Production of Platform Chemicals in Bioenergy Crops: Stacking Low-Recalcitrance Traits with Co-Products

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Project Goals: Establish the scientific knowledge and new technologies to transform the maximum amount of carbon available in bioenergy crops into biofuels and bioproducts.

Muconic acid (MA) is used for the production of important chemicals such as adipic acid, terephthalic acid, and caprolactam. 2-Pyrone-4,6-dicarboxylic acid (PDC) is a promising building block chemical used to make diverse biodegradable polyesters with novel functionalities. There is no chemical synthesis method currently available for manufacturing PDC, whereas synthesis of MA utilizes petroleum-derived chemicals. Therefore, the development of alternative strategies for bio-based production of MA and PDC has garnered significant interest. Plants represent advantageous hosts for engineered metabolic pathways towards the production of chemicals. We demonstrate that plants can be used for the bio-manufacturing of MA and PDC by re-routing intermediates of the shikimate pathway within chloroplasts. In particular, expression of bacterial 3-dehydroshikimate dehydratase (QsuB) in plastids results in concomitant reductions of lignin and accumulation of protocatechuate (PCA) in biomass. Additional engineering strategies are currently designed to enhance PCA titers and enable its conversion into MA and PDC in-planta. Specifically, bacterial feedback-insensitive 3-deoxy-D-arabino-heptulosonate-7-phosphate synthase was overexpressed to increase carbon flux through the shikimate pathway, co-expression of PCA decarboxylase with catechol 1,2-dioxygenase allowed MA production, and co-expression of PCA 4,5-dioxygenase with 4-carboxy-2-hydroxymuconate-6-semialdehyde dehydrogenase enabled PDC synthesis. The implementation in bioenergy crops (switchgrass, poplar, and sorghum) of MA and PDC biosynthetic routes that divert phenylpropanoid pathway intermediates away from lignin biosynthesis will be presented. These engineering approaches combine in plant biomass the production of value-added chemicals with low-recalcitrance traits towards sustainable development of biorefineries.

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