An appraisal of bacterial Endophytes

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ABSTRACT

In ongoing decades has been the apprehension of vastly diverse microbes that are not the only symbiont in conjunction with the host plants, nonetheless, it has a significant part in the host plant development, resistance, and growth to both abiotic and biotic stresses. The host plant roots serve as a barrier to screening soil microbes from the rhizoplane as well as the rhizosphere. Most data imply that motility, host plant cell wall degradation capacity, and reactive oxygen species (ROS) scavenging are essential attributes for effective endophytic colonization and the foundation of bacteria. Endophytic bacteria have aid host functions, for instance enhancing plant nutrients through the procurement of nitrogen fixation in leaves in addition to nutrients from the soil. Specific endophytes were able to aid in plant defence once pathogen attacks. Owing to the host plant development influences, endophytes are broadly investigated for their function in the enhancement of crop growth. An appraisal into the endophytic interactions and colonization with the host plant. An essential measure inconceivably handling endophytes for practical approaches to expand agricultural production.

INTRODUCTION

Overview of bacterial endophytes

Endophytes are those microbes found within the plant ('endo', inside; 'phyte', plant). They inhabit inside the plant tissues without causing maltreatment or picking up an advantage. Endophytes can be secluded from superficial-cleaned or extracted from inside plant tissue (Kandel et al., 2017; Shweta et al., 2013). Both gram-negative and -positive endophyte microbes have been isolated from few tissue sorts in various plant species.

Moreover, a few diverse bacterial species have been confined from a solitary plant. Endophytes enter plant tissue through the root zone; in any case, aerial portions of plants. For instance, cotyledons stem and flowers or transmitted through spore to colonize the host plant leaves (Hardoim et al., 2015), might likewise be used for entrance. Notably, the microbes enter tissues using sprouting radicals, secondary roots, stomata, or because of foliar damage. Endophytes within the host plant possibly will either become localized at the entry point or dispersed throughout the plant. Most endophytic bacteria enter the plant tissues by wound openings, pathogens (using hydrolytic enzymes), or natural (stomata). In any case, their populace density is generally lower than pathogens. The plants do not perceive most as potential pathogens (Frank et al,
Endophytic bacteria depend heavily on nutrients supplied by the host plant. Subsequently, variables influencing plant nutrition likewise influence the endophytic groups. In place of the host plant, familiar endophytic bases are the adjacent soil roots (exorhizosphere), environment (exophyllosphere) as well as vegetative proliferated plant material, for instance, cuttings, seeds, and stems (Harold et al., 2012). Endophytes could enter into the host plant tissue by root hair cell wall invagination, infiltration of the intersection among root hair and bordering epidermal cells, or by enzymatic processes, of cell wall-bound polysaccharides degradation (Huang, 1986).

**Beneficial roles of endophytes**

For the most part, endophytes can promote plant growth, yield, and act as biocontrol agents. Endophytes can be helpful to their host by yielding an assortment of natural products or bioactive compounds that possibly will be used in industry, agricultural, or health care (Kusari et al., 2013). It has been demonstrated that endophytes can eradicate soil contaminates by enriching phytoremediation also plays a part in soil fertility via nitrogen fixation and phosphate solubilization (Kuźniar et al., 2019). There is expanding enthusiasm in growing the potential biotechnological applications of endophytes for enhancing phytoremediation along with the workable production of non-food harvest for biofuel and biomass manufacture.

Numerous bioactive compounds produced by bacterial endophytes are beneficial to industries, pharmaceuticals, and agriculture. In industries, endophytes have a ground-breaking capacity to break complex compounds. Bioremediation is a technique for elimination of wastes as well as pollutants from the environment with the aid of microbes. It depends on the organic cycles in microorganisms to breakdown these pollutants. This is made conceivable because of microbial diversity. According to (Mastretta et al., 2009), the inoculation of Nicotiana tabaccum with endophytes brought about enhanced biomass production under cadmium stress condition. Likewise, the total plant with cadmium concentration was more significant than noninoculated endophytic plants. These outcomes showed the insightful effects of endophytes on metal accumulation and toxicity.

