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Plant immunity: An attempt to comprehend plant defense mechanism

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***Abstract*---**Immunity is a term closely affiliated with the normal being of an organism as it puts across a cascade of physiological facets that contributes affirmatively towards the knocking down of the invaded pathogen. It is a widely known and accepted fact that cells associated with the immune system serve as driving force in eliminating the disease causing agent and plants are not exempted from this mechanism but the approach of counteracting a pathogenic contender in plants are quite different from that of higher vertebrates. Several factors of internal and external origin have equally contributed towards the development of plant immunity. However, the role of microbes in conferring immunity to plants cannot be denied and their prominence in accordance with the fortifying the plant system against the invading pathogens have been extensively researched. Responses like systemic acquired resistance and induced systemic resistance have been studied in plants which get triggered in response to various micro invaders of pathogenic and non pathogenic echelon. Several studies claim the role of microbes in instigating either of these responses that in turn gives rise to a cascade of reactions within the plants resulting in plant immunity. The current review attempts to provide a comprehensive gist on the hidden insights from the view point of plant immunity and tries to provide a cohesive context on the microbial aspect in stimulating plant immunity. The review also emphasizes on various microbial patterns responsible for initiating plant immunity.

***Keywords*---**plant immunity, microbial pattern, triggered immunity, phytoalexins, elicitors, effector triggered immunity.

Introduction

Agriculture has been practiced since ages and has served as one of the major occupations since the dawn of the civilization age. Demand for agriculture products as a source of income generating means has gained its pace over the last century due to the population outburst. Hence it could be alleged that the growth in global population has increased the demand for agricultural produce and one of the major challenges met by the agriculture sector is by the biological agents that are capable of causing clinical manifestations which in turn compromises the quality of agricultural products. However, microorganisms have known for their affirmative influence towards the growth and development of the plant through instigating pathways at molecular echelon. Plants are sessile life forms and are constantly targeted by a plethora of microorganisms which include pathogenic and beneficial contenders [1]. Overexploitation of chemicals in the form of fertilizers and pesticides have evenly contributed towards the deterioration of the plant products and led to the environmental pollution. The quest for improved quality over a short period has indeed led to the over use of these chemicals that have impacted the plants and the environment in a drastic manner. However, the scenario is on the verge of being stabilized due to the use of eco-friendly inputs for improving the plant product quality. Biological control agents and their prominence in resolving the plant associated setbacks has been one of the widely researched facets for deriving productive outcomes. Plant beneficial microorganisms like Actinomycetes, Bacillus, Pseudomonas, Trichodermaetc have been extensively used as bio control agents for counteracting disease causing organisms. Plants have the ability of switching on a cascade associated with defence mechanism which recognizes the potential pathogen [2].

