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PLANT MICROBE INTERACTIONS, BIOTROPHIC STRUCTURE AND PLANT DEFENSE MECHANISMS – A COMPREHENSIVE REVIEW

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ABSTRACT
Biotrophic pathogens get supplements from living cells by keeping up have reasonability. This host maintenance continues through profoundly particular auxiliary and biochemical relations. Hemibiotrophic plant pathogens initially build up a biotrophic connection with the host plant and later change to a dangerous necrotrophic way of life. Investigations of biotrophic pathogens have demonstrated that they effectively smother plant protections after an underlying organism related sub-atomic example activated enactment. Plant receptor-like kinases (RLKs) work in differing flagging pathways, remembering the reactions to microbial signs for beneficial interaction and protection. This versatility is practiced with a run of the mill for the most part structure: an extra cytoplasmic space (ectodomain) and an intracellular protein kinase territory drew in with downstream sign transduction. Customized cell passing (PCD) is fundamental for appropriate development, improvement, and cell homeostasis in all eukaryotes. The guideline of PCD is of focal significance in plant-organism connections; outstandingly, PCD and highlights related with PCD are seen in many host opposition reactions. In this way, the gathering in charge of PCD has an unmistakable bit of leeway in these fights.

Keywords: Biotrophic, Eukaryotes, Necrotrophic, Pathogens, Receptor-like kinases

Introduction
Plants are often colonized by a broad range of microorganisms including prokaryotes (bacteria), fungi and oomycetes. The strikingly wide spectrum of plant-microbe interactions may result in annihilator diseases, beneficial symbioses or seemingly neutral endophytic copulation [1]. These relationships are classified as biotrophic, hemi-biotrophic, necrotrophic or saprotrophic based on the physiological status of the plant host. Of these biotrophic interactions, i.e. relationships in which microorganisms coordinated with a living plant without killing it, are particularly enchanting since they're supposed to require an advanced level of molecular communication between the plant and the microbe. In the past few years, secreted microbial effector molecules emerged as resolute agents in this molecular dialogue. In this review paper, we have a tendency to welcome contributions on parasitic, mutualistic likewise as endophytic plant-microbe interactions [2]. Quite a lot of plant-pathogenic fungi establish a long-term feeding relationship with the living cells of their hosts, instead of killing the host cells as

a region of the infection method. These pathogens are known as biotrophic [from the Greek: bios means life and trophy means feeding]. Normally, these organisms develop between the host cells and attack just a couple of the phones to deliver supplement retaining structures which are called as haustoria [3]. By their feeding activities, they produce a nutrient sink to the infection site, in order that the host is deprived but isn't killed. This kind of parasitism might lead to serious economic losses of crop plants, and in natural environments it'll reduce the competitive abilities of the host; indeed, some biotrophic pathogens are used successfully as biological control agents of agricultural weeds [4].

Poison (Toxin) neutralizing agent (TA) frameworks are ever-present bacterial frameworks which can act in genome upkeep and metabolic pressure association, anyway are likewise thought to assume a job in harmfulness by helping pathogens endure pressure [5]. TA frameworks are currently thought to build harmfulness through components that may incorporate expanded pressure opposition, persevered cell development, or biofilm arrangement. Plant pathogens region unit ordered put together up with respect to their nourishment strategies [6]. Biotrophic pathogens get supplements from living cells by keeping up have reasonability and this way of life appears differently in relation to that of necrotrophic pathogens effectively slaughter have tissue as they develop on the substance of dead or kicking the bucket cells. The following gathering, hemibiotrophs, show the two types of supplement by means of moving from an early biotrophic stage to necrotrophy recently [7]. The length of the biotrophic or necrotrophic area shifts essentially among hemi-biotrophic pathogens. These distinctive ordered kinds of pathogens show contrasts in resistant reactions because of their methods of supplement take-up. The biotrophic organisms and their plant have exceptionally concentrated relationship fundamentally and furthermore biochemically [8]. Biotrophic parasites infiltrate the host cell film and colonizing the intercellular space utilizing taking care of structures like haustoria to take supplements and smother have protections without disturbing the cell layer. By their taking care of exercises, biotrophic growths produce a supplement sink to the contamination site, all together that the host is denied and shows genuine yield lost. This sort of parasitism is unimaginably complex keeping the host alive as an all-encompassing term gracefully of food [9].

