PRODUCTION

Expanding the Genetic Potential of the Soybean

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ABSTRACT

The primary center of genetic dispersion of the soybean probably is in northeastern China. The soybean plant traveled from its area of origin to Korea and Japan in ancient times and to Europe and America more recently. Although soybeans were confined to the Far East for many centuries, the western world now produces more than 80% of the total, and the United States and Brazil are the main producers. The increased expansion of soybeans in Latin America is largely a result of the advances of genetic and agronomic technology, which have permitted the development of adapted cultivars and improved management systems for the subtropical and tropical areas of this region. The USDA soybean germplasm collection—particularly the gene bank maintained in Mississippi—has been the most important genetic resource for the developing commercial cultivars in Brazil, Columbia, Ecuador and Peru. Germplasm from other countries, e.g., Japan, Korea, Taiwan, Indonesia, India, the Philippines and some African countries, also has contributed to the enrichment of the soybean gene pools in Latin America, mainly through the International Soybean Program (INTSOY). The International Soybean Variety Evaluation Experiment (ISVEX) of INTSOY has been planted in more than 1,200 locations and in more than 107 countries since 1973. In Latin America in 1978, this experiment was planted in 29 locations of 11 countries. The experiment was designed to (a) test the adaptation of cultivars, (b) compare local and introduced cultivars, (c) provide new germplasm for local breeding programs, (d) identify potential areas for soybean production, and (e) evaluate cultivar performance in different environments.

INTRODUCTION

Historic and geographic evidence shows that the cultivated soybean *Glycine max* had its origin in Asia. Some of the native forms of soybean from this region have been introduced to countries in other regions as commercial varieties or as genetic materials for the development of improved cultivars. From its area of origin, the soybean went to Korea, Japan and other countries of the Far East in ancient times, and to Europe and America in more recent times. Since its introduction as a cultivated crop, the soybean has been a factor of progress in industry, science and technology, and has become an important source of calories and proteins for human and animal nutrition. At present, the American continent contributes 80% of the world soybean production in an area that represents 67% of the cultivated area. A considerable expansion of the crop has taken place in all producing countries of Latin America during the last 3 years; some countries of this region have emerged as new producers and others have increased their area of cultivation. Brazil and Argentina are ranked third and fourth in area and production in the world.

WORLD PRODUCTION AND YIELDS

The soybean is presently grown in about 50 countries in areas ranging from 1000 to 25 million hectares. According to the Food and Agriculture Organization (FAO) Production Yearbook, the area harvested in 1978 on the American continent was 35,200,000 hectares. Production was 63,300,000 metric tons, giving an average yield of 1800 kg/ha. Asian countries in 1978 produced 15,000,000 metric tons in an area of 16,000,000 hectares, giving an average yield of 940 kg/ha. In Europe the production was 400,000 metric tons, the area 347,000 hectares, and the yield 1,150 kg/ha. In Africa 200,000 metric tons were harvested in an area of 270,000 hectares, giving a yield of 740 kg/ha.

SITUATION OF SOYBEANS IN LATIN AMERICA

Commercial Production and Cultivar Development

In 1978, the Latin American countries produced 13,160,000 metric tons in an area of 9,450,000 hectares, with an average yield of 1400 kg/ha. The main producers are Brazil, Argentina, Mexico and Paraguay; which in 1978, they produced 98% of the soybeans harvested in Latin America. The average annual increase in cultivation area from 1976 to 1978 was 10% for Brazil, 60% for Argentine, 24% for Mexico, and 7% for Paraguay.

Brazil is third in soybean production in the world after the U.S. and China. In 1965 Brazil produced 1.5% of the world's soybeans; in 1978 the figure was 12%. The soybean was introduced into Brazil at the end of the 19th century, but its commercial importance began to emerge in the early 1960s. The main producing areas of Brazil are located between 20° and 32°S in the states of Rio Grande do Sul, Parana, and Sao Paulo, which together contribute 80% to the national production. The cultivated area increased from 6,400,000 hectares in 1976 to 7,750,000 in 1978. The average yield during this period was 1600 kg/ha.

