Noncellulosic Polysaccharides Biosynthesis in Cotton Fiber Developing

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Abstract: Cotton, an oilseed and fiber crop, is grown in more than seventy countries of the world, and plays an important role in the global economy. Botanically, the cotton fiber is a single-celled hair or trichome developing from individual epidermal cells on the outer integument of cotton ovules. Cotton fiber development can be divided into four discrete yet overlapping phases: initiation, elongation, secondary wall thickening and maturation. Fiber initials elongate by a factor of 1000 to 3000 and then deposit a thick cellulose secondary wall. Because cotton fibers are unique cells that differentiate synchronously and synthesize so much cellulose at secondary wall thickening stage of development, they have become one of the model systems of choice in plants for the study of mechanism and regulation of cellulose. After many years of frustration, exciting progress have being made in studies on cellulose synthesis in the developing cotton fibers. However, very limited work has done on the biosynthesis of the noncellulosic polysaccharides, such as xyloglucans, xylans and pectic polysaccharides, in cotton fibers. Xyloglucan consist of a backbone of β(1,4)-linked glucose residues heavily substitued by α(1,6)-linked xylose residues some of which are further modified by galactosyl or fucosyl-galactosyl substituents. Xylan is polysaccharide with linear backbone of β(1,4)-linked xylosyl units that are frequently branched with terminal arabinosyl units and less frequently with glucuronosyl acid units. Pectic polysaccharides mainly includes homogalacturonan, rhamnogalacturonan and arabinogalactans.

Noncellulosic polysaccharides are synthesized by endomembrane systems, particularly the Golgi apparatus. The noncellulosic polysaccharides were synthesized by the catalysing reactions of corresponding enzyme, including the glycosyltransferases and the enzymes of nucleotide sugar activation, conversion and transport, assembled and co-deposited with cellulose at elongating cotton fibers. Pathways for synthesis of the nucleotide sugar substrates of noncellulosic polysaccharides initiates from the cytoplasmic pool of nucleotide sugars from either sucrose synthase or nucleotide sugar pyrophosphorylases.

And at least three possible scenarios exist for the delivery and utilization of nucleotide sugars by the plant Golgi apparatus. First, specific transporters for each species of nucleotide sugar act in an antiporter process with the corresponding nucleotide monophosphate. Nucleotide sugars are concentrated in the lumen where Type II membrane protein glycosyltransferases produce sites oriented toward the cytosol and would not require transport of nucleotide sugars. Third, nucleotide sugars if produced in the lumen of Golgi apparatus, would require transport of sugars, sugar phosphates, UDP-Glc, and other required compounds for nucleotide sugar conversation.

Glycosyltransferases involved in glycan and polysaccharide synthesis can be classified into two broad groups of integral membrane glycosyltransferases and Type II membrane glycosyltransferase based upon the number of their membrne spanning regions and topology of the catalytic domains. Integral membrane glycosyltransferases possess several membrane spanning regions and both the NH_2 and COOH termini are predicted to be oriented toward the cytosol, while Type II membrane glycosyltransferases are located in the Golgi apparatus. They are characterized by a short NH_2 tail oriented toward the cytoplasm, a single membrane spanning region, and a variable length stem connecting with a globular catalytic region oriented toward the lumen. The diversity of glycosyltransferase sequences is presumably a reflection of the different substrates, the linkages formed, and the acceptor recognition regions. However, glycosyltransferases often have aspartate residues in the active sites and most of the conserved aspartate residues are founed in a DD or DXD motif.

Cellulose forms crystaline microfibrils that impart considerable mechanical strength. These microfibrils are embedded in a matrix of noncellulosic polysaccharides. Pectic polysaccharides are highly negatively charged, and appear to form a three-dimensional network that is interweaved with the cellulose-xyloglucan network. Therefore, the fiber quality, especially fiber strength, must be affected by the degree of cross-linking between cellulose and noncellulose as well as the overall crystallinity and deposition patterns of cellulose during the development of cotton fibers. It is expected that the molecular process of noncullulose polysacchasides biosynthesis will be the another hot topic after the focusing on the study of cellulose biosynthesis in developing cotton fibers.

Key words: cotton; fiber development; noncellulosic polysaccharides; biosynthesis