Varietal Differences in the Sensitivity of Growing Points of Soybean to the Floral Stimulus as Revealed by Grafting Experiments

Masaru NIWA

Faculty of Agriculture, the University of Tokyo, Tokyo 113

Seedlings of photo-insensitive varieties of soybean, as well as 3 photo-sensitive varieties, were grafted onto 36 to 41 day-old soybean plants and served as either donors or receptors of the floral stimulus. Thus, the productivity of, and the sensitivity of growing points to the floral stimulus were compared between the photo-insensitive and -sensitive varieties and within the photo-insensitive varieties.

When the photo-insensitive varieties were used as donors, flowering times of the receptor stocks did not significantly differ with the donor varieties. On the other hand, flowering times of the receptor scions differed significantly with the scion varieties; photo-insensitive varieties flowered earlier as receptor scions than the photo-sensitive varieties, and the earliness of the receptor scions was almost in the order of the inherent earliness of the scion varieties. The varietal differences in flowering time of the receptor scions became more conspicuous on the later stock varieties.

It was suggested that the photo-insensitive early varieties had acquired the higher sensitivity to the floral stimulus in their growing points than the photo-sensitive varieties, and that the response of growing points to the floral stimulus at the early growth stages could be a causal factor for determining the inherent earliness of the photo-insensitive early varieties.

Introduction

Mutually grafting soybean varieties ranging from early to late, my colleague and I revealed in the previous report that the varietal differences in flowering time of soybean were mainly due to the varietal differences in the productivity of floral stimulus, and that the sensitivity of growing points to the floral stimulus did not so much differ among varieties as to decide the inherent earliness of the varieties there used (NIWA *et al.* 1975).

Among the varieties used, however, Tokachinagaha, the earliest and photo-insensitive variety, flowered earliest as receptor scions grafted onto whatever varieties; the growing points of Tokachinagaha seemed to be most sensitive to the floral stimulus. A question arises, here, whether the photo-insensitive varieties of soybean have acquired the high sensitivity to the floral stimulus in their growing points as a result of selections toward earlier varieties. MURFET (1971) reported that a pair of alleles controlled the sensitivity of growing points to the flower inhibitor in *Pisum*.

With the aim to reveal this question, grafting was made among soybean varieties including photo-insensitive and -sensitive ones. The abilities of donors and receptors of the floral stimulus were compared either between the photo-insensitive and -sensitive varieties or within the photo-insensitive ones.

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Materials and Methods

Six photo-insensitive early varieties and 3 photo-sensitive (middle or late) varieties were used in the present experiment. Their names and flowering times under natural day length at Tokyo are listed in Table 1. Those varieties employed as photo-insensitive are the cultivars adapted to Hokkaido, the northeast region of Japan.

Two different types of grafting were made. In the first, photo-insensitive varieties were grafted onto Akisengoku, Nakadeppo and Jackson. All the stock leaves were removed soon after unfolding of the 1st compound leaves of the scions, so that the scions served as donors and the stocks as receptors. The stock and the scion plants were sown on May 13 and June 17, 1975 respectively. Grafting was made on June 23. Four plants were grafted in each graft combination. The plants were grown in the greenhouse throughout the experiment. Twenty four hours photo-period was applied to the stock plants up to the removal of stock leaves. Two 40 W white fluorescent lamps were set 1.5m above the leaf level for the light supplement to sun light.

In the second, grafting was made for stocks to serve as donors and for scions as receptors. Six photo-insensitive varieties, as well as 3 photo-sensitive ones, were grafted onto Tokachinagaha, Jackson and Akisengoku. Sowing dates of the stock and the scion plants were June 2 and July 2 respectively. Grafting was made on July 8. The scion plants were kept under 24h photo-period up to the grafting. All the leaves except cotyledons of the scions were removed before unfolding. Three plants were grafted in each graft combination. The plants were grown in the field condition under natural day length.

The grafting method was the as mentioned previously (Niwa *et al.* 1975). All the axillary buds of the stocks, except the furthest ones from the grafting points, were removed before developing. The date when the 1st flower buds of the plant flowered was regarded as flowering date.

Microscopic observation of floral development was performed by paraffin sectioning. The plants were sown on June 17 and grown in the greenhouse under natural day length. Four plants for each variety were sampled at the interval of about 5 days. The development stages of flower buds were numbered according to FUKUI and GOTOH (1962); stages 1 and 18 correspond to flower initiation and flowering respectively.

