.,2022
NaD1	Plant defensin	Candida albicans	Hayes et al.,2018
ZD32	Plant defensin	Helminthosporium, Fusarium	Kerenga et al.,2019
LCTP1	Lipid transfer protein	Antifungal, antibacterial	Bogdanov *et al*.,2015
G-LTP2	Lipid transfer protein	Botrytis cineria	Kiba *et al*.,2012
M-hevein	Hevein like peptides	Trichoderma viride	Zhao et al.,2011
PINA and PINB	Puroindoline	Botrytis cinerea,Verticillium dahlia,Cochliobolushetero strophes	Zhang et al.,2011
bevuTI	Knottin type peptides	Trypsin inhibitory prolyl oligopeptidase	Retz et al.,2020

Conclusion

The majority of antimicrobial peptides are safe and effective, making them useful for plant protection in agricultural sector. Because of their strong target affinity, AMPs can effectively manage weeds, insects, and diseases with little amounts. A mixture of distinct AMP molecules with complimentary modes of action that can operate at various phases of disease development should be used in order to further improve the broad spectrum resistance of host. If AMP is successfully used in plant protection, it should help eliminate

some plant diseases, lessen the environmental damage caused by intensive agriculture, and enhance the safety and quality of our food.

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