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Photoperiodic changes of soluble sugar levels in Panax ginseng

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Introduction

Korean ginseng, Panax ginseng (C.A. Meyer), and American ginseng, Panax quinauefolius (L.), are obligate shade species. Studies on these plants have shown optimal growth at light intensities between 200-300 µmol.m⁻².s⁻¹, or 10-15% of full sunlight, and at light intensities greater than 500 μ mol.m⁻².s⁻¹ characteristic photoinhibitory symptoms have been reported (Lee, 1988). The underlying mechanism responsible for the susceptibility of ginseng to photoinhibitory conditions has not been established. However, it is possible that carbon metabolism may be a contributing factor in these plants (Huner et al., 1998). When starch levels were determined in both *Panax* species over a 24 h period, the degradation of transitory starch, during a 12 h dark period, was shown to be significantly retarded in *P. quinquefolius* when compared to *P. ginseng*. This result indicated a possible difference in carbon allocation between the two ginseng species (Miskell, 2001). Soluble sugars have been shown to have a role in the inhibition of photosynthesis. For example, photoinhibitory damage has resulted from the removal of sink tissue that led to an increase in the sucrose concentration in leaves (Fover, 1988). The build up of an excessive amount of soluble sugars may result in a reduced demand for NADPH and ATP, thus creating the potential for photoinhibition to occur. Here we report the relative levels of soluble sugars in leaves of P. ginseng and P. quinquefolius in a comparative study that has included pea and spinach.

Materials and methods

Spinach (*Spinacia oleracea* (L.), Yates hybrid 102) was grown hydroponically in Hoaglands solution at a light intensity of 100 μ mol.m⁻².s⁻¹. Pea (*Pisum sativum* (L.)) seeds were germinated in vermiculite and grown at a light intensity of 80 μ mol.m⁻².s⁻¹ and *P. ginseng* and *P. quinquefolius* were also grown at a light intensity of 80 μ mol.m⁻².s⁻¹. All plants were grown with a 12 h light period at 22°C and 68% relative humidity in a growth room equipped with Phillips SonT 400 W high-pressure sodium lamps. An Osram Powerarc 400 W lamp provided additional lighting for spinach plants. At the times indicated in the figure legends, leaf material was ground to a fine powder in a mortar and pestle containing liquid nitrogen and then freeze dried. Soluble sugars were determined using the method of Hendrix (1993).

Results

Figure 1 shows glucose levels over a 24 h period in *P. ginseng*, *P. quinquefolius*, pea and spinach. Spinach, compared to the other species, had significantly lower glucose levels throughout the light/dark cycle. However, compared with the levels at the end of the dark

period, *P. ginseng* and pea showed a significant rise in glucose levels in the first hour of the light period, and a similar change was also observed in spinach. However, in the case of *P. ginseng*, glucose levels then declined until the 9 h time point and then increased before declining during the dark period. Interestingly, the level of glucose also increased towards the end of the dark period in both ginseng species, whereas glucose levels in pea and spinach declined until the light came on.



Fig. 1. Concentration of glucose in leaves from *P. quinquefolius* (closed squares), *P. ginseng* (closed triangles), pea (open circles), and spinach (open diamonds) over a 24 h period. The data are the mean of six independent experiments. Standard error bars not indicated are smaller than the symbols.

The fructose levels during the light/dark cycle are shown in Fig. 2. In general the two ginseng species had higher fructose levels than pea and spinach. However, the most striking feature of these data is the pronounced dip in the fructose levels of *P. ginseng* at 9 h and 20 h. In contrast, in Fig. 3, the sucrose level of *P. ginseng* was observed to peak at 3 h and 16 h. Therefore the sucrose level in *P. ginseng* peaked immediately before the minimum levels measured for glucose and fructose. In comparison, similar oscillations in the soluble sugars were considerably attenuated in *P. quinquefolius*, and were not present in either pea or spinach. However, pea and spinach both showed a similar sucrose profile over the 24 h period, generally rising during the light period and falling when the lights were off.

Discussion

Panax quinquefolius and *P. ginseng* are found in deciduous forests and are uniquely fit for low-light environments but are susceptible to photoinhibition at moderate light intensities that exceed 500 μ mol.m⁻².s⁻¹. The mechanism underlying this obligate shade-plant phenotype is unknown and may result from a limitation at the level of the thylakoid associated reactions of photosynthesis or arise as a consequence of adaptations at the level of carbon metabolism. Recently we observed that leaf starch in *P. quinquefolius* was resistant to degradation during darkness. In fact, levels of leaf starch only declined by approximately 30% after 48 h in the dark, whereas leaf starch in *P. ginseng* was fully degraded during a dark period of 12 h (Miskell, 2001). Since photosynthetic end-product accumulation results in a reduced demand for NADPH and ATP the existence of elevated leaf starch in *P. quinquefolius*, throughout the



Fig. 2. Concentration of fructose in leaves from *P. quinquefolius* (closed squares), *P. ginseng* (closed triangles), pea (open circles), and spinach (open diamonds) over a 24 h period. The data are the mean of six independent experiments. Standard error bars not indicated are smaller than the symbols.



Fig. 3. Concentration of sucrose in leaves from *P. quinquefolius* (closed squares), *P. ginseng* (closed triangles), pea (open circles), and spinach (open diamonds) over a 24 h period. The data are the mean of six independent experiments. Standard error bars not indicated are smaller than the symbols.

photoperiod, could be a contributing factor in the susceptibility of this species to photoinhibition. In this experiment we have measured the levels of glucose, fructose and sucrose and identified a marked periodicity in soluble sugar levels in *P. ginseng* that was not observed in *P. quinquefolius*, or in either pea or spinach. Under a 12 h/12 h light/dark cycle sucrose levels in *P. ginseng* initially peaked at 3 h after the light came on. This was followed at 9 h by a decline of glucose and fructose but the levels of these monosaccharides recovered by the end of the light period. This cycle then repeated approximately 12 h later in the dark period with an even more pronounced oscillation. In particular, the level of fructose in *P. ginseng* was higher than found in the other plants at the beginning and end of the photoperiod.

While these results have not established a role for soluble sugar levels in the susceptibility of *P. ginseng* to photoinhibition they have established that sugar metabolism in *P. ginseng* is quite distinct from *P. quinquefolius* as well as pea and spinach. In particular, the levels in spinach were significantly lower than observed in both of the ginseng species. However, this result is in agreement with Goldshimdt and Huber (1992) who reported that spinach primarily stored carbohydrate as sucrose and starch. Furthermore, there is good evidence that expression of genes encoding Calvin cycle enzymes can be regulated by the level of soluble sugars (Sheen *et al.*, 1999). Therefore, it is possible that the demand for ATP and NADPH is limited in *P. ginseng* due to down-regulation of triose production and ribulose 1,5-bisphosphate regeneration. Certainly these results suggest that a comparative study of sugar-regulated gene expression, that includes ginseng, may make a novel contribution to this topic.

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References

Foyer C (1988) Plant Physiology and Biochemistry 26, 483-492.
Goldshmidt E, Huber S (1992) Plant Physiology 99, 1443-1448.
Hendrix D (1993) Crop Science 33, 1306-1311.
Huner N, Oquist G, Sarhan F (1998) Trends in Plant Science 3, 224-230.
Lee C (1988) Korean Journal of Ginseng Science 12, 11-29.
Miskell J-A (2001) PhD thesis, University of Otago, Dunedin, New Zealand.
Sheen J, Zhou L, Jang J (1999) Current Opinion in Plant Biology 2, 410-418.