4. BREEDING OF SOYBEAN IN JAPAN

Masataka SAITO*

Introduction

The breeding of soybeans has been carried out from of old in Japan. Since 1908, detailed tests on the heredity of various characteristics of soybean have been made by Takahashi and Fukuyama.

In the 1910's the breeding by pure line selection was begun in agricultural experiment stations, and hybridization has been adopted since 1916.

In 1935, Akita, Ibaragi and Kumamoto Prefectures initiated the soybean breeding regularly, being subsidized by the Central Government. After World War II, Japan who suffered from the shortage of fat and oil resources, consolidated the research and experiment system for soybean breeding, aiming at raising the self-supporting ratio of soybean. As a result, the Hokkaido National Agricultural Experiment Station and the Saga Prefectural Agricultural Experiment Station initiated soybean breeding, and then the Hokkaido and the Nagano Prefectural Agricultural Experiment Stations followed.

Along with the recent trend of increasing share of the importation in the soybean consumed in Japan, the researches on soybean have been gradually cut down and breeding works so far carried out in Kumamoto, Saga and Ibaragi Prefectures have been suspended in these years.

Organizations of Breeding

1) Breeding center

Japan is an island-country lying over the long distance from south to north and is quite variegated in temperature and day length throughout the country. This is the reason why a great number of soybean varieties are required in Japan.

Fukui classified soybean varieties of Japan into (I) to (V) according to the number of days from seeding to flowering, and (a) to (c) according to the number of days from flowering to maturing. (Table 1).

The local distributions of soybean varieties from Ia to Vc are roughly clarified by this classification. In Kyushu District, two types of soybean are cultivated in different

Table 1. Classification of soybean varieties by their ecotypes

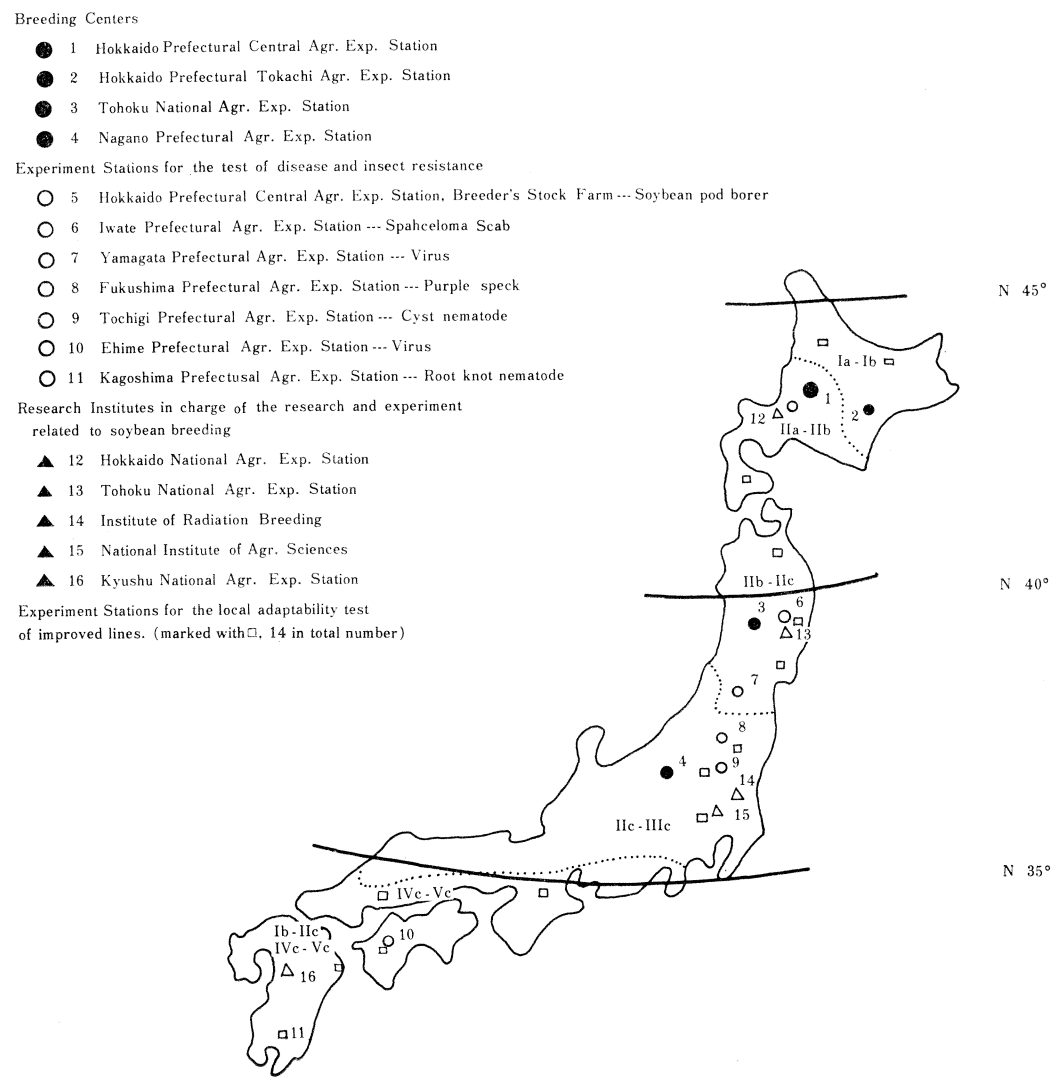
Period	Ecotype of variety								
	I		II			III		IV	V
	a	b	a	b	c	b	c	c	c
Seeding to flowering	very short	very short	short	short	short	medium	medium	long	long
Flowering to maturing	short	medium	short	medium	long	medium	long	long	long

