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Endophytes: An Overview

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Abstract Endophytic bacteria are those that live inside of plants for at least some of the plant's life cycle but do not cause any outwardly apparent symptoms of the disease. In light of the fact that endophytes are a source of phytochemicals of high value, it is essential to bioprospect these microorganisms in order to find a wide variety of related phytochemicals that have some sort of therapeutic effect. Plant endophytes can stimulate plant growth in a number of different ways, including fixing atmospheric nitrogen, creating phytohormones, preventing the spread of phytopathogens, and improving mineral uptake. Endophytes possess different types of bioactivity, such as antibacterial, anticancer, antifungul and antiviral agents.

Keywords Endophytes, fungal endophytes, prokaryotic endophytes, Endophytic bacteria, Metabolites

Introduction

Endophyte

Some bacteria and fungi are able to live within plant tissues without causing any harm to the hosts they are living on, and these organisms are known as endophytes. According to the available findings, microbial endophytes can be found in virtually all of the tissues that make up the host plant [1].

Endophytic bacteria are those that live inside of plants for at least some of the plant's life cycle but do not cause any outwardly apparent symptoms of the disease. Broadened definition of an endophyte includes any organism that colonizes the interior tissue of a plant over the entirety of that plant's life cycle, regardless of whether or not the endophyte is beneficial, detrimental, or neutral to its host. The term "endophyte" originated as an ecological concept, but it is now often understood to refer to a natural component of the plant-microecology system. There are millions of endophytic fungi existing in certain circumstances, ranging from 2.7 Lakh to 4 Lakh different species, in the microtubules of plant cells and the intercellular space. The endophytic fungus Neotyphodium coenophialum was identified as the causal organism of 'fescue toxicosis,' a sickness experienced by cattle fed on pastures of the grass Festuca arundinacea, which facilitated further investigation into this phenomenon. Poisonous alkaloids were discovered in infected plants, although it has been suggested that Neotyphodium species actually help their plant hosts by enhancing their resistance to biotic and abiotic stress.

Endophytes are organisms that live as a symptomless colony inside the host plants, maybe during a portion of their life cycle. To differentiate endophytes from epiphytes, which are organisms that live on the surface of a plant, De Bary (1866) came up with the word "endophyte." Endophytes can be found in a variety of taxonomic groups, including bacteria, fungi, protists, and archaea, and they are typically categorized as mutualists. To the contrary, endophytes are non-pathogenic microorganisms that can be safely isolated from either the surface of sterile explants or directly from the plant tissue. According to Stone et al. 2000 "Endophytes can be recognised as:

1. endophytic Clavicipitaceae
2. fungal endophytes of dicots
3. endophytic fungi
4. other systemic fungal endophytes
5. fungal endophytes of lichens
6. endophytic fungi of bryophytes and ferns;
7. endophytic fungi of tree bark
8. fungal endophytes of xylem
9. fungal endophytes of root
10. fungal endophytes of galls and cysts
11. prokaryotic endophytes of plants (includes endophytic bacteria and actinomycetes)" [2-4]

They benefit from the host plant's defenses and sustenance while also boosting the plant's uptake of nutrients and protecting it from biotic and abiotic stresses and pests. There is mounting evidence that endophytes can have a significant impact on population dynamics, plant community diversity, and ecosystem functioning in addition to their obvious effects on plant development, growth, diversity and fitness. Endophytes have coevolved with their host plants for millions of years, during which time they have perfected their methods of clinging to and benefiting from their hosts. So, unless discussing endophytes directly involved in diseases as causal agents of disease of the host plant, the term "infection" should be avoided when discussing endophytes in general.

A large percentage of plants may harbor endophytic fungus, which live dormantly in plant tissues and cause no visible symptoms. The same endophyte species can be found in multiple plant species, and multiple endophyte species can coexist inside a single plant species. Some endophytes lie dormant within the host plant, while others have the potential to engage in mutualistic interactions with other endophytes, whether they are harmful or not.

