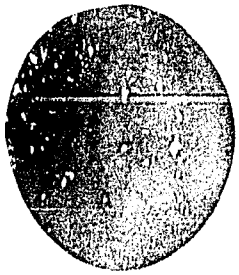

The Soybean Solution: Meeting World Food Needs

INTSOY · College of Agriculture
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Urbana, Illinois November 1986

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International Soybean Program
INTSOY

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Preface

Young children like this little girl from India need protein for proper physical and mental development.

This report is dedicated to the more than 1,000 scientists in 132 countries who have participated in the international soybean testing network since 1973. By sharing their soybean varieties and conducting the trials, each scientist has contributed to our knowledge about soybean germplasm and to the spread of benefits from soybeans to the less developed countries of the world.

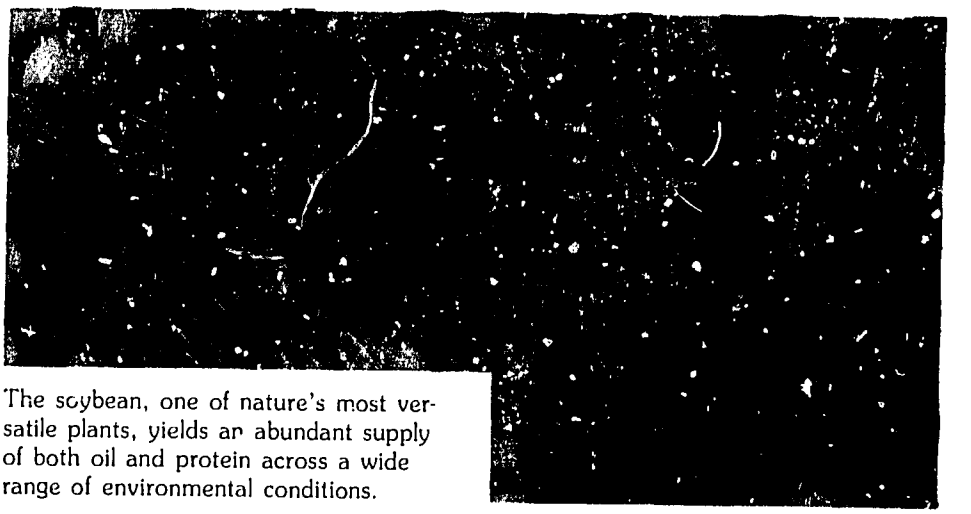
The University of Illinois and INTSOY are proud to be a part of the global effort to expand the use of soybeans for improving human nutrition. This cooperative venture has enabled many countries to carry on their own national soybean research programs. Through the continued cooperation of international organizations and national programs, soybeans can help relieve human hunger in many nations.

Soybeans: Food for a Hungry World

During the mid-1980s, across Ethiopia, the Sudan, and most of sub-Saharan Africa, drought once again exacted its price. But Africa is not alone in facing the grisly consequences of starvation, malnutrition, and hunger. Experts estimate that starvation and diseases related to malnutrition kill, in any given year, some 5 million to 20 million people in every corner of the world. Worst of all, more than half of the victims are children under five years of age.

The devastation from hunger, moreover, reaches far beyond the pockets of outright famine. According to the United Nations Food and Agriculture Organization (FAO), at least 400 million to 500 million children living in the world's 60 poorest countries suffer from chronic malnutrition, which permanently retards their physical and mental growth. More than a fourth of the world's people experience inescapable pangs of hunger during some part of each year.

Yet solving the world hunger problem requires much more than simply increasing caloric intake. The key,



The soybean, one of nature's most versatile plants, yields an abundant supply of both oil and protein across a wide range of environmental conditions.

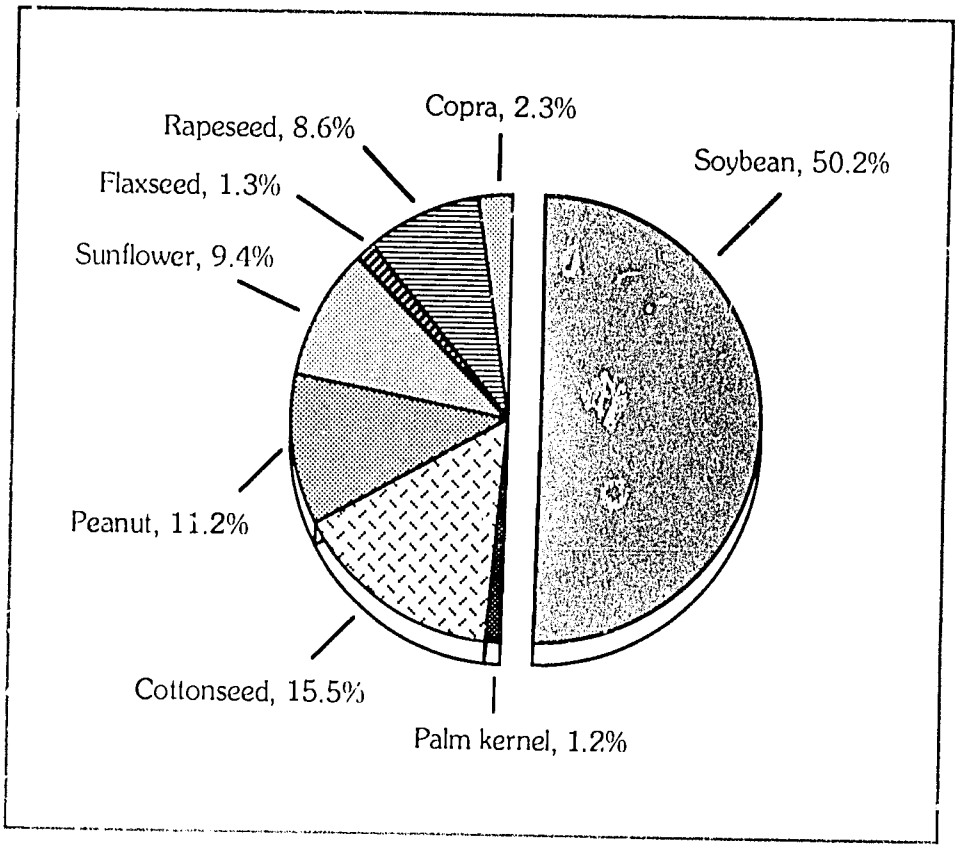


Figure 1. World production of high protein meal. Increasingly, the soybean is regarded as the most likely solution for overcoming the worldwide protein shortage.

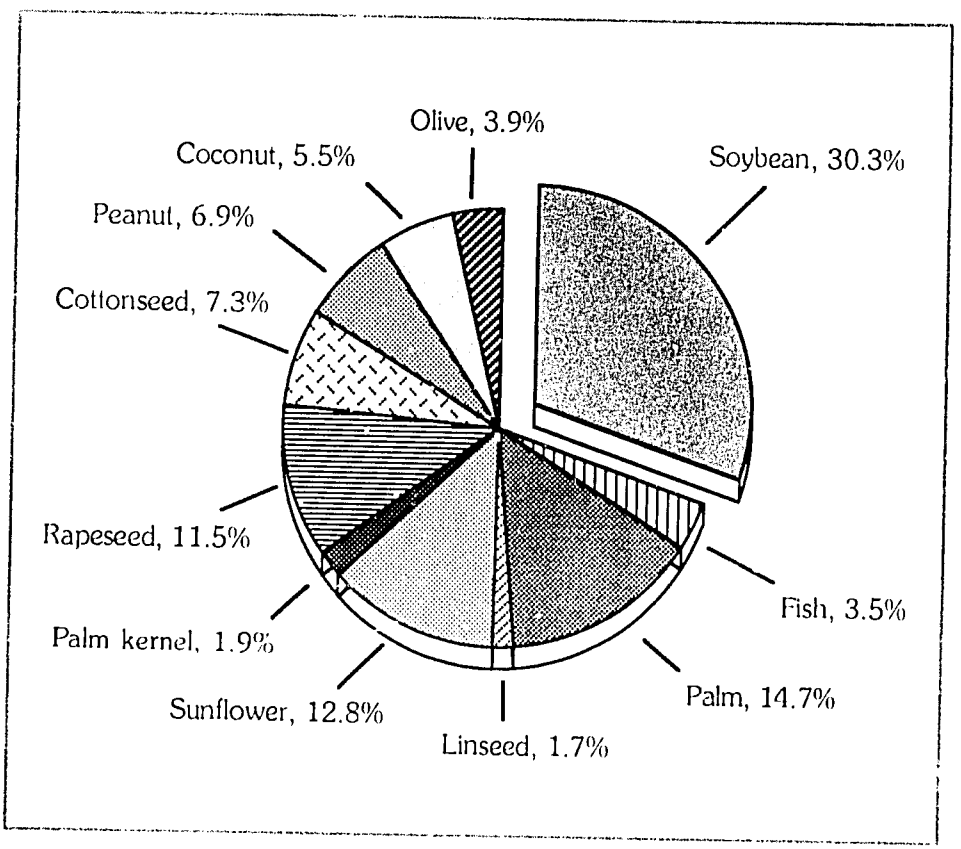


Figure 2. World production of edible oil. Much of the current world demand for soybean oil derives from its popularity as a cooking oil and as a base for margarine and other commercial products.

according to many experts, is to overcome the worldwide shortage of protein. This nutritional component is an absolute necessity in the human diet. Even among those who get enough calories, too little protein can be disastrous. Thus many argue that world hunger — especially among children — should be viewed primarily as protein hunger.