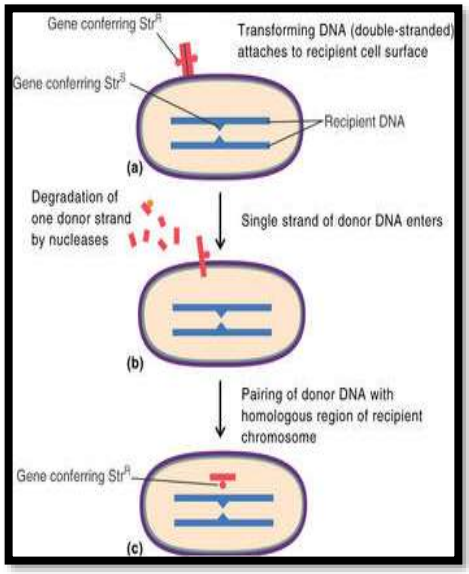
In this audit the most significant gatherings of biotrophic organisms plant pathogens like fine mold parasites, the rust growths and plant guard system have been thought of Programmed cell passing (PCD)/necrobiosis is significant in all eukaryotes for legitimate development, improvement, and cell homeostasis [10]. The guideline of PCD is of focal significance in plant-organism cooperations; strikingly, PCD and highlights related with PCD are seen in different host obstruction reactions. Then again, irresistible specialist or pathogen enlistment of improper cell passing inside the host brings about a helpless phenotype and unwellness. Hence, the gathering in charge of PCD joins unmistakable bit of leeway in these fights. PCD structures appear, apparently, to be of out-of-date source, as showed by the way that various features of cell passing framework are spared among plants and animals; regardless, a segment of the nuances of death execution may differentiate. Mammalian center PCD qualities, similar to caspases, don't appear to be available in plant genomes [11]. Also, antiapoptotic class of mammalian administrative components are missing in plants, in any case, surprisingly, when communicated in plants, effectively sway plant PCD. In this way, unobtrusive auxiliary similitudes independent of arrangement likeness appear to continue operational equality. The vacuole is ascending as a key cell organ inside the regulation of plant PCD. Under very surprising signs for necrobiosis, the vacuole either combines with the plasmalemma film or breaks down [12]. Additionally, the vacuole appears to assume a key job in autophagy; evidence recommends a master endurance perform for autophagy, anyway elective investigations propose a professional passing phenotype. Here, we will in general portray and talk about what we as a whole know and what we don't comprehend about different PCD pathways and the way how the host coordinates signs to initiate 2-hydroxybenzoic corrosive and responsive 02 component pathways that arrange necrobiosis [13].

Plant receptor-like kinases (RLKs) act in different flagging pathways, remembering the reactions to microbial signs for advantageous interaction and safeguard. This adaptability is accomplished with a standard by and large structure: an extra cytoplasmic area (ectodomain) and an intracellular protein

kinase space worried in downstream sign transduction [14]. Various surfaces of the leucine-rich rehash (LRR) ectodomain structure are utilized for communication with the related substance in both plant and creature receptors. RLKs with lysin-theme (LysM) ectodomains give recognitional explicitness toward N-acetylglucosamine-containing particles of flagging, similar to chitin, peptidoglycan (PGN) and rhizobial nodulation factor (NF), that actuate insusceptible or Signaling downstream of RLKs doesn't tail one example; rather, the intricate investigation of brassinosteroid (BR) flagging, inborn invulnerability and beneficial interaction uncovered at least three to a great extent non-covering pathways [15].