Fukui (1951)

* Chief, Laboratory of Soybeen Breeding Hokkaido Tokachi Agricultural Experiment Station, Memuro-cho, Kasai-gun, Hokkaido, Japan.

cropping patterns. One is the summer soybean with high thermo-sensitivity and of Ib and IIb types which are sown in spring and harvested in summer. The other is autumn soybean of IVc and Vc types which are sown in summer and harvested in autumn.

Also an allotment of each breeding center is taken as follows according to the classification of these ecotypes. (Fig. 1)



Note : Ecotype of soybean variety and its local distribution is referred to Fukui (1968, JARQ, Vol 3, No. 3)

Fig. 1.

Hokkaido Prefectural Tokachi Agricultural Experiment Station:	Ia, IIb
Hokkaido Prefectural Central Agricultural Experiment Station:	IIa, IIb
Tohoku National Agricultural Experiment Station:	IIb, IIc
Nagano Prefectural Agricultural Experiment Station:	IIc, IIIc

Kyushu National Agricultural Experiment Station (in preparation):
Ib, IIb, IVc, Vc.

2) Test for disease and insect resistance

In order to test the resistance to major disease and insect pests of the lines distributed from the breeding centers, the following seven prefectural stations, where those pests are easy to outbreak, are designated by the Ministry of Agriculture and Forestry. That is;

soybean pod borer	:	Breeder's Stock Farm of Hokkaido Pref. Central Agricultural Experiment Station
sphaceloma scab	:	Iwate Pref. Agricultural Experiment Station
purple speck	:	Fukushima Pref. Agricultural Experiment Station
soybean cyst nematode	:	Tochigi Pref. Agricultural Experiment Station
soybean virus	:	Yamagata Pref. Agricultural Experiment Station Ehime Pref. Agricultural Experiment Station
root knot nematode	:	Kagoshima Pref. Agricultural Experiment Station

3) Local adaptability test of improved lines

The promising lines bred out in the breeding centers are sent to the fourteen prefectural agricultural experiment stations designated by the Ministry of Agriculture and Forestry and tested on their local adaptability. The lines which are found, in the test, to be adaptable to certain regions are then examined at the prefectural agricultural experiment stations concerned and at farmer's fields as well. After these tests and examinations, the excellent lines are adopted as recommended varieties.

4) The organization for breeding in Hokkaido (as an example)

The organization for breeding in Hokkaido's as follows (Fig. 2):

(1) Breeding centers

The following Stations are in charge of the breeding of improved lines;

