Significance of Growth Habit in Soybean Breeding

I. Varietal Differences in Characteristics of Growth Habit

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Synopsis. Thirty soybean varieties were tested in two different locations to study the variation in the characteristics of growth habits. The soybean varieties may be divided into three types, determinate type, semi-indeterminate type and indeterminate type, based on the pattern of node increase of the main stem. The so-called growth habit is expressed as the percentage of increment of the total node number in the main stem after the first flowering. The relationship of this character with some quantitative characters are discussed from the view point of plant breeding.

Introduction

The growth habit of soybean has been conventionally classified into two types, the determinate type and indeterminate type; the latter type varieties generally show a higher productivity with relatively stable performance in different environmental conditions (FUJIMORI 1964). But they have not been cultivated for seed production in Japan, because the agronomic and ecological characters are not favorable (NAGATA 1960. *etc*).

WOODWORTH (1932) studied the mode of inheritance of the growth habit on the basis of the characteristics of the pod-bearing habit, and this character was found to be controlled by a gene-pair denoted as *Dt* and *dt*. But this result seems to be insufficient for application to soybean breeding because the physiological and morphological relationships be-

tween the pod-bearing habit and the growth habit are not completely clarified and the evaluation of these characteristics seems to be rather difficult.

Accordingly, in order to introduce the merits of indeterminate habit into Japanese varieties, it is desirable to establish a reasonable and an easy criterion for the classification of growth habit and to study its mode of inheritance, as well as to obtain its relationships with other characters. This paper is devoted to the establishment of this criterion and the examination of its usefulness. Furthermore, the authors have indicated the relationship of this character with some morphological and physiological characters which are important for soybean breeding.

Materials and Methods

A total of thirty soybean varieties were used

Table 1. The list of varieties

Variety name	Source	Variety name	Source	Variety name	Source
Koganejro	Japan	Shinsei	Japan	Comet	U.S.A.
Tenpokushirome	"	Kitamishiro	"	Lindarin	"
Hokkaihadaka	"	Sangowase	"	Capital	"
Wasekogane	"	Isuzu	"	Weihein Steptaner	Yugoslavia
Toyosuzu	"	ALTA	Canada	Hokoninska Zluta	Hungary
Okuhara No. 1	"	A 425	Germany	Kokuiku No. 44	China
Kitamusume	"	A 576	"	Shika No. 4	"
Tokachinagaha	"	Harosoy	U.S.A.	Mansokin	"
Suzunari	"	Chippiwa	"	Syokinko No. 1	"
Toshidai No. 7910	"	Pagoda	"	Gainpokin	"

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in this experiment: Of these, 14 were Japanese and 16 foreign varieties (Table 1). On May 20 and 22 in 1971, these varieties were planted in fields of the Tokachi Agricultural Experiment Station and in those of Hokkaido University, respectively. Each variety was grown in single row with two replications, spaced at 60×20 cm. Each row consisted of 15 plants, and 10 of them were used for taking records.

Records on an individual plant basis were taken regarding the following traits: 1) number of days to first flowering (from the day of seeding to the opening of first flower), 2) period of flowering (number of days from the beginning to the end of flowering), 3) node number and plant height on main stem at first flowering and at maturity, 4) first internode length (from the cotyledon node to the node of primary leaf), 5) positional difference on main stem diameter (difference in the diameter between second lower and upper internode on main stem), 6) coefficient of variability of seed weight (used 50 seeds per plant), 7) coefficient of variability of length of petioles on main stem and 8) coefficient of variability of the length of central leaf of the leaflet on main stem.

Fig. 1. Relationship between node number on main stem at first flowering and its increment after first flowering in varieties.