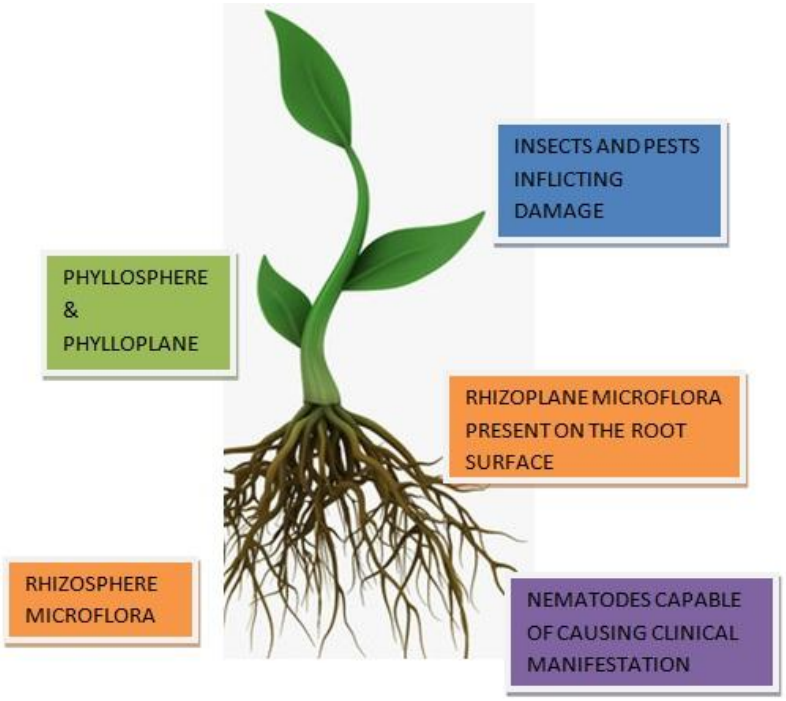

Figure 1. Plant and its affiliation with living organisms

The above diagrammatic representation provides a bird's eye view in relation to plants association with various biotic components that are found at different sites on the plant. The figure attempts to elaborate on microorganisms found within the vicinity of the root system which is commonly referred as rhizospheremicroflora and includes those microbes that are found on the root surface. These are commonly called as rhizoplanemicroflora. In addition to rhizosphere and rhizoplane, phyllosphere and phylloplanemicroflora also play a vital role towards to affirmative contribution. However, it would not be appropriate to always consider these biotic entities as beneficial because some of these have the tendency of causing infections in plants leading to clinical manifestations. Not only microorganisms are threatening the plant growth but nematodes, insects and pests too have a vital role in instigating plant immune system.In addition to biotic component, several studies have validated the prominence of abiotic factors in accordance with the plant immune response. Abiotic stress include non living factors like salt concentration, water quality, type of soil and the ionic composition of the soil, soil pH and the climatic conditions. The influence of these abiotic entities on plants cannot be denied because they have the tendency of causing physiological amendments leading to a clinical manifestation [3].

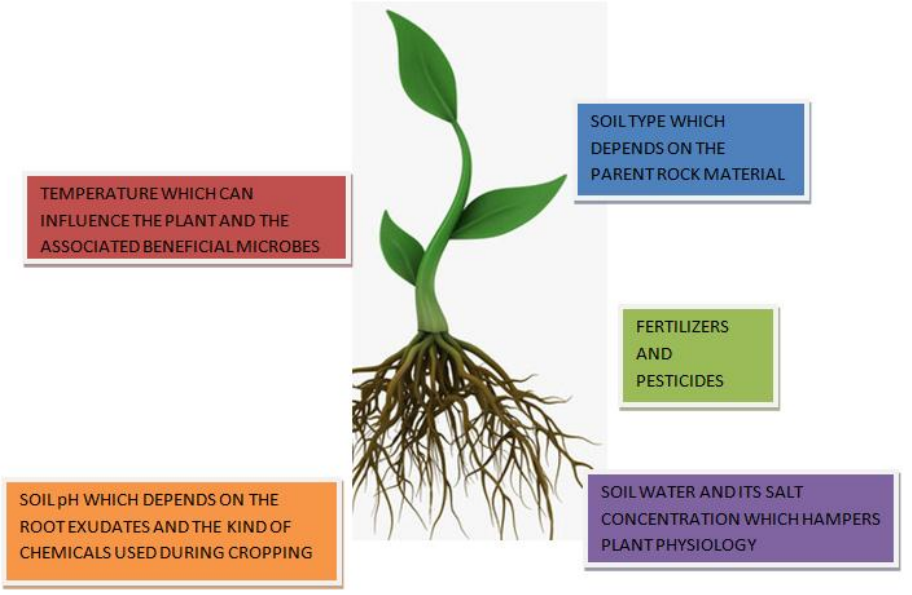

Figure 2. Abiotic components and its influence of plant

Figure 2 depicts the diagrammatic representation of various abiotic components capable of obvious manifestations in plant which can in turn activate plant defence mechanism [3]. Temperature, pH, type of soil and moisture holding and the soil type are some of the vital abiotic entities that decide the degree of well being of a plant. There are several factors that can trigger the cascade of reactions within the plant system for activating the plant immunity from within. Temperature for example is important from the context of both plants and microbes conferring affirmative benefits. pH is important for the normal physiology of the biotic entities. The type of soil decides the physical properties of

the soil which could either lead to positive or dire consequences. It is a well known fact that the type of soil depends on the parent rock material which either makes it good for plants or for the pathogenic contenders causing a disease. Hence plant immunity is a result of all these factors that serve as vital cues for the cell surface receptors which in turn activates plant immunity.

However, the scenario is on the verge of being stabilized due to the use of eco-friendly inputs for improving the plant product quality. Biological control agents and their prominence in resolving the plant associated setbacks has been one of the widely researched facets for deriving productive outcomes. Plant beneficial microorganisms like Actinomycetes, Bacillus, Pseudomonas, Trichodermaetc have been extensively used as bio control agents for counteracting disease causing organisms. Plants have demonstrated the instinctive capability of identifying potential pathogens through a cascade of defence responses which is a consequence of internal molecular system. However, the means adopted by the plants to distinguish beneficial microbes from the pathogenic counterparts is yet to be fully comprehended. Several studies have claimed the importance of specific cell surface receptors in recognizing the invaded pathogen based on the unique pattern exhibited by the pathogen [4&5].

