Engineering and Physical Challenges to Engineered Crops

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Plants can rightly be called masters of microengineering. Their survival and successful reproduction depends on their ability to overcome a series of physical challenges during growth and when transporting material over great distances. An interesting question is therefore which physical effects might influence the performance of engineered plants. In this talk, we focus on the microfluidic cell network responsible for energy transport (the phloem), and discuss the basic physical principles that govern sugar transport in plants. We derive a simple relation between the characteristic sizes of the plant organs, which optimizes the rate of sugar transport. Comparison with experimental data suggests that the pipe network is operating at or near the theoretical optimum. We further consider the coupling between photosynthesis and long-distance transport. While sap with high sugar concentration has the greatest transport potential, viscosity impedes flow, a phenomena analogous to congestion in traffic flows. The optimal sugar concentration for transport in plants is 25%, sweeter than Coke (10%) but much less viscous than maple syrup (65%). Although plants have generally evolved towards the optimum, a number of unusually sweet plants exist. This group consists primarily of crop plants such as corn (40%) and potato (50%), sugar junkies of the natural world.