As for pharmaceuticals, antibiotics are biological compounds generated by microbes as secondary metabolites to inhibit or different microbicidal microorganism. They have a crucial part in the 20th century for infectious treatments. To date, the pharmaceutical industries have fundamentally focused on the medications from fungi, bacteria or other soil organisms. Notable endophytic bacteria, Streptomyces sp, produced approximately 80% of antibiotics, and No less than 7,000 diverse secondary metabolites have been reported from Streptomyces isolates (Bérdy, 2005; Athiaseelan and Stella, 2011; Thenmozhi and Krishnan, 2011). Kakadumycins, ecomycin and pseudomycins are few of the novel antibiotics generated by endophytic bacteria (Bhore et al., 2013).

In the agricultural sector, the association between endophytes and host plants generally involved in the co-evolution represented by colonization, whereby is affected by the agricultural process, plant tissue type, growth phase, physiological condition, genotype and environmental conditions (Mengistu, 2020). This mutualistic or symbiotic existence between endophyte and respective host plant can effect on the development, health, production, growth and the soil quality of the respective host plant (Compant et al., 2008). This relationship yields numerous advantages to the included species and causes favourable effects on the sustainability agro-ecosystems, and agricultural income (Xia et al., 2015). Therefore, prominence surge in plant growth, biomass, grain and dry matter yields. For instance, Burkholderia sp., Herbaspirillum seropedicae endophytic bacteria predominantly enhance in grain production in the rice field. Whereby it involved in the synthesis of indoleacetic acid (IAA) and nitrogen fixation (Bao et al., 2013).

**The host plant-bacterium symbiosis**

The classic example of host plant-bacterium symbiosis is the interaction involving rhizobia and leguminous plants. The interaction of nitrogen-fixing microbes belongs to the species Rhizobium, Bradyrhizobium, Sinorhizobium, Mesorhizobium, Ensifer, and Azorhizobium are equipped for initiating differentiation in root nodule construct, exhibited in Parasponia as well as Fabaceae plants (Oldroyd, 2013; Wasai and Minamisawa, 2018). Typical indications of leguminous plant roots tainted by rhizobia are root hairs twisting in addition to the presence of disease threats and nodule primordia in the interior root layer. The procedures interceded by a signal exchange between rhizobia and plants. In primordium cells, the microorganisms get to be distinctly encompassed by the plant membrane. Together shapes the symbioses, in which atmospheric nitrogen (N2) is fixed and moved in return for starch (Choudhury et al., 2019). Symbioses have a structure like that of mycorrhizal arbuscular, additionally encompassed by a plant membrane. Intriguingly, various legume-
nodulating rhizobial strains shape the endophyte relationship with the monocotyledons host plant. Though nodule primordia were not seen, rhizobial nifH transcripts were observed within the rice roots and sugarcane (Burbano et al., 2011; Sessitsch et al., 2012).

According to (Hoeksema et al., 2010), studies uncovered that the nature of arbuscular rhizobia and mycorrhizal fungi with the host plant species could be parasitic or opportunistic, non-symbiotic, or mutualistic. A meta-analysis exhibited that the plant reaction to arbuscular mycorrhizal fungi and rhizobia relies on different factors, in particular the host plant type and fertilization (Hoeksema et al., 2010). Aside from mutualistic rhizobia, parasitic strains which taint legumes but fix low nitrogen amount have been testified (Mouhamd et al., 2017). The rhizobium-legume symbiosis is described by various symbiotic relations, in most cases reliant on the genetic factor presences required for the mutualistic interaction.