Mechanism of Biotrophic Pathogen Infection

Pathogens have to pass the complex multi-layered defense system of plants for compatible interaction. Fungal protection may include fungal chitin shield, scrounger, which protects the fungal cell wall and the chitin fragments from chitinases. As an example, effector of fungal species namely, *Cladosporium fulvum* holds a functional chitin-binding domain [16]. Plants secrete/release ß-1,3-glucanases to break fungal cell walls but some pathogen produces glucanase inhibitor protein. Different effectors (proteinase inhibitors and phytoalexin detoxifying compounds) may help the pathogen achievement as well. Extensive stretches of coevolution among plants and microorganisms have prompted complex instruments of offense and resistance that focal point of the inborn invulnerable arrangement of host plants that going up against destructiveness determinants of pathogens. These collaborations are layered: Basal resistance, which is the principal line of protection, is wide in its viability and is predicated on the acknowledgment of pathogen explicit microbial particles [microbe-related sub-atomic examples (MAMPs) or pathogen-related sub-atomic examples (PAMPs)]. The fundamental parts in such receptor-based acknowledgment are exceptionally monitored components, including flagellin, peptidoglycan, and chitin, that are normal however explicit over the microbial species . These sorts of parts are carefully misused by plants since it is likely hard for microorganisms to transform and to conquer such obstruction or adjust such essential segments and in this way sidestep plant acknowledgment in light of serious wellness punishments to the pathogen. PTI is seen as a basal degree of guard [18].



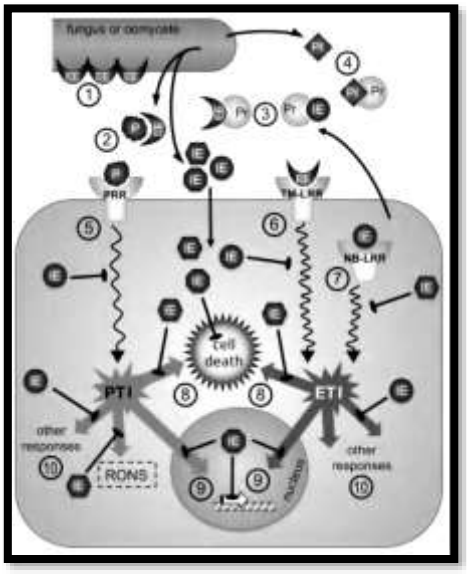


Figure 1: Transformation of the DNA into the host cell., **Figure 2:** Effectors entering the host cells through different pathways.

For the accomplishment of pathogenesis including connection, have acknowledgment, entrance and expansion biotrophic growths use to make the contamination structure and the structure arrangement

is confined by some directed quality articulation and complex administrative pathways. For significant destructiveness action, biotrophic organisms have some trademark highlights, for example, profoundly created contamination structures; restricted secretory movement, particularly of lytic chemicals; starch rich and protein-containing interfacial layers, which separate contagious and plant plasma layers; long haul concealment of host barrier; haustoria that utilized for supplement assimilation and digestion. Biotrophic growths additionally have a few instruments to protect their effectors from plant receptor particles. When the parasitic effector passes plant safeguard system the plant won't avoid and it will turn out to be dead [19]. Therefore, the plant decreases creation of protection flagging atom like salicylic corrosive (**Figure 2**).

To accentuate the contamination procedure in have plant by biotrophic growths are clarified here-
Cladosporium fulvum: It is a biotrophic contagious pathogen that causes leaf form sickness of tomato plant. The disease, colonization, and concealment of host resistances by *C. fulvum* are made by a number out of effector proteins. So as to stay away from have acknowledgment by have PRRs *C. fulvum* discharges the effector Ecp6 that contains a chitin restricting space called-LysM. To limit the arrival of chitin oligosaccharides by restricting chitin in the unblemished contagious cell divider *C. fulvum* likewise secretes the Avr4. Notwithstanding chitin restricting proteins, secretes the effector Avr2, which hinders plant extracellular cysteine proteases required for basal guard additionally emitted by *C. fulvum* for effective host guard concealment [20, 21].

