THE CHALLENGES OF STRENGTHENING SOYBEAN RESEARCH AND DEVELOPMENT ACTIVITIES IN THE TROPICS AND SUBTROPICS

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Abstract

The International Soybean Program (INTSOY) of the University of Illinois is seeking to improve human nutrition and economic conditions through the use of soybeans. INTSOY works collaboratively with like-minded national, regional, and international organizations in a) germplasm enhancement and testing ; b) developing effective production practices for a range of cropping systems and different agro-climatic conditions ; and c) the developing of locally accepted soy products. Funding for most INTSOY activities comes from the US Agency for International Development.

INTSOY collaborates with scientists in 80 different countries who participate in the global soybean testing program. Trials for three target environments are organized : tropical, subtropical, and temperate regions. Most cultivars originated from the USA when the testing program began but now a majority of the cultivars tested originate from other countries. Results of the past 10 years of trials show conclusively that soybeans are adapted to a wide range of environments and cropping system conditions. A number of countries have made direct use of the test cultivars for commercial production and a larger number have used the cultivars in their local breeding program.

Although the soybean genetic potential has been demonstrated to be high, expanded breeding efforts are needed to develop improved cultivars for many of the adverse conditions which soybeans are exposed to if they are to become widely used in tropical and subtropical cropping systems. INTSOY is, therefore working with other organizations to develop strong national and regional efforts to develop improved soybean germplasm. INTSOY is working with a number of organizations to develop an International Soybean Consortium/Network which can help developing countries meet their rapidly increasing needs for edible oil and protein.

Introduction

The purpose of the International Soybean Program (INTSOY) is to assist developing countries exploit the inherent potential of the soybean as an efficient source of high quality protein and edible oil. Major attention has been given to countries in the tropics and subtropics who in the past have not shared widely in the benefits from soybeans. In the effort to develop a strong global research, education, and service network, INTSOY has cooperated with many national, regional, and international organizations.

This paper will briefly review some INTSOY activities which relate to cropping systems, discuss results of a recent survey of cooperators in the INTSOY varietal testing program, and outline ways we feel the international effort in soybean research and development for tropical and subtropical countries can be strengthened.

History of INTSOY

INTSOY was formally organized in 1973 as a collaborative effort of the University of Illinois at Urbana-Champaign and the University of Puerto Rico, Mayaguez, as a variant of the highly successful food crop oriented International Agriculture Centers (IARCs) supported by the Consultative Group for International Agriculture Research (CGIAR).

Domestically, its antecedents date to the late 1800s when the University of Illinois pioneered

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soybean research in the USA, and internationally, to the mid-1960s when the University of Illinois development team initiated soybean work in India. The United States Agency for International Development (AID) has provided the basic program support for INTSOY augmented by support from the Rockefeller Foundation, United Nations Development Program (UNDP), Food and Agriculture Organization of the United Nations (FAO), United Nations International Children's Fund (UNICEF), and Cooperative for American Relief, Inc. (CARE). INTSOY programs have focussed on germplasm improvement, plant protection, nitrogen fixation, and soy food utilization. Research, training and information exchanges are avenues followed to meet INTSOY program objectives.

INTSOY activities contributing to cropping system research

INTSOY's research activities in germplasm evaluation and improvement, plant protection and microbiology have been directed toward identifying appropriate technology for soybean production in various cropping systems.

INTSOY's three interrelated variety testing programs - The Soybean Initial Evaluation Variety Experiment (SIEVE), the Soybean Preliminary Observation Trial (SPOT), and the International Soybean Variety Experiment (ISVEX) compose the major germplasm activity. Trials have been conducted in 115 countries since 1973. More than 200 scientists, representing some 100 different research institutions and organizations from 80 different countries, annually participate in this collaborative effort (Table 1). These global trials and the modest tropical breeding program in Puerto Rico complement regional and national efforts in breeding and testing. The trials have stimulated breeding programs in various countries which now contribute more than half of the entries evaluated. The publication of trial results has recently been brought up-to-date with the publication of 1981 trial results.

