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REPORT ON THE SURVEY OF WILD SOYBEAN RESOURCES IN CHINA

National Wild Soybean Surveying Team

Soybean (*Glycine max* (L.) Merril) originated from China, where the resources of its close wild relative-wild soybeans (*G. soja* Sieb. et Zucc.) are very rich. The wild soybeans are rich in protein content, strongly resistant to stresses, thus are important germplasm for soybean breeding. The surveying of the resources of the wild soybeans would undoubtedly extremely enrich the germplasm genetic bank in China.

The collection of, and research on, wild soybeans has increasingly been attracting attention. Massive collection and multidisciplinary research have been being carried out in the United States and Japan, as well as in China. One hundred and fifty five (155) accessions of wild soybean, and 50 accessions of semi-wild soybeans were maintained in Iwate University in Japan (Fukui, 1977). Five hundred and fifty eight (558) accessions of wild soybeans from North Korea, Japan, China and the Soviet Union (Siberia) were introduced into the United States (Nelson and Bernard, 1979).

Some scholars in China carried out some occasional collection of wild soybeans in the past. Xingdong Sun (Sun and Geng, 1952) used to grow and observe wild soybeans in Nanjing (Jiangsu Province), Chongqing and Baoding (Hebei Province). Jinling Wang and co-workers (1973) collected wild soybeans in the 1960s from Fuyuan, Heilongjiang Province in the North to Hengyang, Hunan Province in the South of China and carried some investigations on the day-light and ecological types of wild soybeans. However, large scale of survey and collection had never been carried out in China until recent years. With increasing enlargement of the scope of productive activities, and the gradual reduction of wild soybean resources, it became essential to organize national surveying of wild soybean resources in China. A nationwide surveying was conducted from 1979 in China, and the present paper summarizes some of the results out of the surveying and collection trips on wild soybean resources from 1979 to 1981.

Surveying Methods and Scope

The survey was led by the Research Institutes of Germplasm and the Oil Crops, Chinese Academy of Agricultural Sciences, and Jilin Provincial Academy of Agricultural Sciences, and joined by Academies of Agricultural Sciences from other provinces, municipalities and autonomous regions. Each provincial academy of agricultural sciences is responsible to organize its professional surveying group to

carry out surveying and collection at the natural habitats within its own province. National wild soybean surveying team paid major effort on the provinces along the Yellow River reaches, Daba mountain area and Hainan Island, and assisted the surveying work in the provinces, municipalities and autonomous regions concerned. The scope of the national wild soybean survey was from the town of Mohe (N53°28'), Heilongjiang Province in the north to the Yaxian County (N18°) located in southern Hainan Island; From Fuyuan County (E135 °), Heilongjiang Province and some islands along the south-east coast in the east to Dunhuang (E95 °) at the west of Hexi Corridor in Northwestern China, and to Changdu District of Tibet in the South-west. A thorough survey was conducted across China with 1019 counties included, more than 4000 accessions of wild soybeans were collected and more than 5000 accessions of seeds were harvested.

The Results of the Survey

1. The Geographical Distribution of the Wild Soybeans in China

The results of the survey indicated that the wild soybeans were found in Guilin District of Guangxi Zhuang Autonomous Region, Shaoguan District of Guangdong Province and Longyan District of Fujian Province in southern China. But no wild soybeans were found further south in the tropical regions of Guangdong Province, in the south of Guangxi Zhuang Autonomous Region, southeastern Fujian Province and the Hainan Island. Wild soybeans were found in most areas along the Heilongjiang River valley, but not so further north toward the town of Mohe. Wild soybeans also exist in northwestern China along the Yellow River valley up to Lanzhou, Gansu Province, and in southwestern China from the south of the Daba Mountain in east Sichuan Province to Guizhou Province, northwestern Yunnan Province, and the Chayu County of Changdu District in Tibet. Wild soybeans were also found in most areas along the coasts from Changshan isles to Zhoushan archipelago. It was reported that wild soybeans had also been found in Taiwan Province.

The results of the survey were as follows: the geographical distribution of wild soybeans extends from the Heilongjiang River valley to the northern part of Guangdong Province, with the northernmost part of distribution in Tahe County (N52°55'), Heilongjiang Province and the southernmost point of distribution in Yingde County (N24°), Guangdong Province; to Usuli River valley in the northeast of China with the easternmost part of distribution in Fuyuan County (E135°); to Zhoushan archipelago and Taiwan island in the Southeast; to Jingtai County (E104°) of Gansu Province in the Northwest, and to Chayu County of Tibet in the Southwest.