Ustilago maydis: *U. maydis* is a biotrophic parasite that causes filth maize to the plants by entering the plant cell divider and creates hyphae that are encased by the plant plasma film and are considered to interface for supplement take-up and signal correspondence. A few qualities of this pathogen are up-managed at the hour of contamination for the concealment of host resistance system. Among the most anticipated *U. maydis* effectors, Pep1, which is a little (178 amino acids) protein required for fruitful attack of epidermal cells of Zea mays. Vaccination of leaves with erasure freaks of *U. maydis* lacking Pep1 prompted the disappointment of the pathogen to build up a good connection with the host. A few elements assumes a significant job in contamination procedure of *U. maydis* including the emitted hydrophobin, Hum3, and the hydrophobic tedious and discharged protein, Rsp1 effectors are engaged with cell bond and surface covering too [22, 23].

Blumeria graminis: *B. graminis* (commit biotrophic growth) that causes the fine build-up ailment on wheat and grain. *B. graminis* develops as filamentous hyphae on the leaf surface. Anyway in the wake of infiltrating the mass of the hidden epidermal cells it frames a particular taking care of structures called a haustoria, which encompassed by an unblemished plant plasma layer (**Figure 3**). In the *B. graminis f. sp. hordei* genome, Recently around 248 applicant emitted effector proteins (CSEPs), less homology with other related species, have been distinguished. AVRa10 and AVRk1 effectors, which are recently distinguished have significant job disease upgrade [24, 25].

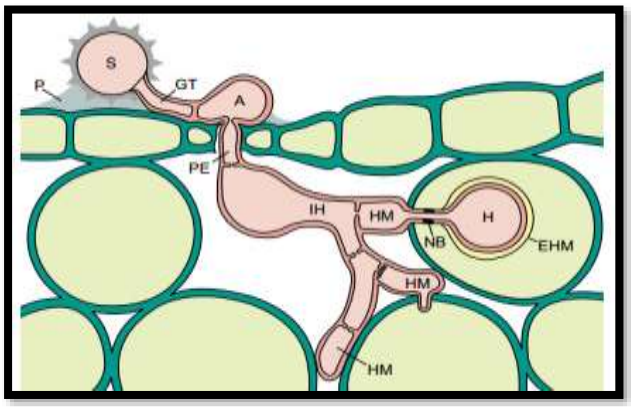


Figure 3: Biotrophic infection by fungi

Erysiphe necator*: E. necator* is an obligate biotrophic fungus that causes powdery mildew in grapevine. This pathogen fully depends on photosynthesis-active tissues to complete its life cycle. When a conidiospore of *E. necator* lands on the epidermis of photosynthesis active tissues, it germinates to form a lobed appressorium. Its germination and development involves through the secretion of fungal lytic enzymes such as chitinases esterases and lipases, which leads to the release of long-chain fatty acid derivatives. A haustorium is a specialized intracellular structure, formed from the lower surface of the appressorium by penetration peg emerges that penetrates the cell wall and invades the host epidermal cell [26]. The haustorium is an interface between the host cell and the fungus that facilitates the dynamic exchange of molecules derived from both fungal and host cells. The fungus obtains amino acids, hexoses, vitamins, and other nutrients from host cells, through the haustorium. If the interaction is compatible, the fungus proliferates via hyphae across the surface at regular intervals. To start a new cycle of infection, after 5–25 days sporulation occurs in the form of conidiophores. During the whole infection process secretion of effecter proteins takes place to suppress host defense mechanism. Adapted PM species are able to successfully penetrate their host plant by secreting effector proteins that suppress host PTI. However, successful penetration by the adapted PM species has been shown to be dependent on the presence of a functional allele of the Mildew resistance Locus O (MLO) in a range of host species. Based on this result the suggestion goes to, adapted PM species are able to utilize MLO proteins to suppress host PTI by the secretion of an effector that targets MLO. For instance, Arabidopsis PM susceptibility protein AtMLO2 acts as a susceptibility factor for infection of by *Pseudomonas syringae* (bacterial pathogen), which is targeted by the *P. syringae* effector HopZ [27].