Currently, more than 70 percent of the world's human protein comes directly from plants. The remaining 30 percent is obtained from animal products. Developed countries, however, are major exceptions to this overall pattern. There, plentiful supplies of meat, eggs, dairy products, and fish account for most of the protein consumed. Also many of the more affluent developing countries in recent years have successfully expanded livestock production and fish farming to meet their protein needs.

But in the world's poorest nations, their spiraling populations, shrinking foreign credits, and dwindling tillable land make livestock production an increasingly untenable source of protein. It takes about 7 kilograms of protein meal to produce one kilogram of livestock protein. Cattle fattened in a feedlot need as much as 15 kilograms. The "feed cost" for an average-sized steak could provide 40 to 50 people with a bowl of cereal grains.

Many undernourished nations in Asia, Africa, and the Americas are continually searching for new ways to maximize the protein from plant sources. Increasingly, the soybean, called by some the Golden Bean because of its color and rich potential, is emerging as the most likely solution for overcoming the world's protein hunger (Figure 1).

The Golden Bean

Nowhere is the soybean's golden future more of a certainty than among the scientists and technicians the International Soybean Program (INTSOY), headquartered at the University of Illinois. With an emphasis on person-to-person contact, INTSOY staff members have worked directly with farmers and researchers in soy-

bean fields from the highland jungles of Peru and the sun-parched savannahs of Zambia to the lush, tropical rain forests of Sri Lanka.

More than 1,000 scientists from 132 countries have added their local expertise through an innovative, cooperative research network. The common goal is to improve nutrition in every part of the world through increased use of soybeans as human food. The task is difficult. Political, social, and economic obstacles are formidable. But none of those problems can obscure the soybean's unique potential to relieve the world's hunger for more protein.

Simply stated, the soybean is one of nature's most efficient protein producers. In fact, the soybean yields more usable protein per acre than any other commonly cultivated crop — at least three times more than rice, wheat, or maize. On average, commercial soybeans contain about 40 percent high quality protein. The ubiquitous rice in Asian diets is only 9 percent protein; maize, popular in many Central and South American countries, 12 percent; wheat, 15 percent; cassava, a mere 2 percent.

While most plant sources are seriously deficient in one or more of the nine essential amino acids, soybeans are an exception. Although methionine is a little deficient, soybeans can be eaten with wheat, maize, or rice, which contain more than enough methionine to compensate. The protein in one-half bowl of dry soybeans or one bowl of cooked beans is virtually equal to that in 150 grams of steak. In addition, the soybean has no cholesterol and is rich in vitamins, minerals, and calories.

The soybean is also an excellent source of unsaturated oil, with most varieties averaging a content of about 20 percent. Much of the demand for soybeans in the United States and other developed countries, as well as in many Asian countries such as India, derives from its popularity as a cooking oil and as a base for margarine and other consumer products (Figure 2).

This incredibly versatile plant even serves as a natural soil fertilizer. Rhizobium bacteria living in the plant's root nodules capture nitrogen from the atmosphere and "fix" it in the soil. Soybeans can fix about 50 kilograms of nitrogen per hectare, roughly equivalent to $60 worth of commercial fertilizer at 1986 prices. Nitrogen is used completely in the soil and thus causes no pollution.

The soybean's amazing attributes are certainly no mystery to the Chinese. For thousands of years, this crop, which probably originated in north central China, has served as a staple of their diet. The soybean was known from ancient times as "the meat of the fields." Today, soy foods such as tofu, miso, shoyu, soy milk, tempeh, and the immature green beans are an important source of protein for more than a billion people in China, Japan, and Korea, as well as Chinese population pockets across East and Southeast Asia.

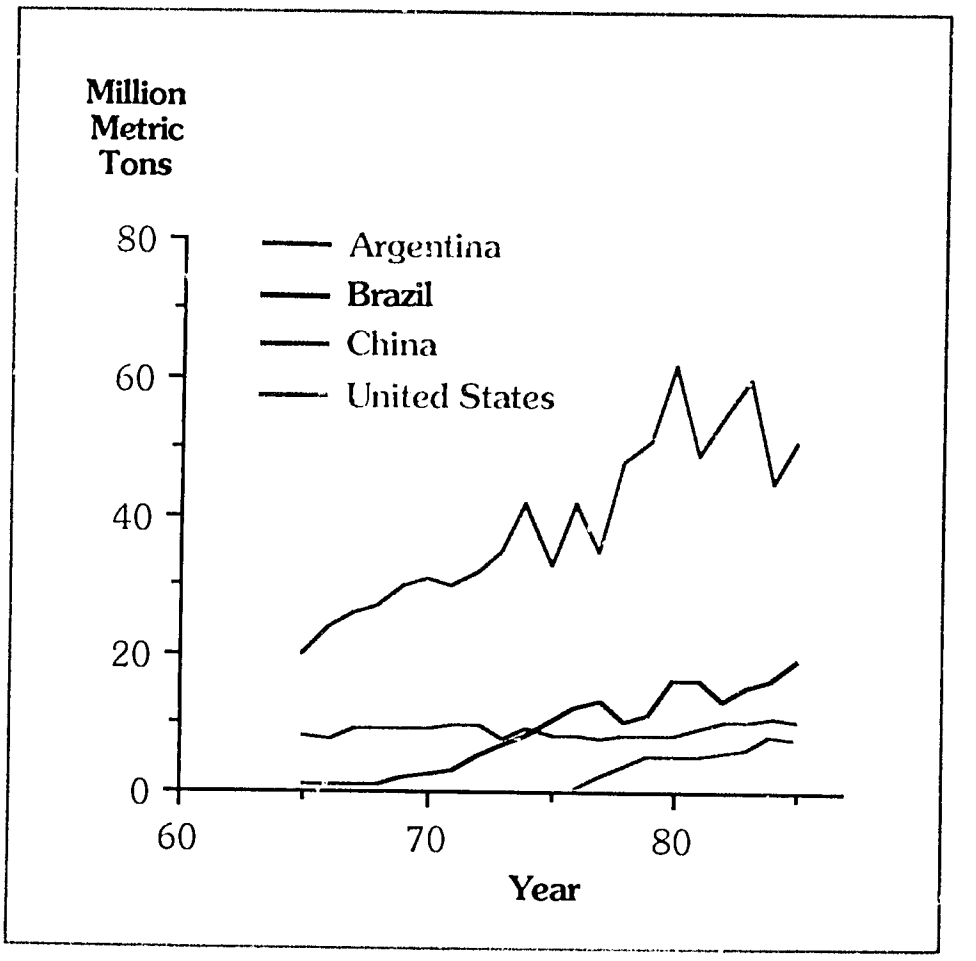


Figure 3. Production of soybeans in the Western Hemisphere and in China, 1965 through 1985. The United States, Brazil, and Argentina now account for more than 80 percent of world soybean production. The United States first moved ahead of China as the leading producer in 1943. Brazil surpassed China by 1975, and Argentina probably will do so during the 1990s.

Soybeans in the West

With the exception of some farmers and commodity brokers, however, the topic of soybeans does not excite most people in Europe and the Americas. The average consumer every day spreads margarine made from soy oil on toast or savors a slice of beef from a steer fattened on soy meal without once thinking about soybeans. Even in the Midwest region of the United States, endless fields of soybeans are routinely reduced to a blur glimpsed through the window of a speeding car.

Yet ironically, it is the Western Hemisphere countries of the United States, Brazil, and Argentina, where the soybean is largely under-appreciated as a direct food source, which now account for more than 80 percent of world production (Figure 3).

Together in the last 50 years they have experienced soybean production gains unparalleled in the history of global agriculture. As early as 1943, the United States first moved ahead of China as the leading producer. Brazil surpassed China by 1975, and Argentina probably will do so during the 1990s.

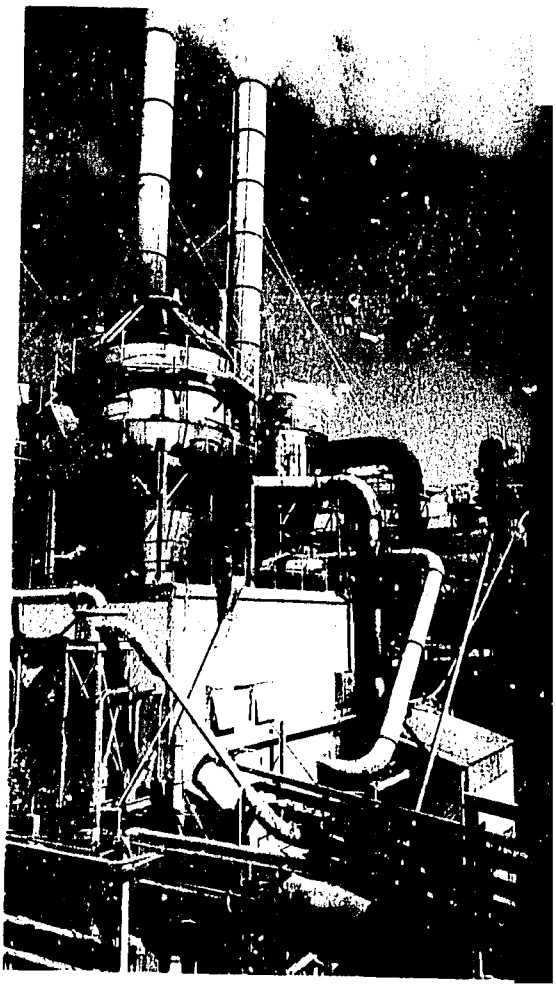
This massive shift in production from Asia to the temperate regions of the Americas began with the transfer of soybean breeding lines from China to the agricultural heartland of the United States. By mixing a heavy measure of sweat with genetic innovation and production know-how, Midwest farmers quickly transformed great chunks of prairie into the world's highest yielding commercial soybean fields. Following this model, Brazil and Argentina opened up the vast pampas to large-scale soybean cultivation.