Table 1 Number of countries conducting ISVEX trials

	Africa	Asia	Americas	Europe	Other	Total
Total since 1973	42	26	27	10	10	115
1982	26	23	19	9	9	86

The following general observations made from international trial results during the past decade give some general leads on breeding strategy for tropical and subtropical environments :

- Average yields tend to be comparable in tropical and temperate regions.
- In the tropics, yields tend to be considerably higher from late-maturing cultivars than from early-maturing cultivars.
- Yields are affected more by changes in altitude than by changes in latitude.
- Yields are usually quite high when soybeans are first introduced into a region but frequently face increasing disease and pest problems when grown widely.
- Seed viability is a universal problem in warm climates, but small-seeded varieties have better seed viability than large seed varieties.
- Small seed size does not appear to restrict yield potential.
- The protein and oil content and chemical composition of a cultivar remain stable in different sites and environments.

The trial results indicate that existing soybean cultivars perform reasonably well in many environments in experimental stations. However, to obtain high stable yields in a wide range of cropping systems environments a vastly increased range of soybean varieties will be needed.

In addition to developing or identifying soybean cultivars for various cropping systems,

INTSOY entomologists, pathologists, and weed scientists have developed integrated pest management practices collaboratively with scientists in several tropical countries. Pest control practices in various crops in a cropping system are essential to obtain and maintain high yield levels over a long period of time. Since soybeans are being introduced into many new areas in the tropics, scientists have the challenge of preventing the build-up of disease, insects, and weeds.

Equally important are ways to improve inoculants for soybeans. Research on inoculant production, distribution and the survival of *Rhizobium* in different types of soils as well as studies on the enhancement of nodulation has significant implication for establishing highly productive soybean technology for various cropping systems—especially in the tropics where soybeans are frequently grown under less than ideal conditions.

INTSOY conferences and workshops in several countries have provided forums for scientists to contribute important knowledge relating to soybean production and utilization practices. Publications of conference proceedings, research results, and the newsletter have aided in the dissemination of information on a global scale.

In several countries, notably India, Sri Lanka, and Peru, INTSOY has had long-term projects of collaboratively establishing and developing national soybean research and utilization programs. The cooperative efforts have resulted in the development of viable wheat/soybean rotations in India, rice/soybean rotations in Sri Lanka, and maize/soybean and rice/soybean rotations in Peru. In these three countries the soybean crop did not replace other crops. Soybean production was successfully popularized on small farms ranging from 1-4 hectares. The cash income which soybeans have brought to thousands of small farmers has helped them economically. These experiences clearly show that such long-term multi-discipline collaborative efforts can lead to the introduction, establishment, and significant gains in soybean production within existing cropping systems of interested nations in the tropics and subtropics.

Soybean research and development activities in cooperating countries

INTSOY recently sent a survey questionnaire to scientists who cooperate in the international soybean trial network to better understand the current soybean research, production, and utilization activities and their needs in various countries. Cooperators from 54 countries responded to the survey with 47 nations being in the tropics or subtropics. Most respondents worked with Ministries of Agriculture and Agricultural Universities and on the average had slightly more than 5 years of experience working on soybeans. More than half had Masters' or Ph.D. degrees and devoted half-or full-time to work on soybeans.

The research programs of tropical and subtropical countries were less well established and the seed and inoculant industry was not well established to support production programs (Table 2). Diseases and drought rated as a more serious problem in the tropics than in the temperate countries. The crops most frequently rotated with soybeans in the tropics in order of importance were maize, rice, and wheat. There was considerable interest in growing soybeans as a single crop and also to grow in rotation with a number of other minor crops. Twenty-seven percent of the respondents indicated soybean was replacing cotton in the cropping pattern in their country.

When comparing various continents, the Americas and Asia had more advanced soybean research programs than did Africa. For example, more than two-thirds of the nations in Asia and the Americas had active breeding efforts, whereas in Africa, less than one-third of the countries had breeding programs. Inoculant and seed industries in African countries were much less prevalent also and the yields were considerably lover when trials were first introduced into Africa. There are many more problems relating to soybean production in Africa but research capabilities are less to overcome these constraints—clearly indicating that a greater research and development effort will be required to establish viable soybean industries in Africa.