Melampsora lini*:* It is a rust biotrophic parasite that causes flax rust in the plant's body. Like fine molds, rust disease can likewise frame haustoria, but instead than leaf surface, rust hyphae duplicate inside the leaf. AvrL567, first distinguished flax rust effector protein was perceived by the L6, L5, and L7 R proteins. In view of enhancing determination process, this effector can grouped into twelve additional variations, some of which through changing surface uncovered amino corrosive deposits have now gotten away from acknowledgment by the related R proteins. Other three discharged flax rust effector proteins, AvrM, AvrP123 and AvrP4 have been recognized, which have significant job in have guard concealment [28, 29].

Interactions Defined by Exchange of Food

Plants are no exemption to the current all-inclusive principle: they share their own space with benefits of organisms. On account of living plants, this may bring about apparently unbiased [30], commonly helpful or inconvenient communications. For this explanation, these kinds of organisms are usually called endophytes, symbionts and pathogens, separately. The best examined associations are those which brings about exchange of assets, including supplements, from one accomplice to the next. These connections are purported "trophic" and are regularly used to group associations among plants and organisms. In basic terms, when the plants stay alive during the supplement trades, we talk about "biotrophic communications" and allude to the microorganisms as "biotrophs". This is normally the situation in harmonious connections, yet in addition including some event of parasitism. Biotrophy is in this way negated to "necrotrophy," that is the point at which the microorganisms slaughter plant cells and tissues, to take care of off the remaining parts, which is trademark for a few phytopathogens. At the point when organisms are essentially ready to take care of off plant which are dead, remains while having no influence in the slaughtering, we call them as saprotrophs [1, 31].

Table 1: List of some economically important biotrophic fungi

Species	Host(s)	Diseases
Erysiphe graminis	Grasses	Powdery Mildew of Grasses
Erysiphe macrospora	Elm	Powdery Mildew of Elm
Erysiphe necator	Grape	Powdery Mildew of Grape
Leveillura Taurica	Cotton	Powdery Mildew of Cotton and many other
Phyllactinia alnicola	Oak, Alder	Powdery Mildew of Oak, Alder
Ovariopsis	Hazel, Ash	Powdery Mildew of Hazel, Ash
Podosphaera macularis	Hops	Powdery Mildew of Hops
Coleosporium ipomoeae	Sweet potato, pine needle	Sweet potato Rust, Pine needle Rust
Cronartium flaccidum	Scotch pine Blister	Scotch pine Blister Rust
Melampsora epitea	Poplar-Conifer	Poplar-Conifer Rust
Phakopsora pachyrhizi	Soybean	Soybean Rust
Kuehneola uredines	Blackberry	Blackberry stem and leaf Rust
Phragmidium tuberculatum	Blackberry, Rose	Rust of Blackberry, Rust of Rose
Phragmidium violaceum	Blackberry	Blackberry Rust
Gymnosporangium sabinae	Pear	Incense Cedar-Pear Rust, Juniper Gall Rust, Pear Trellis Rust

The congruity is that saprotrophy is represents plant-related microorganisms [32] Necessities expected to get to supplements from dead plants fuse the ability to corrupt biopolymers, successfully explore solid issue, and oversee perhaps harmful blends left by the dead plant. Partner with a live plant accessory requires considerably more incredible and baffled segments, first and initialise the capacity to oversee and accept accountability for plant opposition, which created to shield plants from bothersome, damaging assault [33] (Figure 4).