The survey results showed that the vertical distribution of the wild soybeans was as follows: the upper limit was 1300 meters above sea level in the Northeast, 1500—1700 meters above sea level in the Yellow River and Yangze River valleys. The highest point of distribution of the wild soybeans was 2,650 meters above sea level in the Ninglang Autonomous County of Yunnan Province.

The distribution of the wild soybeans in the world was mainly in China, Korea, Japan and some regions in the Soviet Union adjacent to the Northeast China, and it was most widely distributed in China. Taken together, the wild soybeans belong to a

species of the flora in the temperate zone of East Asia.

2. The botanical characteristics of the wild soybeans

The wild soybeans belong to the subgenus *Soja*, genus *Glycine*, subfamily Papilionoideae, family Leguminosae. The morphology of the wild soybeans is described below:

(1) Root: The root system of the wild soybeans belongs to taproot. The taproot can reach the depth of more than 50 cm below ground, and rootlets are mainly distributed in the surface layer of the ground forming net-like structure and distributed parallel to the ground. The tubercles (nodules) are mainly formed around the base of the taproot near the ground, and some of them seem to be active even at the pod-bearing stage for they still look rosy.

(2) Stem: The stem of the wild soybeans is weak, slim and trailing; usually climbing to other plants growing together, or creeping on the ground. The plant height varies from 10 cm to more than 6 meters depending on growth and developmental conditions and the availability of other kind of plants to climb about. A plant of wild soybean with the height of 6.19 meters was collected in Yueyang, Hunan Province. The differentiation between the main stem and the branches is not significant, and the branches are numerous and slim. Generally there are primary and secondary branches, while tertiary and quaternary branches are rare. The total number of the branches of all levels can be 100 or more. Some plants have no branches, and the number of nodes is varied, and can be more than 50.

(3) Leaf: The first pair of leaves of the wild soybeans is opposite and unifoliate. The following leaves are pinnate ternate compound leaves. Most leaves are oval, elliptical or lanceolate. For some plants, the lower leaves are smaller, but the middle and upper leaves are larger. The morphology of the leaves from different parts of a plant may be varied. The size of leaves varies significantly: the leaves of small-leaf wild soybeans is about 1.5 cm in length, and 0.7 cm in width, while those of large-leaf wild soybeans is about 11.0 cm in length, and 7.1 cm in width which are similar to those of the cultivated soybeans.

(4) Flower: Short raceme, papilionaceous flower, with colors of dark purple, purple and mauve, small-sized.

(5) Pod: The pod of the wild soybeans is about 2 cm in length. The pods are mostly sickle-shaped, and sometimes are straight-gourd-shaped. There are 1 to 4 seeds in each pod, mostly 2 to 3 seeds, but occasionally 5 seeds. The colors of the mature pods are dark-brown or black, some are brown or light brown. The pods are easily burst-open when get mature. All the wild soybeans have the potential of bearing seed pods unlimitedly

(6) Hair: Hairs may appear on the stem, leaf and pod of wild soybeans with varying thickness; most hairs are brown, some are gray, and a few plants are nearly hairless.

(7) Seeds: The seeds are of small grain, black, and covered with tunic. One hundred grains weigh 1 to 2 grams, some less than 1 gram, and those more evolved

weigh more than 3 grams. Most seeds possess black or brown hilum and yellow cotyledons. The grains are mostly elliptical or flat-elliptical. Some wild soybeans that possess some special characteristics different from those mentioned above will be described below.

3. The biological properties of the wild soybeans

(1) Sunlight: the wild soybeans are sun plants usually growing under sunlight. When the wild soybeans are creeping on the ground, their branches and leaves will extend out to receive sunlight. During surveying in Mengjin County, Henan Province, one wild soybean plant was found covering an area of 4 square meters with more than 100 branches. If the wild soybeans are climbing around other plants, they would compete with others for growing and sunlight. The wild soybeans can not survive under high forest, dense bushes and bamboo forest due to the deficiency of sunlight.

(2) Water-tolerance: the wild soybeans usually grows in places with an ample water supply, mostly growing with other water-prone or water-soaked wild plants such as reed (*Phragmites communis* Trin.), water knotweed (marshpepper smartweed, *Polygonum hydropiper* L.), waterwillow (*Homonoia riparia* Lour.) etc. In many places, the wild soybeans could be found growing normally and bear seed pods even with their roots in the water. These facts indicate that the wetness-tolerance of the wild soybeans is remarkably strong.