Results

Flowering times of the varieties used in the present experiment under natural day length are listed in Table 1. The later the sowing date was, the shorter the interval between sowing and flowering was. This tendency was more conspicuous in the photo-sensitive varieties, Nakadeppo, Jackson and Akisengoku, than the photo-insensitive varieties (from Hokkaihadaka to Tokachinagaha in Table 1). Significant differences in flowering time were observed not only between the photo-insensitive and -sensitive varieties but also within

Table 1. Number of days from sowing to flowering of the soybean varieties used as affected by sowing date

Variety	Sowing Date				Mean
	May 13	Jun 11	Jun 17*	Jul 7	
Hokkaihadaka	40.4	32.8	30.0	26.3	32.4
Shinsei	41.0	32.2	29.3	29.0	32.9
Ooyachi 2	40.6	33.2	30.5	29.5	33.5
Wasemidori	43.2	33.4	30.0	30.0	34.2
Nagahajiro	43.6	36.8	32.0	30.0	35.6
Tokachinagaha	45.5	35.8	32.3	30.7	36.1
Nakadeppo	73.8	53.4	—	43.0	—
Jackson	79.0	60.5	—	48.5	—
Akisengoku	94.0	70.5	—	56.7	—

* Grown in the greenhouse.

Table 2. Number of days from grafting to flowering of the receptor stocks onto which the various scion varieties were grafted as donors

Scion	Stock			Mean	Cont.*
	Akisengoku	Nakadeppo	Jackson		
Hokkaihadaka	35.3	33.3	39.7	36.1	24.0
Shinsei	39.0	37.3	36.7	37.7	23.3
Ooyachi 2	37.8	35.8	33.0	35.5	24.5
Wasemidori	38.3	34.8	35.3	36.1	24.3
Nagahajiro	35.5	33.0	34.0	34.2	28.0
Tokachinagaha	36.5	30.0	39.8	35.4	27.3
Mean	37.2	33.9	36.4	35.8	—
Control*	53.0	36.0	39.3	—	—

* Intact plants without grafting.

Table 3. Analysis of variance applied to the data in Table 2

Source	D. F.	M. S.
Stock	2	67.92***
Scion	5	13.02
Stock × Scion	10	21.25*
Residue	46	8.02

*** Significant at 0.5% level.

* Significant at 2.5% level.

the photo-insensitive varieties. Hokkaihadaka and Shinsei were relatively early as compared with Nagahajiro and Tokachinagaha. Ooyachi 2 and Wasemidori were the moderate among the photo-insensitive varieties here used.

Flowering times of the receptor stocks are listed in Table 2. Maybe due to the strong decapitation of axillary buds of the stocks, considerable variations in flowering time were observed between

stocks even within the same graft combination. The analysis of variance in Table 3 told that the differences in flowering time of stock plants due to the scion variety as donors were of no significance. No consistent relationships were found between the mean flowering times of the stock plants and the control plants to the donor varieties. The stock plants, whose donor scions were the latest variety Nagahajiro, flowered earliest of

Table 4. Number of days from grafting to flowering of the receptor scions grafted onto the various stock varieties as donors

Scion	Stock			Mean	Cont.*
	Tokachinagaha	Jackson	Akisengoku		
Hokkaihadaka	21.7	28.3	33.0	27.7	20.3
Shinsei	23.0	32.0	39.0	31.3	23.0
Ooyachi 2	23.0	36.0	41.3	33.4	23.5
Wasemidori	22.0	31.5	39.5	31.0	24.0
Nagahajiro	23.5	33.3	46.5	34.4	24.0
Tokachinagaha	22.3	37.3	45.0	34.9	24.7
Nakadeppo	21.0	38.7	52.5	37.4	37.0
Jackson	21.7	39.7	49.0	36.8	42.5
Akisengoku	22.5	42.7	50.5	38.6	50.7
Mean	22.3	35.5	44.0	—	—
Control*	3.3	29.3	42.3	—	—

* Intact plants without grafting.

Table 5. Analysis of variance applied to the data in Table 4

Source	D. F.	M. S.
Stock	2	2671.82***
Scion	8	94.66***
Stock × Scion	16	25.59***
Residue	44	3.91

*** Significant at 0.5% level.

previously (NIWA *et al.* 1975).