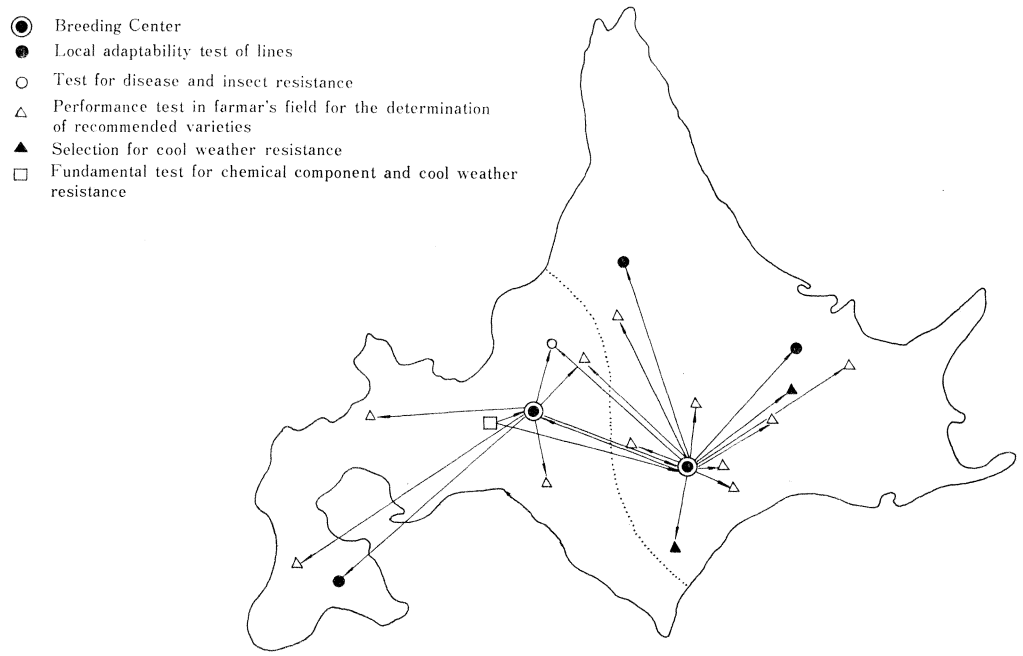


Fig. 2.

Hokkaido Pref. Central Agr. Exp. Station
– do – Tokachi Agr. Exp. Station

(2) Test for disease and insect resistance
The promising lines bred out at the centers are tested on soybean pod borer resistance at the Breeder's Stock Farm of Hokkaido Pref. Cent. Agr. Exp. Station

(3) Local adaptability test.
Those promising lines are also tested on local adaptability at the following Stations;

Hokkaido Pref. Kitami Agr. Exp. Station
– do – Donan Agr. Exp. Station
– do – Kamikawa Agr. Exp. Station

(4) Performance test for determination of recommended variety.
The lines which were found very promising in the tests mentioned above, are examined on their performances at the following Stations;

Hokkaido Pref. Kitami Agr. Exp. Station
– do – Kamikawa Agr. Exp. Station
Breeder's Stock Farm of Cent. Agr. Exp. Station

(5) Performance tests at the farmers' fields.
The lines selected in the performance test are examined at the farmers' fields of eleven municipalities of Hokkaido for two years at least, on the commission of prefectural government.

(6) Determination of the candidate for recommended variety.
The results of the field tests are discussed at the meeting which is held at the Hokkaido National Agr. Exp. Station. The lines evaluated superior at this meeting are adopted as the candidates for recommended variety.

(7) Determination of recommended variety.
Those candidates are then discussed at the nation-wide meeting which is held at the Ministry of Agriculture and Forestry. After the discussion those candidates are registered as new recommended varieties being given Norin number.

The deliberative council for seeds and seedlings which determines the adoption of new varieties, and the distribution and multiplication of their seeds and seedlings, as well as the abandonment of old varieties has been organized as a consultative committee of the prefectural governor of Hokkaido.

As for the seed production and multiplication, the seeds of the lines adopted as recommended varieties are sent to breeder's stock farm from breeding center to be multiplied. The breeder's stock produced at the farm is further multiplied at the foundation stock farm managed by agricultural organizations and is then distributed to farmers through the seed production farms of each municipality.

Thus, the organization for breeding is useful for the dissemination of new varieties and the replenishment of seed.

5) Fundamental research for breeding, and introduction and preservation of breeding materials

Fundamental experiments which support the breeding are carried out in the national research institutes as follows:

The studies on the comparison between pedigree method and bulk method and those on hereditability have been made at the National Institute of Agricultural Sciences and Tokyo University;

The utilization of radiation for breeding, at the Institute of Radiation Breedind;

High yielding ability and ecotype, at the National Institute of Agricultural

Sciences and Kobe University;

Bean components, at the National Food Research Institute and Iwate University;

Cool-weather resistance, at the Hokkaido National Agricultural Experiment Station;

The resistance to disease and insect pests, at the Hokkaido and Tohoku National Agricultural Experiment Stations, etc.

The research findings of those studies have contributed very much to the soybean breeding. Besides, the National Institute of Agricultural Sciences is in charge of the introduction of breeding materials from abroad and their long-term storage.