(3) Cold tolerance: The temperature in winter in North China could drop to -40 °C or lower, but the seeds of the wild soybeans can over-winter safely and then grow and develop in the coming year. It was found during the survey that even in some places where the cultivated soybean could not grow due to low temperature and short frost-free period, the wild soybeans could grow well. This fact suggested that the wild soybeans possess stronger cold tolerance than the cultivated ones.

(4) Adaptability to soil: the wild soybeans have rather lenient requirements for soil, with such strong adaptability that they could survive in various soils. They could be found in soils with pH 4.5 to saline-alkaline land of pH 9.2. In some islands, the wild soybeans could survive and climb around common seepweed (*Suaeda* spp.) on the beaches only 7 meters from the sea.

(5) Disease resistance: Under natural conditions, the wild soybeans grow quite well, seldom suffer from diseases or insect pests. The diseases and other pests found on the wild soybeans during this survey were: downy mildew (*Peronospora manshurica* Syd.), frog-eye leaf spot (*Cercospora sojina* Hara), bacterial spot, mosaic virus diseases, an insect pest (*Grapholita glycinivorella*), a cyst nematode (*Heterodera glycines* Ichinohe), and a dodder (*Cuscuta chinensis* Lam.), mostly distributed sporadically. But after observation and investigation in the plots, it is found that viral diseases occurred most severely. Therefore, it is not appropriate simply saying that the wild soybeans were resistant to diseases and insect pests. Strict identification should be conducted to screen resistant materials.

4. Special types of wild soybeans in China

Many special types of wild soybeans found in China during the survey were different from the above-mentioned characteristics. The major types are as follows:

(1) White flower type: the characteristics of plants and grains are the same with common wild soybeans, but the flowers are white. They distributed in populations.

(2) Linear leaf type: the leaves are narrow and long, the width does not vary much from the tip to the base. It is typically so for the leaves grown in the middle of a plant.

(3) Long inflorescence type: white soybeans usually possess a short raceme, with a rachis as short as 1 to 2 cm. But the length of raceme of long inflorescence type is more than 10 cm. This type could be found in various places.

(4) Yellow testa type: the seed coat is yellow, without tunic, and the grains are slightly larger; the weight is 3 grams or more for 100 grains. The main stem differentiated significantly.

(5) Green testa type: the seed coat is green or yellowish-green, without tunic, the weight for 100 grains can be 2 grams or 3 grams for larger grains.

(6) Bicolor testa type: the seed coat is green or yellow with black spots.

(7) Black testa- tunicless type: with or without luster, no tunic on the testa.

These types of wild soybeans remarkably enriched the genetic bank of soybean, provided extremely valuable materials for the investigations on the origin, evolution, taxonomy and genetics of soybeans

5. The chemical composition of the seed of wild soybeans in China

The chemical composition of some seeds was determined from the wild soybeans collected from many places. Protein content in seeds of the wild soybeans from Northeast China is the highest (Table 1). Researchers from Jilin Province measured the protein content in seeds of 105 accessions of wild soybeans, and the average content is 49.4%. The protein content in seeds of 11 accessions was more than 52%, with the highest 55.37%. Results from Heilongjiang Province were as follows: the highest protein content in seeds of some of the 324 accessions of wild soybeans is 54.06%, and the protein content of seeds from 18.2% of the accessions is higher than 50%, thus, much higher than that in the cultivated soybeans.

The amino acid composition of the proteins in the seeds of wild soybeans is similar to that of the semi-wild and cultivated soybeans (Table 2). All the 8 essential amino acids are contained in soybeans, and the content of lysine is relatively high

(more than 5%). The content of fat in wild soybeans is much lower than that in cultivated soybeans (Table 3) with an average of about 10—20%. The analytical results from other places are more or less the same.

As to the composition of fatty acids, the levels of palmitic acid, linoleic acid in wild soybeans, are similar to those in the cultivated soybeans; while the level of linolenic acid in wild soybeans is 1—2 times higher than that in the cultivated soybeans; but the level of oleic acid in wild soybeans is only about half that in the cultivated soybeans. Linolenic acid is an unsaturated fatty acid and can easily be oxidized, thus the iodine value of the oil from the wild soybeans is higher.

Table 1. The protein content of wild, semi-wild and cultivated soybeans in the 3 provinces in Northeast China.

Province	Wild Soybeans		Semi- Wild Soybeans		Cultivated Soybeans	
	Average	Variation Span	Average	Variation Span	Average	Variation Span
Heilongjiang	47.60		43.95		40.11	
Jilin	49.40		45.23		40.70	
Liaoning	45.79		44.41		39.56	

Note: The data were summarized from the analytical results from the Provincial Academies of Agricultural Sciences of Heilongjiang and Jilin, and the Tieling Agricultural Institute, Liaoning Academy of Agricultural Sciences.