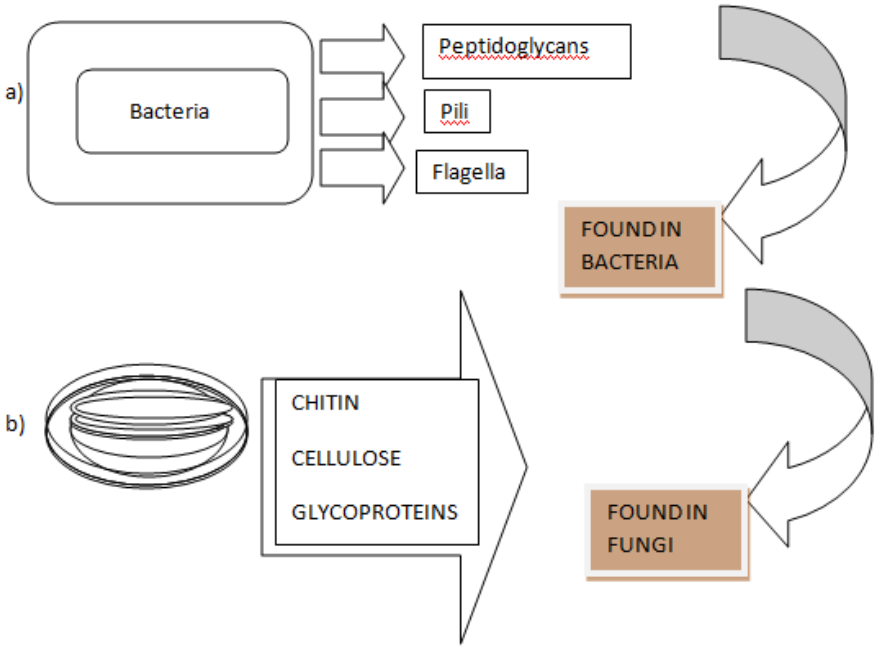

Figure 3. The diagrammatic representation lists out the various cellular components in the microbe responsible for initiating pamps or mamps

PTI- pattern triggered immunity

MAMPs (microbial associated molecular patterns) and PAMPs (pathogen associated molecular patterns) have been very often related to plant defence mechanism because of their proximity with plant immune system. These patterns are inimitable and inclusive to specific microbe which varies from an external

appendage to a vital chemical molecule present in the cellular compartments. Some of these are peptidoglycan of bacterial cell wall, chitin and cellulose found in fungal cell wall, capsule in some microbes or any protein present in the external appendages like flagellin present in the flagella [6].

The first line of defence mechanism that gets triggered in response to molecular or pathogenic pattern is PTI commonly known as pattern triggered immunity. Pattern recognizing receptors play a significant role in identifying the invaded pathogen but there are instances where the pathogen escapes the first level defence mechanism by evading the pattern recognizing receptors. Studies have claimed the role of effector molecules produced by the pathogenic microbes in counteracting the efficacy of pattern triggered immunity. Effectors are virulent molecules capable of compromising the pattern triggered immunity. They are delivered in to plants through microbial secretions and have the ability of subduing the host immune system [7]. The next level of immune response in plants that follows pattern triggered immunity if effector triggered immunity (ETI). As it get activated in response to effector molecules produced by the pathogens, it is widely regarded as effector triggered immunity. Secretions of microbial origin in the plant tissues serve as effector molecules. However, some studies claim the importance of effector molecules in activating pattern recognising receptors [8&9]. The plant microbe interaction seems to be intense and intricate which is yet to be fully understood because these complex interactions involve a plethora of molecular entities that are affiliated with proteins responsible for instigating plant immunity. As a matter of fact, these interactions between plants and microbes serve as the basis for inducing plant defence mechanism.