Endophytes have developed mechanisms that allow them to exist inside plants by protecting themselves from the plants' many physical and chemical defenses. For example, the plant Camptotheca acuminata produces the anticancer substance camptothecin, which binds to topoisomerase I and prevents cell divisions. In order to protect itself from the potentially detrimental effects of camptothecin, the endophytic fungus Fusarium solani altered the amino acid sequences at the bidding site of its topoisomerase. As a result, endophytes offer a two-pronged strategy: first, they provide a means to acquire novel bioactive secondary metabolites using cutting-edge chemistry, and second, they offer a hint as to the mechanism of action of these metabolites [5-6].

Mycorrhizal fungi associate with plant roots in one of two ways: as ectomycorrhiza or endomycorrhiza. These associations play an important part in the ecosystem because mycorrhizal fungi modulate nutrient uptake and the carbon cycle, and they also influence soil structure and, as a result, the functionality of the ecosystem.

Types of Endophytes

The microbes that endophytes are associated with are the primary factor used to classify endophytes.

- Endophytic fungi
  - Balansiaceous Endophytes or Grass Endophytes
  - Non-balansiaceous Endophytes
- Endophytic bacteria

- Endophytic fungi

A plant's tissues, such as its stems, leaves, and roots, can be infected with an endophytic fungus, which can cause the infection without the plant showing any symptoms. At least for a period of time, it has been reported that an endophytic fungus can be found residing within the living plant in mycelial form as part of the biological organization. In light of the fact that it is only occasionally possible to identify a fungus based solely on its hyphal features, the identification techniques will need to include methods for the detection of immunofluorescence, the sequencing of DNA, and the comparison of the sequence to homologous sequences that have been registered in gene banks. From the arctic to the tropics, and from agricultural fields to the most diverse tropical forest, endophytic fungi are found to associate with the aboveground tissue of liverworts, hornworts, mosses, lycophytes, equisetopsids, ferns, and seed plants. These associations can be found all over the world. Endophytes could be beneficial to plants in a roundabout way, for as by increasing a plant's resilience to herbivores, pathogens, or stress, or by some other unknown mechanism. Endophytic fungi have been found in certain research to be able to shield their host plant from the effects of drought. Salt tolerance was also detected in plants that had endophytes present and had been infected. Endophytic fungi have been shown to improve their host's resistance to heat. Endophytes serve as a biological trigger that prompts a stress response in symbiotic plants to be activated more quickly and forcefully than in nonsymbiotic plants. There are a few different kinds of endophytic fungi that have been discovered to be sources of chemicals that are immunosuppressive, anticancer, anti-diabetic, and that kill insects. Endophytic fungi have the potential to create compounds that have a role in thermoprotection.

Marine plants are not immune to endophytic fungus. Ascochyta salicorniae, an endophytic and obligate marine fungus, was also found in green algae. Endophytic fungi are also widely distributed because of their beneficial effects on plant growth and resistance to pests and diseases. There are two main ecological categories of fungal endophytes: balansiaceous, sometimes known as "grass endophytes," and non-balansiaceous.

- Balansiaceous Endophytes or Grass Endophytes

Because of their significance to the environment and the economy, they have received the most attention from researchers. Balansiaceous endophytes are a separate group of fungi that are closely related to one another. These fungi have ecological requirements and adaptations that are distinct from those of other endophytes. Inside the aboveground plant organs of grasses, they develop in three different ways: systemically, epicuticularly, and intercellularly. This results in the vertical transfer of the endophytes through the seed. These are members of the clavicipitaceous genera Epichlo and Balansia, as well as their respective anamorphs Neotyphodium and Ephelis. Balansiaceous endophytes are responsible for the production of a wide variety of secondary metabolites. Toxic alkaloids include the insect-killing alkaloids peramine and lolines, as well as the vertebrate-killing alkaloids loliterm B and ergovaline. The principal advantages enjoyed by the fungal partner are nutritional, but they also include fortification against abiotic stress, such as desiccation, and against epiphytic organisms that compete for space. The plant is protected from herbivores by toxic alkaloids that are produced by fungal endophytes during the symbiotic association, and the fungal endophytes also mediate induced resistance by activating the host defense system through both constitutive and resistance. The interaction between the plant and the fungus is advantageous for the plant. Even in uninfected plants of the Festuca pratensis species, traces of the loline alkaloid have been found. In grasses that have been colonized by endophytic fungi belonging to the genus Epichlo, a class of chemicals known as lolines are formed. These lolines have the ability to kill insects as well as discourage their presence (anamorphic species: Neotyphodium). It is possible that lolines protect endophyte-infected plants against environmental stresses like as dehydration and spatial competition in addition to increasing the plants' resistance to insect herbivores, which lolines do by increasing the grasses' resistance to endophyte infection.