Maize/soybeans was the most popular cropping system in Africa and the Americas, whereas rice/soybeans was the most popular system in Asia. In Asia, maize/soybean and soybean/other

Table 2 Comparisons between tropical/subtropical and temperate areas

	Tropical/Subtropical	Temperate
A. Respondents :		
- Number of countries	47	7
- Location of countries (%)	85	15
B. National Soybean Program		
- Have inoculant industry in country (%)	30	67
- Have seed industry in country (%)	38	67
- Important cropping sequence in countries of respondents (%)		
-Rice/soybean (%)	42	0
-Wheat/soybean	25	92
-Maize/soybean	57	42
-Soybean/other crop	43	17
-Single crop	40	17
-Replacement for cotton	27	8
C. International Soybean Trials		
- Reasons for yield reduction in trials (%)		
-Drought	37	8
-Disease	28	8
-Insects	13	17

crops were next most important, whereas in Africa, soybean/other crops was of second most importance and mono-culture of soybeans third. In the Americas, wheat/soybean was second and soybean mono-culture was third (Table 3).

Most comments on desired cultivar characteristics for each of the three regions appear to reflect the type of cropping systems in which soybean will be grown. For example, in Asia short duration cultivars (80-100 days) were top priority to apparently fit into the rice/soybean cropping systems. In Africa, 100-120 day cultivars were most frequently desired to fit into their maize/soybean cropping sytems. In the Americas, 120-140 day varieties were listed as most desirable, possibly because of higher percentage of mono-culture or more flexibility in their cropping rotation.

Disease resistance and tolerance to water stress were rated as the most important breeding objectives in the three regions. Insect resistance was rated high in Asia and the Americas. Tolerance to acid soils was also rated high in Asia and very important in tropical Africa and the Americas.

In all three regions protein meal was mentioned as the most important use for soybeans, both currently and as having greatest growth potential (Table 4). Soy foods rated as the second most important use of soybeans in Asia with edible oils a close third. Asian respondents perceive soy foods as having the greatest growth potential. In Africa, soy food and edible oil were a distant second and third in current use but both were expected to become very important in the future. In the Americas, edible oil was nearly as important as protein meal but soy foods were perceived as a significant growth area.

These results clearly illustrate the commonality of breeding, production, and research needs within a given region and the differences between regions. To develop appropriate technology for each country, regional cooperation will be essential.

Table 3 Staffing, soybean programs, ISVEX trials : comparisons between Africa, Asia, and the Americas from survey respondents

	Africa(20)*	Asia(14)	Americas(14)	Other	Overall average
A. Educational attainment of respondents(%)					
- Ph.D.	28	33	14	75	30
- M.Sc.	28	38	45	25	35
- B. Sc.	20	21	14	—	16
- Ing. Agr.	16	—	27	—	12
Percentage of staff working 1/2 to full-time	56	38	73	50	54
B. National soybean programs :					
- Have active breeding programs(%)	32	63	77	62	
- Have inoculant industry in country(%)	20	42	40	50	
- Primary cropping sequences in countries of respondents	Maize/Soybean Soybean/Other Soybean	Rice/Soybean Maize/Soybean Soybean/Other	Maize/Soybean Wheat/Soybean Soybean		
- Have soybean seed industry in country (%)	44	29	55	38	
C. ISVEX trials :					
- Average yields at first introduction	2,000 ton/ha	3,000 ton/ha	3,000 ton/ha	2.5ton/ha	
- Reasons cited for yield reduction in ISVEX trials :					
(1) Drought(%)	32	38	36	13	
(2) Disease(%)	20	38	23	13	
(3) Insects(%)	12	16	14	14	
- Countries which have released varieties from ISVEX (%)	40	42	40	50	

*Number of countries in parenthesis.

Table 4 Respondents comments on current and future uses of soybeans in Africa, Asia, and the Americas

	Africa	Asia	Americas
Current Uses*			
- Protein meal	64	75	82
- Edible oil	28	63	73
- Soy foods	36	67	27
Growth Potential for Future Uses*			
- Protein meal	76	79	82
- Edible oil	68	79	45
- Soy foods	56	79	45

*% of respondents saying was of major importance.

Global soybean research and development needs

It is clear that an expanded international effort is required if the nations in the tropics and subtropics are to fulfill their potential as soybean producers and consumers in the near future to enable them to meet their rapidly increasing edible oil and protein needs. The groundwork for such international cooperation has been laid during the past decade but improved coordinated efforts and funding must be made available to accelerate activity in the future.

A number of research areas must be addressed. The respondents in the survey listed improved germplasm and the training of their scientists as their most important needs for their individual countries (Table 5). Next most important were the needs for improved research facilities and production technologies. Respondents from Africa indicated that production techniques were their most important need.

