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Characteristics of Flowering and Pod Set in Wild and Cultivated Types of Soybean

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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 flowering habit of the wild type was similar to that of the indeterminate 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, and iii) the number of pods decreased, but seed size became bigger.

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

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. 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.

Miyashita et al. (1999) compared the flower production and pod set of chasmogamous and cleistogamous flowers between wild and cultivated soybean genotypes, but limited data is available for the characteristics of flowers on different nodes and raceme order.

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

Materials and Methods

1. 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 Univ., were compared with those in two cultivated type, cultivar Enrei (determinate type) and Touzan 69 (indeterminate type). The plants were grown in 1/5000 a Wagner pots (one plant per pot) in a vinyl house to avoid rainfall. Two seeds of each cultivar and line were sown on June 18, 1998, after soaking the seed in water in a petri dish for 36 hours. The edge of the seeds was cut with a knife to promote imbibition. 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 in the form of ammonium sulphate, fused magnesium phosphate and potassium chloride, respectively, by mixing in the top of the soil. After emergence, seedlings were thinned to a single plant per pot. Because of the pole climbing characteristics, the plant of wild soybean was supported by a pole and vinyl strap. The plants were irrigated as required to avoid the water stress.

2. 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

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Table 1. Genotypic differences in the number of nodes and growth characters of wild and cultivated types of 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 compound leaf	Total				
Enrei	111 bc	38 a	12.4 d	23.6 c	11.2 c	47.2 c	44.8 d	41.5 b	8.3 b	1.67 a
Touzan 69	114 b	30 b	18.2 c	38.8 c	10.6 c	67.6 c	81.9 c	42.1 b	10.8 b	1.21 a
A3	122 a	40 a	31.6 a	131.2 b	161.2 b	320.4 b	369.1 a	51.7 ab	19.9 a	0.47 b
E2	107 c	32 b	24.4 b	373.4 a	353.4 a	751.2 a	275.5 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.

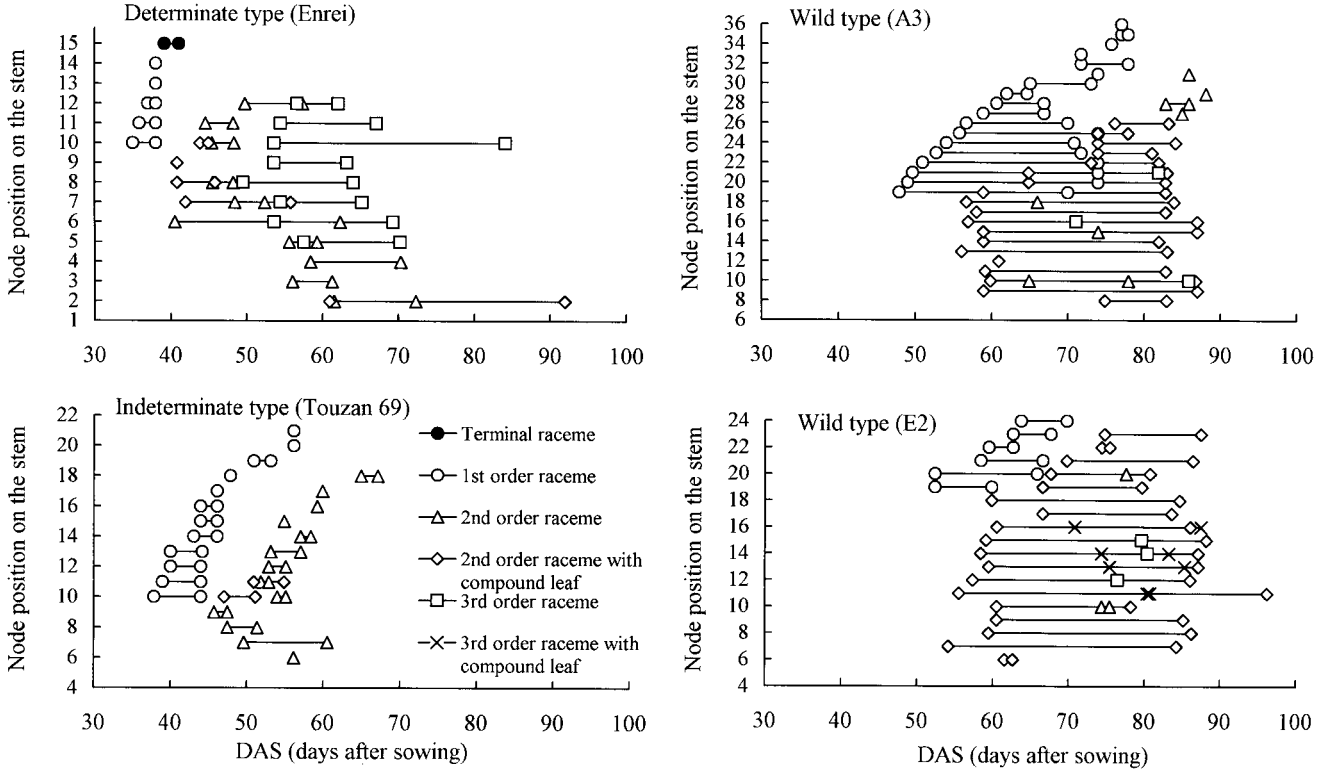

Fig. 1. Flowering duration according to node position and raceme order.

axillary buds of the first order raceme, and the third order raceme from those of the second order raceme. The terminal raceme of the stem is called zero (0) order raceme. The zero and first order racemes are defined as basal order racemes, and higher order racemes are collectively called as upper order racemes. Some racemes on the upper order racemes have compound leaves.