In the 1930s, new solvent extraction technology for removing oil arrived from Germany just as the explosion in soybean production threatened to overwhelm existing processing facilities. This complex process — with its endless twists of piping and its baffling array of evaporators, cookers, and condensers — thrives on huge volume. In a solvent extraction plant, the more soybeans devoured in its mechanical maw, the more economical it is to operate. An average-sized facility easily consumes 2,000 tons of soybeans in one day.

Although even the smallest plant costs at least $20 million to build, the central process of soaking the beans in hexane, a petroleum-based product, is remarkably efficient in extracting edible oil. Nearly 99 percent is removed in solvent extraction. This compares with no more than 75 percent from other processes. The protein meal by-product provides large quantities of cheap animal feed and the base for numerous commercial uses.

The extremely low cost of oil and meal from solvent extraction, combined with the concentration of production in the temperate regions, has allowed a handful of nations in the Western Hemisphere to hold a virtual monopoly over world soybean markets. Developing countries in the tropics and subtropics simply lack the production and processing technology to compete. Even Asian countries such as Indonesia, Thailand, and Vietnam, where soy foods are widely eaten, have until recently treated soybeans as a minor crop.

Most of the world's highest yielding commercial soybean fields are concentrated in the temperate regions of the Western Hemisphere. The rich soils of Illinois, pictured above, are especially well suited to soybean production.



The solvent extraction facilities used in most developed countries are expensive to build and require a huge volume of soybeans to operate economically.

Simple processes for making a nutritious soy milk in the home have recently been adapted for use in several Latin American countries.

The INTSOY Solution

Some people argue that soybeans are in fact practical only as a large-scale cash crop, grown in temperate regions as raw material for the solvent extraction of edible oil and protein meal for animal feed. Developing countries in the tropics and subtropics, according to this point of view, should fill their needs by importing soybeans, rather than by growing them. Underlying this argument is the assumption that yields in the tropics and subtropics are inherently lower than those in temperate regions.

This position, however, has been repeatedly challenged by the first-hand experience and data that INTSOY gathered during more than a decade of cooperative international research. For the first time, the assumptions about the soybean's genetic potential have been subjected to rigorous scientific analysis. And the message that emerges from the resulting rows of numbers is one of hope for people in the world's undernourished nations.

Starting in 1973, INTSOY initially focused on a unique series of variety trials aimed at exchanging and testing an unprecented range of soybean germplasm. Through that program, INTSOY has collected, evaluated, disseminated, and preserved more than 2,000 soybean cultivars and breeding lines. The final results of the trials, along with practical knowledge gleaned from farmers in less developed countries, show without doubt that soybeans can be grown with high yields as a food crop in the tropics and subtropics.

The variety trials also confirmed that the soybean can adapt well to equatorial rain forests, craggy mountain terraces, or sparse, semi-arid lowlands. This genetic workhorse retains its high oil and protein content across a startling range of environmental conditions. Seed size, plant maturity, and plant height can be manipulated to fit local cropping systems. The soybean's potential is seemingly unlimited.

But as thousands of needlessly starving victims in Ethiopia confirm, it is real food that quiets hungry

stomachs, not promises and potential. With that in mind, the INTSOY staff is determined to have its achievements judged not only in laboratories, but also in the fields and villages of undernourished nations. INTSOY food scientists have spent literally thousands of hours working with soy food programs in Peru, India, and Sri Lanka to ensure that soy-based products developed at the University of Illinois are fully adaptable to local needs.

In Sri Lanka, the success of that approach has startled even its most optimistic backers. Starting with some basic concepts that INTSOY developed, the Sri Lankan staff of Soyabean Foods Research Centre has refined a great many flavorful, nutritious, and often spicy soy foods suited to local tastes. Several small-scale commercial operations now supply consumers with affordable soy products such as soy flour, soy milk, and an improved weaning food.

Through training programs at the center, more than 20,000 extension workers have learned simple techniques to process and cook whole soybeans in the home. They in turn have trained thousands of urban dwellers and farm families in easy methods to transform whole soybeans into delicious, low-cost meals.

Several small-scale operations now supply consumers in Sri Lanka with a high protein food supplement and affordable bread containing soy flour. These commercial enterprises were an outgrowth of a national soy foods research program.

This soybean bagging operation in Ecuador is an example of the economic activity that results when soybeans are introduced as a commercial crop.

Spreading the Benefits

Nevertheless, in many areas of the world, the shortage of efficient, small-scale processing equipment and poor local marketing systems continues to impede the acceptance of soybeans as a food crop for humans. Solvent extraction is unsuitable for many less developed countries because the processing facilities are expensive to build and require a huge volume of soybeans to operate economically. And simple Oriental processing techniques have not been accepted widely outside of East Asia because many consumers cannot get used to the "beany" flavor of traditional soy foods.

Small, commercial plants for processing soybeans, as well as extrusion cooking and oil expelling equipment designed for village use, have so far had only a limited impact. In fact, many of the world's middle-income countries still remain dependent on solvent plants originally built to extract cottonseed oil. These help meet the demand for edible oil but have had only marginal success in improving the diets of the urban poor or subsistence farmers.

For the least developed nations of the world, the current situation is even more dismal. Overwhelming foreign exchange problems and the lack of production and processing assistance have severely restricted the spread of soybeans. Clearly, most of the world's poorest nations will not benefit from the soybean's bounty until they are shown better ways of producing soybeans and can learn efficient, low-cost methods for processing them.

But INTSOY scientists are convinced that the soybean's protein power is equal to the challenge. Experiences in Egypt, Turkey, India, Peru, and Sri Lanka show that production and processing assistance can indeed spark a soybean explosion. Demand usually outstrips local production capacity. The net results are an improved agricultural economy, expanded markets for both imported and locally grown soybeans, and in many cases a more nutritious local diet.

In an effort to build on those successes, INTSOY scientists are intensifying their research on affordable extruders and oil expellers suitable for processing soybeans in small commercial plants and at the village level. Food scientists continue to search for new ways to pack more soy protein into a vast array of foods that have no trace of an off-flavor. Other researchers are refining ways to process and cook whole soybeans in the home.

This approach centers on the key premise that turning the soybean's potential into reality calls for processing technologies and food products that fit the needs of individual countries. The knowledge gained through the cooperative scientific network has already pointed out the way. INTSOY scientists are determined to follow that well-marked road. The goal is within reach. And millions of undernourished people around the world are the ones who will ultimately reap the benefits.

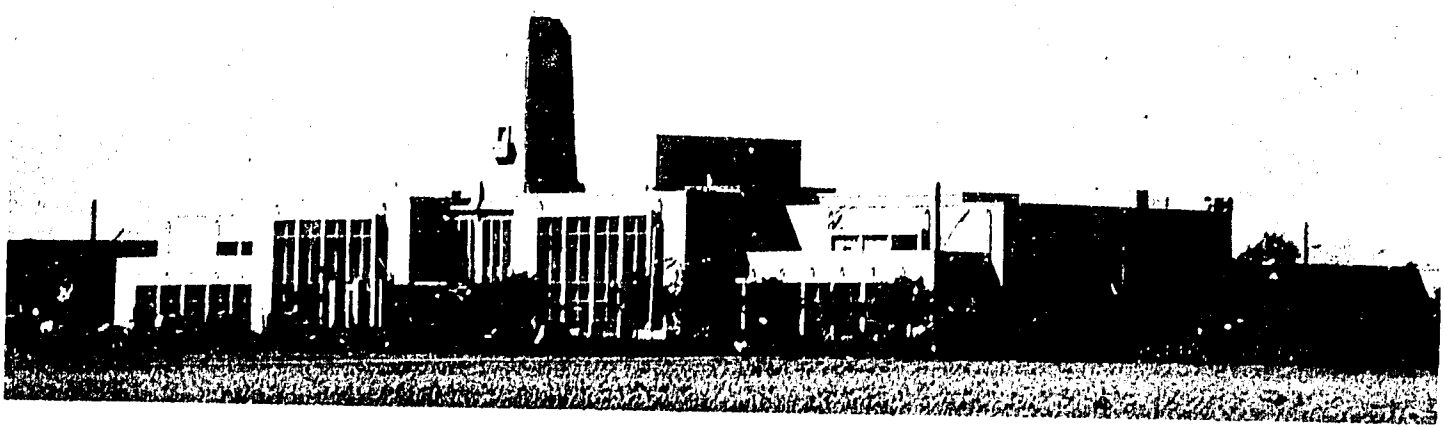
INTSOY: Building a Cooperative Network

As hunger refuses to loosen its grip on large parts of the world, more and more nations are rejecting the idea that large-scale technology is always the best way to produce food. In underdeveloped countries where abandoned fields and rusted tractors litter the rural landscape, big solutions have suddenly lost their allure. No longer is small equated with backward. Instead, many policymakers now view scaled-down technology as a potent new force for change.

