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Plant Armor: Strengthening Natural Defense for Biotic Stresses

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Introduction

Higher plants are always affected with a wide range of stresses. Biotic stresses include herbivores which may be biting and sucking pest or chewing and lapping pests and includes microorganisms like bacteria, fungi, viruses, competitive weed species and nematodes. Abiotic stresses include temperature stress which may have occurred due to changes in photoperiods and diurnal temperatures. Changes in irrigation and environmental changes may lead to drought or floods. Variations in the content of salt in soil may lead to salinity stress. To combat all these stresses, plants require defense mechanism.

Higher plants possess a diverse array of mechanisms to shield themselves from a myriad of threats, encompassing physical, chemical and biological stresses. These stresses prompt intricate biochemical and physiological alterations in plants, including the reinforcement of cell walls through processes like lignification, suberization and callose deposition. Additionally, plants generate a range of defensive compounds such as phenolic compounds, phytoalexins, and pathogenesis-related (PR) proteins, crucial for thwarting pathogen intrusion. The production and accumulation of PR proteins in response to invading pathogens or stressful conditions stand out as particularly vital. The plant's response to these infection factors is highly intricate, involving the activation of specific genes encoding diverse proteins. Plants face challenges in all stages of their growth and to all their organs. Plant defense can be defined as promoting the survivability of the plant by protecting it from its enemies. Potential for any pathogen to cause disease also depends upon host-microbe compatibility, hostreceptors and sites for toxins, essential nutrients, growth factors and also recognition factors. In broad terms, constitutive or continuous defenses include many preformed barriers such as cell walls, waxy epidermal cuticles and bark which protect the plant from invasion and also give strength and rigidity to plants. The inducible defenses include production of toxic chemicals, pathogen degrading enzymes and cell suicide. Plants often wait until pathogens are detected before

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producing toxic chemicals or defense related proteins because of the higher energy costs and nutrient requirements associated with their production and maintenance.

Plants defend themselves against pathogens and herbivores in two ways:

1. Structural characteristics that act as physical barriers
2. Biochemical reactions in cells and tissues that are either toxic to the pathogen or create conditions that inhibit the growth of the pathogen in plant.

Methods of developing resistance

- **Introduction:** Introducing a resistant variety/crop/wild species/wild relative to a place where it was not cultivated earlier.
- **Selection:** The process of selecting the resistant and superior ones and allowing the multiplication of those desirable types among a population is selection.
- **Transgenic:** Development of resistance can be achieved through the transgenic approach and it is based on recombinant DNA technology, in which the first step is to isolate the gene of interest, followed by its cloning in the desired vector with required selectable markers.
- **Hybridization:** Selecting the best and resistant hybrid after crossing with the superior ones. Multiple disease resistance can be developed.
- **Backcross:** Backcross is the crossing of F1 with the one of its parents or an individual genetically similar to its parent, to achieve offspring with a genetic identity closer to that of the parent, mainly followed for 78 generations for inserting a gene of interest. Gene of interest is the resistant gene.
- **Mutation:** Mutation can be referred as the sudden inheritable change caused due to mutagens.
- **Grafting:** Joining of two plants together to grow as one is called as grafting.
- **External application of regulators:** External application of regulators include application of jasmonic and salicylic acids.

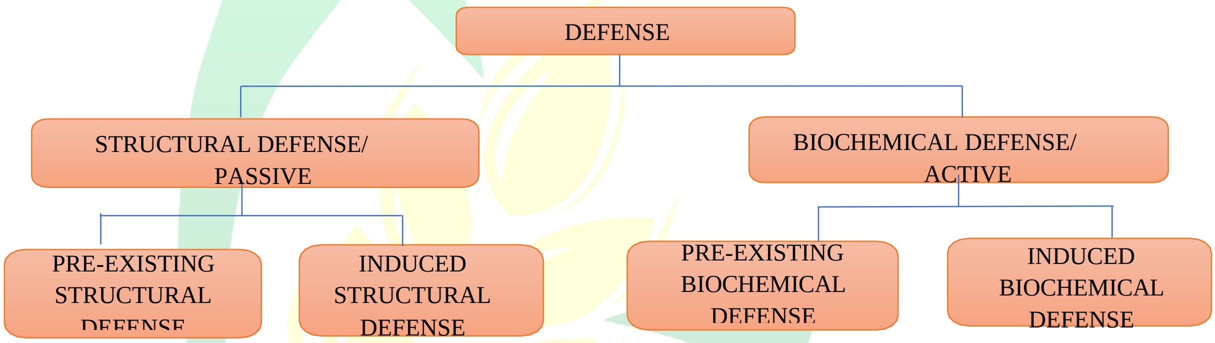
Advantages of strengthening of defense mechanism

- **Eco friendly management:** It is a better alternative to strengthen the defense mechanism than to use chemical fungicides and pesticides. Instead of polluting the earth and soil by the residues this approach could be a better alternative.
- **Residue reduction:** The residue of the chemicals will be present in the food we consume,

it comes as a cycle but it is minimum when strengthening of defense mechanism is done.

