Engineering of Apocarotenoid Production in Pseudomonas putida KT2440 for Promoting Rice Growth and Resilience

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Global food demand requires sustainable strategies to enhance cereal productivity beyond conventional agricultural inputs. The apocarotenoids beta-Cyclocitral (beta-CC) and 3-OH-beta-Cyclocitral (3-OH-beta-CC) are signaling molecules known to promote plant growth and stress tolerance. However, no efficient and environmentally sustainable delivery system currently exists for their agricultural application. This study aims to engineer P. putida KT2440 as a rhizosphere-colonizing microbial platform capable of producing those signaling molecules. A carotenoid biosynthetic pathway was introduced, followed by integration of a carotenoid cleavage enzyme to enable apocarotenoid production. Engineered strains were evaluated for metabolite production, growth characteristics, and plant growth-promoting effects in Oryza sativa L. Engineered strains successfully accumulated carotenoids, including zeaxanthin and beta-carotene, and produced the apocarotenoid derivatives, beta-apo-8'-carotenal and 3-OH-beta-apo-8'-carotenal, confirming beta-CC and 3-OH-beta-CC formation. Although pathway integration reduced growth rate (OD600 0.623 vs 2.365 in wild-type), colony-forming units increased significantly by 2-fold. Under normal conditions, seedlings treatment increased the freshweight by 85%. And under drought conditions, the treated seedlings again outperformed the controls, with 15% greater freshweight. These results demonstrate that engineered P. putida can function as an effective in situ delivery system for apocarotenoid phytostimulants, significantly enhancing plant growth. This work highlights a scalable and sustainable microbial approach for improving crop productivity, with potential applications under environmentally relevant stress conditions.

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