- Non-balansiaceous Endophytes

They exhibit a wide variety of life cycle approaches in addition to displaying a diversified evolutionary tree. The Ascomycota are home to non-balansiaceous endophytes, which can colonize either inter or intracellular spaces and can be either localized or systematic. In the case of non-balansiaceous kinds, the word "endophyte" typically refers to a fungus that is capable of cryptic activity of plant tissue and describes a temporary situation. This is the case for non-balansiaceous types. The fungi are not obligately host specific; instead, they have a certain level of adaptation that allows them to live on a variety of hosts. However, some of the fungi are more specific and can only be found in certain organs of certain plants [7-8].

- Endophytic Bacteria

When compared to rhizospheric bacteria or bacterial pathogens, the population densities at which endophytic bacteria originate are lower. There is a possibility that endophytic bacteria are better shielded from the effects of environmental pressures than rhizospheric bacteria. Because bacterial endophytes are capable of inhibiting nematode multiplication, using them in crop rotation alongside host plants could be beneficial to other types of plants. The intercellular space and the vascular tissue of the plant are often where endophytic bacteria can be found. More than 129 species of endophytic bacteria, representing over 54 different genera, were isolated from a variety of crop plants. These bacteria ranged from Gram-negative to Gram-positive species and included both types. The former Pseudomonas group and the enterobacteriaceae family are the most important bacterial taxonomic families. There were 98 different nonsymbiotic endophytic bacterial strains that were recovered from a total of 150 root nodules in soybean. Plant growth-promoting bacterial endophytes, often known as PGPBs, have been found, but there has been minimal success in predicting their ability to positively influence plant development under field conditions. Endophytes are beneficial to plants because they increase their development and yield, prevent disease caused by infections, and may help eliminate pollutants, assemble nitrogen for plants, or solubilize phosphate. According to the results of a molecular research, defensive mechanisms serve to control the bacterial population within plants [9-11].

Endophyte Diversity

Since the nineteenth century, scientists have been aware of the occurrence of asymptomatic endophytic fungi in plants. It is believed that there are more than one million different species of endophytic fungi. This number compares to the number of different species of vascular plants at a ratio of 1:4–5 fungi per plant. There have been reports of bacterial endophytes coming from over 200 different bacterial genera and 16 different phyla, including both culturable and unculturable bacteria. Yet, the actual numbers of endophytes that have been detected are quite low. Endophytes have recently gained relevance because to the increased commercial and industrial utilization of their products. It was following the groundbreaking finding of toxicosis caused by Neotyphodium coenophialum (Family Clavicipitaceae) in cattle who consumed Festuca arundinacea as their source of nutrition. It was discovered that the grass had a systemic infection caused by the fungus, but there were no obvious signs, which is why the damaged leaves went unnoticed. The toxicosis in cattle was caused by the fungus, which produces numerous different alkaloids that are toxic to animals. This is just one example of a deadly fungal endophyte, but grasses can be home to a wide variety of endophytes, some of which may lie dormant for long periods of time. There may be a major difference between the endophytes of cultivated plants and their wild cousins as a result of adaptation and evolution. Conventionally, microorganisms are classified based on the morphological characteristics of their structures; however, in the case of bacteria, it is difficult to characterize them based on the morphological characteristics of their structures due to their small size. For the purpose of identification, therefore, several physiological characteristics of growth and feeding have been incorporated. The use of contemporary methods and technologies in molecular biology and genetics, such as genetic bar coding, are extremely helpful in unequivocally determining their identity. In order to characterize the species of plants and animals, bar coding has already been done, and this method is currently being used to microorganisms. As a result of the utilization of this data in the taxonomic classification of the organisms, the morphological characteristics have been relegated to a position of secondary significance. Ribosomal DNA is utilized for taxonomy, phylogeny, and identification reasons in place of mitochondrial DNA in mammals, algae, plants, and fungi. This is due to the fact that mitochondrial DNA in these organisms has not undergone significant changes during the course of evolution. When it comes to molecular identification of endophytes for use in ecological and diversity research, the Internal transcribed spacer (ITS) is the DNA barcode that is utilized the most frequently. In the process of identifying endophytes, modern molecular biology techniques can be helpful. The availability of such facilities in more laboratories, in conjunction with microscopic techniques, will help in the accurate characterisation of a large number of endophytes and will establish their diversity [12-15].