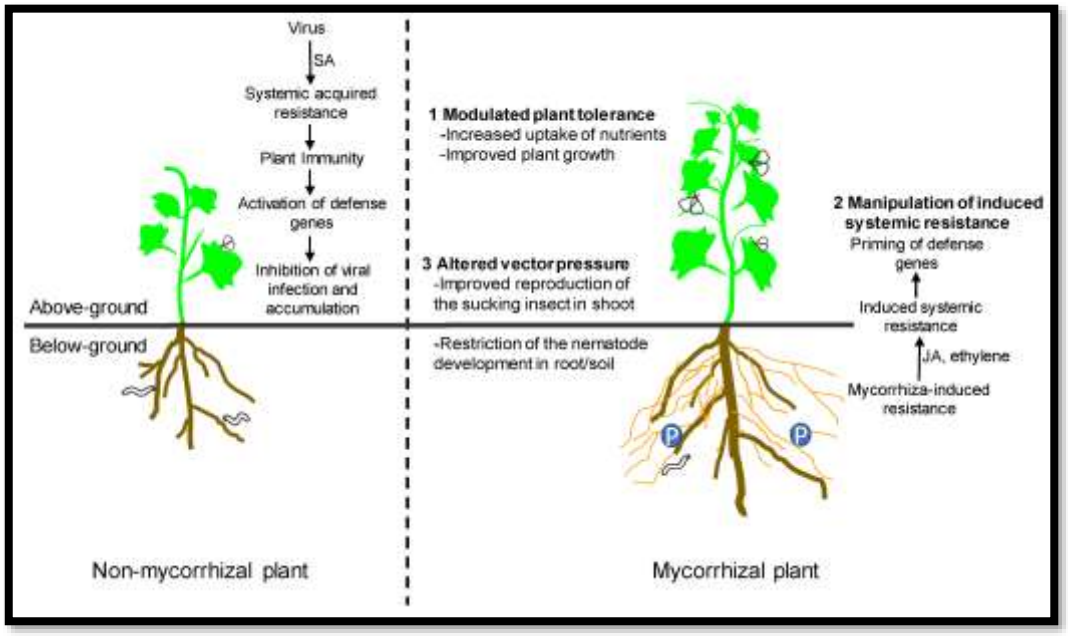


Figure 4: Mutualism relationship between plant and microbes.

Is Killing Simpler than Sharing?

For a long time, biotrophy has been reviewed as the most perplexing type of trophic connection between living beings. This has driven numerous to consider biotrophy to be increasingly "exceptional" [2, 34], as it might be a questionable and not especially valuable term. As of late, there has been an update of this: genuine necrotrophy ways of life are upheld by exceptionally complex/developed executing components (Oliver and Solomon, 2010). They are not straight forward blunderers that have created from saprotrophic living beings [34].

It has been generally acknowledged that the difference among biotrophic and necrotrophic collaborations may likewise be unquestionable in explicit pathways that host plants use to flag reactions to the attacking organism. Through this procedure, salicylic corrosive intervened reactions are viewed as common of responses to biotrophic assault, while jasmonic corrosive and ethylene-interceded ones are accepted to be related with necrotrophy. This differentiation is presently brought into question, with information uncovering jobs for jasmonic corrosive motioning inside the vehemently biotrophic association of grapevine with wool mold [35].

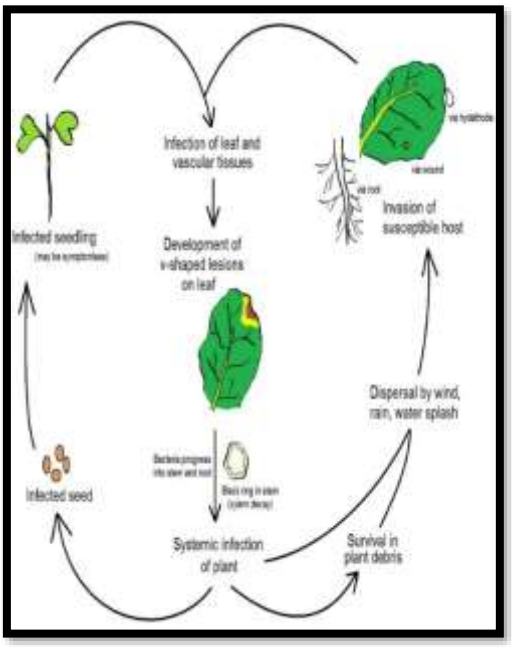


Figure 5: Infection process in the host.

The Compulsion to Feed Off Life: Obligate Biotrophs

This modification all things considered, biotrophic microorganisms have grown outstandingly complex systems to get to plant assets. The rich specialty spoke to by a plant have been portrayed by having less microbial contenders than, soil or water. Along these lines, opening access arrange a noteworthy preferred position: plenteous assets accessible with "unsurprising" recurrence all through reality. When this space was involved, a few microorganisms seem to have lost the first ability to develop on non-live material: these are perceived as the "commit biotrophs." [36]. The principal outrageous of the commit biotrophs become so reliant of a live host that we can't reproduce a worthy domain in axenic societies under lab conditions. Instances of these are the exceptionally antiquated mutualistic symbiont arbuscular mycorrhizal growths that are close to universal colonizers of plant roots, the normal fine build-up and rust organisms (uncommonly ascomycetes and basidiomycetes), just as a portion of the oomycetes, for example, fleece molds and white rusts [37].

