Engineering Sporopollenin and its Carbon Supply

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To significantly enhance the capture of carbon in soils, one of the first major challenges is to store it in a form that is stable so that it is not released back into the atmosphere for centuries or millennia. A second major challenge is to capture carbon in quantities that are sufficiently large to achieve a significant reduction in the amount of atmospheric carbon dioxide. A novel way to address these challenges is to directly capture carbon into plant products that are almost 'indestructible' from degradation, in species that are widely cultivated. Sporopollenin – often referred to as the 'plant diamond' – is such a product. Sporopollenin, the outer shell of pollen grains, was an innovation from terrestrial plants to protect pollen from sources of environmental stress. Because of its critical role in plant survival, sporopollenin is produced by a pathway that is highly conserved among different species. It is also distinct from the plant products most often considered for carbon capture and storage (cutin, suberin, and lignin) because of its extreme resistance to degradation – sporopollenin is stable over centuries or more vs. decades or less. Consequently, introducing the production of sporopollenin in the roots of plants can be an opportunity for large-scale, near-permanent capture and storage of carbon in the soil. This potential could be further maximized if applied to widely planted bioenergy or agricultural crops. The goal of this research is to identify the genes that are required to produce sporopollenin in plant roots and release it in the soil. This goal will be achieved using two alternative and complementary approaches. First, a set of genes previously known to be major regulators of sporopollenin synthesis in the developing plant flower will be selected, to be expressed in the roots of poplar trees. In parallel, previously unknown elements that improve the synthesis, transport, and assembly of sporopollenin in poplar roots will be discovered. To test the effectiveness of these approaches, methods to rapidly modify the gene content of poplar roots and evaluate the consequence of these changes in the root structure and composition will be applied. While poplar is being selected as the target species for this study, because the synthesis of sporopollenin is highly conserved among plant species, discoveries made in this research could be applicable to a wide range of biomass and food/feed/biofuel crops such as maize, sorghum, and sugarcane. Finally, the proposed strategy, when deployed at scale, has the potential to remove substantial amounts of carbon from the atmosphere. Considering typical poplar biomass yields (5–10 dry metric tons/ha/yr) and allocation of that biomass belowground (20–25%), engineering roots to contain 5% of sporopollenin could near-permanently store 32–80 kg/ha of carbon in soils annually. Furthermore, it is estimated that engineering the 36-million-hectare U.S. maize crop for 5% sporopollenin content in roots and stover could enable the sequestration of 54 million metric tons of CO_2 per year. This is two- to five-fold the current best-practice estimate for annual, long-term carbon sequestration on maize cropland and would significantly increase soil carbon stocks.

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