Breeding Objectives and their Allotment

Although the main objectives of soybean breeding had aimed at oil production some time after World War II, it was changed, along with the increment of soybean importation, to high protein content and good quality which could not be covered by the imported one. It means to try to unify soybean quality for intermediate size of seed (the weight of 100 seeds is above 25 g) or large size of seed (the same is above 35 g) with yellowish white seed coat and hilum, aiming at obtaining the materials for good quality of bean paste (miso), boiled bean and confectionary. At the same time it comes necessary to increase the yield sharply. Besides these two points which are common objectives in every breeding center, there are several factors which retard the production. As for the resistance to these factors each center is carrying out the breeding works based upon each assignment.

1) High yielding ability

As soybean is a crop with few actual results in the raising of yield, compared with rice and other crops, the breakthrough of yield is the most important objective of breeding. The Nagano Phefectural Agricultural Experiment Station has carryed out the studies searching for the characters related to yield, and it has been proved that there is a high correlation between the weight of stem and the yield per unit area, and that seed stem ratio is a good indicator of translocation efficiency to seed. The Station is now carrying out on the soybean breeding with the objective of the yield, 4 tons per hectare.

From the results of the studies on photosynthetic capacity carried out at the National Instiute of Agricultural Sciences, it has been found that the chance to get varieties of high photosynthetic capacity is high in the combination of the varieties of high photosynthetic capacity, and that most of improved varieties are selected in the direction of high unit photosynthetic capacity. Moreover, it has been clarified that the photosytnhetic capacity is one of the quantitative characters and it shows nearly normal distribution in F_2 generation. Also, from the results of the measurement of dry matter production at the Hokkaido Prefectural Tokachi Agricultural Experiment Station, it has been proved that a larger quantity of dry matter production at the early stage of growing is necessary to get the higher yield in the district where the growing period is liimted. The relation between the quantity of dry matter production and the yield is now being examined in the Station.

2) Seed component

Judging from the present condition of the soybean consumption in Japan, high protein content is the major objective of breeding so far as seed component is concerned. The breeding along this direction is carried out at those Agricultural Experiment Stations such as the Hokkaido Prefectural Tokachi, Nagano Prefectural and Tohoku National. The selection based on the chemical analysis of seed and its specific gravity is also being carried out, and the Hokkaido National Agricultural Experiment Station is in charge of the chemical analysis of seed. The details are remained for another presen-

tation.

3) Cool-weather resistance

The high frequency of cool-weather damage is the most influential condition which constrains the production of soybean in Hokkaido, the major producing area of soybean in Japan. The soybean yields in Tokachi district from 1955 to 1972 are shown in Fig. 3.

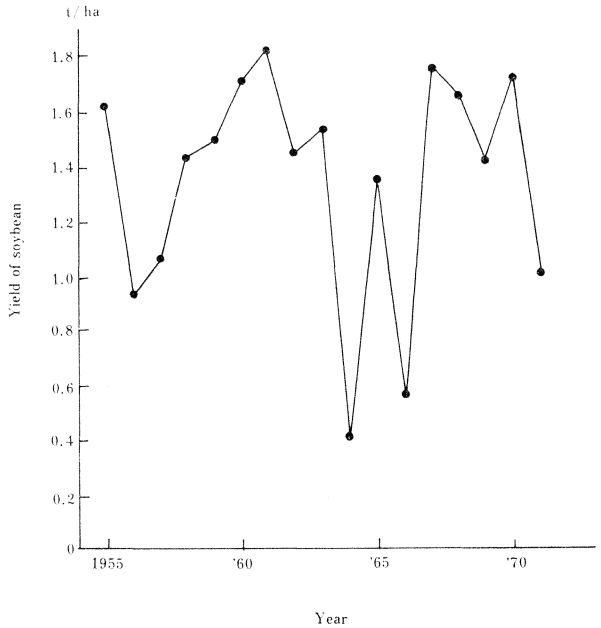


Fig. 3.

The low yield in some years in this Figure should be attributed to cool-weather damage. The soybean is a crop sensitive to temperature. A high correlation between the average yield of soybean in Tokachi district and the average temperature from July to August in the district is observed in Fig. 4. It is considered that, besides the low