Isolation and Identification of Endophytes from Different Sources

A close relationship exists between the criteria for isolating bioactive molecules and the criteria for isolating endophytes. These criteria include the significance of the plant and the bioactive molecule it produces, the rarity of the compound, and the endemic nature of the plant and the environment in which it grows. Endophytes are typically extracted from tissues that have undergone surface disinfection and have been cultured on a synthetic medium. This medium may or may not contain extracts of the host tissues. However, synthetic media might not be able to support the growth of obligate parasites, which would mean that information regarding such endophytes would not be obtained. Endophytes have been isolated from nearly every component of the plant, including the leaves, scales, roots, stem, resin canals, and even meristems. The same physical characteristics of colony, vegetative hyphae, and asexual/sexual spores are utilized for identifying endophytic fungus as are used for identifying other types of fungi (conidial development, size, shape, conidia, attachment of conidia and shape of conidial head). It has been possible, thanks to the development of tools and methods in the field of molecular biology, to characterize these microorganisms on the basis of the molecular markers they possess and to determine their identities. The identification of a great number of additional endophytes was not possible until the development of molecular biology technologies. These methods are gaining significance in determining the phylogenetic link between various taxa as well, which is another application of their use [16-20].

Endophytes and Plant Protection

Endophytes are known to give their host plant with a variety of different sorts of protection, including the ability to withstand growing in hot springs, the ability to discourage herbivores by creating harmful alkaloids in grasses, and the ability to protect dicots from pests. Endophytes and an invading pathogen in the host plant are intimately connected and share everything. There is mounting evidence that endophytes interact with pathogens in distinct ways depending on the host. As a consequence, changed physiology may restrict the growth of the pathogen, shift the nutritional balance in favor of the endophyte, or increase the plant's defense system. A great number of endophytic organisms produce antibiotics and antifungal substances, which both offer protection against pathogens and lessen the severity of their effects. A superior defense against plant nematodes can be attained through the colonization of plants by endophytic fungi. This is a complicated occurrence, and the mechanism underlying this antagonistic relationship is not completely understood. As a result, endophytes have an effect on the operation of the pathosystem, which in turn has an effect on the survival, diversity, and conservation of plants. There are over one thousand insect harmful fungi that have been identified as occurring as endophytes. These fungi belong to the classes Chytridiomycetes and Basidiomycetes and are closely linked to grass endophytic fungus such as Claviceps and Epichlo. In the case of viruses, the method of cross-protection has been thoroughly researched and developed. Endophytes, in a manner analogous to cross-protection, offer defense against a variety of herbivores and pests. It is necessary to have an understanding of the mechanism underlying this process in order to utilize it for the purpose of crop protection.

