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Auxin Signaling and Polar Auxin Transport Play an Important Role in Regulating Root Development during Plant-Beneficial Microbes Interactions

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Short Communication

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ABSTRACT

Plant roots are colonized by an immense number of microbes, including epiphytic and endophytic microbes, which can promote plant growth and alter host root development. Previous studies showed that auxin plays key roles in regulating many different aspects of plant growth and development. However, the precise role of auxin signaling and polar auxin transport in modulating root development during plant-beneficial microbe interactions is unknown. The present short communication summarizes the scattered evidence in support of known host root alterations by beneficial microbes, implying the key role of auxin signaling and polar auxin transport in modulating beneficial effects of microbes in plants.

INTRODUCTION

Like animals, plants have their own microbiome that protects them from various adverse environmental conditions [1]. Plant roots live in close association with a large set of bacteria that thrive in the rhizosphere. Some of these microbes have a significant impact on root morphogenesis [2,3]. Plant growth-promoting bacteria (PGPB) refer to rhizobacteria and endophytes that enhance the growth of their hosts. Among these rhizobacteria, some can promote plant growth and provide a better environment for plant growth through indirect or direct means. For example, *Bacillus megaterium* can promote *Arabidopsis* shoot and root fresh weight and *Arabidopsis* endophytic microbe *Bacillus* sp. LZR216 can promote *Arabidopsis* shoot weight and alter the root system architecture [4,5]. The contribution of beneficial microbes to plant root development can be exerted by mechanisms including secretion of plant growth-regulating substance such as auxin and bacterial volatiles [6,7]. Bacterial secretion of phytohormones can overproduce root hairs and lateral roots and subsequently increase nutrient and water uptake, thus contributing to growth promotion [8]. To elucidate auxin signaling mechanisms by which beneficial microbes modify plant root system architecture, we used *Arabidopsis* as a model plant to clarify the roles of auxin signaling pathway during microbes-regulated root development.

Roles of Auxin Signaling in Plant Root System Architecture Alteration by Beneficial Microbes

The auxin-responsive *DR5::GUS* transgenic lines can indirectly provide insights into changes of auxin levels and signaling during plant-beneficial microbe interactions. For example, rhizosphere *Phyllobacterium brassicacearum* STM196 enhances the *DR5::GUS* expression in primary and lateral root tips, but it does not enhance lateral root numbers in *aux1* and *axr1* mutants, indicating that auxin signaling plays an important role during beneficial microbe-regulated root development. Moreover, *Pseudomonas fluorescens* WCS417 can increase the shoot fresh weight and alter the root system architecture. Furthermore, WCS417 enhances the expression of *DR5::vYFP* and *pAUX1: AUX1-YFP* in *Arabidopsis* primary root tips, but it does not increase lateral root numbers and root hair numbers in the *tir1afb2afb3* mutant [6]. Another study shows that *Trichoderma virens*, a plant beneficial fungus, can increase the *DR5: GUS* expression in shoots and primary root tips, but fails in increasing lateral root

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numbers in the *axr1-3* mutant [9,10]. Auxin gene expression profiling studies have shed light on components of auxin signaling involved in microbe-induced root architectural changes. For example, The *TIR1* gene expression level is down-regulated in the roots but slightly up-regulated in the shoots by *Phyllobacterium brassicacearum* STM196 [9]. In *Populus*, auxin-responsive transcription factors of the *Aux/IAA* family are transiently induced during co-culture with *Laccaria bicolor* [11]. Examples mentioned above show that auxin signaling is important during plant-microbes interactions.

Roles of Polar Auxin Transport in Plant Root System Architecture Alteration by Beneficial Microbes

Auxin transport inhibitor can block auxin accumulation at sites of biosynthesis in shoots of *Arabidopsis* inoculated with *Bacillus subtilis*, suppress the level of auxin in roots and reduce the growth-promoting effects [7]. This example indicates that polar auxin transport is also essential for plant-beneficial microbe interaction. Inoculation of *Arabidopsis* auxin transport mutants *pin2* with *Trichoderma virens* reduces the growth compared with wild-type plants [10], indicating that normal auxin transport is important for the promoting effects of *Trichoderma virens* on root development. Recently, a study shows that *Bacillus* sp. LZR216 does not enhance lateral root number per plant in the mutant *aux1-7* [5]. In *Arabidopsis*, after *Laccaria bicolor* treatment, *aux1* and *pin3* exhibit similar induction of lateral root numbers while less stimulation is observed in single mutant *pin2* and quadruple mutant *pin2,3,4,7* [11]. Inoculation with *Phyllobacterium brassicacearum* STM196 induces a weak increase in transcript levels of *PIN1* and *PIN2* in shoots, but not in roots [9]. Furthermore, the study shows that *Bacillus* sp. LZR216 significantly reduces the expression of *PIN1*, *PIN2*, *PIN3*, and *AUX1* in root tips [5].

CONCLUSION

These aforementioned results provide evidence that auxin transport machinery is involved in plant-microbe interactions.

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