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DISTRIBUTION AND ECOLOGICAL FEATURES OF WILD SOYBEANS (*GLYCINE SOJA* SIEB. *ET* ZUCC.) IN HOKKAIDO

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Introduction

Glycine soja SIEB. *et* ZUCC. has been considered as the most probable progenitor of cultivated soybeans, *G. max* (L.) MERRIL. and known to occur in China, USSR, Korea, Taiwan and Japan (HYMOWITZ 1970, HYMOWITZ and NEWELL 1981). This species certainly gives us an important material to study the phylogenetic systematics and the evolution of soybeans. It is, however, also known that *G. soja* is an invaluable genetic resource to introduce higher seed protein contents than cultivated soybeans as well as other favorable characters for forage such as rapid growth of stem and large mass of leaves (WILLIAMS 1948, SEKIZUKA and YOSHIYAMA 1960, KAIZUMA and FUKUI 1974). For those purposes, morphological and ecological differentiations of various characters of *G. soja* growing in Japan have been also investigated (FUKUI and KAIZUMA 1971).

However, most of the studies on *G. soja* were made by using materials collected from various parts of Japan with exception of Hokkaido (northern island of Japan) because until the report of SANBUICHI (1974), the distribution of this species in Hokkaido was unknown. Then, the present study aims to clarify further detailed distribution range of *G. soja* in Hokkaido and investigate their ecological features including reproductive characteristics in Hokkaido as northern limit of the distribution in Japan.

Materials and Methods

The soybean is taxonomically classified in the genus *Glycine* which consists of two subgenera, i. e., *Glycine* and *Soja*. Of nine species of the genus *Glycine*, *G. soja* (2n=40) and cultivated species *G. max* (2n=40), belong to latter subgenera (HYMOWITZ and NEWELL 1981). *Glycine soja* is annual twining vine. It produces small, hard, and black coat seeds. The pods are easy to shatter after the

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maturity.

The field expeditions and sampling of materials were carried out in 1987 and 1988. Since SANBUICHI (1974) reported that *G. soja* was grown on riverbanks of Saru River in Hidaka region and was not found in the eastern part of Hokkaido, the field expeditions were conducted mainly along rivers in the southwestern part of Hokkaido.

At flowering time (August), we checked not only the distribution, but also the growth stages, if we found, based on 5 individuals randomly chosen from the populations. At fruiting time (October), matured seeds were collected from each population and 100 seed weights were measured. For reproductive biology, plants were also collected from Mu River before shattering of pods. For analysis, the plants were dismembered into their component organs and dried in an oven for at least 48 hr, at 80°C and weighed.

Results

The field surveys were made along 31 rivers in the southwestern part of Hokkaido. *G. soja* was found along 16 rivers and most of those rivers were