- **Resistance against pesticides and fungicides:** Due to the repeated use of the same chemical fungicides and pesticides, the pathogen/ herbivore develop resistance to those chemicals. Then the control of the disease will be decreased but pollution will increase and hence strengthening could be a better alternative.
- **Cost effective:** Strengthening occurs the cost until we develop resistance but may be a huge investment whereas it is a permanent alternative. When it comes to chemicals, continuous input leads to continuous pollution and investment.

Classification of Defence Mechanism



1. Structural Defense Mechanism

The surface of the plant acts as the first line of defense against the pathogen and insect herbivores. The structures present in the plant defend their enemies and hence the name.It is also known as passive defense because there is no involvement in production of chemicals for defense or any active mechanism involved in defense. The pathogen must adhere to the surface and penetrate if it has to cause an infection. The pathogen or the herbivore require a surface to penetrate and multiply. The pre-existing structural defenses include waxes, structure of epidermal cells, thick cuticle, lenticels, trichomes and spines. Induced structural defense include modification of stomata, formation of cork layer, abscission layer, tyloses also deposition of gums. These defense systems are affected by type of the organ affected, nutritional status of the host and environmental conditions.

a) Waxes and cuticle

The epidermal cells of plants are shielded by a cuticle, comprising a pectin layer, a cutinized layer and a wax layer. Cutin, predominantly made up of fatty acids, forms a crucial component of this protective layer. Waxes, composed of long-chain aliphatic compounds, play a pivotal role in preventing water retention on the plant surface, which is essential to inhibit spore germination. Fatty acids on leaf surfaces often induce a negative charge, effectively repelling airborne spores or propagules. Enzymatic dissolution of cutin is a rare occurrence, with only a few pathogens known to possess this capability, Ex: wax in amaranthus.

b) Epidermal cells

The first layer of living host cells that an attacking bacterium comes into contact with is the epidermis. The lignin mineral components, hemicelluloses, polymerized organic compounds, suberin, and cellulose polymers are responsible for the toughness of epidermis. *Pythium debaryanum*-resistant potato tubers have more fiber. The buildup of silicon in epidemal walls protects against fungal invasion.

c) Lenticels

Lenticels are apertures in the outer walls of plants that facilitate gaseous exchange. These structures serve as potential weak points in plant defense unless the cork cells within them undergo suberization. Upon suberization and the formation of periderm, lenticels become significantly more resilient to invasion by pathogens.

d) Trichomes

Trichomes are small, hair-like structures found on plant surfaces that aid in capturing insect body parts and hinder the spread of pests to other areas. Their nutrient-poor environment often leads to their eventual demise.

e) Modification of stomata

A functional defense mechanism has been observed in some varieties in which stomata open late in the day when moisture on leaf surface has dried and the infection tunes have become non-functional. Stomata is an opening through which the fungal hyphae can enter easily and multiply inside the system after affecting the crop but here it is modified in such a way that the size of the stomatal opening reduces and hence the hyphae cannot enter into them.

f) Formation of a cork layer

In various plant species, infected cells are encased by suberized cells, effectively isolating them from healthy tissue. The formation of a corky layer serves as a component of the plant's natural healing process. Common scab of potatoes and rot of sweet potatoes serve as notable examples of this phenomenon.

g) **Tyloses**

Tyloses form as a result of the protrusion of xylem parenchyma cell walls through pits into xylem vessels. They physically obstruct the vessel, with their size and quantity blocking its passage. Tyloses are induced well in advance of infection, effectively halting the spread of pathogens. This process suggests the involvement of biochemical elicitors and the movement of a tylose-inducing factor (TIF) up the stem. Sweet potatoes, affected by *Fusarium oxysporum* f. sp. *batatas*, demonstrate this defensive mechanism.

h) **Deposition of gums**

The gums and vascular gels rapidly gather and occupy the intercellular spaces or the vicinity surrounding infection threads and haustoria within cells. Consequently, this deprivation of nutrients leads to the starvation or demise of the pathogens.

i) **Lignification**

The presence of lignified cell walls serves as an efficient barrier against hyphal penetration, effectively impeding the movement of pathogens. Additionally, these lignified walls act as impermeable barriers, preventing the free flow of nutrients and ultimately causing starvation of the pathogen. Examples: In Cucumber lignification occurs against *Cladosporium cucumerium* and *Colletorichum lagenarium*, in carrot: *Botrytis cineria*, in radish: *Peronospora parasitica* and*Alternaria japonica* and in potato: *Phytophtora infestans*.