Approximately one-third of the respondents indicated that the marketing and processing facilities and the development of soy products were most important to strengthening their national soybean programs. These needs were much higher in Asia and Africa than in the Americas where the soybean industry is more widely established.

This survey reinforces the views that the following programs must be strengthened through global cooperation in research and development:

Table 5 Perception of future need of respondents (%)

	Africa	Asia	Americas	Other	Overall importance
Improved germplasm	72*	83	72	50	75
Production techniques	76	42	41	13	49
Training of scientist	64	75	68	63	68
Research facilities	60	46	64	25	53
Marketing and processing facilities	32	50	23	25	34
Development of soy products	32	42	18	13	29

*Percentage of respondents indicating this to be important.

(1) Germplasm preservation, evaluation and enhancement: To globally preserve, document, evaluate, and enhance soybean germplasm, a dynamic network of collaborating varietal improvement scientists representing national, regional, and international organizations must be established.

For soybean germplasm preservation various organizations must work closely with the International Board of Plant Genetic Resources (IBPGR) to make a global inventory of soybean germplasm collections. The primary collection of cultivated species, related wild annual species and perennial species in a number of Asian countries must be speeded up. Financial support must be found to improve maintenance facilities for base collection in Australia, China, Japan, and USA and working collections in various countries.

Germplasm enhancement must be greatly expanded in tropical and subtropical environments. Dynamic breeding programs at regional network centers, AVRDC (Asia), IITA (Africa), and INTSOY/CIAT/ICA (Latin America) and in larger national programs such as Brazil, China, India and the USA must be expanded to serve as the collaborative base for regional networks to better exploit genetic diversity in gene pools for the tropics and subtropics.

National programs must be strengthened in the tropics and subtropics through regional network collaboration and training activities.

Existing international and regional and national testing programs should be integrated to effectively increase the number and diversity of germplasm tested. Tests must be expanded to include conditions common to those experiences in various cropping systems. More on-farm testing will be required.

(2) Improved production technology for various cropping systems: The IARCs and national programs must develop appropriate and economical agronomic production practices for a wide range of tropical and subtropical environments. Collaborative activities to develop integrated pest management practices to control diseases, insects, and weeds for various cropping systems environments are essential.

Improved technology must be developed for *Rhizobium japonicum* production and management under tropical conditions. This must be done in collaboration with NifTAL, BNF programs of several IARCs and national programs.

(3) Marketing, processing and utilization: The most urgent overall goal will be to encourage and increase soybean processing and need in most tropical and subtropical countries to establish processing facilities and soy products tailored to each country's needs and conditions.

There is a significant need to increase soybean utilization for human food on a global basis.

Global cooperation

It is clear that global cooperation is essential to exploit the significant potential for soybean production and utilization in the tropics and subtropics.

Strong national research and development programs are the foundation for successful soybean industries. Regional programs in genetic improvement and cropping systems agronomy located at the International Agriculture Research Centers (Asia: AVRDC, IRRI, and ICRISAT), (Africa: IITA), and (Latin America: INTSOY/CIAT/ICA) can support and strengthen production research in various countries. INTSOY can concentrate on utilization and basic research aspects of genetic improvement and evaluation and documentation.

A consortium approach among various international research organizations and selected national programs may provide the coordinating mechanism required to give proper attention to soybean production and utilization in tropical and subtropical countries.

Discussion

Palaniyappan, K. (India) : I would like to know whether INTSOY would help private companies in India in the cooperative research efforts for the promotion of soybean cropping and for establishing processing units ?

Answer : It is certainly important that both government agencies and the private sector be involved in this effort.

Carangal, V.R. (IRRI) : Can you elaborate more on how the international soybean research consortium would be organized and operate ?

Answer : The research consortium concept in soybean dates back to about 10 years. This consortium can be proposed as a mechanism to intensify soybean research for the tropics through improved cooperation of national, regional and international soybean programs. A secretariat could be established and member organizations could discuss and determine research priorities. The secretariat would work to obtain funds from donors to support member individual and joint research. There is a considerable amount of expertise in soybean research in many countries such as Brazil, the USA, India, China. Testing of germplasm should be promoted. It is important to strengthen regional and national breeding programs to generate improved germplasm so as to be able to increase soybean yields, in particular in the tropics.