Sugar Partitioning and Sink-Source Modification in Plants

Mohammad Reza Siahpoosh

Department of Agronomy and Plant Breeding, Shahid Chamran University, Ahwaz, Iran

Corresponding author: Mohammad Reza Siahpoosh, Department of Agronomy and Plant Breeding, College of Agriculture, Shahid Chamran University, Ahwaz, Iran, Tel: +98 61 3330010-20; Email: siahpoosh@scu.ac.ir

Rec date: Sep 30, 2014, Acc date: Oct 10, 2014, Pub date: Oct 15, 2014

Copyright: © 2014 Siahpoosh. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Editorial

Solar energy is converted to chemical energy and stored as assimilates through a phenomenon called photosynthesis. Plant leaves function as the principle site of resource acquisition by utilizing the free energy captured via photosynthesis for the reductive assimilation of oxidized forms of carbon into carbohydrates. Photosynthetic carbon fixation provides vital energy for metabolism and precursors for all other biosynthetic pathways in the plant. Most of these precursors are required for biosynthesis of amino acids that form the building blocks for many compounds in plants. The regulation of assimilate partitioning in leaves is considered as allocation of carbon between sucrose and starch synthesis, storage, and export, and carbohydrate metabolism [1,2]. Sucrose is the most important metabolite in this system of resource allocation because it is generally the major end product of photosynthetic carbon metabolism and, in most plants it is the predominant form of carbohydrate transported to the heterotrophic tissues [3-5]. Sucrose accumulation between tissues is a fundamental process in all multicellular organisms. Indeed, as much as 80% of the carbon acquired in photosynthesis is transported in the plant’s vascular system to import-dependent organs [6].

Moreover, in many plants, energy-dependent sucrose accumulation in the phloem generates the high hydrostatic pressure that drives the long-distance flow of resources. The systemic distribution of photosynthate is known as assimilate partitioning, and it is a major determinant of plant growth and productivity [7]. Our understanding of assimilate partitioning has advanced considerably over the last 30 years with the successful biochemical and molecular descriptions of several proteins that participate in this essential process (e.g. [8-11]). The current concept of phloem transport comprises three steps: (i) loading of photosynthates into the sieve element companion cell complex (se-cc complex) of minor veins in exporting leaves, (ii) translocation from source to sink, and (iii) unloading in growing or storing sinks [12].

Active transport by specific carriers across the apoplastic, and symplastic transport via plasmodesmata, has been discussed as possible mechanisms for sucrose transport [13]. The transport is active and has been described as a sucrose-proton co-transport with a 1:1 stoichiometry [14].

Sink or source regulated modification of sucrose partitioning in plants is speculated to be a good strategy either for enhancing yield performance and improving plant-stress interactions, and for unravelling the biochemical, physiological and molecular mechanisms underlying sucrose partitioning in plants. To this end, modification could be achieved in two ways: (i) external treatments such as leaf girdling by hot wax collars to prevent export of assimilates from the leaves [15] or such as defoliating [16], or (ii), in vivo molecular manipulation [17,18]. In regard to the latter, one of the molecular candidates for increasing or decreasing sink and source strength through intervention with assimilate loading or unloading is sucrose transporters. Another powerful tool for studying sucrose metabolism and sink/source interactions is apoplastic invertase, as it cleaves sucrose into the monosaccharide glucose and fructose [19].

Using sucrose proton co-transporter antisense lines, [13] showed clear evidence for an essential role of the sucrose transporter in phloem loading and assimilate partitioning. The antisense plants strongly support an apoplastic model for phloem loading, in which the sucrose transporter located at the phloem plasma membrane represents the primary route for sugar uptake into the long distance distribution network. Invertase cleaves sucrose into glucose and fructose. A range of studies supports the hypothesis that the primary function of invertases is to supply carbohydrates to the sink tissues [20,21].

