J. Plant Biochem. Biotechnol. (July–September 2015) 24(3):255–256
DOI 10.1007/s13562-014-0297-z

EDITORIAL

Exploitation of microbial biodiversity to engineer efficient photosynthetic system and tolerance to abiotic stresses in plants

Vedpal Singh Malik

Received: 27 October 2014 / Accepted: 29 December 2014 / Published online: 9 February 2015

Abbreviations

Rubisco	D-Ribulose 1, 5-busphosphate carboxylase/Oxygenase
RbcX	assembly chaperone
CcmM35	carboxysomal protein

The Solar energy trapped by the route of photosynthesis is the source of vitality for the earth inhabitants. The multifaceted machinery of photosynthesis involves interaction of numerous proteins and small molecules. The energy transformation machine is vital part of thylakoid membrane system of chloroplasts where photosynthesis happens (Stryker 2012).

The photosynthetic machine and RUBISCO of current plants likely evolved and were selected under different environment than today. The enzyme Rubisco in crop plants seizes both carbon dioxide and oxygen since it did not evolve to distinguish between the two. Due to associated O_2 addiction of Rubisco which results in photorepiration, photosynthetic efficiency is reduced by 30 % in C3 plants. Photosynthetic organisms avoid the problematic increasing atmospheric O_2 levels by creating more Rubisco or by concentrating CO_2 levels in neighborhood of the enzyme. The existing photosynthetic machinery is sluggish in current environment of high O_2 levels.

Enzyme D-ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) retain oxygenase activity and also has slow turnover. It adds O_2 to Ribulose 1,5-bisphosphate to produce phosphoglycolate and 3-phosphoglycerate. A specific phosphatase hydrolyzes phosphoglycolate to glycolate which is oxidized to glyxolate by glycolate oxidase The H_2O_2 formed in this reaction is chopped by catalase to yield H_2O and O_2. Glyxolate is further transaminated to glycine, two molecules of which are abridged to serine liberating CO_2 and NH_4+. Three of the four carbons of two molecules of glycolate end up in serine but one carbon is vanished as CO_2. In addition, one of two amino groups donated in transamination is lost as NH_{4+}. Because of consumption of Oxygen and release of CO_2, this route is baptized as phosphorespiration. This is the consequence of evolution of inadequate RBISCO in many crop plants where carbon is vanished by conversion to CO_2 without generating ATP or NADPH. The oxygenase activity of RUBISCO surges swiftly with temperature. The C 4 plants like sugarcane escape wasteful photorespiration by concentrating high level of CO_2 at location of Calvin Cycle in their photosynthetic machine (Hibberd and Covshoff 2010).

Crop productivity could be increased by eliminating the Oxygenase activity of Rubisco. Deplorably, It has thus far not been possible to improve upon the nature's design of Rubisco by new methodology of genetic engineering. The multifaceted assembly of Rubisco has repelled its genetic selection and improvement.

Besides, crop plants, Algae, cyanobacteria and other organisms have Rubisco that might have followed a different evolutionary path and thus differ in photosynthetic efficiency. Expression of these different Rubisco of microbial origin in crop plants could enhance photosynthetic productivity. The improvement of photosynthesis of tobacco plants by expressing cyanobacteria Rubisco backs such premise (Lin et al. 2014). These tobacco plants with the Rubisco from a cyanobacterium photosynthesize faster with greater rates of CO_2 turnover.

Besides increasing CO_2 levels around the leaf, introduction of CO_2 concentrating mechanisms of other living organisms such as cyanobacteria, microalgae and weeds could augment

V. S. Malik (✉)
USDA, 4700 River Road, Riverdale, MD 20227, USA
e-mail: vedpalms@yahoo.com

photosynthetic CO_2 fixation. This may be achieved by transplanting CO_2 concentrating pumps such as membrane-based pumps for CO_2 and bicarbonate (HCO3−), and distinct micro booths called carboxysomes, which surround Rubisco (Brown et al. (2011)). In the carboxysomes, Carbonic anhydrase, after HCO_3− is pumped into the cell, transforms it to CO_2 resulting in high local CO_2 concentrations and thus upsurge Rubisco efficiency while virtually rejecting O_2 fixation.

Rubisco is a complex of eight large subunits and five to eight small subunits. Lin et al. (2014) replaced the sequence of DNA that encodes the large subunit of Rubisco in the tobacco chloroplasts with the sequence encoding the cyanobacterial enzyme Rubisco which is nearly three times as proficient as compared to Rubisco of most crops. In addition to the cyanobacterial Rubisco, they also coexpressed proteins required for Rubisco assembly. Both, the RbcX chaperone involved in protein folding and a carboxysomal protein (CcmM35) were equally operative at creating efficient Rubisco. Since CcmM35 impersonates three of Rubisco's small subunits, it is amalgamated into Rubisco producing large complexes of enzyme aggregates. The addition of CcmM35 or RbcX may not be necessary in expressing microbial Rubisco in crop plants and at least some of the activities may be accomplished by resident proteins. This approach, however, unlocks the potentials for creation of functional carboxysomes in chloroplasts of crops important to food security.

Biodiversity has been a focus of frequent dialogue and valuable collection of algae survives in India and other places. These collections should be stretched to include strains that have been selected under different CO_2 levels and are tolerant to desiccation, salinity and other abiotic stresses. These collections maybe used to obtain valuable genes for unique fatty acids, pigments and proficient Rubisco and tolerance to abiotic stresses. Robosomal RNA sequence of all algal strains in the collection could be used to allocate them an evolutionary position. Rubisco representing each unique alga may be expressed into crop plants to enhance photosynthetic efficiency. This is very important work that should be pursued and financed considerably in developing countries. If the limiting photosynthetic efficiency of legumes is increased, then provocative possibility exists that such plants may be efficient in Symbiotic nitrogen fixation. With the recent advances in genome editing technologies, manipulation and addition of such novel genes that enhance crop productivity to crop plants is the future (Voytas 2013; Malik 2013).

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