Effects on plant physiology

Endophytes are known to have many effects on the host plant. Endophyte-infected plants may produce more in seeds and fluorescence than uninfected plants. This can be explained by the more prominent vegetative vigor of endophyte-infected plants (Clay, 1988; Nagabhyru et al., 2013). Seeds of few grass genera, for instance, tall fescue and perennial ryegrass germinate as well as grow faster by an endophyte. Endophyte – infected seeds have a higher concentration of alkaloids, which may clarify the growth and germination rate. The alkaloids concentration makes it more improbable for the seed to be eaten by invertebrates and vertebrates seed and plant feeders. Endophyte-infected grasses have tillers that are more profuse and spread horizontally through rhizomes and stolon (Clay, 1988; Hardoim et al., 2015). The enhanced growth rate of infected plants was likewise shown with perennial purple nutsedge and ryegrass (Young et al., 2013).

Test conducted on photosynthetic metabolism uncovers that endophytes were continually changing plant sucrose into sugar alcohols that are unavailable to the plant to metabolize (Lobo et al., 2015; Nagabhyru et al., 2013). If the photosynthetic activity degree is high, the plant sugar metabolism unable to work efficiently. Sucrose build-up will trigger the plant feedback inhibition mechanism, prompting to decrease in photosynthetic action. However, endophytes prevent the feedback inhibition of photosynthetic rates, consequently increase the average plant growth. Root borne endophytes, siderophores are produced and increases the nutrient solubility in the rhizosphere (Philippot et al., 2013; Rosenblueth and Martinez-Romero, 2006).

The above schematic diagram in Figure 1, illustrates the plants immunized (IM) with endophytes has significantly promoted the plant growth contrasted with non-inoculated (IN) plants. Different microorganisms, specifically fungi, and bacteria, can reside within the inner plant tissue. Within the plant, the endophytes interact with the plant cells and with encompassing microbes. As the plant originated carbon source, essentially sucrose (Su), is traded for endophytes delivered nitrogen (N2), potassium (K+), and phosphate (Pi) components. The cytoplasmic sucrose is transferred to the periarbuscular area, which changed to hexose (HEX) (Calabrese et al., 2019; Hardoim et al., 2015). Hexose (HEX) is changed over to glycogen for transport. Phosphate (Pi) and nitrogen (N2) are transferred into the cytoplasm like polyphosphate granules. Then converted as arginine (Arg) and phosphate (Pi) in the arbuscular. Phosphate (Pi) is transferred towards the host cytoplasms, though Arginine (Arg) is at first changed over to urea (Ur) and later to ammonium (NH4+). The plant hormones, for example, polyamines, volatile organic compounds (VC), gibberellins (GAs), auxins (IAA), cytokines (CK), and secondary metabolites (SM), are sent to the plant host (Hardoim et al., 2015).

Different bacterial structures, including pili, flagella, secretion system, lipopolysaccharides, bacterium-inferred molecules and proteins (autoinducers, effectors (EF), antibiotics) are distinguished by the cells and activate the systematic resistance (SR) reaction. Acetyl-CoA carboxylase (ACC), direct ethylene (ET) precursor, is metabolized by bacterial enzyme ACC deaminase. Therefore, improving abiotic stress. A series of ROS detoxification enzymes may likewise induce plant stress. Diazotrophic endophytes are proficient in fixing nitrogen (N2) into nitrate (NO3−) as well as ammonium (NH4+). The bacterial siderophore production (Sid) is essential in plant growth advancement, phytoremediation, and biocontrol. Different substrates on which the transmembrane proteins are augmented among endophytes and Transcriptional regulators (TR). Interchanges, as well as interactions between cells of microorganisms, reside within the plant tissue are stimulated by an antibiotic (A), autoinducer particles, and growth factor (GF) (Hardoim et al., 2015; Pineda et al., 2010).