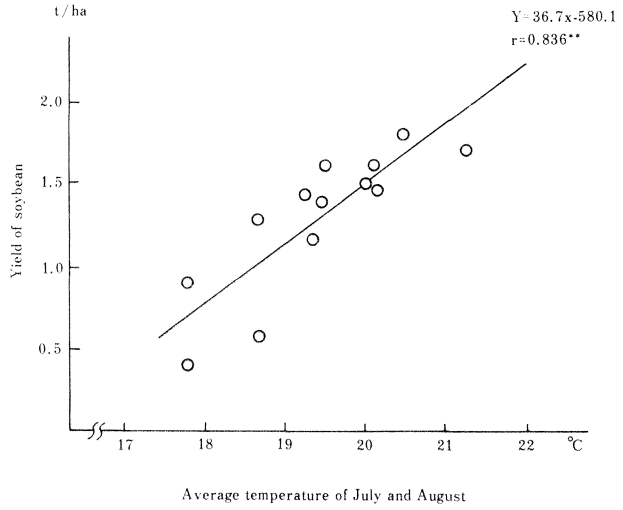


Fig. 4.

temperature, want of sunshine and excess of moisture due to much rainfall may be also the causes to decrease the yield in the year of cool-weather. Remarkable differences among varieties has been observed on the extent of yield decrease in the years of cool-weather damage. In 1964, the facilities for the experiment in low temperature (Phytotron) were set up at the Hokkaido Prefectural Tokachi Agricultural Experiment Station and the selection of parents and the test of improved lines were made. However, there still remain some problems as for the experimental method. In actual breeding, the selection of the breeding materials for cool-weather resistance has been made at the farmers' field of the selected sites at the foot of a mountain of low temperature and on the coast of sunshine duration.

As for the mechanism of cool-weather damage on leguminous crops, the studies were made at the Hokkaido National Agricultural Experiment Station since 1953. It is reported that the most critical stage for low temperature is around the flowering time, and the abnormality of pollen has considerable effects.

4) Resistance to soybean cyst nematode

Soybean cyst nematode which is widely distributed all over the country is one of the serious causes to diminish yield. At the Tohoku National Agricultural Experiment Station it was found that the local variety "Geden-Shirazu" had the resistance to soybean cyst nematode. From this local variety, "Nemashirazu" was bred out by pure line selection, and then two varieties, "Raiden" and "Raiko" were made by irradiating "Nemashirazu" with Co^{60}. Approximately 50,000 seeds were used for the radiation, and "Raiden" was selected from the irradiated plot of 10 KR. The development of this commercial soybean variety by using radiation is one of the most remarkable schievement in the field of breeding. As for the test method for nematode, the simple test

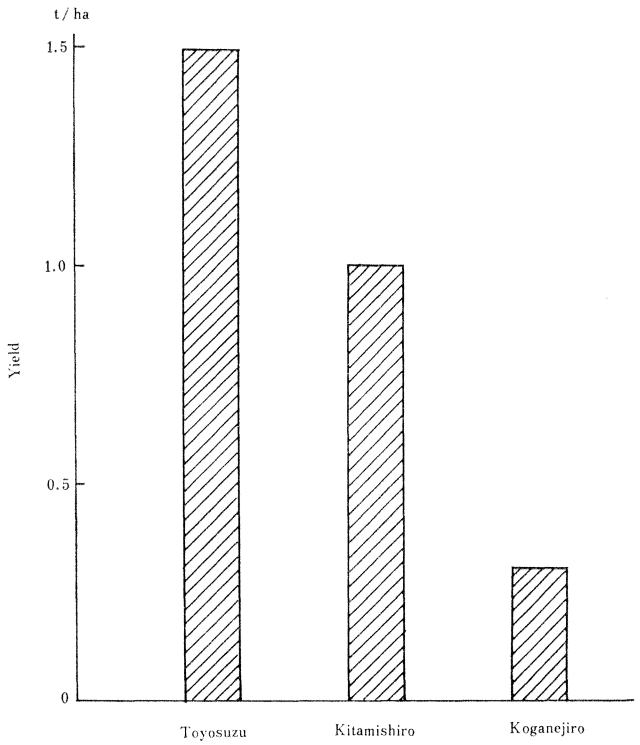


Fig. 5.

method in a green house is applied besides the test in the field infested with nematode.

In the Hokkaido Prefectural Tokachi Agricultural Experiment Station the artificial crossing has been made to bring into use the nematode resistance of "Geden-Shirazu" and other local varieties of the Tohoku region, and two varieties, "Horai" and "Toyosuzu" were bred out. These two varieties have been rapidly disseminated, since the yield does not decrease so much in the field infested with nematode and its seed quality is ramarkably good even though the roots are infested by a few cysts (Fig. 5). Breeding to introduce the high nematode resistance of foreign varieties such as "peking" is being made, but these introduced foreign varieties are very late in maturity and their seeds qualities are not good, so Hokkaido varieties have been used in the breeding as the recurrent parents to improve these inferior qualities.