3. Yield components

At maturity, 5 standard plants were selected from 10 sample plants. After air-drying the number of node, main stem length, and total and stem weight were measured. Then 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. Growth duration was the days from sowing to harvesting time, and was obtained as the mean of three plants.

4. 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

1. 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

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

Cultivar/Line	Number of flowers per plant					Percentage of pod set				
	Main stem	Branches	Basal raceme	Upper raceme	Whole plant	Main stem	Branches	Basal raceme	Upper raceme	Whole plant
Enrei	118 b	112 b	99 b	131 b	230 b	32.5 a	27.4 b	21.9 ab	36.3 a	29.7 a
Touzan 69	119 b	166 b	176 b	109 b	285 b	23.3 b	34.7 a	27.7 a	33.9 a	29.9 a
A3	800 a	1807 a	1607 a	1000 a	2607 a	9.4 d	6.6 c	4.3 b	13.3 b	7.5 b
E2	529 a	2204 a	1312 a	1411 a	2733 a	17.6 c	12.9 c	11.0 b	16.5 b	13.8 b

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

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 wild type, racemes with compound leaves occupied a larger portion of the number of nodes than 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.

2. Flowering and shedding

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 (Fig. 1). 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 fairly 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 during 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 large 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 lager in wild type (11.7, 6.9) than in cultivated type (5.2, 3.3) especially in A3 (Table 3).

Fig. 2 shows the number of abortive (shedded after flowering) and effective (developed into a mature pod) flowers opened on each day. Flower-opening

Table 3. Number of floral organ per raceme of 1st order on the main stem.

Cultivar/Line	No. per raceme		S.D.
Enrei	3.3	±	2.0
Touzan 69	5.2	±	3.3
A3	11.7	±	7.7
E2	6.9	±	2.8

Values are mean of each node on the main stem of three plants.

showed a peak at 3 or 6 days after beginning of flowering, and the flowers destined to abort opened mainly during 10 days after the beginning of flowering in Enrei and Touzan 69. The second peak of flowering, corresponding to that on the upper order racemes (Fig. 1), was observed from 20 to 30 days after the start of flowering.

In wild type, the number of flowering increased gradually and peaked 16 and 34 days after the beginning of flowering in A3 and E2, respectively, and decreased thereafter with high fluctuation. In A3, most flowers were aborted, and pod set was observed only after more than 40 flowers had opened per day. In E2, a few flowers developed into pods at the beginning of flowering, but effective flowers were very few as compared to the abortive flowers. The percentage of effective flowers to total flowers was considerably lower in wild soybean than in cultivated types.

3. Rate of pod set

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. 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

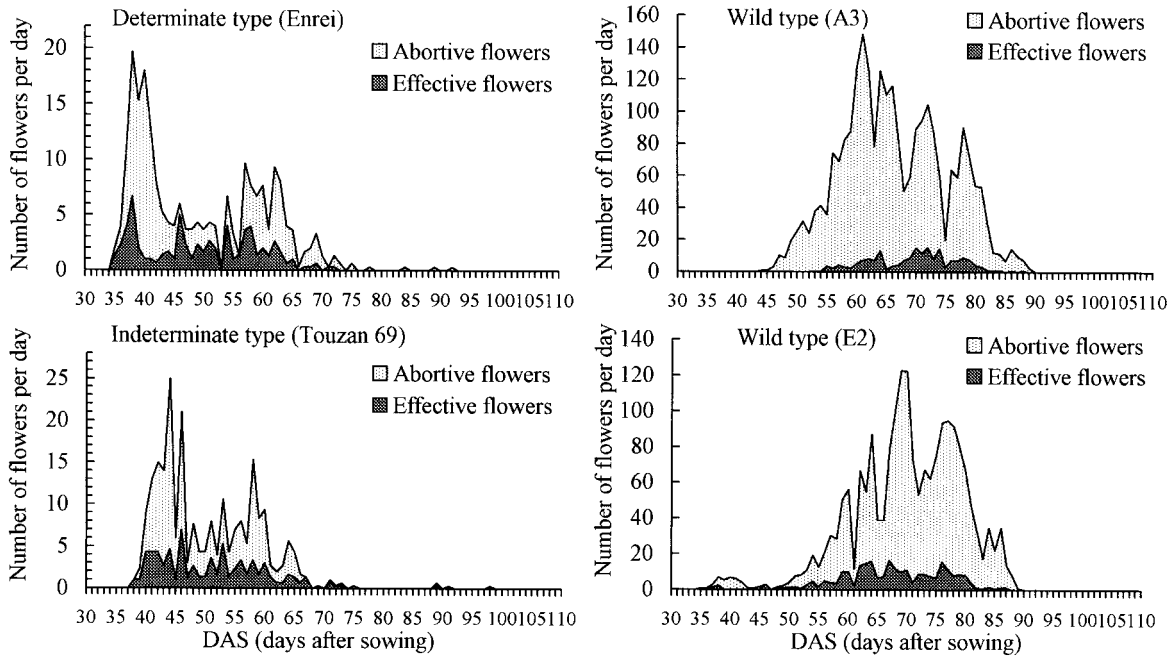

Fig. 2. Changes in the daily number of abortive and effective flowers opened.