Commercial production started with varieties introduced from the United States, such as Hill, Davis, Bragg, Hardee and others; later, breeding lines were introduced and hybridization and selection programs were initiated in the country. Through these programs, national improved varieties were introduced. Between 1967 and 1972, the following varieties were named and recommended for commercial production: Santa Rosa (D49-722 × La 41-1219), Industrial (Mogiana × La 41-1219), Vicoja (D49-2491 × Imp. Pelican), IAS-2 (Hill × D52-810), Planalto (Hood × Kedelee STB 452), Prata (Hood × Hill), IAS-1 (Jackson × D49-2491), Perola (Hood × Industrial), and

Florida (D51-5091 x Jackson). From 1973 to 1977 the following varieties were developed: IAS-5 (Hill x D52-810), Parana (Hill x D52-810), Santa Ana (D51-5437 x D49-2491), BR-1 (Hill x L-356), BR-2 (Hill x Hood), BR-3 (Hampton x Campos Gerais), and Sao Luiz (Hardee x Semmes). The yield potential in the new varieties is greater than that in the old ones, and they have greater tolerance or resistance to disease.

Argentina is second in soybean production in Latin America and fourth among world producers. Its production increased from 695,000 metric tons in 1976 to 2,500,000 in 1978. Its average yield of 2000 kg/ha was one of the highest among producing countries during this period. Most of the recommended varieties were introduced from the United States and adapted to the local growing conditions. Among these are: Clark, Hill, Hood, Jackson, Lee and Bienville.

The soybean was also introduced recently as a commercial crop into Mexico. The states of Sinaloa and Sonora are important producers. The area of cultivation increased from 172,000 hectares in 1976 to 231,000 in 1978, with an average yield of 1600 kg/ha. The initial commercial production of the 1960s was based on introduced varieties such as Bragg, Hood, Davis and Lee 68. Production in more recent years has been based on national varieties developed by the Instituto Nacional de Investigaciones Agropecuarias These varieties have shown better adaptation and higher yield capacity than imported varieties. The locally developed varieties are: Cajeme, Bacatete, Tetabiate, Corerepe, Jalisco, Culiacan, Tropicana and BM-2. Diseases are not a major production problem, although in some areas bud blight disease exists.

Soybean production in Paraguay has also expanded substantially in recent years. In 1972 the country produced 48,000 metric tons, and in 1978 production increased to 300,000 tons. The average yield in 1978 was 1580 kg/ha. A large part of the crop is produced in holdings of less than 20 hectares. The most common varieties are Santa Rosa, Vicoja and Galaxia.

Among the countries that grow less than 100,000 hectares in Latin American are Colombia, Ecuador, Bolivia and Peru.

Colombia introduced soybeans as an experimental crop in 1929 and began its commercial production in 1955 with the varieties Missoy, Mamoth Yellow and Biloxi. These varieties were then replaced by Acadian, which was discarded in 1960 because of its susceptibility to pod shattering. In 1960 a variety testing program was organized and in 1969 the first hybrid variety was recommended for commercial production. Although soybean experimentation is conducted at several experiment stations in Colombia, the commercial crop is produced only in the Cauca Valley, at a latitude of 3°N and an elevation of 1000 meters. The area of cultivation increased from 38,000 hectares in 1976 to 71,000 in 1978; the average yield during this period was 1900 kg/ha. The variety Mandarin S-4-ICA was selected from an heterogeneous introduction and recommended for commercial production in 1964. The new variety became susceptible to new races of *Cercospora sojina* 3 years after its release and was replaced by Pelican-SM-ICA, a selection in Improved Pelican. From 1969 to 1974 the varieties ICA Lili, ICA Taroa, and ICA Pance from the Cross Pelican SM-ICA x Mex 13D-440-B46 were released. ICA Caribe, a variety from Jamaica, was released in 1974 and recommended for lowland areas. In 1976 variety ICA Tunia was released; this variety, which originated from the cross Mandarin S4-ICA x Dortchsoy 67, has a high yield potential in tropical environments. It is of medium plant height, reaches maturity relatively early, and is highly resistant to pod shattering. Two selections from Jupiter, named Victoria and S.V.77, were released by private seed companies in the last 2 years.