The University of Illinois used the building of a new agricultural college in the Indian state of Uttar Pradesh as a springboard into international soybean research.

The concept of molding solutions to fit individual circumstances, however, is nothing new. For more than a decade, thousands of soybean scientists and ordinary farmers around the world have been sharing their knowledge with INTSOY. In turn, INTSOY researchers have listened carefully and responded to the needs of poor nations struggling to feed themselves. The result is a simple but effective formula for change: assess the capabilities of the people and regions involved and then introduce appropriate technology.

The key is to build upon what is possible under existing conditions. If local farmers produce more soybeans than they can use themselves, show neighboring families new ways to prepare the excess beans for cooking in the home. If a village has equipment for extracting oil from kapok, show the villagers how to modify that equipment for soybeans. As people improve their skills and the popularity of soybeans increases, new techniques and equipment can be introduced. The changes are gradual, but the final outcome can transform an entire village.



The Beginning of INTSOY

This pragmatic approach, which from the beginning has characterized INTSOY programs, is certainly no chance occurrence. Its origins are deeply rooted in the no-nonsense work ethic that has defined generations of Illinois farmers. That gritty determination not only transformed the state's countryside from prairie into the best farmland in the world. It also propelled the University of Illinois to the forefront of research on the production and processing of soybeans.

In the mid-1960s, the university expanded into international soybean research as part of a project to establish new agricultural colleges in the Indian states of Uttar Pradesh and Madhya Pradesh. A small group of specialists working in India envisioned some solutions to the world food crisis and then set out to test what they knew best — soybeans from Illinois. The promising performance of new varieties introduced from the United States soon led to the establishment of a national soybean research program in India.

As early as 1969, the University of Illinois began responding to requests from other countries for soybean germplasm to test. This informal program received a major boost in 1973, when INTSOY was established as a base for the worldwide exchange of soybean research information. What had been a modest beginning was quickly expanded into a cooperative research network encompassing hundreds of scientists in every part of the world.

As a first step, INTSOY coordinated a series of international variety trials to assess how well soybeans could grow in the tropics and subtropics. This program was modeled after the pioneer work of the International Center for Wheat and Maize (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines. Scientists at those centers used genebanks and high volume plant breeding programs to develop a diverse range of varieties. The most promising varieties were shared with other countries through the testing program.

Researchers in less developed countries responded by donating new breeding lines to the trials and by conducting tests under a wide range of environmental conditions. The results were carefully compiled and sent to the centers for analysis. Out of this exchange of information between scientists at the centers and those in national programs came the wheat and rice Green Revolution in Asia and Latin America.

In the rural state of Uttar Pradesh (above), the success of new soybean varieties prompted the establishment of a national soybean research program in India (below).

Table 1. *Trials in the ISVEX Program, 1973 to 1985*

Trials	Years	Number of cultivars per year	Target regions: Tropical	Sub-tropical	Temperate
Yield					
ISVEX....	1973 to 1975	16 to 20	X	..	..
	1976 to 1985		X	X	X
SIEVE....	1978 to 1983	26 to 48	..	X	X
SPOT	1976 to 1983	16	..	X	X
Observational					
ISOT	1984 and 1985	100 to 150	X	..	X

Countries That Donated Soybean Germplasm to the ISVEX Program

Asia	Africa	North America	Latin America	Caribbean Basin
Bangladesh	Cameroon	Canada	Argentina	Cuba
China	Ivory Coast	United States	Brazil	Honduras
India	Libya		Colombia	Puerto Rico
Indonesia	Nigeria		Ecuador	
Korea	Senegal		Guyana	
Philippines	Tanzania	**Europe**	Mexico	
Sri Lanka	Uganda	France	Panama	
Thailand	Zaire	Spain	Peru	**Oceania**
Vietnam	Zambia	Sweden	Venezuela	Australia
	Zimbabwe	USSR		

The ISVEX Testing Program

The International Soybean Variety Experiment (ISVEX) program, established by INTSOY in 1973, was specially adapted from the CIMMYT and IRRI models. Rigorous controls were imposed to make sure the results were valid. Thus each cooperating researcher was sent a standardized package of test materials. Each package contained packets of selected seeds, a quantity of granular soil inoculant, a log for recording results, and an instruction booklet in English, French, or Spanish.

Procedures for laying out the test plot were precisely explained. Sixteen different soybean varieties were included for testing at each site. Each variety was planted in four separate subplots located within a field of about 0.1 hectare. An individual subplot contained four rows, each of which was 5 meters long. Local scientists recorded eleven plant and seed variables for each of the 64 subplots and reported on the overall presence of insects and diseases.

Through this method, soybeans for the first time could be tested in a scientific way anywhere in the world. The sites ranged from the equator to 40 degrees north and south latitudes and from sea level to altitudes of 3,000 meters. Nepal at the base of the Himalayas was suddenly on an equal test footing with the sultanate of Brunei on the equatorial island of Borneo. Eventually, 132 countries joined in testing a vast array of soybean germplasm (See map, pp. 14-15).

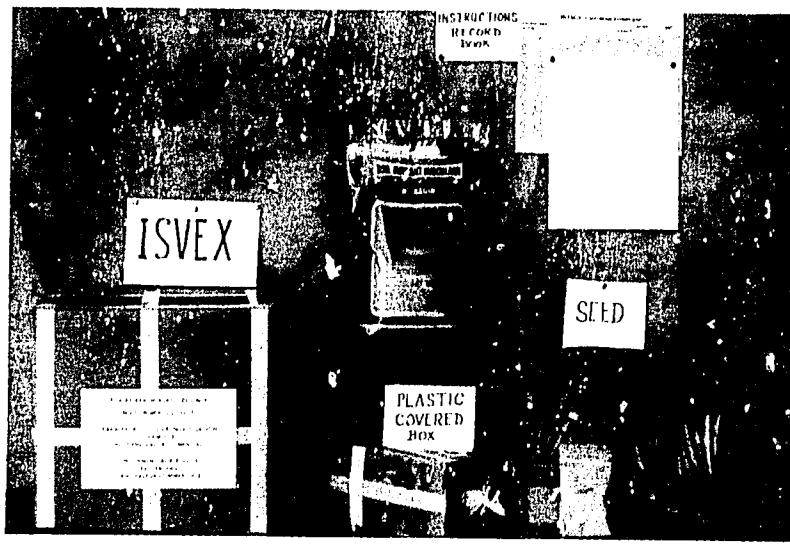
The early trials, however, were limited mostly to commercial varieties from the United States. Only a small quantity of germplasm could be obtained from other sources. Tropical breeding lines were in particularly short supply. To help overcome this problem, INTSOY in 1973 established a tropical breeding program at the University of Puerto Rico. In 1983, this program was moved to the Instituto Colombiano Agropecuario (ICA) in Cali, Colombia.

The dividends from expanding the genetic test base were quick to come. Tropical varieties bred by researchers in less developed countries attracted the interest of new cooperators around the world. As the program progressed, the new ones in turn contributed more of their best performing breeding lines to the trials. Eventually ISVEX was divided into separate tropical, subtropical, and temperate trials.

Two preliminary screening programs were also established to better identify and classify the overflow of new cultivars that had been suggested for future ISVEX trials. The Soybean International Experimental Variety Evaluation (SIEVE) was started in 1978 to test newly nominated varieties at three latitudes.

The best performing SIEVE varieties were then entered in the Soybean Preliminary Observation Trial (SPOT) for further testing at eighteen sites in nine environmental zones. In 1984, the two preliminary trials were combined into the International Soybean Observation Trial (ISOT). The number of varieties in each ISOT ranged from 100 to 150 (Table 1). Only the best performing lines from the preliminary programs made it into the ISVEX trials.

From 1973 until the program ended in 1985, cooperators from 34 countries donated several thousand breeding lines and varieties for evaluation and selection. Of these, about 350 varieties were tested in the SPOT and SIEVE trials and another 550 in the ISOT. By 1985, approximately 540 had been accepted into



The ISVEX testing program reached areas as isolated as the Himalayan foothills of Nepal (left). Each country, no matter how remote, received the same standardized package of ISVEX test materials (middle). During the final weeks of maturity, soybeans change rapidly (bottom). The number of days to maturity was one of eleven plant and seed variables measured in the ISVEX trials.

the larger ISVEX trials.

During the span of this program, more than 2,000 ISVEX trials, each containing sixteen test varieties, were dispatched to researchers around the world. Data from 1,077 trials were eventually analyzed and published in the annual ISVEX reports. The overall rate of return compared favorably with other international testing programs. Even the cooperating scientists who did not submit detailed data used the trials to screen varieties for further testing.

The final results of the ISVEX program confirmed for the first time the broad adaptability of soybeans to diverse environments (Appendix, Table A1). This was particularly encouraging because test varieties represented only a small part of the total soybean germplasm. Many promising subtropical lines, especially from China, where the soybean was first domesticated, have never been evaluated or used in breeding programs.