Plant defence has been a topic of recent interest as it addresses one of the most challenging threats faced by the human community in the form of economic loss incurred as a result of plant pathogens capable if inflicting clinical manifestations. Constant exposure of plants to some of these pathogenic contenders activates the plant immune response in a very unique manner which allows the plants to differentiate the pathogenic organisms from its beneficial counterparts. The hidden insights on how the plant achieves this feat is yet to be fully understood by several studies have claimed the prominence of surface receptors in prompting the plant immune response. Involvement of several genes has been reported in activating the proteins required for plant immunity [10]. The prominence of the environment and the kind of cropping employed also contributed towards the wellbeing of the crop which influences the extent of produce and economic value. Agricultural practices including the type of cropping system, plant variety, irrigation method and kind of chemicals applied for enhancing productivity influences the degree of microbial flora which creates an imbalance between the existing microbial populations. This discrepancy can often lead to the dominance of unwanted contenders capable of causing a disease. Studies have claimed that cropping practices including the cultivation of same kind of crop year after year would have benefitted certain virulent strains of microbes that would have resulted in a major pre harvest losses [11].

Plant microbe interaction

Plants serve as an appropriate environment for the growth and sustenance of microbes of beneficial and pathogenic origin. The mode of microbial contact with the plant occurs through various parts which include aerial and underground structures. The area within the root system has been widely explored to understand its prominence from the view point of establishing initial plant contact. This area commonly referred as rhizosphere is considered to be rich in vital supplies of nutrients that are needed for sustaining microbial life. The exudates that ooze out of the root tips also serve as vital cues in promoting the growth and development of microbes within the vicinity of the root system. This is one of the initial contacts of microbes with the plant system. The exudates let out through the root tips comprise of organic acids, sugars, amino acids and bio molecules of high molecular weight. The carbon source required for the microbes are provided by the sugars and the organic acids and amino acids serve as major reserve of nitrogen supply. Root exudates have known to manifest the soil properties at physical and chemical level which makes the environment conducive for the establishment of soil microbes. However, it would not be appropriate to consider all these to be beneficial because soil is a reservoir consisting of plethora of microbes of diverse nature which include pathogenic contenders responsible for causing clinical manifestations [12 & 13]. As a matter of fact, plant microbe interaction has existed since the time even before plants became the centre of research prominence. Several studies have dated this interaction back to millions of years even before the existence of human beings. The complicated plant microbe interactions have indeed given rise to the emergence of ecological facet called as holobiont[14]. These biotic interactions between plants and microbes can be beneficial or sometimes detrimental which depends on the extent of biotic compatibility and sensitivity of the host towards the invading pathogen. Direct and indirect mechanisms of plant microbe have been extensively explored to disclose the hidden insights from the context of plant growth and development.

Plant roots as a major site for microbial entry

Rhizosphere has been widely regarded as one of the areas known for supporting plant growth and development due to the amount of growth factors that gets concentrated as a consequence of root exudates. The rhizosphere is also known for its microbial diversity which ranges from bacteria to fungi and actinomycetes. It is estimated that rhizosphereharbours over 10^9bacteria followed by fungi and nematodes which accounts to 10^5 and 10^2 respectively [15 & 16]. Studies have claimed the presence of beneficial microbes and harmful pathogens residing within the proximity of the plant root system. Plant growth promoting rhizobacteria and soil borne pathogens are affiliated with the root system. It is believed that roots serve as the major entry points for beneficial and pathogenic bacteria to gain access in to the internal system which might either lead to affirmative or dire outcomes. As a matter of fact, the plant roots are considered as one of the most conducive entries for the microbes to seep inside the plant system. It is believed that the junction at the main and the lateral roots serve as vital points that favour the entry of microbes in to the plants.In addition, the tip of the root cap cells also serve as means for microbial entry in to the plants [17]. Therefore, it is quite vital for the roots system in plants to detect the incoming

pathogen and produce defence mechanism in response. Several studies have validated the environment within the proximity of the root system in either favouring the microbial sustenance or inhibiting. The type of root secretions which are otherwise known as root exudates play a prominent role in benefitting or hindering microbial density. The pH within the rhizosphere gets influenced in accordance with the kind of substrate getting processed by the microbes and the secretions that seep in to the deeper layers of the soil from the plant root tips [18]. It is therefore vital from the plant roots context towards the fortification of plant physiology through activating defence mechanism as a means to counteract the pathogenic microbes. Several demonstrative studies have attempted to substantiate the prominence of rhizoflora in plant growth and development and major aspects in relation to plant immunity are yet to be fully understood. Several molecules of plant and microbial origins are involved in the stimulation of plant defence mechanism.

