Comparisons of growth and photosynthetic characteristics between wild and cultivated types of soybeans

Kuniyuki Saitoh[1], Kuniko Nishimura[1] and Toshirou Kuroda[1]

[1] Faculty of Agriculture, Okayama University, www.okayama-u.ac.jp Email ksaitoh@cc.okayama-u.ac.jp

Abstract

Characteristics of flowering and pod set were compared between wild and cultivated types of soybean grown in pots (1/5000 a) in a vinyl house. The wild type had 10-fold more nodes than the cultivated type. The wild type developed 10-fold more flowers than the cultivated type, but set relatively few pods. During the process of domestication from wild to cultivated type, i) the pole climbing characteristic disappeared and 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 became bigger, and iv) photosynthetic capacity might be improved and the leaves became larger, with increased rate of dry-matter production.

Media summary

During the domestication of soybean, flower production decreased, the rate of pod set increased, the number of pods decreased, seed size became bigger, and photosynthetic capacity might be improved and the leaves became larger.

Key Words

Cultivated soybean, Flowering habit, *Glyicine max, Glycine soja,* Rate of pod set, Wild soybean.

Introduction

The ancestor wild species of soybean is considered to be *Glycine soja* Sieb. et Zucc. (Hymowitz 1970), which grows naturally in the north eastern China, Korea and Japan (Figure 1). 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 and Hymowitz 1973). In Japan, the wild type of soybean grows vigorously and has been used as a breeding material of the cultivated type of soybean for green feed (Fukui 1977). In China, it is utilized for breeding of high-protein, high-yielding, and salt tolerant cultivars and also to breed cultivars for green manure, vegetable sprout and fermented soybeans (Wang et al. 2002).

It is well known that the cultivated type of soybean sets pods 20 to 60 percent of the total number of flowers (Yoshida et al., 1983). Although the higher production of flowers looks wasteful, Saitoh et al. (1998) observed that the seed yield of soybean cultivar grown under three planting densities for three years closely correlated with the number of flowers opened, but not with the rate of pod set. This suggests that the potential of flower production is important for higher seed yield rather than the rate of reproductive abortion.

This study was conducted to clarify the changes of flowering and pod setting characteristics, and the leaf photosynthetic capacity during the domestication process of soybean.

Figure 1. Flowering and pod set in the wild type of soybean (*Glycine soja* Sieb. et Zucc.)

Materials and Methods

Plant cultivation : The flowering and pod set performance in two lines of wild type, A3 (from Akita Pref., Japan) and E2 (from Iwate Pref., Japan), which were collected and stored at the Faculty of Agriculture, Kyusyu University were compared with those in two cultivated type, cultivar Enrei (determinate type) and Touzan 69 (indeterminate type). The three seeds were sown in 1/5000 a Wagner pots (10 pots for each genotype) on June 18 1998 in a green house at the Field Science Center of the Okayama University, Okayama city, Japan (34.41?N, 133.55?W). 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 P_2O_5 and 0.29 g K_2O mixing in the top of the soil. After emergence plants were thinned to one plants per pot.

Flowering and pod set : The dates of flower opening, and of flower or pod shedding were recorded daily for each node position, raceme order, and intra-raceme position from 38 to 108 days after sowing (DAS) for three plants of each genotype. Raceme order was defined by Torigoe et al. (1982) as follows. The first order raceme develops from the axil just above the petiole on the stem. The second order raceme develops from right and left axillary buds of the first order raceme, and so on. *Yield components*. The yield components, number of pod, seeds per pod, 100 seeds weight, seed setting ratio (number of all seeds / no. of ovule), and seed yield at each node and raceme order were examined.

Photosynthetic measurement : The carbon dioxide (CO_2) exchange rate (CER) of the fully expanded terminal leaflet numbered from the cotyledon, was measured, using a portable photosynthesis measurement system (SPB-H4, Shimadzu, Kyoto, Japan) from the 32nd to 85th DAS (Days After Sowing) at about 10-days intervals.

Leaf length : The length of the central vein of the terminal leaflet of compound leaves at each nodal position of the main stem was measured from the top to the base at the early-seed growth stage with three replication.

Results

Growth of plant : Table 1 shows the growth habit of the plants of cultivated type Enrei and Touzan 69, and wild type A3 and E2. The growth duration was 114?7 days, and the flowering duration was shortest in Touzan 69 (30 days) and longest in A3 (40 days). Wild type had more nodes on the main stem, branches and racemes with compound leaves than cultivated type. E2 had 16-hold more nodes than Enrei. In the wild type, racemes with compound leaves occupied a larger portion of the number of nodes than in the cultivated type. Wild type had longer main stem and heavier stem, so that seed/stem ratio in the wild type was lower than in the cultivated type.

Table 1. Genotypic differences in the number of nodes and growth characters of wild and cultivated soybeans.