Results

1. Classification of the varieties by the pattern of increase of node number on the main stem

The node number on the main stem was recorded at the time of first flowering and at maturity (Fig. 1). As can be seen, in some of the varieties, the node number did not increase after the first flowering, whilst others increased the node number even after the first flowering. Thus, the 30 varieties can be classified into three types as follows:

1) Determinate type variety: the node number does not increase after the first flowering. (Toyosuzu, Okuhara No. 1, Kitamusume, Tokachinagaha, Suzunari, Toshidai No. 7910, Shinsei, Kitamishiro, Sangowase and Isuzu).

2) Semi-indeterminate type variety: the increment of node number after the first flowering is equal to or less than the node number at the first flowering. (Koganejiro, Tenpoku-shirome, Hokkaihadaka, Wasekogane, A 425, A 576, Pagoda, Comet, Lindarin, Capital, Weihin Steptaner, Hokoninska Zluta, ALTA and Kokuiku No. 44).

3) Indeterminate type variety: the increment of node number after first flowering is greater than the node number at the first flowering. (Harosoy, Chippiwa, Shika No. 4, Mansokin, Syokinko No. 1 and Gainpokin).

These three types can also be described with the degree of growth habit as follows:

Degree of growth habit = $(A/(A+B)) \times 100$ where,

A = node number increase after first flowering.

B = node number at maturity.

Table 2. Variance analysis of growth habit

Source of variation	D.F.	M.S.
Location (L)	1	0.45
Variety	19	450.95**
Between group	1	2513.50**
Within group II	13	267.06**
group III	5	13.19**
Variety × Location	19	0.13
Group II × L	13	0.14
Group III × L	5	0.13
Error	14	0.37

** Significance at 1% level.

Table 3. Variance analysis of some characters

Source of variation	D.F.	Mean of square			
		Period of flowering	Plant height ⁽¹⁾	C.V. of petiole length	C.V. of seed weight
Location (L)	1	0.53	296.83**	1.41	0.04
Variety	29	630.56**	1122.67**	587.50**	693.74**
Between group	2	8323.44**	13864.34**	6568.50**	8168.68**
Within group I	9	11.65**	65.98**	80.00**	23.31**
group II	13	112.65**	293.80**	145.57**	190.65**
group III	5	15.00**	82.97**	257.54**	253.60**
Variety×Location	29	0.31	7.55**	1.18	0.17
Group I×L	9	0.04	6.78**	1.19	0.13
Group II×L	13	0.30	4.77**	1.68	0.07
Group III×L	5	0.77	3.17**	0.14	0.10
Error	61	0.66	0.41	0.99	0.44

** Significance at 1% level.

⁽¹⁾ Plant height increase after first flowering.

Thus,

Determinate type = $(A/(A+B)) \times 100$ equal zero.

Semi-indeterminate type = $(A/(A+B)) \times 100$ equal to or less than 50%.

Indeterminate type = $(A/(A+B)) \times 100$ greater than 50%.

It was occasionally found that some varieties classified as one type had the same total node number as those belonging to another type.

2. Location variation of several characters in three types

As mentioned above, the experimental ma-

terials were grown in two different districts for estimating the effect of environmental conditions. A variance of analysis is shown in Tables 2 and 3. Table 2 shows that the degree of growth habit was not influenced by environmental change. Therefore, the classification of growth habit based on the pattern of increased node on the main stem may be a preferable method. Absence of significant interactions between each type and location in all observed characters (Table 3), may suggest that these characteristics are stable in different environments.

3. Variations in several characters among three different types

As noted above, the different varieties differ remarkably in their pattern of node increase on the main stem. The pattern of node increase may be expressed as a quantitative factor. The degree of growth habit is calculated by the increment of node number after first flowering as a percent of the total node number on main stem. This provides a standardized basis for comparison of the different varieties in some characters.

1) Number of days to first flowering:

The differences in the date of first flowering for three types are shown in Fig. 2. The flowering of determinate type varieties was considerably later than the semi-indeterminate type and the indeterminate type varieties, but difference was not marked between semi-indeterminate and indeterminate type varieties.