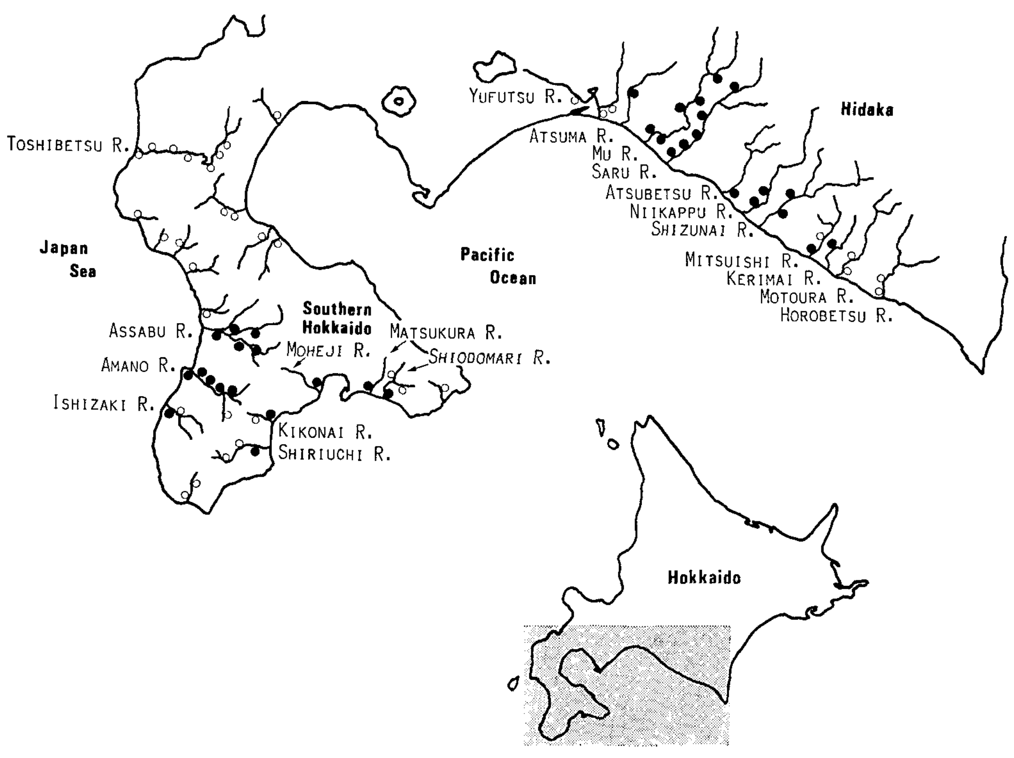

Fig. 1. Distribution of *Glycine soja* in the southwestern part of Hokkaido. Solid circles indicate the localities where *G. soja* was found; open circles, those where *G. soja* was not found.

larger than others (Fig. 1). *Glycine soja* was dominant at open areas of riverbanks and river bottoms with sandy soil. Contrary to cultivated soybeans, *G. soja* has twining habit. Then, they were mainly growing with twining their vines around relatively tall herbs such as *Miscanthus sinensis*, *Phragmites communis*, *Artemisia montana*, *Solidago altissima*. On the other hand, most of the rivers where *G. soja* was not found were relatively small and the development of riverbanks was not enough for growth of *G. soja* as well as above-mentioned associated species. It is, however, interesting to note here that although observed areas were still limited, the distribution was discontinuous between southern Hokkaido (it includes Oshima and Hiyama subprefectural units) and Hidaka (it includes Iburi and Hidaka subprefectural units) regions. That is, although there were several large rivers, e. g., Toshibetsu R. and Yufutsu R., which seemed to be suitable for growth of *G. soja* because of well developed riverbanks as well as the compositions of other herbaceous plants, the distribution of *G. soja* was not confirmed (Fig. 1). Furthermore, the distribution was also discontinuous in the southern part of Hidaka region, i. e., *G. soja* was not found along Motoura R. and Horobetsu R.. Hence, the northern limit of the distribution of this species in Hokkaido, so far, was Assabu R. in southern Hokkaido region and Atsuma R. in Hidaka region, and the southern limit was Shiriuchi R. in southern Hokkaido

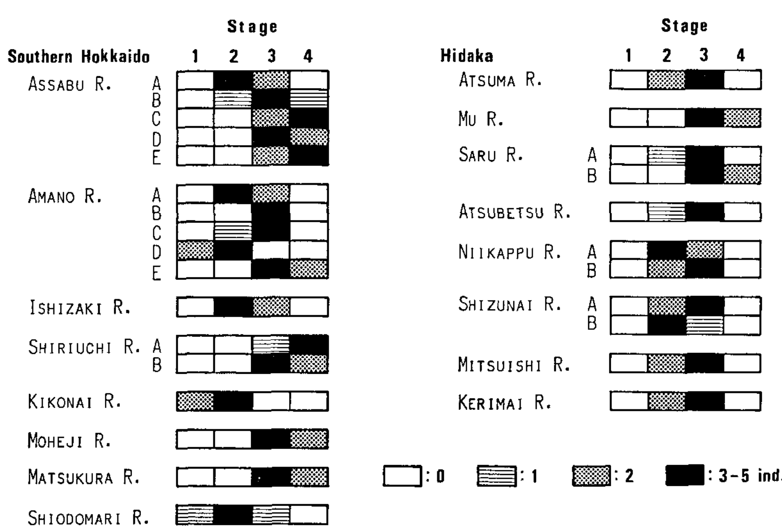

Fig. 2. Comparisons of growth period among the populations of *Glycine soja* found in the southwestern part of Hokkaido. The observations were conducted on 25-26th, August, 1988, in Hidaka region, and on 29-31st, August, 1988 in southern Hokkaido region. Five individuals randomly chosen from each population were classified into four different growth stages.

Stage 1: flowering with flower buds; Stage 2: mostly flowering;
Stage 3: flowering with premature pods; Stage 4: mostly premature pods.

region and Kerimai R. in Hidaka region.

Figure 2 illustrates the comparison of growth stages among different populations in both southern Hokkaido and Hidaka regions. Since the observations were carried out on the different days, we cannot compare and discuss directly the differences between these two regions. One can, however, recognize that in contrast to the similarity of growth stage in Hidaka region, wide variations of growth stage were obvious in southern Hokkaido region, even among the populations in the same river, e. g., Assabu R. and Amano R..