Table 2. The amino acid composition in the grains of the wild, semi-wild and cultivated soybeans. (1980, Harbin)

Amino Acid	Wild Soybeans		Semi-Wild Soybeans		Cultivated Soybeans	
	Long 78-2	Long 75-3172	Long 76-27-1	Long 76-2	Heinong 26	Heihe 3
Asp						
Thr						
Ser						
Glu						
Gly						
Ala						
Cys						
Val						
Met						
Ile						
Leu						
Tyr						
Phe						
Lys						
His						
Arg						
Pro						

Note: The analytical results were from the Heilongjiang Academy of Agricultural Sciences.

Table 3. The content of fat and the fatty acid composition in the grains of the wild soybeans. (1979, Taiyuan)

Site of Collection	Latitude	Raw Fat (%)	Composition of Fatty Acids			
			Palmitic acid	Oleic acid	Linoleic acid	Linolenic acid
Youyu Jijiagou						
Hequ Quyu						
Wutai Chengguan						
Taiyuan Fenhe						
Liulin Qianxiaocheng						
Qinxian Chengguan						
Yongji Puzhou						
Reicheng Siqian						
Jindou 1 (Soybean)						
Jindou 3 (Black soybean)						

Note: the data were cited from the results of survey and research on the wild soybeans carried out by Shanxi Province.

Discussion

1. The relationships of the wild soybeans and the ecological environment

The wild soybeans could thrive generation after generation in nature because they adapted to the ecological environment in which they existed. Different ecological types of wild soybeans were formed under different environmental conditions. It is useful and important to know the relationships between the wild soybeans and the environmental conditions for determining the objectives of soybean breeding, studying the ecological divisions of soybeans and for soybean cultivation.

In cold regions such as the northern parts of Northeast China, Shanxi and Shaanxi Provinces, the wild soybeans are short in plant height, and small for the leaves, legumes and seeds (only about 1 gram per 100 grains), matures earlier due to the low temperature, scarce precipitation and the short frost-free period.

Along the Yellow (Huanghe) River valley, the growing and developmental conditions for the wild soybeans are much better, therefore they could grow vigorously,

the plants are bigger and the height could be more than 5 meters. In the Yangze (Changjiang) River valley, the wild soybeans are much more thriving, the highest plants could be more than 6 meters, the leaves, legumes and seeds are bigger (more than 2 grams per 100 grains), and they mature significantly late.

As the altitude increases, the temperature gets lower and the frost-free period shorter, the growth of wild soybeans distributed at different altitudes will change accordingly. Those wild soybeans distributed at lower altitudes grow and develop under better conditions and thus show higher plants, larger leaves and more nodes. As the altitude increases, the plants get shorter, and the numbers of nodes and branches become less. This trend can be clearly perceived from the growing situation of the wild soybeans distributed at different altitudes in the Wutai mountain area of Shanxi Province (Table 4).

Table 4. The display of characteristics of the wild soybeans distributed at different altitudes in the Wutai mountain area of Shanxi Province. (1979, Taiyuan)

Location	Altitude (meter)	Plant Height (cm)	Number of Branches	Number of Nodes on Main Stem	Width of Stems (cm)			Size of Leaves (cm)		
					Up.	Mid	Low	Up.	Mid	Low
Dongye	700.0	120								
Chengguan	1100.0	70								
Baitou'an	1500.0	44								

Note: the data were cited from the results of survey and research on the wild soybeans carried out by Shanxi Province.

When there are other plants growing around, the wild soybeans will, in most cases, climb up to the supporting plants. Then the main stem becomes very pronouncing and the stems and leaves in the middle or upper parts of the plant are larger, especially for those grown in the pools with reeds or in the forests of small trees. In contrast, if no other plants growing around, the wild soybeans would be creeping on the ground with shorter plant and the main stem would not be pronouncing, and the upper and lower leaves would be of similar size (Table 5). That situation is reasonable, because if no other plants to climb about, the different developmental stages of the wild soybeans would be under similar conditions. For those wild soybeans grown in the pools with reeds or in the forests of small trees, the growing conditions of the middle or upper parts of the plant are better with sufficient airflow and sunlight, thus could develop to their potential. This is the typical reflection of adaptability of the wild soybeans.

2. The ideal traits of the wild soybeans and breeding

Some excellent traits of the wild soybeans were discovered through the survey and the analysis of chemical composition, they would prove to be useful for soybean breeding.

Table 5. The corresponding characteristics of the wild soybeans distributed at different habitats along the middle and lower reaches of the Yellow River.