Endophytes and Metabolites

Vincristine, vinblastine, camptothecin, quinine, and taxol are just few of the essential medications that may be extracted from plants. On the other hand, there are more than 8500 bioactive metabolites that originate from fungi. Establishment of an association with an endophytic fungus The discovery that Taxomyces adreanae, which is found in Taxus baccata, is involved in the manufacture of taxol fueled the hunt for endophytic fungi associated with potentially useful bioactive compounds and their derivatives. This has two repercussions: first, the possibility of getting new bioactive substances, and second, the complicated evolutionary information regarding the microorganisms and the host plants. Isolation and identification of endophytes is still a tough undertaking. Establishing a correlation between endophyte production and the creation of bioactive molecules is another significant challenge. There are a lot of obstacles standing in the way of their commercial production. Endophytes have the potential to produce a wide variety of compounds, as evidenced by the time-honored example of gibberellin production by Fusarium oxysporum, which is responsible for the stupid seedling disease that affects rice. Alkaloids, essential oils, terpenes, azadirachtins, coumarins, flavonoids, lignans, and a number of other types of compounds are all included in the other categories of chemicals. A large number of secondary metabolites with potential therapeutic value in cancer, as antioxidants and antimicrobials, have been isolated from endophytes, and some of the selected examples for bioactive molecules produced by endophytes are as follows: azadirachtin A, B, camptothecin, citrinal B, cytochalasin N, diosgenin, gliotoxin, germacrene-type sesquiterpenes, ginkgolide In addition to their production, biotransformation of secondary metabolites utilizing endophytes as the catalyst has been tried and found to be successful. The chemical change of an exogenous material that takes place within or on the behalf of a biological system is referred to as biotransformation. It has been discovered that changes to the fundamental molecule can result in a more powerful physiologically active chemical. For instance, the semisynthetic compounds produced from taxol and podophyllotoxin are more powerful than the fundamental molecule itself. Endophytes are responsible for the production of a number of chemicals, some of which are extremely useful in the medical, agricultural, and industrial fields. Recent reviews on endophytes should be consulted in order to obtain specifics regarding secondary metabolites and other helpful compounds. Endophytes have the ability to affect not only the development and metabolism of the host plant, but also the creation of the host plant's bioactive secondary metabolites. This occurs because endophytes have an effect on the uptake and endurance of nutrients. The production of secondary metabolites by an endophyte will proceed in the same manner as the production of secondary metabolites by a plant or fungus. After the endophyte has been isolated and the production of metabolites has been established, it will be possible to devise strategies for its large-scale production through the manipulation of biosynthetic pathways and other forms of biotechnology. Use of heterologous expression systems and production on a larger scale are two helpful steps towards the synthesis of secondary metabolites in an industrial setting. In most cases, the presence of bacterial endophytes is linked to the production of polysaccharides and enzymes. Because of this, the process of gummosis is thought to be caused by the association of endophytes in the majority of the trees that produce gum. In addition to enzymes, a number of additional proteins have been purified and analyzed after being extracted from bacterial endophytes. In recent years, cyclic and non-cyclic peptides from numerous endophytes have been extracted and characterized. These peptides indicate potential for a variety of uses, including anticancer, immunosuppressant, and antifungal activity. The above description makes it abundantly clear that endophytes are responsible for the production of a wide array of advantageous metabolites. It is necessary to combine the various technologies that are currently available, such as the tools of molecular biology for their identification, the use of tools from the field of chemistry for the identification of bioactive metabolites, and biotechnology for the scaled-up production of metabolites, in order to investigate and make use of the potential that endophytes have for improving human well-being [21-25].

Endophytes in Agriculture

Agriculture is a key economic activity and the primary means of subsistence for millions of people, particularly in nations that are still developing. The rising number of people that need to be fed necessitates an increase in the output and productivity of agricultural goods, and this calls for the development of innovative techniques. Endophytes are becoming increasingly significant as a result of the roles that they play in plant growth stimulation, protection against biotic and abiotic stressors and pests via modulation of growth hormone signaling, increased seed yield, and plant growth hormones. As a direct consequence of this, it has significant repercussions on the agricultural characteristics of crop plants, characteristics that hold great promise for environmentally and economically sustainable agriculture. The wild relatives of wheat, such as Triticum dicoccoides and Aegilops sharonensis, host a large number of beneficial endophytes belonging to a variety of taxonomic groupings. These endophytes are not present in the wheat that is farmed today. The use of contemporary agricultural methods, such as fertilizer and chemicals to control infections and pests, disrupts the natural equilibrium between endophytes and the hosts that they live on, in addition to changing the structure and function of the soil. Wild relatives do not live in an environment with these kinds of chemicals, hence endophytes are able to flourish in the system. In a similar vein, contemporary breeding techniques produce changes in the genotype of cultivated plants, which in turn renders those plants resistant to a number of insects, pests, and endophytes. These shifts will have a significant impact on agricultural features as well as the associations between endophytes. As a result, bacterial endophytes hold a great deal of potential for the creation of environmentally friendly agriculture, in addition to their benefits for health and nutrition [26-27].

