SHORT COMMUNICATION

SINK STRENGTH AFFECTS ASSIMILATE DISTRIBUTION AND PHOTOSYNTHESIS IN SUGARCANE

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Abstract

It has been suggested that sucrose accumulation by sugarcane is regulated at the level of the sink, and strong evidence exists that sink tissues exert an influence on the net photosynthetic rates and carbon status of source organs. A role of sugar molecules as effectors of this relationship has also been established. The existence of a robust sugar-dependent relationship between source and sink tissues in sugarcane could represent a potentially fundamental limiting factor for sucrose accumulation in the stalk and consequently play a major role in overall sucrose crop yield. In this study, the relationship in sugarcane between photosynthetic source tissue and sink material was examined through manipulation of sink strength of field grown *Saccharum* spp. hybrid *cv.* N19 (N19). To enhance sink strength, all leaves, except for the third fully-expanded leaf, were enclosed in 90% shading cloth for varying time periods. In this way, leaves that served as source were converted to sink, producing an overall increase in plant sink strength. Variations in sucrose, glucose and fructose levels were then measured and the effects on gas exchange characteristics and leaf fluorescence recorded. Following a decline in sucrose concentrations in young internodal tissue and shaded leaves, significant increases in the light saturated photosynthetic rate (J_{max}), carboxylation efficiency (V_{rubisco}) and electron transport rate were observed in non-shaded leaves after 6-8 days of shading treatment. Changes in carbon partitioning due to shading were further examined based on the uptake of a $^{14}CO_2$ label. It was concluded that increased sink strength is correlated with a decrease in overall source assimilate availability which in turn may act to up-regulate source leaf photosynthetic capacity. This relationship will be investigated further by identifying putative regulatory occurrences using genomic, proteomic and metabolomic strategies.

Keywords: carbon, partitioning, photosynthesis, sink, sucrose, sugarcane

There is increasing evidence that sugars not only function as a carbon source for growth of plant tissues, but also affect sugar sensing systems that initiate changes in photosynthetic gene expression and assimilate partitioning (Koch, 1996; Chiou and Bush, 1998). It has been suggested that sucrose accumulation in sugarcane is regulated at the level of the sink (Whitaker and Botha, 1997) and strong evidence exists that the carbon demand of sink tissues exerts an influence on the net photosynthetic rates and carbon status of source organs (Paul and Foyer, 2001). The declining photosynthetic rate of sugarcane as it matures is a well-documented phenomenon (Hartt and Burr, 1967; Bull and Tovey, 1974; Amaya *et al.*, 1995) and may be due to a decrease in sink strength as sucrose accumulates. The existence of a sugar-mediated negative correlation between source and sink tissues in sugarcane could thus represent a potentially fundamental limiting factor for sucrose accumulation in the stalk and consequently play a major role in overall sucrose crop yield. In this study, the relationship in sugarcane between photosynthetic activity in source tissue and sugar content of sink material was examined through manipulation of sink strength of field grown *Saccharum* spp. hybrid *cv.* N19 (N19). To enhance sink strength, all leaves, except for the third fully-expanded leaf (leaf 6), were enclosed in 90% shade cloth for varying time periods. In this way, leaves that served as source were converted to sink, producing an overall increase in plant sink strength. Variations in sucrose, glucose and fructose levels were then measured and the effects on gas exchange characteristics and leaf fluorescence recorded.

Experimental findings include the following:

- Shaded leaf material and immature culm sinks supplied by these leaves showed a steady decline in sucrose levels over a two week period.
- Subsequent to declining sucrose concentrations in young internodal tissue and shaded leaves, significant increases in the light saturated photosynthetic rate (J_{max}; Lawlor, 1987), carboxylation efficiency (V_{rubisco}; Lawlor, 1987), and electron transport rate were measured in leaf 6 after 6-8 days of shading treatment.
- While sucrose levels in leaf 6 remained fairly constant, a steady decline in hexose levels was observed. Under conditions of increased sink strength a decreased preference over time towards maintaining a nominal hexose pool in favour of higher sucrose turnover for increased export might be expected. Furthermore, as hexoses are known inhibitors of photosynthesis (Goldschmidt and Huber, 1992), this phenomenon could be indicative of a regulatory mechanism for controlling leaf carbon assimilation rates.
- Uptake of a $^{14}CO_2$ label in plants selectively shaded for 10 days revealed an increased partitioning of assimilate towards younger tissue above the sole source leaf, as opposed to natural basipetal translocation (MacDonald, 2000). Furthermore, a substantial increase in assimilate partitioning towards shaded leaf tissue was observed, indicating a physiological shift for these leaves from source to sink function.

The fact that sugarcane exhibits a steady decrease in photosynthetic assimilation as it matures (Hartt and Burr, 1967; Bull and Tovey, 1974; Amaya *et al.*, 1995) suggests that there is a link between sugar levels in the sink and the capacity of the leaves to produce sucrose. Data from the current study, however, indicates that the metabolic response of source material to changes in sink strength is a complex and well organised feedback mechanism. Leaves appear to retain their ability to shift photosynthetic efficiency according to the demand of the sinks, as well as to draw on other source material in times of stress. Similarly, young internodes deprived of a regular source of fixed carbon are given greater preference in assimilate distribution under conditions of low assimilate availability. The results of this study indicated that the decrease in overall source assimilate availability produced an increase in sink strength which in turn influenced source assimilation rates and consequently export of assimilated carbon to the phloem. This strongly suggests that leaf photosynthetic assimilation rate is linked to the sucrose levels in phloem by a signalling mechanism. The regulatory steps governing this relationship are currently being investigated by examining changes in levels of photosynthetic and putative source/sink-related gene transcripts, as well as the activity of their corresponding proteins.

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