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Endophytic bacteria and their potential application in agriculture: A review

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ABSTRACT

Evolution and biodiversity of plants may depend on their mutual relationship with soil microbes. Endophytes are such microbes that grow within the plants and can be isolated from leaves, stem, roots, seeds, fruits and flowers. This review gives information on the importance of endophytic bacteria and their role in agriculture by giving some of the products which is more beneficial in improving the agriculture and a detailed knowledge about the potential biotechnological applications of endophytic bacteria in agriculture.

Key words: Auxin production, Endophytes, Induced resistance, Nitrogen fixation, Siderophore.

Microorganisms such as fungi and bacteria associate with host plant tissues without causing any adverse effects and promote plant growth by secreting various bioactive substances are called endophytes (Strobel *et al*., 2004). As reported by Kusari *et al*. (2012), the term endophyte (endo-inside, phyte-plant) was introduced by De Bary in 1866 and the first endophyte was isolated from *Lolium temulentum* by Freeman in1904. Endophytes are involved in the synthesis of siderophores, in the production of plant hormones, in nitrogen fixation, solubilization of immobilized phosphorus, in nutrient cycling, production of volatile organic compounds, pathogenic resistance and stress tolerance. Normally plant roots help the plant tissues to grow by absorbing the water and nutrients and in addition a rich source of organic acids, amino acids and sugars are released into the soil which makes the soil to colonize with microorganisms around the surface of plant roots. In addition, any seeds during germination also release low molecular weight organic compounds into the surroundings thereby attracting the microbes in the rhizosphere and rhizoplane (Thrall *et al*., 2007). Many endophytes were reported to be found in rhizosphere (Rosenblueth and Martinez-Romero, 2004). Some selected microorganisms occupy the internal root tissues and reaches the xylem. At this stage the microorganism gets differentiated into pathogenic, associative, symbiotic, or neutralistic adaptation within the plant, and plant beneficial microorganism become endophytic (Hayat *et al*., 2010).Moreover, endophytes can enter plants through lenticles, wounds (which occurs at emerging site of lateral root and root tips),through vascular system or xylem vessels or germinating radicles, secondary roots, stomata or through foliar damage and also through seeds and leaves (Mano and Morisaki, 2008). Inside seeds, they found to be present in the embryonic stage through the endosperm. Later, when the seeds germinate, the endophytes are released into the external environment and invade into the internal tissues of the growing plants (Johnston-Monje and Raizada, 2011). By this mode, endophytes are transferred from generation to generation. The endophytes entering the plants through various routes can be localized at a single point or may spread to the whole plant (Strobel *et al*., 2004).The organic compounds of plants act as chemoattractants and facilitate the movement of bacteria by flagellum-mediated chemotaxis (Buschart *et al*., 2012). Plant secondary metabolites like flavanoids are chemoattractants for colonization of bacteria (Santi *et al*., 2013; Bhattacharyya and Jha, 2012; Chamam *et al*., 2013). Plants growing in low phosphate environment release organic acids like malic acid to attract the microbes (Pineros *et al*., 2002). Similarly, the products of microbes produced during their metabolism influences the plant colonization (Surette *et al*., 2003). It was reported that endophyte has lipopolysaccharides on their surface and plant derived isoflavanoids recognize these lipopolysaccharide (Chang *et al*., 2009). Endophytes such as *Azospirillum brasilense* move towards the extract of seeds like cereals with strong adhesion due to its protein called Major Outer Membrane Protein (MOMPS) present in their glycosylated flagellum (Lugtenberg and Kamilova, 2009) whereas *Pseudomonas* species involves the use of type IV pili in colonizing the plants (Reinhold-Hurek *et al*., 2006). Besides, *Pseudomonas fluorescens*uses secretion system such as SSIII for their entry into plant roots (Preston, 2007) and *Azoarcus* endophyte uses type IV pili and twitching motility for their colonization (Dulla *et al*., 2012).

Isolation of endophytes: The bacterial endophytes are isolated from all types of plants such as from wild to agricultural crops (Bacon and White, 2000; Arnold, 2007). From a single plant, different species of bacterial endophytes

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