Bacterial Endophytes of Plants: Diversity, Invasion Mechaniss and Effects on the Host

Endophytes of plants that are not legumes can be either rhizobial or non-rhizobial. Endophytic bacteria have been isolated from a diverse range of plant species, which hints at their pervasive existence in the vast majority of higher plants. The composition of these communities is determined by the biotic and abiotic soil elements that influence bacterial survival, the host characteristics that make colonization possible, and the microbial determinants that shape the endophytes' capacity to survive and compete inside their plant hosts. Microorganisms have the potential to infect plants through a wide variety of pathways, including the ground itself, the water that results from precipitation or irrigation, the falling of dust from the atmosphere or the wind, animals that are capable of transporting microorganisms, seeds, seedlings, plants that have traveled from far away, and plant remnants (litter, crop residues). In addition, seed endophytes have the potential to be vertically transmitted from one generation of a plant to the next in the case of vegetatively propagated plants. While studying the plant's endophytic community using modern methods such as next generation sequencing technologies, it was discovered that the plant's endophytic community's composition is significantly underestimated. Hardoim et al. (2015) constructed and analyzed a database of all currently available 16S rDNA sequences assigned to endophytes. This database included both cultured and uncultured microorganisms. They discovered that, despite the fact that the sequences belong to 23 different bacterial phyla, only four of those phyla (Proteobacteria, Actinobacteria, Firmicutes, and Bacteroidetes) encompass for 96% of the Proteobacteria accounts for more than half of all of the sequences in the database and is one of these organisms. Isolates belonging to the Gammaproteobacteria subclass are the ones that are most frequently discovered as endophytes within this phylum. This subclass contains genera such as Pseudomonas, Enterobacter, Pantoea, Stenotrophomonas, Acinetobacter, and Serratia, among others. On the other hand, genera such as Streptomyces, Microbacterium, Mycobacterium, and Arthrobacter (all of which belong to the order Actinobacteria), as well as Bacillus, Paenibacillus, and Staphylococcus (all of which belong to the order Firmicutes), are also well represented among endophytic microorganisms (Hardoim et al. 2015). It has been hypothesized that the endophytic microbial community is a subpopulation of the rhizospheric bacteria. This is due to the fact that species from all of these genera are frequently found in soils. It is still not completely understood how plants are able to select a certain population of endophytes to live within their cells. Rhizobia are a broad group of soil bacteria that are most recognized for their capacity to form a symbiotic relationship with legumes. This relationship benefits both parties. They do this by encouraging the growth of nodules within their plant host, which are the homes of nitrogen-fixing bacteria. It is interesting to note that rhizobia have also been identified invading the tissues of non-legume plants; however, the induction of nodule formation in these plants has never been recorded, with the exception of Parasponia. Endophytic rhizobia have been shown in multiple studies to stimulate the growth of plants that are not legumes; hence, the use of endophytic rhizobia as biofertilizers may be an effective technique for achieving sustainable agriculture [28-31].

Plant Growth Promotion by Endophytes

Plant endophytes can stimulate plant growth in a number of different ways, including fixing atmospheric nitrogen, creating phytohormones, preventing the spread of phytopathogens, and improving mineral uptake. According to this interpretation, numerous investigations have shown that endophytes have positive effects on their hosts. Gluconacetobacter diazotrophicus, for example, is an endophytic diazotrophic bacteria that helps sugarcane grow more successfully. The role of endophytic diazotrophic bacteria in N nutrition has been proven by quantifying 15N in this plant as well as in other plants that are not legumes. By the formation of abscisic acid and gibberellins, the endophyte Azospirillum lipoferum in Zea mays is able to ameliorate the symptoms of drought stress. The endophyte Burkholderia sp., which is found in Solanum tuberosum and Vitis vinifera, stimulates plant growth by lowering the amount of the growth-inhibiting hormone ethylene. This is accomplished through the production of high levels of the enzyme 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase. Curtobacterium flaccumfaciens, an endophyte, acted as a shield for citrus plants, providing defense against the disease Xylella fastidiosa. Bacillus sp. was used to inoculate Arachis hypogaea plants, which resulted in the induction of systemic resistance to Sclerotium rolfsii. According to the findings of certain investigations, a potentially useful alternative to individual PGPR inoculation is the co-inoculation of endophytes that inhabit various ecological niches. For instance, Avicennia germinans, Laguncurlaria racemosa, and Rhizophora mangle plants exhibited better nitrogen and phosphorous assimilation when they were co-inoculated with the phosphate-solubilizing Bacillus licheniformis and the nitrogen-fixing Phyllobacterium sp. than when they were inoculated individually with the endophytic bacteria. It is essential to emphasize that the co-inoculation of beneficial endophytes does not necessarily result in an increased plant growth effect when compared to individual inoculation, as this is not always the case. Although if both strains of rhizobacteria can individually be beneficial to plant growth, the ability of some rhizobacteria in Pinus contorta to promote plant growth can be greatly diminished when another strain of rhizobacteria is present [32-34].