The Soybean's Genetic Potential

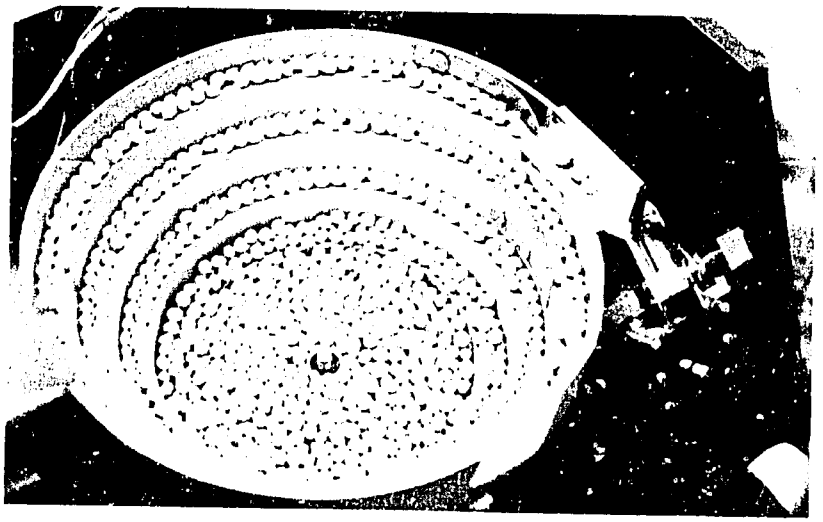
Yet despite the need to explore the potential of additional germplasm more fully, the final results of this thirteen-year study produced important information in several areas:

Yield potential. Summary analysis showed that the average yield for ISVEX varieties under experimental conditions was almost the same in the tropics (1,973 kilograms per hectare), the subtropics (1,925), and the temperate zone (1,946). Currently, however, farmers in many tropical areas often must grow soybeans under less than the best conditions. The result is average yields much lower than those in temperate growing regions.

Plant maturity. The number of days to maturity for trial varieties ranged from 87 to 150 days. Most countries need varieties of short duration to grow soybeans successfully

Countries That Participated in the ISVEX Trials

This map was adapted from *Illinois Research*, Winter 1985.



Seed size for each variety in the ISVEX trials was determined by the average weight in grams of 100 seeds sorted with an automatic counter.

in their present cropping systems. Based on the ISVEX results, cultivars from Brazil, Colombia, Ecuador, India, Zimbabwe, and the United States were released as commercial lines in other countries.

Plant height. The height of varieties in the trials varied from 27 centimeters to 122 centimeters. Although not strongly associated with yield, plant height is an important consideration if the crop is mechanically harvested. If the plants are too short, pods will be left on the stubble and if too tall, the plants tend to lodge.

Seed size and longevity. Seed sizes in the trials ranged from 7.6 grams to 20.6 grams per 100 seeds. Evidence indicated that large-seeded varieties will not remain viable in storage under tropical conditions for as long as certain small-seeded varieties. Large-seed types, however, are preferred for processing. 'MTD10', a large-seeded variety from Vietnam, showed exceptional longevity.

Oil and protein content. Samples submitted for measuring oil and protein content showed levels consistent across a range of years and environments (Appendix, Table A2). Average protein content was 42.3 percent, with a range from 37.6 to 45.1 percent. The average for oil was 21.8 percent, ranging from 18.5 to 24.0 percent. As expected, there was a negative relationship between protein and oil contents.

A Program of Mutual Benefits

From the beginning, however, the ISVEX research network was much more than a handy way to gather data. For scientists in a number of less developed countries, the testing program provided the push needed to upgrade their research. By working directly in the experimental plots, cooperating scientists learned valuable production and testing techniques. These skills in turn were passed on through local workshops and field days to farmers interested in growing soybeans.

INTSOY bolstered this in-country training by sponsoring regional conferences in Puerto Rico, Ethiopia, Thailand, Sri Lanka, Egypt, Colombia, and Indonesia. People who had been merely names on a roster thus had a chance to meet each other face to face. Through these sessions, researchers could exchange valuable scientific information with their colleagues from around the world.

INTSOY also provided intensive training courses on both production techniques and processing soybeans for food uses. From 1975 to 1985, about 200 people from at least 40 less developed countries attended these annual 10-week sessions on the University of Illinois campus.

This mix of conferences, workshops, and training sessions provided the catalyst to set in motion the worldwide exchange of information. Major new research developments were scattered from East to West through INTSOY's publications. Over the years, this series has included annual ISVEX reports, conference proceedings, reports on soy food research, and economic studies. INTSOY staff members have added to this flow of ideas by publishing some 400 articles in scientific journals.

Tropical and subtropical countries, as well as major producing nations in temperate regions, further benefited from the ISVEX network through the introduction of new germplasm. The resulting genetic diversity is essential to increase and stabilize soybean productivity in all parts of the world.

The trials also gave scientists a chance to study certain diseases and insects that do not occur in their own countries. Crop losses as high as 100 percent have been recorded in Asia and Africa from diseases that are not yet present in other parts of the world. Research in countries where these problems occur is essential for finding techniques to control them. It also helps prepare scientists to meet the threat from diseases and insects that might later be accidentally introduced into other areas.

Already, as a result of collaborative research with other countries, INTSOY plant pathologists have found a quick and easy way to test soybean seedlings for potential resistance to the fungus that causes the disease anthracnose. The technique has been used to screen a major portion of the U.S. Department of Agriculture's soybean germplasm collection for resistant lines.

Research with colleagues in several Asian and African countries has

also told scientists more about the organisms that cause soybean rust and Pyrenochaeta leaf blotch. Capable of devastating an entire soybean crop, these diseases have not yet reached the Western Hemisphere. By working where the two diseases occur, however, scientists can be prepared with innovative control measures should either one find its way into major growing regions.

At the same time, INTSOY entomologists have concentrated on measures to control soybean mosaic virus and the aphids that spread it. The virus is a major problem in Asia, where potential aphid vectors colonize soybeans. This strenuous research effort resulted in development of a computer model that predicts yield loss and recommends appropriate control measures.

As the research program grew, however, a number of countries moved from testing to trying out soybeans as a food crop. Within the cooperative network, there was a surge of interest in finding new ways of processing and using soybeans. INTSOY responded by focusing on the development of more efficient, low-cost processing equipment and new soy foods suitable for the needs of individual countries. INTSOY also worked closely with other international organizations to establish national soy food programs in India, Peru, and Sri Lanka.

In fact, INTSOY has now shifted completely from research on production and disease control to work on new ways to process and use soybeans as human food. But even as the ISVEX trials come to an end and priorities change, the worldwide research network remains in place to provide guidance for the future.

INTSOY-sponsored collaborative research has resulted in innovative measures to control the spread of potentially devastating diseases such as soybean rust (above). A large quantity of new germplasm from the ISVEX program is preserved in the extensive U.S. Department of Agriculture collection located at the University of Illinois (below).

Table 2. *Soybean Production, Imports, and Value of Imports for Selected Countries*

		Soybean production	Imports: Raw beans	Imports: Oil	Imports: Meal	Value of imports
		1,000 metric tons	*1,000 metric tons*			*$1,000*
Sri Lanka	1974-1976	0[a]	...	121	...	102
	1982	17[a]	...	469	1,357	847
	1983	15[a]	...	1,140	4,093	2,295
	1984	12[a]	...	500	8,150	3,100
Peru	1974-1976	2	...	...	...	...
	1982	8	700	64,293	26,126	36,685
	1983	2	9,612	74,994	20,162	42,718
	1984	2	4,300	50,000	10,000	37,100
Mexico	1974-1976	592[a]	257,510	28,345	...	86,257
	1982	550[a]	517,508	104,455	39,000	236,942
	1983	600[a]	894,104	37	169,000	273,820
	1984	550[a]	1,313,378	86,124	118,450	502,554
Ethiopia	1974-1976	15	...	...	...	...
	1982	12	...	500	...	655
	1983	6	...	3,145	...	3,417
	1984	6F[b]	...	6,800	...	7,500
Indonesia	1974-1976	566	63,233	35	3,105	7,182
	1982	521	361,000	226	71,769	115,968
	1983	568	221,515	216	103,569	89,180
	1984	615	401,024	13,600	206,077	187,998
Egypt	1974-1976	62	...	29,772	...	24,148
	1982	103	22,671	30,780	111,717	61,711
	1983	100	21,562	43,468	120,468	77,984
	1984	60	43,000	60,000	220,000	129,200
Turkey	1974-1976	8	10	45,768	150	30,731
	1982	36	299	64,293	...	65,751
	1983	46	2,459	74,994	...	42,589
	1984	60	58,000	50,000	...	123,403

SOURCE: *FAO Production Yearbook*, 1977, 1984, and 1985.
[a] Data from USDA. [b] F = Forecast.
NOTE: Data for Zambia and Costa Rica not available.