In Ecuador the area cropped with soybeans increased from 500 hectares in 1972 to 25,000 in 1978; the average yield during the latter year was 1450 kg/ha. The soybean research program of the Instituto Nacional de Investigaciones Agropecuarias (INIAP) conducts work on introduction, selection and hybridization of germplasm with the purpose of developing adapted varieties to the tropical conditions of the country. The following improved varieties have been released for commercial production: Americana, from a selection in an unidentified introduction; Manabi, from a selection in Americana; and INIAP-Jupiter, from a composite of 6 lines selected in Jupiter. The 3 varieties have good yield potential, medium plant height and plant maturity, and show tolerance to the Soybean Mosaic Virus disease.

The 1970s also marked the initiation and expansion of the soybean crop in Bolivia. From an area of 1000 hectares, recorded in 1971, the area planted with soybeans grew 19,000 hectares in 1978. The varieties most commonly grown are Pelicano, Acadian and Colombiana.

Uruguay also went from 1000 hectares in 1971 to 25,000 in 1978, with an average yield of 1400 kg/ha in 1978. The research is conducted by the Centro de Investigaciones Agrícolas "A. Goerger;" this center has recommended varieties Hill, Davis, L68 and Bragg for commercial production.

Evaluation of soybean germplasma in Peru was initiated in 1929 at La Molina Experiment Station, but commercial production is a recent development in this country. Both coastal and jungle areas are suitable for soybean production. The following varieties have been adapted for commercial production: National, from unknown origin, tall and late, suitable for irrigated areas; Jupiter, selected from the ISVEX trials of INTSOY, suitable for irrigated as well as rain-fed areas; Improved Pelican, selected from the ISVEX trials of INTSOY, relatively early in the tropics, has good seed quality and is suitable for rainfed areas. More recently, 2 new varieties have been developed with the assistance of the INTSOY/Peru Project; they are named Tulumayo-1 and Tulumayo-2. The first came from a selection in an unidentified introduction, and the second from the cross Jupiter x Davis. Both varieties are suitable for the more humid areas of the high jungle due to their tolerance to frog eye leaf spot caused by *Cercospora sojina*. The production of soybeans in Peru is being assisted by INTSOY in the areas of economics, extension, processing, and agronomic and breeding research. The variety testing program of this project has identified cultivars Davis and Tunia as high yielders in experimental plots. In addition to variety testing work, the project has introduced from the INTSOY breeding program of Puerto Rico about 600 segregating progenies for selection under local conditions, and has established a crossing program at the Experiment Station in Tarapoto in the high jungle area.

Genetic Limitations

Although the soybean programs of Latin American countries have succeeded in the identification and development of adapted cultivars, one of the main limitations to improving production is the lack of cultivars more property adapted to the tropical and subtropical conditions of the region. The germplasm with medium-late and late plant maturity that was developed and released in southern U.S. has played an important role in the adaptation and development of improved cultivars, but to solve specific problems of various producing regions, it is desirable to intensify the

introduction, evaluation and utilization of germplasm. Diseases caused by virus, fungi and bacteria are common in all producing countries; however, some problems are more specific to certain countries. The soybean mosaic virus (SMV) disease seems to be more important in Ecuador, Brazil and Peru, whereas the "Machismo" disease, which is probably caused by a mycoplasma, is localized in Colombia.

Most of the bacterial and fungi diseases that affect soybeans in other parts of the world are also present in the Latin American region, but soybean rust, a disease of the Far East, is not a threat at present to the soybean crop on this side of the world. The cyst nematode, a problem in the United States and some Asian countries, has not been reported in Latin America, but the root knot nematode is very common in all producing areas of this region.