TABLE 1. Individual biomass and reproductive traits of *Glycine soja*

Biomass (g)	3.34± 1.88* (0.85～ 9.28)**
Reproductive allocation (%)	79.22± 3.70 (69.31～84.61)
Harvest Index (%)	44.42± 2.93 (36.02～48.84)
No. of ovules/flower	2.82± 0.26 (1～5)
No. of pods/plant	25.1±13.1 (7～65)
No. of seeds/pod	2.22± 0.29 (0～4)
No. of seeds/plant	56.5±31.8 (21～160)
Seed setting rate (%)	81.26± 7.63 (61.79～95.45)

* Mean±S.D.
** Ranges of values

Table 1 summarizes reproductive characteristics of *G. soja* based on 40 individuals sampled from Mu River. Although the individual biomass varied widely from 0.85 to 9.28 g, reproductive allocation (RA) to total reproductive organs (not only seeds, but also pods) at the fruiting stages was 79%, on the average. Furthermore, dry matter allocation to seeds, so-called harvest index, was 44%, on the average.

The number of ovules per flower which represent the potential maximum number of seed set per pod ranged from 1 to 5. Since flower and fruit abscissions occur before the maturity in cultivated soybeans (HANSEN and SHIBLES 1978, WIEBOLD *et al.* 1981), it is very difficult to determine the actual number of flowers produced per plant. However, with respect to the number of pods produced and remained on the plant, the larger individuals tended to produce more pods ($r=0.987$, $P<0.001$). Consequently, they produced the average of 25 pods per plant and each pod contained 0 to 4 seeds. The number of seeds produced per plant also increased with plant size as well as the number of pods ($r=0.988$, $P<0.001$) and they produced more than 50 seeds per plant, on the average.

Seed setting rates were calculated from the number of seeds and undeveloped ovules in the pods. Since actual number of flower and ovule number per plant before flower and fruit abscissions are unknown, the seed setting rates may be overestimate. It is, however, important to note that although *G. soja* widely varied for the number of pods and seeds produced in relation to the plant size, seed seeting rates which are determined by the species' own pollination and breeding systems were 81%, on the average. That is, as far as the pods were produced and remained, they produced high percentage of mature seeds to the ovules.

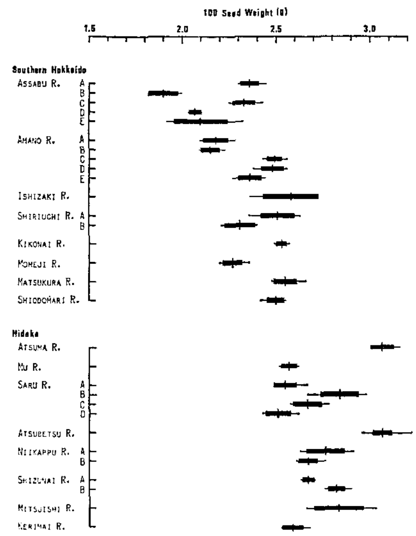

Fig. 3. 100 seed weights of *Glycine soja* collected from different populations in the southwestern part of Hokkaido. The vertical line indicates the mean value, thicker line the standard deviation, and horizontal line the range.

TABLE 2. Analysis of variance in seed size of *Glycine soja* between southern Hokkaido and Hidaka regions

	df	MS ($\times 10^{-2}$)	F
Between populations	20	38.14	52.44**
Southern Hokkaido vs Hidaka	1	606.33	33.95**
within southern Hokkaido	16	19.45	26.74**
within Hidaka	12	15.72	21.61**
Error	120	0.72	

**<0.01

The variation in 100 seed weight of *G. soja* sampled from 30 populations of 16 rivers was shown in Fig. 3. Seed size was much smaller than that of cultivated soybeans. The average 100 seed weight ranged from 1.90 g in Assabu R. (B population) to 2.83 g in Ishizaki R. in southern Hokkaido region, and from 2.51 g in Saru R. (D population) to 3.06 g in Atsuma R. and Atsubetsu R. in Hidaka region. Although the values varied widely among the rivers and also among the populations within the same rivers, e. g., Assabu R., Amano R. and Saru R., notable difference in the seed size was recognized between southern Hokkaido and Hidaka regions. That is, *G. soja* occurring in Hidaka region tended to produce larger seeds than those occurring in southern Hokkaido region (Table 2).