Table 3. *Selected Countries Involved in the ISVEX Program*

	Climate: Tropical	Climate: Subtropical	Climate: Temperate	INTSOY involvement: Long-term program	INTSOY involvement: ISVEX	Production gains: Major	Production gains: Modest	Production gains: Minor	Processing: Solvent extraction	Processing: Small-scale	Increase in imports: Major	Increase in imports: Minor
India	..	X	..	X	X	X	..	..	X	..	X	..
Sri Lanka	X	..	..	X	X	..	X	..	..	X	..	X
Peru	X	..	..	X	X	..	..	X	..	X	..	X
Mexico	X	..	..	..	X	..	X	..	X	X	X	..
Costa Rica	X	..	..	..	X	..	X	..	..	X	..	X
Zambia	X	..	..	..	X	..	X	..	X	..	..	X
Ethiopia	X	..	..	..	X	..	..	X	..	X	..	X
Indonesia	X	..	..	.	X	..	X	..	..	X	X	..
Egypt	..	X	..	..	X	X	..	..	X	..	X	..
Turkey	..	..	X	..	X	X	..	..	X	..	X	..

Results for Selected Countries

A number of examples show the many ways that nations have already benefited from the ISVEX program (Tables 2 and 3):

India. Indigenous, black-seeded soybeans were grown for many centuries in the north and central regions of India. Mahatma Gandhi encouraged the poor to grow and use soybeans in other parts of the country. This effort had little lasting effect, however. Modern soybean varieties were first successfully introduced in the late 1960s through the joint efforts of University of Illinois faculty and Indian scientists. Researchers from the national soybean program, established in 1967, were among the first in the world to introduce new germplasm through the ISVEX trials.

By crossing the newly introduced varieties with local lines, cooperators created a number of adapted varieties. Soybean cultivation grew rapidly in the summer fallow areas of Madhya Pradesh, reaching 750,000 hectares in 1985. The cooperative Madhya Pradesh Oilseed Federation helped the expansion by providing production technology and by purchasing and processing the beans.

Donations of U.S. soybean oil to India under the Food for Peace program (PL 480) played an important role in supporting the federation's efforts. Proceeds from the sale of donated oil were used to organize cooperatives and to teach farmers how to grow soybeans. These funds were also spent on improving the local marketing and processing systems.

Despite increased production, India's supply of soybean oil still falls far short of demand (Table 4). In fact, the value of imported edible oil reached $1 billion in 1985. On the other hand, most of the protein meal from domestic processing is exported, rather than used locally as human food or animal feed.

Sri Lanka. INTSOY's efforts also helped promote soybeans in Sri Lanka, where local cooperators conducted a total of 50 ISVEX trials. By 1983, commercial production, which began in 1975, had reached 15,000 hectares. INTSOY, along with other international organizations, aided in setting up the soy foods research center. All soybeans produced in Sri Lanka are consumed locally. In addition, some textured soy protein products are imported to fill the strong demand.

Peru. From 1977 to 1981, INTSOY staff members worked closely with the government of Peru to help soybeans gain a foothold in the high jungle regions of the northeast. Production increased from virtually nothing in 1977 to 13,000 metric tons in 1983. Locally accepted foods, such as a soy beverage in liquid and powdered form and soy-fortified bread and noodles, were widely available. Marketing and transportation problems, however, have restricted expansion in recent years.

Mexico and Costa Rica. The ISVEX program allowed both Mexico and Costa Rica for the first time to evaluate numerous tropical soybean varieties. Mexico conducted a total of 24 trials and Costa Rica 19 trials.

The new germplasm enabled the Mexican scientists to significantly strengthen their breeding and testing programs. Soybean production in Mexico has remained relatively constant since 1975. Mexico's imports of edible oil and protein meal have continued to grow at a much faster rate than domestic production. Most of the protein meal is used for animal feed. The American Soybean Association is currently working with Mexican officials to promote soy foods for humans.

By 1975, Costa Rica was commercially growing the best performing varieties from the ISVEX trials. Several thousand hectares are now grown specifically for processing in a small-scale plant that produces weaning food and a corn-soy meal for school lunch programs.

Zambia. In the late 1960s, soybeans were brought into Zambia from the neighboring country of Zimbabwe. By 1974, the ISVEX program was contributing new varieties to overcome a shortage of edible oil. A total of 37 ISVEX trials were conducted from 1973 to 1985.

Several varieties from the trials proved suitable for larger commercial

Table 4. *Soybean Area and Production in India; Imports of Soybean Oil and Other Oil, 1973-74 Through 1984-85*

Crop year	Area	Production	Soybean oil imports: Total	Soybean oil imports: PL 480[1]	Other oil imports: Palm oil	Other oil imports: Rapeseed oil
	1,000 hectares		*1,000 metric tons*			
1973-74	57	40	..	..	..	..
1974-75	92	65	..	..	..	..
1975-76	130	100	..	..	..	..
1976-77	185	135	436	49.7	199	186
1977-78	195	160	498	59.1	405	295
1978-79	350	294	524	52.1	434	112
1979-80	491	350	637	56.7	586	140
1980-81	560	450	635	52.8	407	117
1981-82	622	467	441	14.9	397	91
1982-83	770	491	454	19.8	529	99
1983-84	836	614	725	26.5	604	178
1984-85	1,192	934	529	18.6	720	247

SOURCE: *Oil World Update*, 1973-74 through 1985-86.
[1] Donation of U.S. soybean oil to India under the Food for Peace Program (Public Law 480)

Indian women sort seeds according to quality as a means of controlling the spread of crop diseases such as soybean mosaic virus.

In many Asian countries such as Sri Lanka, soybeans are often grown on rice-paddy bunds or under coconut trees.

operations. Small-scale farmers found the most productive varieties to be those nodulated with naturally existing strains of nitrogen-fixing bacteria. Soybeans are processed in a solvent extraction plant originally built for removing oil from cottonseed. The soybean oil is in great demand for cooking, and the meal is used as feed for cattle.

Ethiopia. Ethiopia conducted 35 ISVEX trials from 1973 to 1985. The main goal was to have on hand a supply of soybeans for a processing plant making soy flour and weaning food. Unfortunately soybean production has not been successful on a large scale because of widespread political and economic problems.

Indonesia. The Southeast Asian country of Indonesia has a history of soybean use dating back several centuries. Some of its traditional soy foods are completely different from those eaten in Japan and China. Average yields in Indonesia have always been low because soybeans generally are grown during the off-season, when they suffer many environmental stresses.

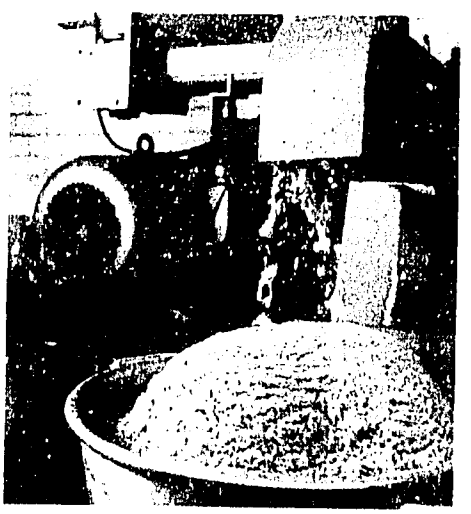
Indonesia has conducted 23 ISVEX trials since 1973. One South American variety from the trials was released for commerical use. Most of the test varieties, however, took too long to mature and could not be grown successfully in the country's intense cropping system. As a result of stagnant production rates, soybean imports have more than doubled in the past five years.

Egypt and Turkey. Both Egypt and Turkey have greatly expanded their oil and meal markets in recent years. Egypt first introduced soybeans through the ISVEX program in 1973. Turkey joined the trials in 1978. Both countries selected varieties adapted to local growing conditions and launched commercial production.

Most soybeans are processed in solvent extraction plants built for the cotton industry. The oil is used for cooking and the meal for feeding poultry. The market for soy foods is still rather small despite great interest in the soybean's potential as a human food. Meanwhile, rapidly growing populations in both countries have led to continued increases in soybean imports during the last five years.

Fulfilling the Soybean's Promise

A good-tasting, corn-soy granola bar (above) is one of several high protein products that can be produced from soybeans through extrusion cooking. The extruder pictured below uses a cooking time of less than 30 seconds. This is long enough to sterilize the raw materials and destroy the antinutritional components without damaging the protein.



Still, despite its many successes, the ISVEX program marks only a beginning in the effort to ease the worldwide shortage of human protein. New programs and ideas on how to use and process soybeans are needed to turn the basic knowledge gained from the trials into food for undernourished people. Fulfilling the soybean's promise will undoubtedly also require an expanded, cooperative network that links developing countries with each other and with researchers in developed countries.

For its part, INTSOY is committed to a new, three-part program spanning the period from 1985 to 1991. The first phase is an intensified research effort aimed at developing new soy products and processes. This phase is to be followed by simple "how-to" manuals and equipment lists for less developed countries and entrepreneurs interested in producing soy foods on a small or a large commercial scale. The last phase consists of on-site technical help for governments and private firms in less developed countries.

The INTSOY Research Effort

Already INTSOY researchers are intensifying work on small-sized and medium-sized processing equipment that can be used at the village and home levels. A major focus is on developing low-cost equipment for extrusion cooking and oil extraction. Improved extruders and oil expellers, for example, would allow farmers to remove as much as 75 percent of the oil with little or no damage to the resulting cake. The protein cake or meal could then be used in the same way as whole soybeans to make a number of food products. This technology has great potential for expanding soybean use in countries where there is a shortage of edible oil and a limited amount of capital for solvent extraction plants.

Work is also under way, in collaboration with University of Illinois food scientists, on a broad range of new soy products. Initial research concentrated on ways to inactivate the enzyme lipoxygenase before it can cause the "beany" flavor that so many consumers have objected to in traditional soy foods. This effort resulted in the development of numerous good-tasting, soy-based foods. The emphasis for all these products is on palatability and low cost.