Microbial metabolites

As illustrated in Figure 2, the metabolic processes are the premise of life, permitting the cells to grow and reproduce, react to their surroundings, and
Figure 1: The schematic diagram of Beneficial properties of endophytes

Figure 2: The metabolism pathway of secondary metabolites
maintain their structures. Metabolism is divided into two classes: namely catabolic and anabolic reaction. The catabolic reaction yield energy, an illustration being the food breakdown in cellular respiration. The anabolic reaction uses the energy to build cell components, for example, nucleic acids and proteins. Primary metabolism refers to the catabolic and anabolic reactions required for growth, nutrient assimilation, and respiration, which required for cell proliferation and maintenance. However, secondary metabolism refers to compounds produced that are not necessary for cell development (Kliebenstein, 2004; Wink, 2010).

The differences between primary and secondary metabolism are depicted in Table 1. Some secondary metabolites may permit the organism to contend that metabolites are produced from a few intermediate products that accumulate either in cells or culture media, during primary metabolism (Lee et al., 2013). Secondary metabolites were first perceived by Sachs in 1873 and referred to as natural products. The aggregate number of microbial metabolites recognized is around 50,000 (Bérdy, 2005).

**Role of secondary metabolites**

Nature creates an astounding abundance of secondary metabolites with critical biological functions. Some of the biological activities are yet obscure (Mazid et al., 2011). The secondary metabolites often have obscure capacities in the organisms yet have significance to humanity as it shows a wide variety of practical biological and pharmaceutical and also less immunomodulatory activities. There are few theories proposed on the role of metabolism type in organisms as illustrated below.

**Ecological role**

Secondary metabolites play a diverse role in different lifestyles in microorganisms. For instance, phytotoxins delivered by plant pathogenic fungi against the host plants are proven virulence factors. Antibiotics produce by saprophytes against the competitors who play a significant role in the defense mechanism. The toxin produced by endophytes and other symbiotic fungi has a significance in mutualism and environment adaptation. The most manifest fungal natural products are the pigments (Bode, 2009; Zähner et al., 1983). It mainly gives coloration to spores appressorium, sexual bodies, and other development structures. Studies on pigment function demonstrate that it acts as a virulence factor in animals and plants or it required for antigrowth deterrents, ROS scavengers, presumably as UV protection, or survival.

**Biological role**

The biological role of metabolites is unclear, but rather a standout amongst the most conceivable that the secondary metabolism is essential, regardless of
### Table 1: Differences between primary and secondary metabolism

| Primary characteristics | Primary metabolism | Secondary metabolism |
|-------------------------|--------------------|----------------------|
| Definition              | Essential for growth and development | Not essential for growth and development |
| Defense reactions       | Not crucial for the ecological adaptation or defense reactions | Essential for the ecological adaptation of the organism. Secondary metabolites heavily involved in defense reactions |
| Between organisms       | Most primary metabolites are conservative between organisms. | Secondary metabolites are abundant and diverse. |
| Production phase        | Produced in large quantities during the growth cell phase (trophophase) | Produced in small quantities during non-growth cell phase (idophase) |
| Example                 | Relatively simpler structures, including carbohydrates, lipids, and proteins | The highly complex structure and a large number of specific enzymatic reactions for the synthesis. For instance, phenolics, alkaloids, lignins, steroids, sterols, and essential oils are several secondary metabolites. |

The end product. Thus, the organism may need to keep up the fundamental metabolic pathways amid periods when growth is confined. However, the regular metabolic pathways intermediates cannot be permitted to accumulate since it could disturb metabolic control. Thus, there are intermediates shunted into secondary metabolites which either sent out from the cells or stored as inactive products. Hence, it is accepted or escapes value, to expel intermediates from the fundamental metabolic pathways when growth is temporarily confined (Mazid et al., 2011; Thirumurugan et al., 2018).

### CONCLUSIONS

On-going years have seen enthusiasm among researchers in the investigations on endophytes, on account of more straightforward techniques for isolation and distinguishing. Numerous bioactive compounds produced by bacterial endophytes are beneficial to industries, pharmaceuticals, and agriculture. Because of their significance, reasonable to review on past accomplishments in the related endophytic research and opening up more extensive prospects in the scientific community.

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### Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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