The most common insect damage problems in the region are those caused by leaf, pod and seed feeding insects.

STORAGE AND DISTRIBUTION OF GERMPLASM

Germplasm Banks

The increase in crop production sought by breeders and agronomists could not be possible without the collection, cataloging, conservation and distribution of the species genetic reservoir. A germplasm bank can store germplasm of wide genetic variability such as genera, species, cultivars, or strains, or it can contain germplasm of narrow genetic variability such as isogenic lines of a given strain.

To this author's knowledge, there are no soybean germplasm banks in Latin America, although working collections of germplasm exist in certain countries of the region where soybean research is done. At present, there are small-to-large soybean germplasm collections in other parts of the world, where breeders can inquire about obtaining soybean strains for research purposes. The most important of these collections is the USDA Soybean Germplasm Collection, which stores more than 5000 entries including named varieties, FC and PI entries, the genetic collection and the species collection. The collection of named varities comprises the old and new varieties developed in the United States and Canada; the early maturity group of this collection is preserved in Urbana, Illinois, and the late maturity group in Stoneville, Mississippi. The FC and PI entries are a collection of strains from countries where soybeans are grown. The genetic collection comprises mutants, isogenic lines and cytogenetic materials. The species collection comprises introductions of the annual species *Glycine soja* and perennial species of the genus *Glycine*.

Other soybean collections are stored in South Korea at the Applied Genetics Laboratory, KAERI, where more than 1300 native strains are preserved; in Japan where about 3000 entries are maintained in the National Institute of Agricultural Sciences at Hiratzuka; and in India, where about 4,000 entries are stored at Pantnagar.

Distribution of Germplasm

At present, there are 3 international institutions that conduct soybean breeding work and have facilities to provide germplasm, scientific information and training to soybean researchers of the developing countries. These are: The International Institute of Tropical Agriculture (IITA), The Asian Vegetable Research and Development Center (AVRDC), and The International Soybean Program (INTSOY).

INTSOY is a program of the University of Illinois and the University of Puerto Rico to expand the use of soybeans for human food. It has a soybean breeding project at the Isabela Experiment Station in Puerto Rico where work is currently conducted to develop strains with high, stable yields, resistance to pests and diseases, and adaptability to tropical and subtropical environments. Cultivars and strains developed by the breeding project are tested and distributed through the international soybean trials known as Soybean International Experimental Variety Evaluation (SIEVE), Soybean Preliminary Observation Trial (SPOT), and International Soybean Variety Evaluation Experiment (ISVEX). The SIEVE trial is planted at two tropical and one sub-tropical latitude, and it comprises cultivars and strains developed by INTSOY and national soybean programs of different countries. Promising entries of SIEVE are then tested in SPOT, which exists at about 20 locations to provide evaluation results under a wider range of environmental conditions. The ISVEX trial is composed of promising entries in SPOT and is distributed to research cooperators all over the world. Since its inception in 1973, the ISVEX experiment has been placed in more than 1200 locations in 107 countries. In 1978 data was recorded in 91 locations, of which 34 were in Africa, 29 in Latin America, 14 in Asia, 5 in the Middle East, 3 in Oceania, 5 in Europe and 1 in North America.

The objectives of the INTSOY international soybean trials are to study the adaptability of cultivars under a wide range of environmental conditions, to provide the opportunity to compare local and introduced varieties, to provide new sources of germplasm for local programs, and to identify potential areas for soybean production.

RECOMMENDATIONS

Positive results in the following areas of genetic research would contribute to expanding production of soybeans in developing countries: (a) development of photoperiod insensitive and high-yielding cultivars; (b) development of virus resistant germplasm; (c) development of insect resistant germplasm; (d) development of germplasm with improved potential for N_2 fixation; (e) development of germplasm with improved longevity of seed in storage and with improved quality of planting seed; (f) development of cultivars suitable for mixed cropping systems.

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