CHAPTER-II

REVIEW OF LITERATURE

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It is established that plants harbour microorganisms, collectively known as endophytes. Exploring the as-yet untapped natural products from the endophytes increases the chances of finding novel compound. Endophytes are ubiquitous and have been isolated from all plants examined till date. De Bary (1886), the German botanist, who is considered as the father of plant pathology, coined the term 'Endophyte' to describe microorganisms that colonize internal tissues of stems and leaves (De Bary, 1886). This definition was later revised to specify that infections caused by endophytes are asymptomatic, that roots as well as shoots may be colonized, and that an endophyte may not remain an endophyte throughout its life cycle (Porras-Alfaro and Bayman, 2011).

Ethnobotanical knowledge has led to the isolation of novel bioactive compounds. However, plant availability is viewed to be the limiting factor in the commercial success of some natural products. At times, a large quantity of plant is required to produce sufficient amounts of the bioactive compounds for clinical use. In other cases, compounds have been isolated from endangered or highly endemic plants.

Endophytic microorganisms (mostly fungi and bacteria) colonising internal tissues of plants at a particular time, whose presence is unobtrusive and asymptomatic (Schulz and Boyle, 2006). Most plant species that have been previously studied host at least one endophytic microbe (Ryan et al., 2008), with plants growing in unique environmental settings generally hosting novel endophytic microorganisms (Strobel, 2003).

Endophytes form a symbiotic relationship with their plant host. It is believed that in many cases the microbes function as the biological defence for the plant against foreign phytopathogens. The protection mechanism of the endophytes are exerted directly, by releasing metabolites to attack any antagonists or lyse affected cells, and indirectly, by either inducing host defence mechanisms or promoting growth.

Antibiotics or hydrolytic enzymes can be released by endophytes to prevent colonisation of microbial plant pathogens (Strobel, 2003; Berg and Hallmann, 2006), or prevent insects (Azevedo et al., 2000) and nematodes (Hallmann et al., 1998) from infecting plants. In other cases endophytes release metabolites which activate host defence mechanism against other pathogenic organisms, in a process known as induced systemic resistance. Similarly, endophytes can also promote plant growth in an attempt to outcompete cell apoptosis induced by infecting pathogens (Berg and Hallmann, 2006). Plant growth promotion by endophytes may be exerted by several mechanisms, such as production of phytohormones, synthesis of siderophores, nitrogen fixation, solubilisation of minerals such as phosphorus, or *via* enzymatic activities, such as ethylene suppression by 1-aminocyclopropane-1-carboxylate deaminase.

Endophytes can produce the same or similar secondary metabolites as their host. Bioactive compounds which are co-produced by the plants as well as their associated endophytes include the anticancer drug camptothecin, the anticancer drug lead compound podophyllotoxin (Puri et al., 2006), and the natural insecticide azadirachtin (Kusari et al., 2012). There are several mechanisms proposed for the simultaneous production of these biological compounds. In some cases, such as that of gibberellin, the biosynthetic mechanism of the same compound evolves independently in plants and their microbial counterparts (Bömke and Tudzynski, 2009). On the other hand, horizontal gene transfer between the plant host and its endophytes have long been hypothesised, although so far this process has only been shown to occur between microbial endophytes (Tejesvii et al., 2005). It has been strongly suggested, however, that interactions between endophytes and their respective plant host contributes to the co-production of these bioactive molecules.

Endophytes have recently generated significant interest in the microbial chemistry community due to their immense potential to contribute to the discovery of new bioactive compounds. It has been suggested that the close biological association between endophytes and their plant host results in the production of a greater number and diversity of biological molecules compared to epiphytes or soil-related microbes (Strobel, 2003). Moreover, the symbiotic nature of this relationship indicates that endophytic bioactive compounds are likely to possess reduced cell toxicity, as these chemicals do not kill the eukaryotic host system. This is of significance to the medical community as potential drugs may not adversely affect human cells.

One of the most successful stories of natural products from endophytes is the multibillion-dollar anticancer drug Taxol (paclitaxel). The compound was initially isolated from the Pacific yew tree, *Taxus brevifolia* (Wani et al., 1971), a traditional medicinal plant used by Native Americans.

Plant-associated microorganisms have been found to produce novel bioactive metabolites with wide-ranging medicinal applications such as antibiotics, immunosuppressants, antiparasitics, and anticancer agents (Stierle et al., 1993). Therefore, it is hypothesised that endophytes could be useful sources of lead compounds in drug discovery.

Turmeric (*Curcuma longa* L.) is a medicinal plant that is commonly used as spice and preservative. Many types of endophytic fungi namely *Acremonium, Aspergillus, Exophiala, Fusarium, Penicillium, Phoma, and Stachybotrys, Arthrobotrys foliicola,* Cochliobolus kusanoi, *Daldinia eschscholzii*, Fusarium *oxysporum*, Fusarium proliferatum, Fusarium solani, *Fusarium verticillioides*, and *Phaeosphaeria ammophilae and bacteria namely Bacillus cereus, Bacillus thuringiensis, Bacillus sp., Bacillus pumilus, Pseudomonas putida, Clavibacter michiganensis, Alcaligenes faecalis and Enterobacter* have been reported as being associated with medicinal plants and able to synthesize secondary metabolites and have the properties of promoting plant growth.

Kumar et al. (2016) worked on bacterial endophytes of *C. longa* L. They recovered fourteen endophytic bacteria with antimicrobial activity and plant growth promoting properties from the rhizome of *C. longa* L. All the endophytic strains they had isolated, utilized glucose, sucrose and yeast extract as a carbon source where as glycine, alanine, cystine and glutamine as nitrogen source. The strains were mostly sensitive to antibiotic chloramphenicol followed by erythromycin while resistant to polymixin B. The endophytic strains effectively inhibit the growth of *Escherichia coli*, *Klebsiella pneumoniae* and some of the fungal strains like *Fusarium solani* and *Alterneria alternata.*

Sahadevan et al. (2016) isolated about fifty endophytic bacteria from *C. longa*. The results from their study showed that diverse community of endohytic bacteria are associated with the rhizome of curcumin. Among these endohytic bacteria they had isolated *Enterobacter* sp and *Alcaligenes faecalis* were found to have the plant growth promoting properties. These isolates were also found have the capacity to perform phosphate solubilisation which has a high effect on plant growth. The isolates recovered during their research can be considered to have growth promoting effect in turmeric.

Endophytes from medicinal plants represent a potential source of bioactive compounds (Gupta et al., 2016). During their investigation, a total of 207 endophytic fungal isolates were obtained from the rhizome of *C. longa*. Endophytic *Phoma herbarum* isolated from *C. longa* showed significant activity against *Colletotrichum gloeosporioides*.

Endophytic mycobiota and biotransformation of curcumin from the rhizome of *C. longa* was also studied by Jalgaonwala (2013) and recovered a large number of endophytes with good antimicrobial activity.