Structural defense in vegetables

Host	Disease/Pest	Physical barrier/Elicitor
Amaranthus	White blister	Vax
Potato	Scab	ignification, modified nticles
Onion	Thrips	lossy foliage
French bean	Aphids	ooked trichomes
Crucifers	DBM	Vax bloom
Okra	Leaf hopper	richome
Beet	Cercospora leaf spot	tomata modification
Potato and tomato	Aphids	landular trichomes
Cucurbits	Squash vine borer	ascular bundle odification

Pea	*Botrytis cineraria*	welling of cell wall
Potato, Radish, Carrot	Rhizoctonia	orky layer

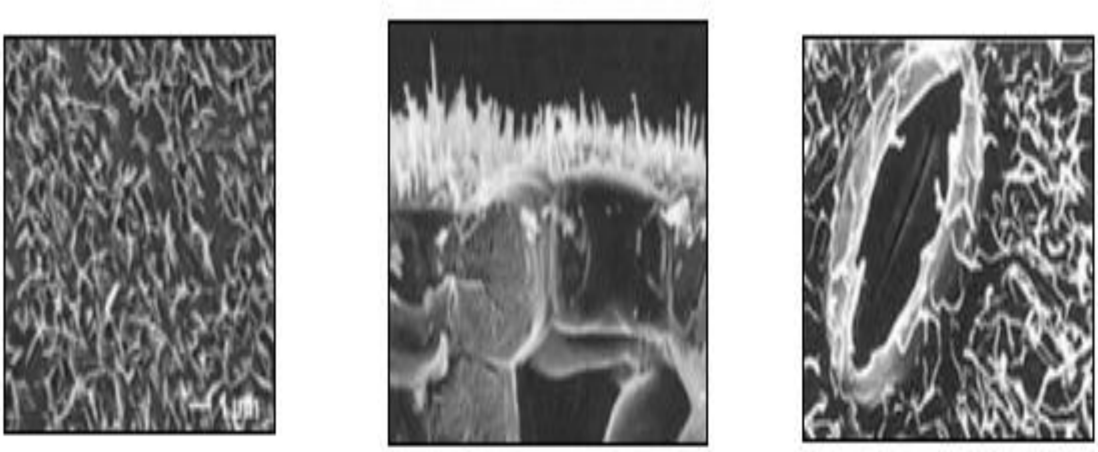


Fig.: Waxes in leaves inhibiting the fungal spores

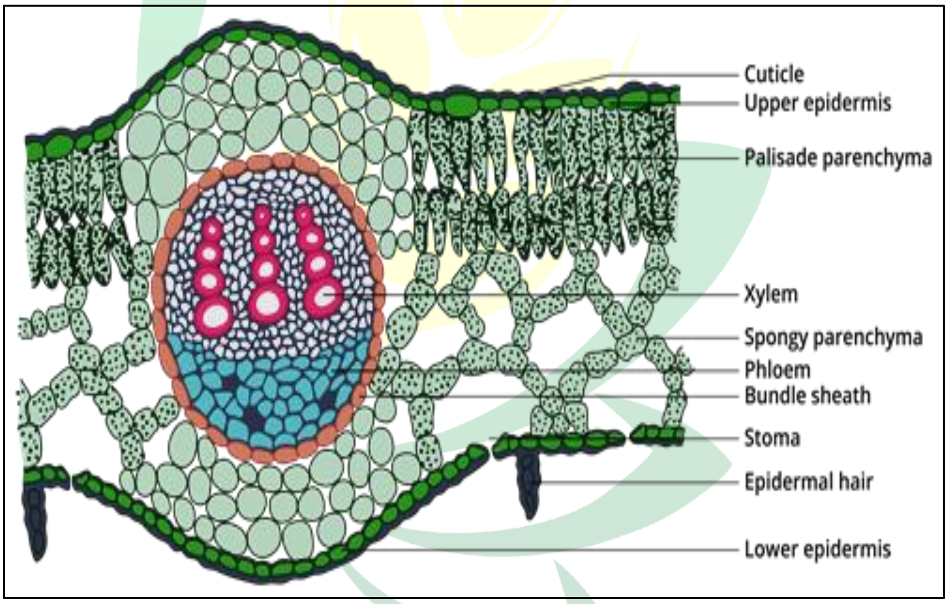


Fig.: Cuticle formation

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Fig.: Lenticels

Fig.: Glossy foliage of onion

Fig.: Formation of tyloses

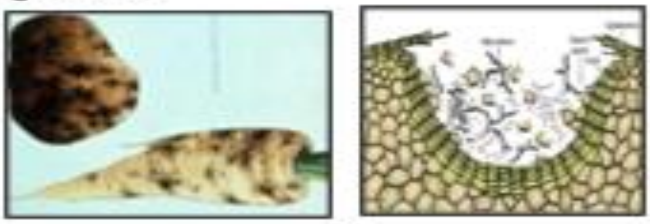

Fig.: Formation of corky layer to prevent infection by *Rhizoctonia*

Fig.: Glandular trichomes of the plants

Conclusion:

The utilization of innovative strategies for fortifying these plant defense mechanisms offer promising avenues for sustainable agriculture. By integrating scientific knowledge with practical applications, we can cultivate resilient crops that thrive amidst diverse environmental challenges, ultimately ensuring food security and environmental stewardship for future generations.