Cultivar /Line	Growth duration* (days)	Flowering duration* (days)	Number of node				Main stem length (cm)	Total weight (g)	Stem weight (g)	Seed/stem ratio
			Main stem	Branches	Racemes with leaves	Total				
Enrei	111 bc	38 a	12 d	24 c	11 c	47 c	45 d	41.5 b	8.3 b	1.67 a
Touzan 69	114 b	30 b	18 c	39 c	11 c	68 c	82 c	42.1 b	10.8 b	1.21 a
A3	122 a	40 a	32 a	131 b	161 b	320 b	369 a	51.7 ab	19.9 a	0.47 b
E2	107 c	32 b	24 b	373 a	353 a	751 a	276 b	63.4 a	23.4 a	0.66 b

* : n=3, others were n=5. Mean values followed by the same letter are not significantly different at 5% level according to Fisher's PLSD.

Flowering and pod set. The flowering started on the first order raceme at the 10th node with no branches in Enrei and Touzan 69 and at the 19th node in A3, and progressed toward the apical part (data not shown). A similar trend of flowering habit, i.e., progressive flowering from the basal to apical part was observed in upper order racemes in all genotypes. Flowers on basal order racemes spread upward on the main stem more rapidly in the order of Enrei > Touzan 69 > A3, E2, and flowering duration at each node was longer in A3 and E2 than in cultivated type.In Enrei, after the first order raceme finished flowering, the second order raceme with and without compound leaves began to flower, but in Touzan 69, A3 and E2, the second and third order racemes began to flower while the first order raceme on the apical part of the main stem was still flowering. This tendency was more marked in A3 and E2. Wild-type plants, A3 and E2, developed 10-fold more flowers than cultivated type, Enrei and Touzan 69 (Table 2). In the wild type, the number of flowers on branches relative to that on the main stem was higher than in cultivated type. The wild-type plants were classified into indeterminate type as was Touzan 69, with a larger portion of total flowers on the basal order raceme than Enrei (determinate type). The number of floral organ per raceme varied within genotypes, that of 1st order raceme on the main stem was larger in wild type (11.7, 6.9) than in cultivated type (5.2, 3.3) especially in A3.

The rate of pod set (pods / flowers) in the whole plant in Enrei was similar to that in Touzan 69 (Table 2), but the rate of pod set was relatively higher on the main stem in Enrei and on the branches in Touzan 69. In wild type, the rate of pod set in the whole plant was markedly lower than in Enrei and Touzan 69, especially on branches, due to the production of a large number of flowers.. Wild-type plants, A3 and E2, developed 10-fold more flowers than cultivated type, Enrei and Touzan 69 (Table 2). In the wild type, the number of flowers on branches relative to that on the main stem was higher than in cultivated type. The rate of pod set (pods / flowers) in Enrei was similar to that in Touzan 69 (Table 2), but in wild type, the rate of pod set was markedly lower than in Enrei and Touzan 69, especially on branches, due to the production of a large number of flowers. The rate of pod set on the upper order racemes was higher than that on the basal order racemes in both cultivated and wild type probably due to the higher number of flowers on the basal order racemes with the exception of Enrei.

Cultivar /Line	Number of flowers per plant			Percentage of pod set		
	Main stem	Branches	Whole plant	Main stem	Branches	Whole plant
Enrei	118 b	112 b	230 b	32.5 a	27.4 b	29.7 a
Touzan 69	119 b	166 b	285 b	23.3 b	34.7 a	29.9 a
A3	800 a	1807 a	2607 a	9.4 d	6.6 c	7.5 b
E2	529 a	2204 a	2733 a	17.6 c	12.9 c	13.8 b

n=3. Mean values followed by the same letter are not significantly different at 5% level according to Fisher's PLSD.

Table 2. Genotypic differences in the number of flowers and percentage of pod set.

Yield and yield components : The number of pods per plant was about 70 in cultivated type (Table 3), and 160 and 348 in wild type A3 and E2, respectively. The number of seeds per pod was similar in all genotypes. Seed weight was considerably light in the wild type, and lightest in E2 (2.8 g per 100 seeds). The seed setting ratio was 55-73 %, and there was no difference between the wild-type and cultivated-type. Seed yield per plant in Enrei and Touzan 69 was 11.5g and 13.9g, respectively, and was lower 8.9g in A3, and higher 15.3g in E2.

Table 3. Genotypic differences in yield components*.

Cultivar /Line	No. of pods per plant	Seeds per pod	100 seeds weight (g)	Seed setting ratio# (%)	Seed yield (g per plant)
Enrei	68.6 c	1.68 b	24.0 a	68.7 ab	13.9 a
Touzan 69	71.4 c	1.73 ab	21.5 b	54.7 c	11.5 ab
A3	160.4 b	1.62 b	8.9 c	58.4 bc	8.9 b
E2	348.2 a	1.89 a	2.8 d	73.0 a	15.3 a

*: n=5. #: number of all seeds / no. of ovule.
Mean values followed by the same letter are not significantly different at 5% level according to Fisher's PLSD.