Table 4. 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.

probably due to the higher number of flowers on the basal order racemes with the exception of Enrei.

4. Yield and yield components

The number of pods per plant was about 70 in cultivated type (Table 4), 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.

5. Leaf length

The higher the node position from the top, i.e., the lower the node from the base, 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 (Fig. 3).

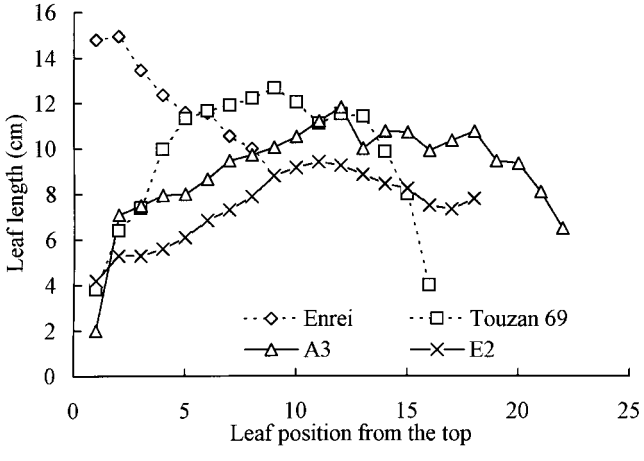

Fig. 3. Genotypic differences in the length of terminal leaflet according to the position on the main stem.

Discussion

Wild soybean is classified into an indeterminate type, because it continues to expand leaves at the top of the stems and bears no terminal raceme. The higher the leaf position, the longer the leaf length in the determinate type Enrei, but the shorter the leaf length in the wild-type and indeterminate-type Touzan 69 (Fig.3). The same tendency was observed by Nagata (1960).

Flowering at each node proceeded from the basal order racemes to the upper-order racemes in both cultivated and wild type (Fig. 1), as reported by Gai et al. (1984), Kuroda et al. (1992) and Saitoh et al. (1998). Flowering duration of the 1st order raceme and the 2nd order raceme with compound leaf at each node in wild type was fairly longer than in the cultivated type (Fig. 1), because wild type had many flowering organs per raceme than cultivated type (Table 3).

In the cultivated type, vegetative growth continues during reproductive stages, and the earlier the flower opening, the higher the rate of pod set (Fig. 2, Yoshida et al., 1983; Saitoh et al., 1998). In the wild type, however, most flowers opened at the early stage of flowering period, were aborted and effective flower (developed into a mature pod) opened at the middle of the flowering period (Fig. 2). It is considered that pod set competed remarkably with the leaf expansion and stem elongation, resulted in a lower rate of pod set at the early stage of the flowering period in wild type.

In Enrei the upper order raceme started to flower after the basal order raceme finished flowering, but in Touzan 69 and the wild-type, the first order raceme on the apical part of the main stem continued to flower even after the upper order racemes began to flower. Flowering on the first order raceme in Enrei spreads upward more rapidly than in Touzan 69 and wild type, in which flowering and expansion of leaves proceeded simultaneously. It was confirmed that flowering habit of wild type is the same as that of indeterminate Touzan 69, but different from that of determinate Enrei.

Wild type developed 10-fold more flowers than cultivated type, but set pods at a lower rate (Table 2). Although the production of so many flowers appears wasteful, it may be an important survival strategy when exposed to stress, especially shading stress. The wild-type have a pole climbing nature, and elongate twisting vines around the neighbor plants producing flowers until they meet a good sunlight condition. During this process, many flowers might be aborted, but the remaining flowers can produce enough seeds to disperse.

In spite of its small seed size, E2 exhibited a higher yield than Enrei (not significant) by producing a larger number of pods, although A3 had a lower yield (Table 4). Nagato et al. (1988) also reported a higher yield in wild soybean as compared with cultivated soybean. Matsumoto et al. (1982) and Ogata et al. (1984) observed that wild soybean had a larger number of nodes, smaller phytomass and seed yield than cultivated soybean. Since our experiment was conducted in pots, further yield trials under field conditions are needed. Wang et al. (2002) mentioned that wild soybean is utilized for breeding of a high-yielding cultivar, but it is very hard because of small seed size.

During the process of domestication from wild to cultivated types of soybean; 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, and seed size increased. In this study, we used limited lines of wild soybean and further studies with more lines of wild soybean from diverse collection sites are needed.

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* In Japanese with English abstract or summary.
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