Comparison of Leaf Photosynthesis between Wild and Cultivated Types of Soybean

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The ancestor wild species of soybean is considered to be Glycine soja Sieb. et Zucc. (Hymowitz, 1970), which grows naturally in the north-eastern section of China, Korea and Japan. With the progress of cultivation, it lost the habit of pole climbing, production of hard seed and dormancy, and on the other hand acquired upright standing, pod-cracking resistance and large seed (Hardley et al., 1973). Saitoh et al. (2004) reported that during the process of domestication from wild type to cultivated type, i) development of branches and racemes with compound leaves was repressed, resulting in a decreased number of nodes, ii) flower production decreased and the rate of pod set increased markedly, iii) the number of pods decreased, but seed size increased. There are many studies on the leaf photosynthetic rate of wild and cultivated crop species, e.g., wheat (Evans et al., 1970), rice (Takano et al., 1971), barley (Chapin et al., 1989). Most investigators reported that the leaf photosynthetic rate of some wild relatives of crop species was higher than that of the cultivated species. Kokubun et al. (1988) compared the leaf photosynthetic rates among six species of subgenus Glycine and obtained the same differences as reported for other crop species, but limited studies have been reported on the leaf photosynthetic characteristics of Glycine soja. This study was conducted to clarify the changes in the leaf photosynthetic capacity during the domestication process of soybean.

Materials and Methods

1. Plant cultivation

Two lines of wild type, A3 and E2, and two cultivated types, Enrei (determinate type) and Touzan 69 (indeterminate type), as used previously (Saitoh et al., 2004), were grown in 1/5000a Wagner pots (one plant per pot) in a vinyl house. Two seeds of each cultivar and line were sown on June 18, 1998. Each pot was filled with 3.5 kg of sandy clay soil and basal fertilizer was applied at the rate of 0.08 g N, 0.4 g P₂O₅ and 0.29 g K₂O in the form of ammonium sulphate, fused magnesium phosphate and potassium chloride, respectively. After emergence, seedlings were thinned to a single plant per pot. Because of the pole climbing characteristics, the wild soybean plant was supported by a pole and vinyl straps. The plants were irrigated as required to avoid water stress. Although the soil was not inoculated with Bradyrhizobium japonicum, vigorous growth and enough nodulation were observed.

2. Photosynthetic measurement

The carbon dioxide (CO₂) exchange rate (CER) of the fully expanded terminal leaflet, i.e., the 10th leaf in Enrei, the 9th leaf in Touzan 69, the 11th and 12th leaf in A3 and E2, respectively, numbered from the cotyledon, was measured, using a portable photosynthesis measurement system (SPB-H4, Shimadzu, Kyoto, Japan) from the 32 to 85 days after sowing (DAS) at about 10-day intervals. The measurement was carried out during 10:00 and 13:00 on a clear day, and repeated three times for different plants of each genotype. The flow rate of air in the chamber was maintained at 200 mL min⁻¹ at a CO₂ concentration of 350 µL L⁻¹. The PAR (photosynthetically active radiation) on the measured leaves (6.25 cm²) was higher than 1500 µE m⁻² s⁻¹. As the air temperature in the chamber was not controlled, the leaf temperature fluctuated within a range of 28 and 32°C. After the measurement, the index of leaf chlorophyll content, i.e., SPAD value was measured with a SPAD meter (SPAD-502, Minolta Ltd.) at where CER was measured.

3. Leaf size and SPAD value according to leaf position

In order to investigate the difference in leaf size among genotypes, we measured the length and width of the terminal leaflet were measured at 66 DAS (early
seed growth stage, R5 according to Fehr et al., 1971). The leaf size expressed as length multiplied by width was measured at each node position on the main stem. The SPAD value at each node position was also measured by the same procedure as described above. Measurements were repeated three times on different plants of each genotype.

**Results and Discussion**

The leaf CER increased gradually until 53 DAS (pod expansion stage, R4), and rapidly decreased thereafter in Enrei, Touzan 69 and A3 (Fig. 1). However, in E2 leaf CER was highest at the start of the measurement, and rapidly decreased, thereafter reaching nearly zero at 65 DAS (early seed growth stage, R5). The cultivated type exhibited a higher leaf CER than wild type throughout the whole growth period.

The SPAD value was the highest at 65 DAS (early seed growth stage, R5) followed by a gradual decrease in all genotypes (Fig. 2). As in the CER, the SPAD value of cultivated type, Enrei and Touzan 69, was higher than that of wild type, A3 and E2, throughout the whole period.

The higher the node position, the larger the leaf size and SPAD value in Enrei at 66 DAS (Fig. 3, 4). In Touzan 69 and wild type, however, leaf size and SPAD value increased with increasing node position from the cotyledon to the middle and to about two thirds of the nodes on the main stem; respectively, beyond these positions, both values decreased gradually. The highest SPAD value was slightly larger in the cultivated type, Enrei (45.2) and Touzan 69 (42.6), than the wild type, A3 (40.3) and E2 (41.6).

Kokubun et al. (1988) reported that cultivated soybean had larger leaves and showed a lower photosynthetic rate than subgenus Glycine species. In our experiment, the wild type (Glycine soja) showed a lower photosynthetic rate than cultivated type (Fig. 1) in spite of having smaller leaves (Fig. 3).

Kobayashi et al. (1994) mentioned that the photosynthetic rate of the wild type of soybean was not significantly different from that of the cultivated type of soybean at the earlier growth stage, although it was lower than that of the cultivated type at a later
growth stage. The lower photosynthetic rate in wild soybean might be due to the competition for nitrogen between leaves because pole climbing plants expand many leaves together with internode elongation. The wild type maintained the photosynthetic capacity approximately equivalent to that of the cultivated type by expanding many trifoliolate compound leaves composed of a small leaflet (Fig. 3). We reconfirmed that the leaf photosynthetic rate of soybean varies with the cultivars (Ojima et al., 1968) and is higher in soybean cultivars improved by breeding (Ojima et al., 1968).

In the present study, the cultivated type of soybean showed a higher leaf photosynthetic rate than the wild type. This suggested that during the process of domestication from wild to cultivated type of the photosynthetic capacity of soybean might be improved and the leaves became larger, with increased rate of dry-matter production. We used a limited number of lines of wild soybean and further studies with more lines of wild soybean from diverse collection sites are needed.

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References

Chapin, F.S. et al. 1989. Oecologia 79: 96-105.
Evans, L.T. et al. 1970. Aust. J. Biol. Sci. 23 : 725-741.
Fehr, W.R. et al. 1971. Crop Sci. 11:929-931.
Hardley, H.H. et al. 1973. Soybeans. ASA Publi., Madison. 97-116.
Hymowitz, T. 1970. Econ. Bot. 24 : 408-421.
Kobayashi, T. et al. 1994. Hokuriku Crop Sci. 29: 77-79**.
Kokubun, M. et al. 1988. Jpn. J. Crop Sci. 57 : 211-219.
Ojima, M. et al. 1968. Proc. Crop Sci. Soc., Japan 37 : 667-675*.
Ojima, M. et al. 1968. Proc. Crop Sci. Soc. Japan 37 : 676-679*.
Saitoh, K. et al. 2004. Plant Prod. Sci. 7 : 172-177.
Takano, Y. et al. 1971. Jpn. J. Breed. 21 : 69-76.

* In Japanese with English abstract or summary.
** In Japanese.