Fig. 2. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and date at first flowering.

Fig. 3. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and period of flowering.

2) Period of flowering:

The duration of the flowering period follows the same trend as the increment of the node after the first flowering as shown in Fig. 3. It could be obviously pointed out that the flowering period was shortened in the determinate type in comparison with the other two types, and the indeterminate type showed a

Fig. 4. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and first internode length.

Fig. 5. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and diameter difference. * It means difference between lower and upper second internode of main stem.

more prolonged flowering period than the semi-indeterminate type.

3) First internode length:

The first internode length was compared among three types in relation to the degree of growth habit as shown in Fig. 4. It was found that the internodes of the determinate type varieties were generally longer than those of the semi-indeterminate and indeterminate type varieties.

4) Positional difference in main stem diameter:

The diameter difference measured between the second lower and upper internode on the

Fig. 6. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and plant height increased after first flowering.

Fig. 7. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and coefficient of variability in seed weight.

main stem is presented in Fig. 5. It was small in the determinate type varieties, medium in the semi-indeterminate type, and great in the indeterminate type varieties.

5) **Plant height increase after the first flowering (Fig. 6):**

Determinate type varieties did not show a marked increase in their height after the first flowering, semi-indeterminate type and inde-

Fig. 8. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and coefficient of variability in central leaf length of leaflet.

Fig. 9. Determinate, semi-indeterminate and indeterminate varieties scattered according to the degree of growth habit and coefficient of variability in petiole length.

terminate type showed steady growth after the first flowering.

6) **Coefficient of variability of seed weight:**

The coefficient of variability of seed weight was estimated on a per plant basis, and the average value in each variety is shown in Fig. 7. It was found that coefficient increased according to the increase in degree of growth habit, although, it was noted that there was little increase in determinate type varieties. As shown by NAGATA(1967), the seed weight was inconstant in the indeterminate type varieties due to the long flowering period.

7) **Coefficient of variability of the length of petiole and central leaflet in main stem (Fig. 8 and 9):**

The coefficient of variability increased gradually from small to large along with the degree of growth habit in these two characters.

Discussion

The growth habit of soybean has been classified into determinate type and indeterminate type varieties since the pioneer work of WOODWORTH(1932, 1933). It is known that varieties of determinate type usually stop producing foliar buds when flower buds are formed, while the indeterminate type still continues to produce foliar buds after flower bud formation, and they have both foliar and floral buds simultaneously (NAGATA 1960 *etc.*). Although the developmental pattern is different between

determinate type varieties and indeterminate type ones, the reasonable and practical method for distinguishing the growth habit has not been developed.

In this study, the increment of node number after first flowering, expressed in percent of the total node number on main stem, was obtained from each variety, and on the basis of this criterion designated as degree of growth habit. The varieties were divided into three types, determinate type, semi-indeterminate type and indeterminate type.

The variations among the three types were tested in two different environmental conditions, and the absence of interaction between type and location in growth habit showed that the distinction of growth habit of three types was not influenced by the environment.

Another advantage of this criterion is that the growth habit can be treated as a quantitative character and, thus, the relationship between this growth habit and other quantitative characters will be able to be studied more effectively.

Several reports have been published concerning agronomic characters of indeterminate and determinate type varieties (NAGATA 1960 a, b, c, 1967; WOODWORTH 1933). According to NAGATA (1967), the seed size is not uniform in the indeterminate type varieties due to their long flowering period. In the present study, the authors found that the variation of seed weight was smallest in determinate type varieties, medium in semi-indeterminate type, and largest in indeterminate type varieties.

NAGATA (1960 b) classified the variation of leaf length into five types in soybean varieties. The leaf length of determinate type varieties becomes longer toward the top or middle part of the stem. In contrast, leaf length of the indeterminate type becomes longer toward the middle part, and decreases gradually toward the top. The authors tested the variation in leaflet length and petiole length. The coefficient of variability of both petiole length and central leaflet length on the main stem was increased along with the degree of growth habit. Consequently, the plant type of indeterminate type varieties showed a cone-shaped appearance.