One Haustorium does Not Make a Biotroph

Furthermore, to complex atomic systems pointed toward tuning plant invulnerability, numerous biotrophic microbial eukaryotes produce challenging morphological structures splendidly adjusted at abstracting supplement from plant cells: these are named haustoria. They're terminal branch development of the microbial cells and hyphae that infiltrate through
the cell dividers. The most forcing of these are seen in the Arbuscular mycorrhizae, which produce the eponymous "arbuscules" taking after little trees or shrubberies [38]. Comparative structures are made by a portion of the fine molds, in a wonderful case of the developmental union standard. At the opposite finish of the multifaceted nature range, we find the straightforward bulbous haustoria made by rust organisms and oomycetes. The regular component of every single genuine haustorium/arbuscules is that they're framed by hyphae that infiltrate the host cell divider, yet don't

pervade the plant cell film [26]. Or maybe, the plasma film invaginates and produce another structure, the perihaustorial/periarbuscular layer, with extremely extraordinary properties that are particular from the commensurate plasma film. In the life forms that make them, the majority of the significant supplement and flagging trades are thought to occur here [39].

Be that as it may, biotrophs don't appear to be confined to haustoria framing growths. There are different simply apoplastic biotrophs, for example biotrophs that don't approve any exceptionally particular haustoria. Instances of this include the parasitic tomato pathogen *Cladosporium fulvum* and along these lines the corn muck pathogen *U. maydis* [26, 40]. Self-obviously, trades between plant have and, in this manner, the microbial "visitor" must happen inside the apoplast in these examples. However, that apoplastic flagging can likewise be allowable in connections where haustoria are shaped. A most extraordinary type of apoplastic biotrophy is prominent in the alleged "endophytic" microorganisms. These are microorganisms that colonize plant has, at first sight asymptomatically. Lately, the significance and capability of these co-operations has been perceived and prompted coordinated endeavors at using the focal points haggles on the host regarding upgraded protection from pathogen disease [1, 41].

Hemibiotrophs: Interactions that Straddle the Divide

Commonplace hemi-biotrophic microorganisms start off with an asymptomatic stage, which at that point changes to a slaughtering frenzy the necrotrophic stage when have cell passing is regularly connected with broad microbial colonization and sporulation. An intriguing inquiry is whether the asymptomatic stage can be partner with genuine biotrophy [35, 42]. The convincing point is whether as of now the organism is dynamic, developing and taking up supplements from the host (in which case we have genuine biotrophy), or whether they are essentially making due on endogenous put away saves (in which case they are not so much biotrophs), and a further chance is that the microbial accomplice is really lethargic and subsequently it may be genuinely defended to call this an inactive stage. A last choice is that the microorganism is basically imperceptible, comparative with the obviously noticeable biomass at later stages, when exponential development accompanies the necrotrophic stage, and sporulation. Characterizing which of those is genuine is testing in light of the fact that there's next to zero microbial biomass for every plant tissue right now [43].

If the primary time of tainting in hemi-biotrophs is truly biotrophic, we may then request ourselves what the circumstance from unique necrotrophs really is. In Botrytis, that perspective is ordinarily depicted as inert. It is ending up being evident that there are drawing in events of truly endophytic Botrytis species [44]. These are consistently camouflaged as a result of their characteristically asymptomatic nature. By then there are pathogens that haven't the faintest idea what they are: take Leptosphaeria maculans, the parasite that causes dim leg on brassicas [45]. These take off with a brief an intriguing/biotrophic defilement on leaves, which change to necrotrophy clear as dead leaf wounds. The disease by then goes to an asymptomatic/biotrophic and endophytic stage in which the development grows intercellularly, showing up at the crown of the create plant where necrotrophic contaminations are surrounded [46].