Also the Nagano Prefectural Agricultural Experiment Station which has the major objective to breed cyst nematode resistant, varieties has succeeded in the breeding of "Nasushirome" and is trying to introduce higher resistance. From these experimental results, it is safely assumed that the genes controlling high resistance to nematode consist of four pair and the resistance has a linkage with seed colour. Consequently breeding of the varieties with high resistance to nematode as well as of good quality does not seem to be easy. Moreover, it is observed that the number of infesting cyst to the same variety differs according to the physiological races of the nematode. This is a problem which has to be urgently solved.

The tests of improved lines for cyst nematode resistance have been carried out at the Tochigi Prefectural Agricultural Experiment Station.

5) Resistance to virus

Soybean virus also severely retards the production of soybean. Since soybean mosaic virus and soybean stunt virus are distributed in Honshu (the main island of Japan), the breeding for the resistance to these virus is the important objective especially at the Tohoku National Agricultural Experiment Station. Four or five races are identified in these virus, and the resistance to these virus is usually different by the races. So, the breeding for the resistance to all races seems to be difficult.

At present, the line which is resistant to A to D race of mosaic virus as well as all other races of stunt virus have been obtained from the progeney of the combination of "Nemashirazu" and "Harosoy". The breeding for virus resistance has been made in the close cooperation of breeders and virus specialists as well.

Soybean dwarf virus was recently identified in Hokkaido and began to prevail year by year. It was proved that the dwarf virus is infected only through juice sucking by foxglove aphid but not through contagion or seed infection. However, the varietal difference of the dwarf virus resistance is not clarified.

The Hokkaido Prefectural Central Agricultural Experiment Station is now searching for the variety resistant to the virus.

The tests of improved lines for virus resistance have been carried out at the Yamagata and Ehime Prefectural Agricultural Experiment Stations.

6) Resistance to other diseases and insect pests

The tests for the resistance to sphaceloma scab have been made at the Iwate Prefectural Agricultural Experiment Station. The variety resistant to sphaceloma scab will be easily obtained, since the resistance is controlled by only one gene which acts dominantly

Purple speck is widely distributed in Honshu (main island) and the resistance to this disease can be tested by watering method. The breeding of the variety resistant to purple speck has been carried out mainly at the Ibaragi Prefectural Agricultural Experiment Station.

The tests of improved lines for purple speck resistance have been made at the Fuku-

shima Prefectural Agricultural Experiment Station.

Soybean pod borer is distributed all over the country and the damage is serious. The breeding for resistance to the borer has been carried out at the Hokkaido Prefectural Tokachi Agricultural Experiment Station. The tests of improved lines for the borer resistance have been made at the Breeder's Stock Farm of the Hokkaido Prefectural Central Agricultural Experiment Station. Up to now glabrous varieties are likely to be most resistant to the borer, but these varieties are inferior to pubescent ones in cool-weather resistance and yielding ability. The problem has to be solved.

7) Adaptability to mechanization

Soybean is generally harvested by hands at present, but the mechanization will be a necessary condition for soybean cultivation in the future. Thus, resistance to lodging and low shattering, and uniform seed matuing will be the major breeding objectives for mechanization. The breeding for low shattering is already included in the breeding program of the Hokkaido Prefectural Tokachi Agricultural Experiment Station. The test methods on mechanization adaptability of varieties are being examined at the Tohoku National Agricultural Experiment tSation.

Results of Breeding

1) Breeding method

Breeding of soybean was begun in the 1910's, and a great number of recommended varieties were bred out by means of comparing test of local and introduced varieties firstly and pure line selection secondarily. Since about 1930, hybridization method by which most of varieties were bred out was introduced. Since about 1950, bulk method and recurrent parents method were adopted in addition to pedigree method. Radiation breeding method was adopted on a large scale since 1957.