References

1. Gifford RM, Thorne JH, Hitz WD, Giaquinta RT (1984) Crop productivity and photoassimilate partitioning. Science 225: 801-808.
2. Lunn JE (2007) Compartmentation in plant metabolism. J Exp Bot 58: 35-47.
3. Ziegler H, Zimmermann MH (1975) Transport in Plants I: Phloem Transport, Springer, Berlin.
4. Avigd G (1982) Encyclopedia of Plant Physiology, Springer, Berlin.
5. Siahpoosh Mohammad R, Diego H. Sanchez, Armin Schlereth et.al (2012) Modifiication of OsSUT1 gene expression modulates the salt response of rice Oryza sativa cv. Taiapi 309. Plant Science 182:101-111.
6. Chiuo TJ, Bush DR (1998) Sucrose is a signal molecule in assimilate partitioning. Proc Natl Acad Sci U S A 95: 4784-4788.
7. Gifford RM, Thorne JH, Hitz WD, Giaquinta RT (1984) Crop productivity and photoassimilate partitioning. Science 225: 801-808.
8. Scofield GN, Hirose T, Gaudron JA, Upadhyaya NM, Ohsugi R, Furbank RT(2002) Antisense suppression of the rice sucrose transporter gene, OsSUT1, leads to impaired grain filling and germination but does not affect photosynthesis. Func Plant Biol 29: 815-826.
9. Aoki N1, Hirose T, Scofield GN, Whitfield PR, Furbank RT (2003) The sucrose transporter gene family in rice. Plant Cell Physiol 44: 223-232.
10. Yamaguchi J, Matsukura C, Takeda T (2007) Rice sucrose transporter gene promoter. Japan Tobacco Inc, Syngenta Limited.
11. Sun AJ, Xu HL, Gong WK, Zhai HL, Meng K, et al. (2008) Cloning and expression analysis of rice sucrose transporter genes OsSUT2M and OsSUT5Z. J Integr Plant Biol 50: 62-75.
12. Grimm E, Bernhardt G, Rothe K, Jacob F (1990) Mechanism of sucrose retrieval along the phloem path - a kinetic approach. Planta 182: 480-485.
13. Riesmeier JW, Willmitzer L, Frommer WB (1992) Isolation and characterization of a sucrose carrier cDNA from spinach by functional expression in yeast. EMBO J : 4705-4713.
14. Bush DR (1990) Electrogenicity, pH-Dependence, and Stoichiometry of the Proton-Sucrose Symport. Plant Physiol 93: 1590-1596.
15. Goldschmidt EE, Huber SC (1992) Regulation of photosynthesis by end-product accumulation in leaves of plants storing starch, sucrose, and hexose sugars. Plant Physiol 99: 1443-1448.
16. Lee JM, Donaghy DJ, Roche JR (2008) Effect of defoliation severity on regrowth and nutritive value of perennial ryegrass dominant swards. Agron J 100:308-314.
17. Lemoine R (2000) Sucrose transporters in plants: update on function and structure. Biochim Biophys Acta 1465: 246-262.
18. Leggewie G, Kolbe A, Lemoine R, Roessner U, Lytovchenko A, et al. (2003) Overexpression of the sucrose transporter SoSUT1 in potato results in alterations in leaf carbon partitioning and in tuber metabolism but has little impact on tuber morphology. Planta 217: 158-167.
19. Van Camp W (2005) Yield enhancement genes: seeds for growth. Curr Opin Biotechnol 16: 147-153.
20. Sonnewald U1, Brauer M, von Schaewen A, Stitt M, Willmitzer L (1991) Transgenic tobacco plants expressing yeast-derived invertase in either the cytosol, vacuole or apoplast: a powerful tool for studying sucrose metabolism and sink/source interactions. Plant J: 95-106.
21. Koch KE, Wu Y, Xu J (1996) Sugar and metabolic regulation of genes for sucrose metabolism: potential influence of maize sucrose synthase and soluble invertase responses on carbon partitioning and sugar sensing. J Exp Bot 47:1179–1185.