Resistance against Biotrophic Pathogens

The plant resistant system created to adjust moreover to biotrophic pathogens. A key starting event of obstruction is the perspective on pathogen-decided particles ("structures") by membraneresident receptors (routinely named plan affirmation receptors [47]. A second layer of plant boundary lays on the prompt or indirect affirmation of released pathogen effectors, by consistently cytoplasmic immune sensors ("resistance proteins"; similarly named nucleotide binding oligomerisation space (NOD)- like receptors) that regularly give segregate express obstacle [48]. Execution of the genuine shield response as often as possible incorporates re-relationship of the host cytoskeleton (Figure 6) and secretory activity [49, 50]. Additionally, phytohormone hailing and other plant sections may add to restriction or opposition might be formed by the nonattendance of major host factors [51].

Mutual Influence of Biotrophs and other Microbes

A to a great extent disregarded part of the science of connections among plants and biotrophic microorganisms is their adjustment by any third partner(s). Truth be told, the rhizosphere and phyllosphere of plants is colonized by different epi-/endophytes, and various pathogens or potentially symbionts may happen simultaneously on a given plant. Subsequently, biotrophic organisms may need to rival different microorganisms for their environmental specialty [52]. This may cause adjusted contamination phenotypes of biotrophic pathogens within the sight of different pathogens (Orton and Brown) or epi-/endophytes and furthermore could bring about regulation of advantageous cooperations by phytopathogens (Figure 7) [34].

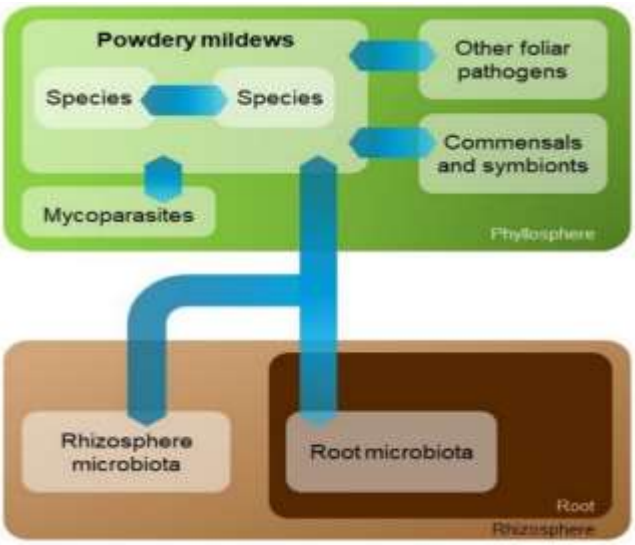


Figure 7: Mutual influence of Biotrophs and other Microbes

Conclusion

In this article, we explored the occasion of plant-microorganism communications and along these lines the components, and a couple of the principal dangerous plant illnesses around the world. In the same way as other types of *Cladosporium fulvum, Ustilago maydis, Blumeria graminis* and some of them are hemi-biotroph, during the underlying phase of disease, it colonizes have tissue intracellularly without causing host cell demise. Most biotrophs achieve biotrophic development by effectively stifling the unwellness reactions of the plant. Plant natural safe reactions PTI and ETI happen to initiate resistance signal particles because of the notoriety of effectors by design acknowledgment receptors and R proteins individually. Biotrophic growths have numerous components to protect their effectors from plant receptor particles and conjointly fast advancing arrangement of their putative effectors. When the parasitic effector passes plant safeguard system the plant won't help it. Hence the plant lessens creation of safeguard signal atom like hydroxy corrosive. Comprehension of the association between pathogen destructiveness and are making some amazing progress. A few inquiries yet not replied. The vast majority of parasitic effectors work inside the cytoplasm of plant need clear signals development component from their underlying grouping. In this way, the procedure how effectors stamped and conveyed into have plant plasma part isn't clear. Due to the inferable from the different parasitic effectors and less closeness succession with realized proteins construct hard to know their jobs in infection and which leads to the host cell death.

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