Classification of the recommended varieties of Hokkaido by the breeding methods applied for them are shown in Fig. 6 as an example of the progress of the breeding method. In Fig. 6, it is seen that the breeding method has changed from variety test to pure line selection and then to hybridization. The varieties disseminated to farmers

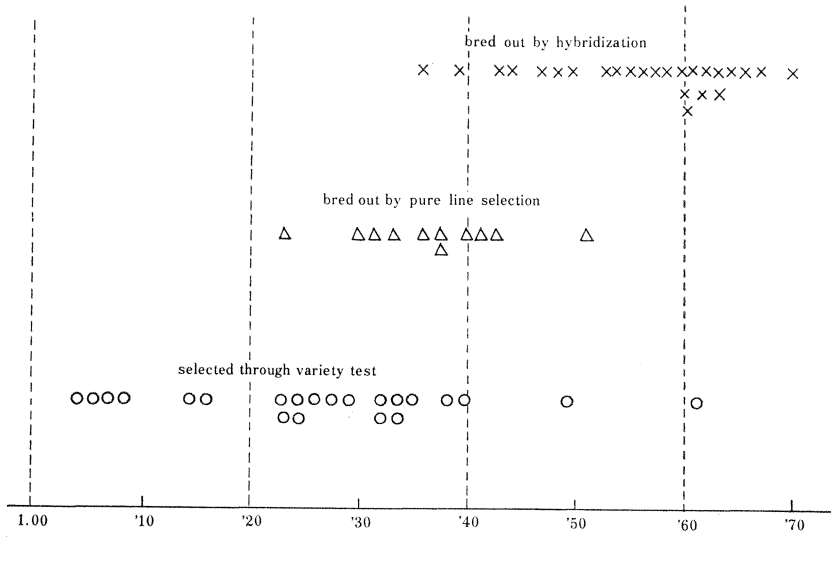


Fig. 6.

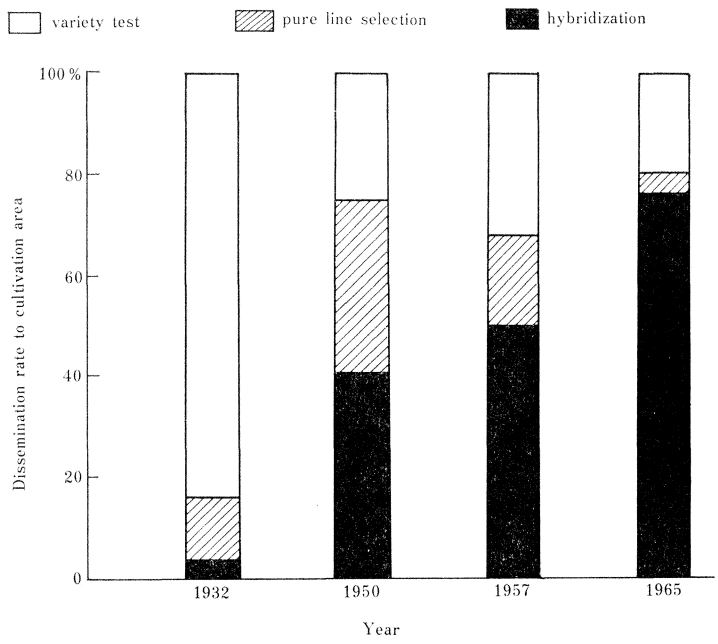


Fig. 7.

with reference to breeding methods are shown in Fig. 7, which shows that the varieties bred out by hybridization method have yearly increased.

2) Breeding of recommended varieties

Breeding of soybean had been mainly made by designated experiments commissioned by the Ministry of Agriculture and Forestry. The number of variety registered with Norin Number amounts to 59, which accounts for most of recommended varieties disseminated all over the country. There are not a few recommended varieties bred out independently at other prefectural agricultural experiment stations, but all the varieties registered recently are the ones bred out at the experiment stations commissioned by the Ministry.

3) Major varieties disseminated at present

"Kitamusume": "Karikachi" × "Kitami-Shiro"

This is a variety which was bred out in Hokkaido, with the objectives of cool-weather resistance and high-yielding. It shows high-yielding ability in the north-eastern district of Hokkaido, and the yield does not decline so much even in the year of cool-weather damage. Its hilum is coloured dark brown, the weight of 100 seeds in about 29 g, and the quality is good.

"Toyosuzu": "Geden-Shirazu 1" × "Toshi-Dai—7910"

It has the medium resistance to soybean cyst nematode, and there is little decrease in yield though roots are infested by a few cysts. It is a variety of good quality and with yellowish white seed coat and hilum. The weight of 100 seeds is 32 g, and has been cultivated mainly in the north-eastern district of Hokkaido.

"Raiden": This is a variety bred out from "Nemashirazu", a variety resistant to cyst nematode, by the radiation with 60^{60}. The growing period was shortened by about 25 days as compared with the original one. It has the similar resistance to cyst nematode as that of "Nemashirazu", and it is also resistant to sphaceloma scab, soybean mosaic virus of A and B races and soybean stunt virus of A and B races.