Non-Rhizobial Endophytic Bacteria Within Legume Nodules

Although though the inside of any plant organ can be colonized, the endophytic colonization of legume root nodules is a distinct type of endophytic colonization. We refer to the residents of the nodules that are unable to stimulate their development as nodule endophytic bacteria. This means that suitable rhizobia are not included in this category. At first, nodule endophytic bacteria were thought to be artifacts that resulted from insufficient root nodule surface cleaning. Subsequently, it was discovered that they were able to successfully colonize the interior of nodules that had been produced by rhizobial strains that were compatible with each other. Endophytic colonization of legume nodules is currently a promising subject for the identification of bacterial strains with new plant growth promoting (PGP) activities or for the optimization of plant growth promoting rhizobacteria (PGPR) inoculation. In point of fact, these endophytes share the nodule resources with rhizobia and, at the very least, in theory, have the potential to influence the biological nitrogen fixation process either favorably or negatively. In addition, nodules provide a habitat that is both managed and abundant in sources of carbon, which is ideal for the proliferation of endophytic bacteria. After that, the release of bacteria from senescent nodules that have PGP qualities could be a new source of inoculum for the soil [35-37].

Microbial Endophytes as Source of Drug against Various Diseases

Because these fungi are so resourceful in their production of secondary metabolites, there has been a dramatic increase in the number of papers that discuss substances derived from fungal endophytes over the course of the previous two decades. In addition, there is a growing demand for novel antimicrobials, antimalarial medications, chemotherapeutic or pharmacological agents that are not only highly effective but also contain low toxicity and have a minimal influence on the environment. Both the evolution of medication resistance in infectious germs like Staphylococcus, Mycobacterium, and Streptococcus and the presence of species that are naturally resistant pose a threat to the human race. The research and development of novel medicines is required because of the emergence of new diseases such as AIDS, SARS, and NDM-1. A weakened immune system as a result of AIDS not only requires specific drugs for treatment, but also requires new therapies to combat the secondary problems that have arisen as a result of it. In addition to this, the HI virus is developing resistance towards the existing drugs, which makes it more difficult to treat with those drugs. Patients who are immunocompromised and patients who require organ transplants are particularly susceptible to the virulence of opportunistic infections such Aspergillus, Cryptococcus, and Candida. In addition, parasitic protozoan and nematodal illnesses such as malaria, leishmaniasis, trypanomiasis, and filariasis are generating severe issues in a number of nations, and better medications to combat these infections are required. According to the NIAID Global Health Research Plan for HIV/AIDS 2001, the disease malaria is responsible for more deaths each year than diseases caused by any other infectious agent, with the exception of AIDS and tuberculosis. In addition, enteric infections are responsible for more deaths among children each year than any other disease. As a result of all of these factors, there is a never-ending search for innovative natural products. Because of the history of the substances created by microbes presenting prospects for innovation in medication discovery and development, many scientists and researchers have turned their looks back to the world of microorganisms. To experience the excitement and thrill of engaging in the discovery of endophytes, their biology, and the potential applications of endophytes, there are exciting possibilities available to those who are willing to take risks and venture into the unexplored territories of the world. These exciting possibilities exist for those who are willing to take risks and venture into the unexplored territories of the world. Endophytic microorganisms have come to the attention of scientists as a promising new source for the development of innovative medications during the course of the last decade. Through the use of fermentation technology, a number of different microbial metabolites have been made available in volumes of up to hundreds of kilos. The examination of a very large number of microbial extracts led to the discovery of an unexpectedly diverse collection of naturally occurring chemicals that participate in a wide range of biological activities. Hence, rather than the plants themselves, the microbes that are linked with plants have the potential to serve as a raw material with great therapeutic potential. Endophytic microbial metabolites have been investigated for a wide variety of activities up until this point, including activity against oomycetes, bacteria, fungi, cancer, and immunosuppressants. The discovery of the biosynthesis of Taxol® and a variety of other antibacterial, antifungal, and anticancer metabolites from the endophytic fungus Taxomyces andreae and Pestalotiopsis spp. lent substantial legitimacy to endophytes as potential sources of new chemicals. Endophytes have the potential to serve as a source of new metabolites for applications in agriculture, medicine, and industry. The most effective method for discovering new bioactive chemicals is to survey endophytes from plants that are native to particular regions. This is done as a means of isolating fungi that were probably not investigated in any of the earlier screening studies [38-41].