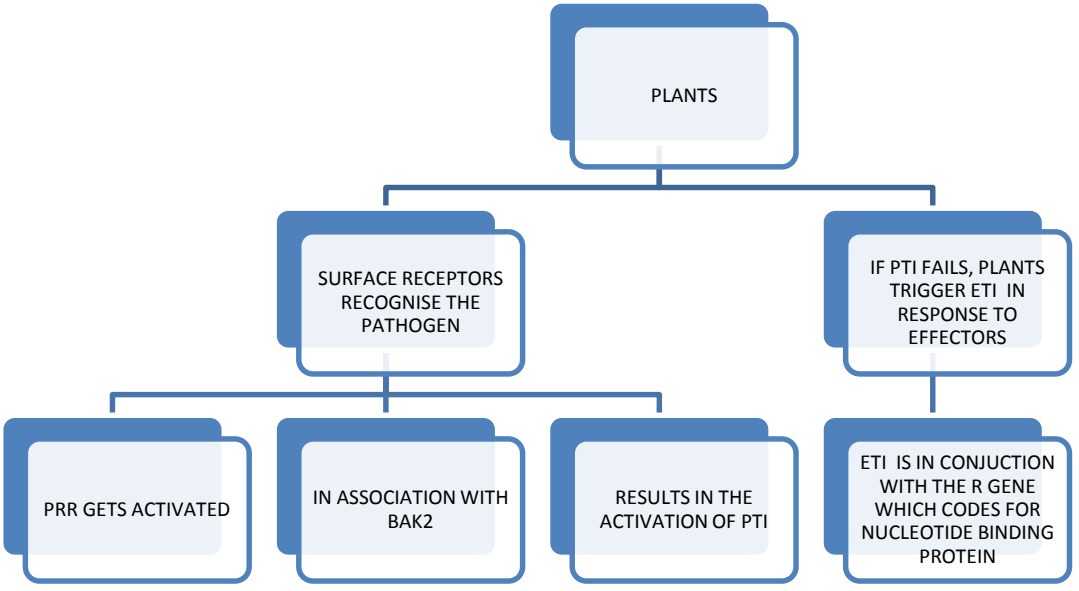

Figure 4. Illustrates the diagrammatic representation of pti and eti in response to specific signals

ETI- effector triggered immunity

The above diagrammatic illustration provides a gist of plant immunity that gets activated at different points in response to different cues. Presence of specific receptors called as pattern recognizing receptors play a vital role in stimulating pattern triggered immunity commonly referred to as PTI. The incoming pathogen serves as the cue for activating plant defence based specific pattern exhibited by the microbe/pathogen (PAMPs/MAMPs). The above illustration attempts to disclose the prominence of PRR (pattern recognizing receptors) in inducing PTI

(pattern triggered immunity). So PTI can be regarded as the first mode of defence in plants [19]. However, there are instances where the pathogenic contender tends to escape pattern triggered immunity by secreting effector molecules. The immunity that gets activated in response to effector molecules is called effector triggered immunity commonly referred to as ETI. The ETI also known as the gene to gene resistance occurs with the assistance of R receptor which is a cytoplasmic receptor and is a nucleic acid binding protein consisting of leucine rich repeats [20]. It is quite obvious that plants have the tendency of counteracting the incoming pathogen by activating a plethora of factors at the molecular level that are capable of instigating defense mechanism in plants in response to a variety of cues. Resistance among plants to a range of disease causing agents is initiated through surface or cytoplasmic receptors in turn leading to pattern triggered immunity or effector triggered immunity. The surface receptors embedded in the cell membrane serve as major points for activating pattern triggered response causing pattern triggered immunity which is based on the pattern exhibited by the invading pathogen.

Several studies have claimed this mechanism as the initial mode immunity exhibited by the plants against the invaded pathogen [21]. In addition to PTI, plants have other means of counteracting the pathogenic microbes which relies on cytoplasmic proteins that are nucleotide binding due to the presence of nucleotide binding domain. The leucine rich repeats in these receptors are very vital for their potentiality as these repeats serve as hot spots in activating immune response against effector molecules produced by the invaded pathogens. As this mechanism gets activated in response to effector molecules, it is commonly called as effector triggered immunity and the cytoplasmic receptors involved in stimulating this process are effector recognizing receptors [22]. Though these contrasting classes of receptors respond to different signaling molecules and have known to follow specific pathways, studies have attempted to disclose the similarities between these as there are evidences which try to validate the similarities between these classes of receptors. Molecular analysis has revealed the existence of complicated relation between pattern triggered and effector triggered immunity [21]. Sub cellular insights and molecular research suggests the existence of interactions between pattern triggered immunity and effector triggered immunity through a cascade of hierarchical molecular interactions which is yet to be completely understood.