Leaf length. The lower the node position from the top, the shorter the leaf length in Enrei. In Touzan 69 and wild type, however, leaf length increased with increasing the position from the top to around 10th position, beyond this position, it decreased rapidly in Touzan 69 and gradually in wild type (Figure 1).

Leaf CER. The leaf CER increased gradually until 53 DAS (pod expansion stage, R4), and rapidly decreased thereafter in Enrei, Touzan 69 and A3 (Figure 3). 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). Cultivated type exhibited a higher leaf CER than wild type throughout the whole growth period. Kokubun and Wardlaw (1988) reported that cultivated soybean had larger leaves and showed a lower photosynthetic rate than subgenus *Glycine* species. In our experiment wild type (*Glycine soja*.) showed a lower photosynthetic rate than cultivated type (Figure 2) in spite of having smaller leaves (Figure 1).

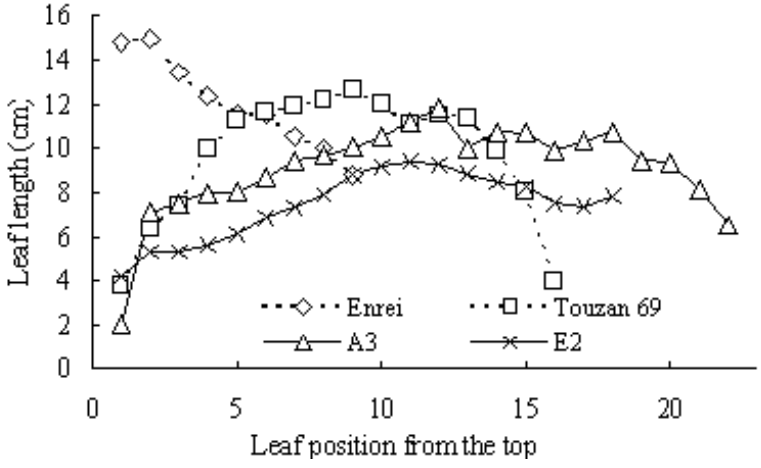

Figure 1. Genotypic differences in the length of terminal leaflet according to leaf position on the main stem.

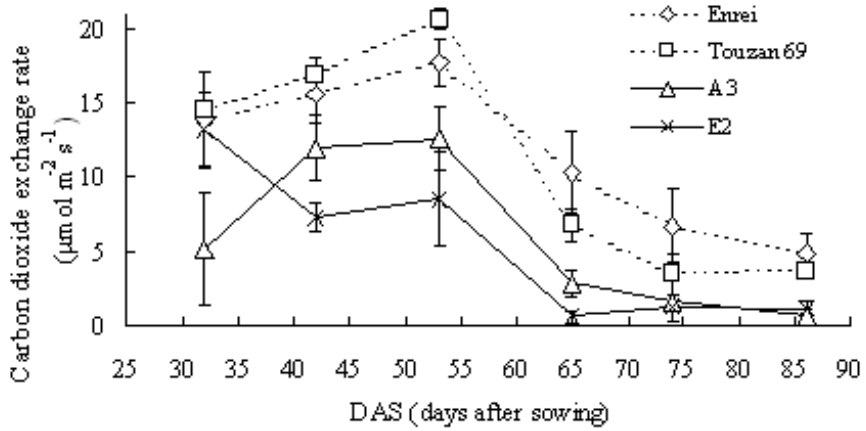

Figure 2. Changes in leaf carbon dioxide exchange rate of wild and cultivated types of soybeans during ontogeny. Vertical bars represent mean ?SD of three leaves.

Conclusion

During the process of domestication from wild to cultivated type, i) the pole climbing characteristic disappeared and 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 became bigger, and iv) photosynthetic capacity might be improved and the leaves became larger, with increased rate of dry-matter production.

References

Fukui J (1977). Collection and preservation of wild soybeans (*Glycine soja*) and its significance on the breeding program. Japanese Journal of Breeding 27, 167-173 (In Japanese.)

Hardley HH and Hymowitz T (1973) In 'Soybeans : Improvement, production and uses'. (Ed. BE Caldwell) pp. 97-116. (American Society of Agronomy, Madison).

Hymowitz T (1970) On the domestication of the soybean. Economic Botany 24, 408-421.

Kokubun M and Wardlaw IF (1988). Temprature adaptation of *Glycine* species as expressed by germination, photosynthesis, photosynthate accumulation and growth. Japanese Journal of Crop Science 57, 211-219.

Torigoe Y, Sinji H and Kurihara H (1982) Studies on developmental morphology and yield determining process of soybeans. II. Developmental regularity of flower clusters and flowering habit from a view point of gross morphology. Japanese Journal of Crop Science 51, 89-96. (In Japanese with English abstract or summary.)

Wang KJ, Takahata Y and Kaizuma N (2002) Present situation of genetic resources of wild soybean (*Glycine soja*) in China and its utilization. Nougyo oyobi Engei 77, 1101-1106**.