Location	Habitat	Sample	Plant Height (cm)	Number of Branches	Number of Nodes	Stem Width (cm)	Size of leaves (cm)	100 Grain weight (gram)
Shanxi	Reed pool	7						
	Weed beach	7						
Henan and Shandong	Reed pool	10				—	—	—
	Weed beach	10				—	—	—

Note: the data were cited from the results of survey and research on the wild soybeans carried out by Shanxi Province and other provinces along the middle and lower reaches of the Yellow River.

(1) Breeding for high yield: For traits related to yield of the wild soybeans, there are big and thriving types, the plants are high with many nodes. One plant collected from Yueyang, Hunan Province bearing more than 3000 pods (legumes), and another plant from Dali, Shaanxi Province bearing over 4000 pods on more than 100 branches. The number of grains in each pod is larger than that of the cultivated soybeans as well. These high-yield factors are useful for breeding high-yield soybean cultivars. The researchers from the Jinzhou Institute of Agricultural Sciences in Liaoning Province the variety “Xiongyue- Xiaoli- Huang” with another one “Feng-Di-Huang” and obtained via screening the new line “5621” which is disease-resistant, high-yielding and packed with pods; and researchers from the Tie-ling Institute of Agricultural Sciences took “5021” as a parent and crosses it with other varieties and obtained via screening 5 cultivars including “Tie-feng 18”; and researchers from the Jilin Academy of Agricultural Sciences crossed the semi-wild soybean (100 grain weight less than 4 grams) with the cultivated soybean cv. “Ping-ding 4” and obtained the erect type materials from the F2 generation. Thus the exploitation of wild and semi-wild soybeans has a bright future.

(2) Breeding for high-protein content: Screening for high-protein content has become an important target for soybean breeding. Weber (1950) hybridized wild soybean (protein content was 52.01%) with cultivated soybean (protein content was 42.34%), and obtained hybrid soybean with the average protein content of 50.79% in F1 generation, and hybrid soybean with the average protein content of 49.54% in F2 generation. The distribution curve clearly approaches the high-protein direction and showed the phenomenon of hybrid vigor. This phenomenon suggested that the trait for high-protein content is partially dominant. The higher protein content in the materials of generations F2 and F3 clearly indicated the additive effect. Therefore it is possible to generate soybean cultivars with high-protein content from the wild soybeans.

(3) Breeding for resistance: The damages caused by diseases and insect pests are becoming increasingly serious in the soybean production, thus resistance has been an important objective in soybean breeding. The researchers from the Jilin Academy of Agricultural Sciences identified some lines of wild soybeans resistant to soybean

mosaic virus diseases. Researchers from the Heilongjiang Academy of Agricultural Sciences investigated the resistance of the wild soybeans to the insect pest *G. glycinivorella*. Among the 157 accessions of wild soybeans assessed, the average damage rate is only 0.4%, and 81 accessions were exempted from the damage, while the average damage rate of 6 cultivars of cultivated soybeans was 17%. This result indicated that resistant genetic resources to insect pest were definitely available for exploitation. But some wild soybeans could also be infested by some diseases and insect pests, thus vigorous identification should be carried out before utilization to obtain highly-resistant materials for use after screening.

3. Studies on the origin, evolution and taxonomy of soybeans

It was well-known among the soybean scholars that soybeans originated from China. Nonetheless controversy exists as to in which region of China soybean was originated. The surveying of the wild soybeans provided ample materials for studies on this important topic. The wild soybeans distributed extensively in Northeast China, the Yellow River and Yangze Rive valleys and to the south of the valleys, and the spreading speed of wild soybeans was very rapid. It was discovered during the surveys that wild soybeans distributed extensively and in large populations along the middle and lower reaches of the Yellow River located in Shaanxi, Shanxi and Henan Provinces, and the types of wild soybeans were most plentiful in these regions where existed various evolution-stages of wild and semi-wild soybeans in the wildness. The types of wild soybeans were plentiful in southern parts of Northeast China, eastern parts of North China and the Yangze Rive valley as well. These data provided important conditions for the study of the origin of soybeans. Many new types of wild soybeans have been found during this nationwide survey: they represented varying degrees of evolution and belong to some special types. These findings suggested that some minute variations could accumulate continuously under the action of natural selections, and the wild soybeans would evolve toward cultivated soybeans gradually as a result of the cultivating activities of human beings and artificial selections. These special types of the wild soybeans should have their own status in the studies of taxonomy of the genus *Glycine*. These plentiful materials should undergo identification by trial growing and be tested for their stability, and scientific classification of the wild soybeans should be carried out after discussions among the soybean scientists.