It is well known that the branch number is

negatively correlated with the planting space in soybean. The mechanical cultivation of soybean requires a close density of planting (GOTOH 1966). In such a case, the plant type will be an important factor controlling the light penetration, and the cone-shaped plant type may be desirable.

The correlation coefficients for node number vs. other characters were computed within each type. The node number on main stem was positively correlated with the days to maturity (0.825**, 0.770**) and the bean yield (0.802**, 0.786**) in both determinate type and indeterminate type varieties, and not correlated with days to first flowering in indeterminate types. In addition, the date of first flowering in indeterminate type is earlier than the determinate type varieties.

As mentioned in the introduction, the majority of soybean varieties grown in Japan are determinate type varieties. In China, the United States and other soybean growing countries, indeterminate type varieties are extensively grown. Indeterminate type varieties generally have a higher productivity than determinate type varieties, and their yield is relatively stable in various environmental conditions.

Our studies indicated that varieties of determinate type have uniform seed size, but, if the node number on main stem is strongly increased, the first flowering and maturation are delayed. Varieties of indeterminate type showed early-flowering, greater node number on main stem and cone-shaped plant types, which seem to be favorable for seed production. However, when indeterminate type varieties are grown in Japan and the flowering period is greatly prolonged, poor uniformity of seed size will result in low seed quality. Furthermore, in varieties of semi-indeterminate type, the characters of growth habit are of an intermediate nature, falling between the determinate and indeterminate type varieties.

From this viewpoint, introduction of indeterminate type habits into determinate type varieties for breeding of semi-indeterminate types, seems to be promising in soybean breeding. On the other hand, the genetic information of hybrid between determinate type and indeterminate type varieties should be

studied in the future.

Summary

A total of thirty soybean varieties were tested in two different locations. The degree of growth habit is calculated by the increment of node number after the first flowering in percent of total node number on main stem. Using the degree of growth habit, the soybean varieties were divided into three types as follows:

Determinate type: $(A/(A+B)) \times 100$ equals zero.

Semi-indeterminate type: $(A/(A+B)) \times 100$ equals to or less than 50%.

Indeterminate type: $(A/(A+B)) \times 100$ greater than 50%.

where,

A : node number increased after first flowering.

B : node number at maturity.

Three types have apparently small variance due to type $\times$ locations.

Comparing the three types in coefficient of variability of seed weight, petiole length and central leaflet, the coefficient was largest in indeterminate type, medium in semi-indeterminate type, and smallest in determinate type. It was also found that the positional difference in main stem diameter, period of flowering and the plant height increase after the first flowering, increased according to the increase of the degree of growth habit. In addition, it was found that the determinate type varieties were considerably later-flowering and larger in the first internode length than both semi-indeterminate and indeterminate type varieties, although the differences were not so great between semi-indeterminate and indeterminate varieties.

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大豆の伸育性に関する育種学的研究

I. 伸育性形質による品種間変異

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大豆の伸育性による品種間変異を育種学的な見地から解明するために 30 品種を用いて、十勝農業試験場および北海道大学農場の 2 箇所で試験をおこなった。

開花期以後に増加する節数の程度を指標とし、大豆 30 品種を 3 群にわけた。すなわち有限、半無限および無限である。また異なる試験圃場における量的各形質について分散分析をおこなった結果、群間には有意な差が認められたが、群と場所の間では相互作用は統計的に有意と

は認められなかった。

開花期については、有限と半無限品種の間に統計的に有意な差は認められないが、粒大、葉柄長、小葉長の変異、主茎の基部と先端部との太さの差および開花期間等は、伸育性程度の増加に伴って増大することが認められた。

また葉の形質の特長から半無限および無限品種の草型が円錐形をなすことが観察された。