Differences in Leaf Senescence among Reciprocally Grafted Plants of Two Soybean Cultivars, Enrei and Tachinagaha

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The soybean cultivar, Tachinagaha maintained a higher rate of photosynthesis than the Enrei cultivar due to delayed leaf senescence during ripening. The higher rate of photosynthesis was reflected in the increased production of dry matter and a higher grain yield (Ookawa et al., 1998). Stems and upper leaves of Tachinagaha remained green with high moisture contents even after the pods and seeds had completely matured at the University farm in Fuchu, Tokyo. This phenomenon has been known as delayed stem maturation (Umesaki et al., 1991) and this trait should be eliminated in breeding programs, because it decreases labor efficiency, grain quality at harvest and subsequent processing of soybeans. This study was performed to clarify the role of roots and the above-ground parts of the plant in leaf senescence, using self-grafted plants and reciprocally grafted plants of the two cultivars.

Materials and Methods

The seeds of the Enrei and Tachinagaha cultivars were planted on 30 June 1997 in small pots (8 cm in diameter, 7 cm in depth). On the 8th day after planting, we made self grafts (i.e., Enrei/Enrei(E/E) and Tachinagaha/Tachinagaha(T/T) (scion/rootstock)) and reciprocal grafts (i.e., Enrei/Tachinagaha(E/T) and Tachinagaha/Enrei(T/E)), 40 grafts for each combination. Scions and rootstocks were joined at the cotyledonary node by the wedge-grafting technique, and grafted joints were reinforced with laboratory film (Parafilm, American National Can Inc.). The grafted plants were grown in a mist room with the 50% shading for one week to establish the grafts. On the 7th day after grafting, the grafted plants selected for uniformity were transplanted to larger pots (25 cm in diameter, 30 cm in depth; 2 plants per pot) filled with Tama River alluvial and Kanto alluvial soils (1:1, v/v), with compound fertilizer (14-14-14) at 7 g pot−1, and grown with adequate moisture in the soil. The grafted plants grew well and there were no differences in the rate of leaf emergence or in the number of nodes on the main stems in all scions.

The chlorophyll content of leaves was estimated at the central region of terminal leaflets, excluding the main vein, with an in situ chlorophyll meter (SPAD-302, Minolta Inc., Tokyo). Readings of the chlorophyll meter were compared with the chlorophyll contents determined by the method of Winternans et al. (1965).

Results and Discussion

No differences in the chlorophyll content of leaves were found at the flowering stage among the reciprocally grafted plants. However, differences in chlorophyll content clearly appeared during the seed filling stage. At the beginning of seed filling stage (R5) on the 23rd day after flowering, the chlorophyll content of leaves at lower nodes, namely, from the 5th to the 7th node on the stem was higher in T/T and E/T grafts than in T/E or E/E grafts (Fig. 1). Thus, the chlorophyll content at this stage was related to the cultivar of the stock independent of the cultivar of the scion (Fig. 1). The 4th leaves were still alive at this stage in T/T and E/T grafts, but they had been shed by E/E and T/E grafts. These results clearly indicate that leaf senescence was affected by the properties of the underground part of the plant at the beginning of the seed filling stage. The development of the root system and the amounts of cytokinins and/or nutrients (nitrogen, etc.) transported from the roots to the above-ground part might be involved in these properties (Hirasawa et al., 1994 ; Hida et al., 1995 ; Noodén and Letham, 1993 ; Mauk et al., 1990 ; Soejima et al., 1995).

At later seed filling stage (R6) on the 55th day after flowering, the 6th and 7th leaves were still alive in plants for which Tachinagaha had been used as the scions, irrespective of the cultivar of the rootstock. By contrast, these leaves had already been shed from the plants for which Enrei had been used as the scion. The chlorophyll content of leaves at the upper nodes, from the 8th to the 11th node was significantly higher in the T/T and T/E grafts than in the E/E or E/T grafts (Fig. 2).

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Chlorophyll content (relative value)

Fig. 1. Comparison of chlorophyll contents of leaves of grafted plants on the 23rd day after flowering. Self-grafted and reciprocally-grafted plants are represented as scion/rootstock as follows: ☐ Enrei/Enrei; □, Tachinaga-ha/Enrei; ▲, Enrei/Tachinagaha; ▲, Tachinagaha/Tachinagaha. The 1st node refers to the cotyledony node. The 11th node is the uppermost node with the 9th foliage leaf. Bars indicate S.D. (n=6).

Relative values, namely, readings from the chlorophyll meter, were closely correlated with chlorophyll content on a leaf-area basis. Readings of 20 and 40 corresponded to a chlorophyll content of 0.16 and 0.57 g m\(^{-2}\), respectively. Zero values were given for the shed leaves.

Chlorophyll content (relative value)

Fig. 2. Comparison of chlorophyll contents of the leaves of grafted plants on the 50th day after flowering. For details, see legend to Fig. 1.

Fig. 3. Photographs of examples of grafted plants at harvest time.

chlorophyll contents of leaves from the 8th to the 10th node in E/T grafts was lower than those in E/E grafts.

At the maturity stage (R8), all leaves had already been shed from the plants with Enrei as the scion, while several green leaves remained and the delayed matura-tion of the stem was observed in plants with Tachinaga-ha as the scion (Fig. 3). These results clearly indicated that leaf senescence at later seed filling stage and at maturity was affected by the properties of the above-ground part of the plant.

In previous studies with grafted plants, it appeared leaf senescence at the maturity (Kahanak et al., 1978) and the delayed maturation of stems (Umesaki et al., 1991) were largely affected by the properties of the above-ground parts of plants. Properties of nuclei and cytoplasm in the line that stayed green, the transport of abscisic acid from pods to leaves, the accumulation of abscisic acid in leaves, and the translocation of nitrogen from leaves to pods were suggested as explanations for role of the above-ground parts of plants that was related to senescence (Guiaemet et al., 1990; Noodén, 1984; Hayati et al., 1995). Delayed maturation of the stems of the Tachinagaha cultivar is observed in Tokyo and Chiba, namely, the southern parts of the Kanto district, but it is scarcely observed in northern areas, Nagano and Tochigi. Since the air temperature is lower during the ripening season in the latter locations than in the former locations, it is possible that stems and leaves might mature in response to cool temperatures also.

From the results of this study, we can conclude that the source of factors that influenced leaf senescence changed from the root system to the above-ground parts during ripening of the soybean cultivars, and that the delayed senescence of Tachinagaha leaves was caused by the root system at the beginning of the seed filling stage, and by the above-ground parts of the plants at later seed filling stage. Studies are underway on the physiological factors that regulate leaf senescence in soybean, focusing on the time when the source of factors that influenced leaf senescence changes from the root system to the above-ground parts.

References


*In Japanese with English abstract.
**In Japanese.