Discussion

Although many previous studies on *G. soja* have lacked in information of material from Hokkaido, the present investigation strongly indicated that *G. soja* is not rare species and frequently distributed in Hokkaido. Furthermore, its main habitat is open areas of riverbanks with sandy soil developed along relatively large rivers, while it is also known to grow on roadside or in field in other areas (OHWI 1975).

Compared with cultivated soybeans, *Glycine soja* represented several notable differences not only in gross morphology, but also in reproductive characteristics. For example, *G. soja* had much smaller individual biomass and produced smaller seeds, but showed very high reproductive allocation (RA) to total reproductive organs (seeds and pods) of about 80% (OKA 1982; NAGAI and KAWANO 1987). Contrary to the high RA, harvest index, i. e., allocation to seeds, was relatively low (BUZZEL and BUTTERY 1977). This fact may be related to shorter ripening period of seeds than cultivated soybeans, because of the shattering of pods. As mentioned previously, it is known that 20% to 80% of flowers drop before the maturity in cultivated soybeans (HASEN and SHIBLES 1978, WIEBOLD *et al.* 1981). However, as far as pods reached maturity, most of ovules produced seed, possibly due to the predominant inbreeding system (SEKIZUKA and YOSHIYAMA 1960).

The distribution of *G. soja* found in the southwestern part of Hokkaido is very similar to *Castanea crenata* Form, one of the distributional pattern in the temperate elements of the plants in Hokkaido described by WATANABE and OHWKI (1960). The range was, however, disjunctive between southern Hokkaido and Hidaka regions. In this context, growth period and seed size investigated in this study showed the marked differences between these regions, i. e., wide variation of growth stages in southern Hokkaido region and larger seeds in Hidaka region. FUKUI and KAIZUMA (1971) also reported a wide variation on growth period, e. g., strains from northern district in Japan tended to have earlier blooming and ripening than those from southern districts. In the present study, the latitudal differences were not obvious. These phenological and reproductive characters should be, however, also considerably affected by the geographical and subsequent local climatical factors such as rain, frost, snow and thaw etc.. In this connection, although they grow in the similar latitudal ranges, these regions may be different in climatical regimes. It is also noteworthy that contrary to the similarity in the general appearances among the rivers located in Hidaka region, e. g., direction of stream, features of the rivers in southern Hokkaido region are rather complex e. g., Assabu R., Amano R. and Ishizaki R. flow into Japan Sea and others flow into the Pacific Ocean.

Furthermore, with respect to the floral relationships between Honshu (main island of Japan) and Hokkaido, TATEWAKI (1960) proposed two major migration routes of higher plants from Honshu, i. e., Rikuchu (province in northern Honshu)-Hidaka and Mutsu (province in northern Honshu)-Oshima. The disjunctive distribution found in *G. soja* is well coincide with this migration pattern, and there might be a possibility that *G. soja* migrated separately to those two regions. However, for these so-called ruderal species, one should also pay attention to human activities including history of residence and cultivation. Furthermore, since *G. soja* grow with twining their vines around other plant species, composition of species and relationships with accompanying plant species are also very important. Hence, although the migration routes and the relationship between Honshu and Hokkaido in *G. soja* are still unknown at present, it is highly possible that ecological differentiation should be occurred between southern Hokkaido and Hidaka regions.

Although the observations are still limited to the southwestern part of Hokkaido, *G. soja* occurring in Hokkaido represent an important material not only for valuable genetic resource of soybean breeding, but also for studying the ecological differentiation of a species and floral relationships between Honshu and Hokkaido including migration routes. Further critical studies on another morphological and ecological characteristics including materials from Tohoku region (northern Honshu) will unravel the differentiation of *G. soja* in Hokkaido.

Summary

Distribution and ecological features including reproductive characteristics of wild soybeans (*Glycine soja*) occurring in Hokkaido were investigated. In spite of lacking in information of wild soybeans from Hokkaido in many previous papers, *G. soja* was frequently found in the southwestern part of Hokkaido, and its main habitat was open areas of riverbanks with sandy soil developed along relatively large rivers.

With respect to the reproductive characteristics, *G. soja* showed several notable differences from cultivated soybeans. That is, *G. soja* had much smaller biomass and produced smaller seeds. It, however, showed high reproductive allocation (RA) to total reproductive organs with high allocation to pods. *G. soja* also represented high seed setting rate as well as cultivated soybeans, possibly due to the predominant inbreeding system.

The distribution range was somewhat disjunctive between southern Hokkaido and Hidaka regions. In relation to this distribution, ecological differentiation was also observed in growth period and seed size, i. e., growth stage were diversed in southern Hokkaido region and larger seeds were produced in Hidaka region.

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