As receptor scions, the photo-insensitive early varieties flowered earlier than the photo-sensitive varieties. In addition to this, the flowering times of the photo-insensitive varieties as receptor scions were almost in the order of the inherent earliness of the varieties (*c.f.* Table 1); the early group, Hokkaihadaka and Shinsei, flowered earlier as scions than the late group, Nagahajiro and Tokachinagaha. The varietal differences in flowering time of the scions became more conspicuous as the stock plants flowered later. On the latest stock variety Akisengoku, the earliest scion variety Hokkaihadaka flowered 19.5 days earlier than the latest scion Nakadeppo, while the scions flowered at the almost same time on the earliest stock variety Tokachinagaha. Flowering times of Nakadeppo, Jackson and Akisengoku as scions were not in the order of the inherent earliness of those varieties.

In Fig. 1, the development of flower buds at 4th, 5th and 6th nodes of the photo-insensitive varieties is graphically shown. Ooyachi 2 was out of the observation due to the shortness of the materials. The differentiation of flower buds was observed 13 days after sowing in all the varieties. The differences in the developmental stages had become markedly clear between the early and the late group 22 days after sowing. After that, however, the rates of floral development seemed to differ not so much among varieties as in the early developmental stages.

all, while Shinsei, the earliest variety, was the donor of the receptor stocks which flowered latest.

Flowering times of the scions as receptors were listed in Table 4. Here, flowering time differed significantly due to both of the stock and the scion varieties (Table 5). The later the stock varieties flowered, the later the scions flowered, which was consistent with the results reported

Fig. 1. Development of flower buds at 4th and 6th nodes of the photo-insensitive early varieties of soybean as plotted to numbers of days after sowing. The floral stages were numbered according to FUKUI and GOROH (1962), stages 1 and 18 corresponding to flower initiation and flowering, respectively.

Discussion

As shown in Table 1, considerable variations in flowering time were observed with the varieties and the sowing dates. The variations with the sowing dates in the photo-insensitive varieties might be mainly due to the temperature variation. FUKUI *et al.* (1962) reported that the increase of temperature in 2~3°C made the flowering time 5~10 days earlier in soybean plants. In photo-sensitive varieties, however, the flowering times ought to be affected by day length besides temperature.

There might be various causal factors for the differences in flowering time among photo-insensitive varieties. The demand for the critical day length is properly to be ruled out of them. Here, discussions will be made about 3 possible factors;

- (1) duration of juvenile phase,
- (2) productivity of the floral stimulus, and
- (3) sensitivity of growing points to the floral stimulus.

As to the juvenile phase, 2 aspects should be considered as pointed out by ZEEVAART (1962); one is inability of the production of the floral stimulus and another is inability of the response of growing points to the stimulus in the juvenile phase. In Tables 2 and 3, no significant differences in flowering time were found with the scion varieties as donors.

These scions were grafted when they were 6 day-old, so that they could serve as donors from the beginning of stimulus production. As shown in Fig.1, flower buds initiation was observed 13 days after sowing in all the varieties tested. Flowering times of the receptor scions differed little with the scion varieties, when they were grafted onto Tokachinagaha in which sufficient floral stimulus had been prepared at the grafting time (Tables 4 and 5). Thus, no conspicuous evidences could be found that the duration of the juvenile phase was responsible for the varietal differences in flowering time of the photo-insensitive varieties from the both aspects mentioned earlier.

Analysis of variance in Table 3 told that there were no significant differences in flowering time of receptor stocks due to the donor varieties. In addition to this, mean flowering time of the stocks, whose scion variety as donor was common, was of no consistent relationships with the inherent flowering time of the scion variety (*c.f.* Tables 1 and 2). These facts indicate that the photo-insensitive varieties tested here did not differ substantially with one another as donors of the floral stimulus. Hence, it is not plausible that the productivity of the floral stimulus is the causal factors for the varietal differences in flowering time of the photo-insensitive varieties here tested.

On the contrary, flowering times of the receptor scions differed significantly with the scion varieties (Tables 4 and 5). However, the receptor scions flowered at the almost same time, when they were grafted onto Tokachinagaha which was just before flowering at the time of grafting. The differences in flowering time with the scion varieties became conspicuous as the stock plants flowered later. The earliness of the scions coincided almost with the earliness of corresponding varieties (*c.f.* Table 1), indicating that the earlier the photo-insensitive varieties were, the more sensitive the growing points of the varieties to the floral stimulus were, and that the varietal differences in the sensitivity became clearer at the lower level of the floral stimulus.