The weight of 100 seeds is 30 g, its seed coat and hilum are coloured yellowish white, the quality is excellent. The variety is adaptable for cultivation in the central and northern district of Tohoku region.

"Okushirome": "Nemashirazu" × "Nangun-Takedate"

This variety has the resistance to sphaceloma scab, soybean mosaic virus and soybean stun virus of A and B races, and has especially high resistance to purple speck and cyst nematode. The weight of 100 seeds is 23 g belonging to medium size. It has good quality and high-yielding ability, and is cultivated in the northern district of Tohoku region.

"Enrei": "Norin 2" × "Shiromeyutaka"

The variety was selected from the combination mentioned above, by bulk selection up to F_3 generation and by individual selection in F_4 generation. The main characteristics are stiff stem, resistance to lodging, high seed-stem ratio, high efficiency of seed production and high-yielding ability. The weight of 100 seeds is 30 g belonging to intermediate size, and the quality is good. It is cultivated in Kanto and Tohoku regions.

"Shirotae": "Soga-Zairai" × "Chuteppo"

This is a branch type variety which belongs to IIIc of ecotype and is resistant to lodging and of high seed-stem ratio. The weight of 100 grains in about 30 g belonging to intermediate size, and the quality is good. It is adaptable for the cultivation in Chugoku, Tokai and Kinki regions.

"Tachisuzunari": "Ani" × "Norin 2"

This is a branch type variety which sets a number of pods and has high-yielding ability. It is adaptable for mechanized cultivation since it has high resistance to lodging. It is cultivated as a high-yielding variety in Kanto region due to the high yield-increase in the case of heavy fertilizing and dense planting cultivation. The weight of 100 seeds is about 20 g belonging to small size. The hilum is brown coloured.

"Akiyoshi": "Shiro-Daizu 3" × "Asomasari"

This variety is autumn soybean which requires long maturing period though it flowers early. It is a branch type variety with a number of pods setting and high-yielding ability. The weight of 100 seeds is 25 g belonging to intermediate size. The colour of seed coat and hilum is yelowish white. The protein content of seed is high and the quality is excellent. It is cultivated in the autumn soybean zone in Chugoku, Shikoku and Kyushu regions.

"Hyuga": "Akasaya" × "Asomusume"

This variety is autumn soybean belonging to IVc of ecotype. The main characteristics are short stem, resistance to lodging, dense pod setting, high-yielding ability as well as resistance to sphaceloma scab and soybean stunt virus. The weight of 100 seeds is about 25 g belonging to intermediate size. The colour of seed coat and hilum is yellowish white and the quality is good. It is adaptable for the cultivation in autumn soybean zone in Chugoku, Shikoku and Kyushu regions.

Problems to be Solved in the Future

The cultivation area of soybean in Japan has decreased along with the increment of importation from abroad, but it is still an indispensable crop in upland farming. The following problems have to be solved:

1) In order to heighten the yield sharply from the present low level, it is necessary to breed out the variety with high efficiency of seed production by introducing new genes.

2) In order to meet the requirement of consumers, the variety of high protein content and of good uniform seed quality are desirable.

3) In order to reduce the production cost of soybean, it is necessary to breed out

the variety adaptable for the mechanized operation of harvesting and threshing.

4) It is urgently needed to breed out varieties which are highly resistant to various environmental factors retarding the yield increase, such as soybean cyst nematode, virus and other diseases and insect pests. The breeding for cool-weather resistance is also needed especially in Hokkaido.

Discussion

C. P. Cheng, Republic of China: What are the selection criteria for breeding the soybean varieties for mechanized cultivation?

Answer: The resistance to shattering and lodging is the main criterion.

Arwooth N. L., Thailand: In the country which has a short day length, is it possible to increase the yield per hectare by extending the growing period?

Answer: Generally speaking, the longer growth period results in the higher hield of soybean. So far I have learned, there are local varieties of the growth period of more than four months in Thailand. I am sure you can breed out the high-yielding variety by making selection for higher productivity.

Arwooth N. L., Thailand: Is there any machines to harvest soybean in the farmers' field?

Answer: Most of farmers have harvested soybean by hands but mechanical harvesting is now increasing in acreage. The harvesting machines are bean harvesters or bean cutters. Combines are not yet used.

P. P. Kurien, India: The trypsin inhibitors in soybean is one of the major toxic factors that affect the protein utilization by human beings. Could it be possible to eliminate or reduce this toxine by breeding? Has anything been done?

Answer: We do not take trypsin inhibitor into consideration in our soybean breeding program, because such a factor has not come out serious in Japan.