Endophytes as a Source of High-Value Phytochemicals: Present Scenario and Future Outlook

In light of the fact that endophytes are a source of phytochemicals of high value, it is essential to bioprospect these microorganisms in order to find a wide variety of related phytochemicals that have some sort of therapeutic effect. Studying the kinetics and production pattern throughout a number of successive subculture generations is also very significant if one wishes to unambiguously authenticate whether an endophyte indigenously generates a chemical or only its precursors. This is very important information to have in order to determine whether or not it is even possible to use an endophyte on a commercial basis. At the molecular level, it is necessary to study the possibility of powerful endophytes coordinating in a synergistic manner with other endophytes that are linked with the plant in response to in planta selection pressure. Recent examples of microbial interspecies cross communication hint to the possibility and necessity of more research on endophytes that is similar to what has already been done. This might be helpful in identifying aspects that could contribute to the solution of the attenuation problem. It has been demonstrated that restarting the production of phytochemicals by previously attenuated endophytic cells can be accomplished with the addition of plant extracts as well as plant-based elicitors. It has also been proven that therapy with a DNA methyl transferase inhibitor can reverse the epigenetic silencing of the phytochemical biosynthesis pathway of endophyte. It has been demonstrated that the addition of ethanol can turn around attenuation in Fusarium solani, leading to an increase in camptothecin synthesis that is greater than tenfold. To combat attenuation and assist in the exploitation of endophyte resources for the production of phytochemicals, a better understanding of the epigenetic features of the phytochemical biosynthetic pathways of endophytes is required. Further fundamental research into the mechanisms by which an endophyte develops the ability to manufacture phytochemicals and the reasons for the loss of such ability on repeated subculturing in artificial media would most likely offer the way forward for the successful exploitation of their potential benefits [42-48].

Conclusion

The term "endophyte" originated as an ecological concept, but it is now often understood to refer to a natural component of the plant-microecology system. Plants live in different environmental conditions, where they interact with many microbes. Endophytes are microbes, that are present in all known plant species and can live different places of plant such as leaf, stem, root, kernel and flower. Endophytyes are those organisms, that can inhabit within plant tissues with no sign of infection or other harmful effect on the host plant. A endophyte *Nothapodytes foetida*, produces Camptothecin is cytotoxic and antifungal agent. A endophyte *Huperzia serrata*, produces Huperzine A (HupA), that can act as a cholinesterase inhibitor. Endophyte *Podophyllum hexandrum* produces, Lignans, that act as cathartics, emetics and cholagogue, are reported to act as anticancer agents. Endophyte P. emodi produces Resins, such as etoposide and teniposide have strong anticancer activity.

Endophytes are the microorganisms that tend to live in the internal tissues of healthy host plants. Most plants on the earth are reported to harbour one or more endophytes. Endophytes have been reported in agronomy crops, plants from harsh environments, tropical and borial forests, mangroves, ferns, gymnosperms, and angiosperms, perennial and wild plants. They can be isolated from above and below ground parts of the plant with higher density of them in roots. The most common colonization route of bacterial endophytes is reported to be rhizosphere [49-56].

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