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Role of the formation of fibers with a tertiary cell wall in the biomechanical system of the whole plant

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The morphogenesis of the plant is based on changes in biomechanical properties of its cell walls. In developing organs where cells that differ in their geometry and physical properties of their cell walls increase their size, a complex and dynamic picture of stress distribution is observed. However, this picture is not much simpler in mature organs where none or few cells are still capable of growing. One of the basic approaches which are used by plants to reshape their grown body parts is the formation of fibers with the gelatinous or tertiary cell walls. The fibers with tertiary cell walls in the phloem of many species are not inducible but constitutive. They are especially well pronounced in so-called bast fiber crops like flax or ramie, though their role in the mechanical performance of these herbaceous plants is much less studied than that of tension wood fibers. Using the set of biomechanical approaches with the examination of different mechanical characteristics at macro and nano-scales and considering the flax stem as the compositional material we have shown that the tertiary cell wall fibers indeed develop tension within the stem. The presence of such tension is one of the reasons of fiber deformations that occur upon fiber processing. We also investigated the biomechanical interplay between xylem and phloem during stem development and tracked down their relationships in mutant plants with stunted fibers development. In flax, the tension generated by phloem fibers is partially compensated by the xylem. The leading role in the stem stiffness formation shifts from phloem to xylem along with the plant development. Evidently, these particular complex relationships allow for flax to achieve its exceptional ratio of stem height to diameter remaining sustainable. Similar principles of composite architecture and the mechanical properties of its components can be adopted in artificial biomimetic constructions.

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