Discussion

Plant defense mechanism has been extensively studied for its intricacies and molecular mechanism that puts across the line of protection against the invading pathogens. Though this process is yet to be completely comprehended, several scientific investigations have attempted to disclose the hidden insights. Studies have revealed the existence of inborn and acquired means of protection in plants in response to the pathogens [23]. Plant immunity is a consequence of several factors ranging from extracellular components to sub cellular facets. Various proteins have known to be associated with a series of hierarchical cascade for the stimulation of protection which occurs in response to vital cues which serve as signals. The association of the signaling molecules with cell specific receptors is the onset of plant defense [24]. Cell independent happenings have been related to

plant immunity which is the part of adaptive immunity that gets stimulated in response to a pathogenic contender. Several ongoing research investigations have disclosed the existence of two strategies employed by plants to counteract the disease causing microbe. The significance of PAMPs or MAMPs in plants cannot be denied as they serve as different levels of plant immunity as they get stimulated in response to a variety of cues. These cues act as initiators for the onset of either of these strategies employed by the plants. Though pattern triggered immunity is capable of warding off the pathogenic microbe, the possibility of the disease causing microbe to escape the consequences of initial defense mechanism has been reported by several studies.

As a matter of fact, this behavior of the pathogenic microbes is due to the production of effector molecules which confers the pathogenic microbe to escape the consequence of PTI (pattern triggered immunity). This is further succeeded by effector triggered immunity (ETI) which gets stimulated in response to the effector molecules produced by the disease causing [25]. The hidden insights of effector triggered immunity has enhanced the understanding of plant and microbial interaction at the molecular level which in turn rely on the resistant genes capable of fortifying the plants against a disease causing agent. These molecular interactions at the sub cellular level have indeed provided a cohesive understanding on vital genes involved in the onset of defense mechanism in response to effector molecules [26].

Several studies have emphasized on the role of biotic stress in switching on the defense cascade in plants. It is a widely accepted fact that plants are constantly challenged by a variety of microbes which ranges from bacteria to fungi including viruses and other pathogenic contenders like insects and pests. All these contribute to biotic stress in plants. The molecular and cellular facets in plants serve as vital landmarks in triggering the defense mechanism under circumstances severe stress [27 & 28]. The prominence of sub cellular entities in fortifying the plants has been experimentally validated which encompass a complicated network through physiological aspects and biochemical abilities. The physiological context and the biochemical traits promote the degree of defense mechanism against the invading pathogen. Prominence of sensory molecules in the plant cells have known to exhibit sensory framework which overcomes the detrimental consequences of the pathogenic counterparts [29]. Scientific investigators have indeed substantiated the fact of varying responses in plants that reveals the intensity of plant immunity against the disease causing agent. Plants have progressed over the course of time and have widened their sensory mechanisms towards a broad range of pathogens [30]. Hence, plants are likely to combat the invaded pathogen by developing immunity through a series of hierarchical cascade that is known for activating specific pathways which in turn switches on the defence mechanism.

Conclusion

Immunity commonly refers to the collection of mechanism within an organism that provides the strength to counteract the pathogen contenders capable of causing clinical manifestation. Plants are not an exception to this process and evidences from the context of plant defence mechanism through molecular

channels have been the topic of research interest. Plants immunity and associated aspects are not new to the scientific community but the exact framework involved in the molecular cascade is yet to be deciphered. Several sensory receptors and associated bio-molecules have known to put across the defence mechanism in an affirmative manner, the exact insights are yet to be understood. Studies have validated the importance of pattern triggered immunity which is widely regarded as the first mode of plant defence mechanism offering immunity against pathogenic microbes based on the specific pattern exhibited by the invading pathogen. Several membrane receptors are involved in this mechanism which responds to a variety of cues causing a defence cascade. Pattern triggered immunity is conducted through pattern recognizing receptors. On the contrary, the presence of effector triggered immunity in plants has been widely studied and is considered to be more intense as it involves a series of sub cellular molecules. A variety of proteins are involved that gets triggered in response to effector molecules produced by the pathogenic microbe. These proteins are believed to be further fortifying the reaction but the exact path of activation is yet to be fully understood. There is a need to further explore the molecular vitals in plants to have a better understanding on their immunity.

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