University scientists have also refined methods to destroy antinutritional agents such as the trypsin inhibitor during the processing of whole soybeans. In addition, they have developed new techniques to tenderize whole beans by adding small amounts of sodium bicarbonate during blanching or cooking.

New Products and Techniques

These initial steps allowed researchers to develop several high quality dairy substitutes such as soy milk, soy yogurt, and soy ice cream. These products have a taste and texture almost indistinguishable from their dairy counterparts. At the same time, the new products are very low in cholesterol. Improved soy milk also offers a safe alternative for children who are allergic to cow's milk.

INTSOY's simple soy milk process (above) can be readily adapted for use in the home or village. The improved soy milk (below), which has no hint of off-flavor, serves as a base for several nutritious, low cholesterol products including soy ice cream and soy yogurt.

Additional research is aimed at increasing the number of products that can be prepared from raw soybeans through extrusion cooking. The relatively small-scale extruder equipment produces heat by friction under pressure. A screw forces the ingredients through a series of restrictions within a cylindrical chamber. This activity liberates heat, which cooks the raw materials. Temperatures can be controlled by varying the materials and the size of the chamber restrictions.

The time it takes to run the raw materials through the chamber is less than 30 seconds. This short cooking time is enough to sterilize the products and destroy the trypsin inhibitor. On the other hand, it is not long enough to destroy important nutritional components such as protein. The final product is a full-fat soy meal with a wide range of uses in preparing soy foods.

The extruder is particularly useful for blending soybeans with grains, vegetables, and even fruits. A protein content as high as 17 to 20 percent can be obtained when soybeans are mixed with corn or cereal grains. Another advantage of this blending process is an improved balance of amino acids. The most commonly used ratio is 30 percent soybeans to 70 percent corn. A low-cost, nutritious granola bar is already being produced using that combination.

The extruder can in fact produce an extraordinary variety of soy-based products, including snack foods, breakfast foods, soups, and soy-enriched additives. Other extruded soy products, such as an improved weaning food and food supplements for infants and young children, have been developed to fill special nutritional needs in the most undernourished parts of the world.

INTSOY food scientists are also refining several methods for preparing good-tasting soybean dishes in the home. Initial work showed that it was possible to tenderize the beans and destroy the enzyme that causes an off-flavor through a very simple process. First, the dry soybeans are broken into bits. The broken beans are then dropped into boiling water containing sodium bicarbonate. The result is a bland, highly nutritious soy base that can be easily mixed with other ingredients in traditional local dishes.

In addition, immature green soybeans, which have twice the protein of peas or lima beans, already show great potential as a frozen or canned vegetable for both domestic and certain foreign markets. Numerous taste tests of the cooked beans have been highly positive. Immature green soybeans do not compete with other soy products and give farmers the choice of an alternative early-season crop. Research is currently under way on improved techniques for harvesting and on better ways to break open the pods during processing.

INTSOY is also searching for simple processes to convert the residues from extrusion cooking into affordable, high quality animal feed. The goals are to determine the key nutritional components of extrusion by-products and to demonstrate the best methods for incorporating them into animal diets. Later, livestock feeding programs tailored specifically to cattle, swine, or poultry could be introduced in areas where extrusion cooking is used to process soybeans for human use.

As new products and techniques are developed, INTSOY food scientists will be available to help both governments and individuals establish new soy food processing facilities. Those receiving assistance could range from an enterprising businessman who wants to build a soy milk or weaning food plant to a government ministry interested in subsidizing the purchase of extruders and oil expellers by a village cooperative.

The choice of an overall strategy to promote the use of soybeans is wide open. Each country can blend different parts of the strategy to fit its own specific needs. For some nations with huge urban populations, solvent extraction technology may best fill the need. For many Asian countries, traditional Oriental processing can serve as a springboard for growth. But almost every country — large or small — can benefit in some way from the nutritious foods and whole soybean processing techniques devised by INTSOY.

The Need for Continued Cooperation

Yet despite all its accomplishments, INTSOY cannot succeed alone. Cooperation from scientists in national programs and at international centers is essential for bringing the soybean's protein power to areas where it is needed most. Already, for example, the International Institute of Tropical Agriculture (IITA) in Nigeria is using a combination of soybean production assistance and training in home processing to relieve chronic protein deficiencies among children in one of the poorest areas of its host country.

The Kersey Children's Home, located in the Ogbomosho region of southwestern Nigeria, is a rural clinic specializing in childhood diseases. Each year, it treats as many as 22,000 outpatients, most of them suffering from protein malnutrition. In 1984, the clinic staff began using soybeans as the major protein source to combat this problem. A nutritious soybean paste forms the base for many recipes used in the clinic.

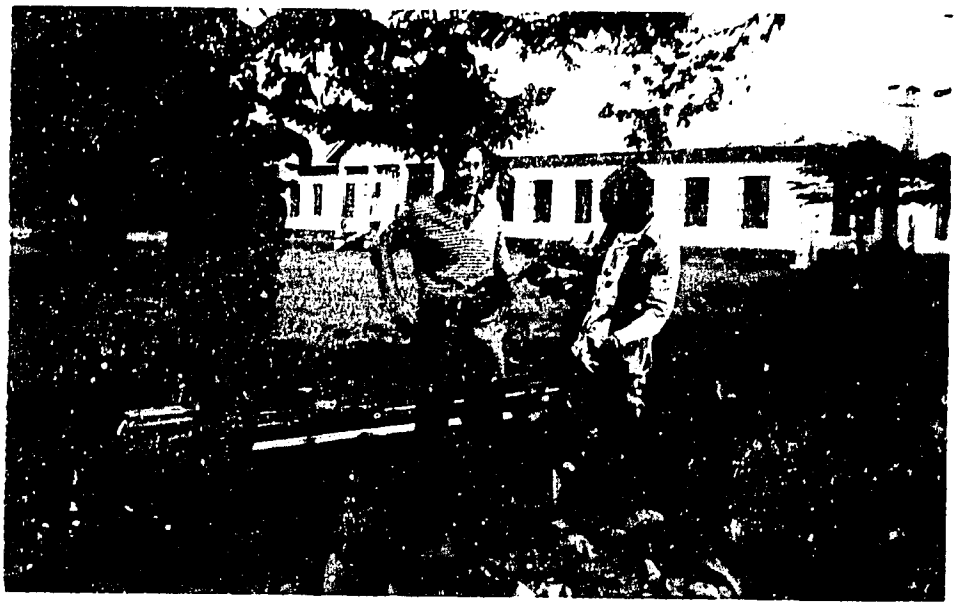
The clinic also launched an effort to teach mothers of small children how to prepare soy milk and use soybeans in local dishes. In addition, the soy base was added to weaning food and was used as a supplement in soup.

In 1985, clinic staff members began working with IITA to clear land and set up a soybean demonstration plot. They also distributed free illustrated pamphlets in local languages and sold seeds at reduced prices to farmers. A number of local farmers are now growing the crop. Soybeans are available in local markets and are widely used in the local diet.

This kind of remarkable success only further confirms INTSOY's basic premise that increased use of soybeans can help meet the world's nutritional needs and, at the same time, benefit those who produce soybeans. Major producing countries can gain from expanded new markets as more and more people become familiar with a wide range of whole soybean foods. Less developed countries benefit through an improved diet and increased economic development as more entrepreneurs produce soy foods on a commercial basis.

No longer can soybeans be dismissed in much of the world as merely a secondary crop, grown in a secondary season, as a secondary farm activity, carried out mostly by secondary farmers. Nor, as the world protein shortage continues to escalate, can soybean researchers ever again be described even in jest as secondary scientists who receive secondary attention and secondary facilities.

Instead, through the efforts of INTSOY and the cooperative network, soybean research around the world has taken on new vigor. Already IITA is a focal point for adapting soybeans to the special needs of Africa. For Asia, the Soyabean Foods Research Centre in Sri Lanka is an important model. The pieces of the puzzle are now in place. New achievements are just beyond the horizon. The outcome could be the release of many people from the bonds of chronic protein hunger.



At the Kersey Children's Home in Nigeria (above), soybeans grown on the clinic's site provide a valuable source of protein. Soy foods are used to treat chronic deficiencies that afflict many children in the neighboring villages (below).

Appendix

Because most varieties in the ISVEX trials were tested for fewer than four years, it is difficult to make a direct comparison of raw data on performance of individual varieties over the many years of the trials. Therefore, results of the most frequently tested varieties have been adjusted in relation to the performance of a check variety that was grown each year. Summary Tables A1 and A2 reflect this adjustment.

The following formula was used in calculating the values for each variety in the tables:

$$\text{Adjusted value} = \frac{\text{Average of the check variety in all trials}}{\text{Average of the check variety in specific year}} \times \text{Yield of test variety}$$

As the analysis shows, the average yield for all varieties was almost the same in the tropics (1,973 kg/ha), the subtropics (1,925 kg/ha), and the temperate zone (1,946 kg/ha). The results indicate that the yield potential is similar in all three growing environments.

The tables also show the variation in days to flower and maturity. The number of days to flower ranged from 27 for 'Foster' in the tropics to 67 for 'Improved Pelican' in the temperate zone. The fewest number of days to maturity was 87 for 'McCall' in the temperate zone and the same for 'Tracy' in the tropics. At the other extreme, 'Jupiter' took 150 days to mature in the temperate region.