Thus, the different sensitivity of growing points to the floral stimulus seems to be the most plausible factor for the differences in flowering time among the photo-insensitive varieties here tested. That the varietal differences in the sensitivity was more conspicuous at the floral stimulus suggests that the differences in flowering time among the photo-insensitive varieties resulted from the differences in the response of growing points to the floral stimulus at the early growth stages, when the level of the floral stimulus was not yet so high. The results shown in Fig.1 suggest that the rate of the development of flower buds at the early stages was more different among the varieties than at the late stages.

It is also noticeable that all the photo-insensitive varieties here tested were earlier in flowering time as receptor scions than the middle and the late varieties (Table 4). The photo-insensitive varieties used here are the cultivars bred through the pure-line selections or the cross breeding among photo-insensitive early varieties. Thus, it may be suggested that the selections toward earlier cultivars of soybean resulted in the increase of the sensitivity of growing points to the floral stimulus.

If the photo-sensitive varieties are taken into consideration, however, the role of the sensitivity of growing points to the floral stimulus in deciding the varietal earliness will

become relatively small, as pointed out previously (NIWA *et al.* 1975). As seen in Table 4, the flowering times of the receptor scions of Nakadeppo, Jackson and Akisengoku were of no consistent relationships with the inherent earliness of those varieties (*c.f.* Table 1).

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Literature Cited

- FUKUI, J. and T. GOTOH 1962. Varietal differences of the effects of day-length and temperature on the development of floral organs in the soybean. I. Developmental stages of floral organs of the soybean. Japan. J. Breed. **12**: 17~27. (In Japanese with English Summary)
- , ——— and S. MATSUMOTO 1962. Idem. II. Comparison of development of floral organs. Ibid. **12**: 75~80. (In Japanese with English summary)
- MURFET, I. C. 1971. Flowering in *Pisum*: Reciprocal grafts between known genotypes. Aust. J. Biol. Sci. **24**: 1089~1101.
- NIWA, M., N. TORIKOSHI, Y. HASHIMOTO and H. FURUTACHI 1975. Studies on the varietal differences in flowering time of soybean by means of grafting. Japan. J. Breed. **25**: 343~348. (In Japanese with English summary)
- ZEEVAART, J. A. D. 1962. The juvenile phase in *Bryophyllum daigremontianum*. Planta **58**: 543~548.

接木実験で見られたダイズ不感光性早生品種間における 花成刺激に対する生長点感受性の差異

丹 羽 勝

(東京大学農学部)

先に報告したダイズ接木実験において、不感光性早生品種の十勝長葉は、他の中、晩生品種にくらべて、一定の花成刺激でより早く開花した(丹羽ら 1975)。この生長点の花成刺激に対する高い感受性が、不感光性早生品種に共通するものであるか、また不感光性品種間の開花期の差にこの感受性が関与しているかどうかを明らかにするために、北海道地方で栽培されているダイズ品種(第1表)を用いて、接木実験を行なった。

まず、不感光性6品種を穂木とする接木を行ない、台木の葉をすべて取り去ることにより、穂木の花成刺激による台木の開花を観察した(第2表)。穂木に用いた品種による台木の開花日の差は有意ではなかった(第3表)。次に、先の不感光性6品種と、感光性の中、晩生品種を穂木として接木を行ない、穂木の葉をすべて取り去ることにより、台木の花成刺激による穂木の開花を観察した(第4表)。穂木の開花日の穂木品種による差は有意であった(第5表)。一般に、穂木の開花日は不感光性品種の方が感光性品種より早く、また不感光性品種間での穂木開花日の早晩は、その品種の早晩性とほぼ一致した。この穂木の品種による開花日の差は、台木の開花日が遅いほど大きくなる傾向を示した。

以上の結果から次のことが推定された。この実験に用いた不感光性早生品種は、感光性のある中、晩生の品種にくらべて、生長点の花成刺激に対する感受性が高く、さらに早生であるほどこの感受性が高い傾向にある。また、生長点の花成刺激に対する感受性の品種間差は、花成刺激が小さいところでより明らかになる。したがって、不感光性早生品種間の開花期の差は、花成刺激が比較的小さい植物の発育初期における、生長点の反応の差によるものであると考えられる。不感光性早生品種の花芽の発育状況を観察したところ、花芽の初期発育における品種間差により、開花期が異なってくることが認められた(第1図)。