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ORIGINAL ARTICLE

Endophytes of opium poppy differentially modulate host plant productivity and genes for the biosynthetic pathway of benzylisoquinoline alkaloids

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Abstract

Main conclusion **Endophytes reside in different parts of the poppy plant and perform the tissue-specific functions. Most leaf endophytes modulate photosynthetic efficiency, plant growth, and productivity while capsule endophytes modulate alkaloid biosynthesis.**

Endophytes promote plant growth, provide protection from environmental stresses and are the source of important secondary metabolites. Here, we established that the endophytes of opium poppy *Papaver somniferum* L. may play a role in the modulation of plant productivity and benzylisoquinoline alkaloid (BIA) biosynthesis. A total of 22 endophytes isolated from leaves, roots, capsules and seeds of the poppy plants were identified. Isolated endophytes were used to inoculate the endophytes free poppy seeds and screened for their ability to improve plant productivity and BIA production. It was evident that the endophytes from leaf were involved in improving photosynthetic efficiency, and thus crop growth and yield and the endophytes from capsule were involved in enhancing BIA biosynthesis. Capsule endophytes of alkaloid-rich *P. somniferum* cv. Sampada enhanced BIA production even in alkaloid-less cv. Sujata. Expression study of the genes involved in BIA biosynthesis conferred the differential regulation of their expression in the presence of capsule endophytes. The capsule endophyte SM1B (*Acinetobacter*) upregulated the expression of the key genes for the BIA biosynthesis except thebaine 6-*O*-demethylase (*T6ODM*) and codeine *O*-demethylase (*CODM*). On the other hand, another capsule endophyte SM3B (*Marmoricola* sp.) could upregulate both *T6ODM* and *CODM*. Colonization of poppy plant by endophytes isolated from leaves, roots and capsules found to be higher in their respective plant parts confirmed their tissue-specific role. Overall, the results demonstrate the specific role of endophytes in the modulation of host plant productivity and BIA production.

Keywords Morphine · Noscapine · *Papaver somniferum* · Papaverine · Plant–microbes interaction · Secondary metabolites

Abbreviations

ACC	1-Aminocyclopropane-1-carboxylate
BIA	Benzylisoquinoline alkaloid
CFU	Colony forming units
CODM	Codeine *O*-demethylase
IAA	Indole acetic acid
T6ODM	Thebaine 6-*O*-demethylase

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