Plant height varied from 122 centimeters for 'Improved Pelican' in the temperate zone to 27 centimeters for 'Hardee' in the tropics. Plant height was not strongly associated with yield. The average seed size of varieties in the trials ranged from 7.6 grams per 100 seeds for 'G2120', an unimproved variety from Indonesia, to 20.6 grams per 100 seeds for 'Hutton', an improved variety from the United States.

Publications of individual trial results for each year from 1973 to 1985 are available through the INTSOY office. Data for 1979 to 1985 are available on computer tapes for analysis by interested scientists. Information on the trials and other programs can be obtained from:

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Table A1. *Performance of Soybean Cultivars Included Two or More Years in ISVEX Trials at Tropical, Subtropical, and Temperate Locations*

Cultivar	Year first tested	No. years tested	Yield, kg/ha	Days to flower	Days to maturity	Plant height, cm	Seed size, g/100
Tropical							
Jupiter	1973	11	2,058	42	109	67	18.2
Davis	1973	10	2,146	32	88	35	18.5
Williams	1973	10	1,941	29	89	45	19.2
Improved Pelican	1973	11	1,970	36	98	70	14.5
Bossier	1974	9	1,906	31	96	39	17.4
UFV 1	1978	6	2,214	35	105	44	16.5
Tuna	1978	4	2,227	32	103	59	19.3
SJ 2	1978	4	1,955	36	102	70	14.8
Caribe	1978	4	1,840	39	116	83	13.5
Forrest	1974	4	1,935	32	92	35	15.2
Ransom	1977	4	1,828	28	96	33	19.4
G2120	1979	3	1,801	47	103	92	8.6
Cobb	1977	3	1,803	31	97	35	18.6
Hampton	1973	3	1,922	33	95	32	19.7
Hardee	1973	3	2,134	36	98	27	17.2
Bragg	1973	3	2,089	33	93	37	18.4
Hill	1973	3	1,856	35	89	36	16.4
Alamo	1980	3	2,079	42	105	53	15.9
Foster	1980	3	1,811	27	91	33	17.2
ICA L-109	1980	3	1,869	39	112	67	12.8
IGH 23	1980	3	1,978	44	111	74	17.2
IGH 24	1980	3	1,988	46	116	74	16.0
SIATSA 194	1982	2	2,233	38	106	83	20.1
Rillito	1978	2	2,079	28	93	47	17.2
Tracy	1974	2	1,443	31	87	32	18.2
Hutton	1973	2	1,930	32	96	33	20.6
Bonus	1973	2	1,871	30	90	44	18.5
Calland	1973	2	2,093	31	95	47	19.4
UFV 1 (BP 2)	1980	2	2,132	34	103	79	15.8
ISRA/IRAT 44A/73	1982	2	2,058	38	105	60	14.4

continued

Table A1. *Performance of Soybean Cultivars — continued*

Cultivar	Year first tested	No. years tested	Yield, kg/ha	Days to flower	Days to maturity	Plant height, cm	Seed size, g/100
Subtropical							
Jupiter	1973	5	1,832	49	119	78	16.4
Davis	1973	10	2,060	41	106	46	16.1
Williams	1973	10	1,934	33	96	47	17.9
Forrest	1974	5	1,932	36	102	44	14.2
Improved Pelican	1973	3	1,968	43	106	77	12.7
Bossier	1974	7	1,679	35	96	40	16.3
UFV 1	1980	3	2,511	36	119	63	14.4
G2120	1979	4	1,500	65	123	105	7.6
Hampton 266	1973	3	1,851	38	98	41	18.1
Bragg	1973	3	1,992	34	102	41	16.5
Alamo	1980	3	1,934	60	120	69	14.2
Braxton	1981	3	1,957	38	103	48	18.7
Ransom	1976	3	1,936	41	108	39	16.9
Rillito	1977	2	1,825	42	109	56	16.1
Calland	1973	3	1,935	33	100	103	18.5
Cobb	1977	2	1,723	45	117	48	15.9
Hardee	1973	2	2,211	38	106	44	16.5
Crawford	1981	2	2,266	35	97	53	16.9
Bay	1980	2	1,991	38	104	46	18.4
Celest	1980	2	2,160	40	104	49	18.3
Mitchell	1977	2	1,984	35	99	51	16.8
Hill	1973	2	1,724	36	95	46	15.0
Bonus	1973	2	1,813	29	90	51	16.8
Cutler 71	1973	2	1,917	34	99	51	18.2
Tracy	1974	2	1,622	28	88	34	17.4
Centennial	1980	2	2,092	39	102	46	15.3
Ecuador 1	1982	2	1,708	52	124	70	16.5
Essex	1981	3	2,071	36	102	39	15.9
Foster	1980	2	1,934	40	106	45	14.7
Gail	1980	2	2,099	39	101	43	18.3
PK 73-94	1980	3	2,151	43	109	53	14.9
PK 73-86	1982	2	2,129	42	117	55	15.5
Ware	1980	2	1,403	34	97	35	21.1
SIATSA 194	1982	2	1,632	54	121	95	17.3

continued

Table A1. *Performance of Soybean Cultivars* — *continued*

Cultivar	Year first tested	No. years tested	Yield, kg/ha	Days to flower	Days to maturity	Plant height, cm	Seed size, g/100
Temperate							
Jupiter	1974	2	2,092	66	150	106	15.1
Davis	1973	6	2,324	53	126	72	15.8
Williams	1973	11	1,964	37	106	64	16.3
Improved Pelican	1973	3	2,177	67	135	122	12.3
Hampton 266A	1973	3	2,203	53	123	64	12.1
Bragg	1973	4	2,388	46	121	86	15.0
Caland	1973	5	2,304	36	107	76	17.4
Bossier	1974	4	1,958	55	137	83	14.8
Columbus	1975	4	1,853	40	114	72	16.0
Corsoy	1979	5	1,829	33	98	89	14.6
Hodgson	1979	4	1,619	30	93	49	15.4
Crawford	1979	4	1,888	42	113	73	15.3
Evans	1979	5	1,604	30	90	43	14.6
Hill	1973	3	2,046	50	113	64	14.0
Cutler 73	1973	3	2,212	37	111	89	17.7
Forrest	1974	3	2,168	50	123	63	14.0
Cobb	1975	3	2,271	50	130	70	14.4
Clark 63	1974	3	1,854	38	111	68	15.7
Mitchell	1977	3	2,024	38	108	70	16.5
Kent	1980	3	1,968	41	114	68	16.8
Tracy	1974	2	2,016	49	124	62	16.0
Woodworth	1975	2	1,597	37	104	60	14.9
Franklin	1978	2	1,805	37	108	69	16.2
Celest	1980	2	1,940	60	127	75	17.9
Essex	1981	2	2,233	54	123	65	14.7
Hardin	1981	2	1,604	33	98	52	14.8
Harlon	1980	2	1,562	31	91	52	16.5
McCall	1979	3	1,464	29	87	42	14.6
Will	1980	2	1,980	36	101	54	15.9
Clay	1982	2	1,580	29	90	39	14.8
Fayette	1982	2	1,924	38	106	66	15.4
Lakota	1982	2	2,031	32	96	60	14.5
Pixie	1982	2	1,907	40	108	40	15.8

Table A2. *Oil and Protein Contents of Soybeans Produced at Tropical, Subtropical, and Temperate Locations*

Year and location	Bossier		Improved Pelican		Williams		Jupiter	
	Protein	Oil	Protein	Oil	Protein	Oil	Protein	Oil
	percent							
1974, Tropical	41.9	23.7	42.9	23.3	41.7	24.0	41.2	24.2
Subtropical	41.5	22.6	42.8	22.3	41.1	22.7	40.6	23.1
Temperate	42.0	21.1	43.3	20.0	40.8	22.4	45.0	19.4
1975, Tropical	44.2	22.7	44.4	22.3	43.1	23.4	43.4	23.6
Subtropical	44.8	22.1	43.7	22.6	42.0	24.0	42.1	23.6
1976, Tropical	41.4	22.2	41.2	22.6	39.2	23.2	39.6	23.5
1977, Tropical	44.9	20.0	45.1	21.7	43.7	22.4	43.2	21.8
1978, Tropical	44.0	21.5	43.8	21.5	43.7	21.5	43.1	20.1
Subtropical	43.2	20.7	42.8	20.9	41.9	21.7	41.2	21.0
1979, Tropical	42.5	21.4	41.9	22.1	42.0	22.3	41.6	21.8
1980, Tropical	43.6	20.9	44.0	21.5	43.1	21.7	43.2	21.2
1981, Tropical	39.1	18.5	39.2	19.1	37.6	19.2	38.5	19.6
Average	42.8	21.4	42.9	21.7	41.7	22.4	41.9	21.9
Standard deviation	1.69	1.37	1.58	1.18	1.82	1.31	1.82	1.68

Analysis of covariance

	df	x^2 (Protein, pct.)	xy	y^2 (Oil, pct.)	r (Correlation)
Total	47	88.425	14.874	145.797	.1310
Location	11	74.202	30.669	113.582	.3341
Cultivar	3	4.367	−7.065	14.147	−.8989
Cultivar x location	33	9.855	−8.730	18.069	−.6542