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Reports on the proceedings of the third regional soybean conference to review all aspects of soybean production, protection, economics, and utilization. It was held in Chiang Mai, Thailand. The purpose was to call attention to the importance of soybeans in human nutrition, to bring together scientists from Asia and Oceania who are working with soybeans, and to encourage the exchange of information among scientists. This report includes all of the gneeral session papers, symposium discussions, and country reports. The papers on soybean production include breeding varieties for the tropics, varieties for southeast Asia, soil fertility and moisture studies, control of seed-borne microorganisms, and concepts of improvement in lower latitudes. Papers on protection include weed control in tropical and Asian soybeans, foliar diseases, root and stem diseases, nematode diseases, virus diseases, and insect pests. Other papers are on fermented soybean foods, nutrition and processing, small scale equipment for oil extraction and the economic aspects of developing soybean markets in India. The symposia topics included soybean rust, biology and control of major insect pests of Asian soybeans, breeding tropical soybeans, small scale soybean processing and extension of the research to the village farmer. Country reports are given from Australia, Bangladesh, India, Indonesia, Iran, Japan, Korea, Malaysia, the Philippines, Saudi Arabia, Sri Lanka, and Thailand.

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EXPANDING the USE of SOYBEANS

PROCEEDINGS OF A CONFERENCE FOR ASIA AND OCEANIA

Held in Chiang Mai, Thailand
February 1976

Robert M. Goodman, Editor

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Foreword

In February 1976 the International Soybean Program (INTSOY), the Asian Vegetable Research and Development Center (AVRDC), and the Government of Thailand, Ministry of Agriculture and Cooperatives, sponsored a conference held in Chiang Mai, Thailand. The purposes of this conference were to call attention to the importance of soybeans in human nutrition, to bring together agricultural scientists of Asia and Oceania who are working with soybeans, and to encourage the exchange of information among scientists from the region and around the world. Financial support was provided by the United States Agency for International Development.

This was the third such regional soybean conference cosponsored by INTSOY to review all aspects of soybean production, protection, economics, and utilization, with emphasis placed on the region in which the conference was held. The first conference convened in Puerto Rico in February 1974 for tropical America. The second was held in Addis Ababa, Ethiopia, in October 1974 for Africa, the Middle East, and South Asia and was cosponsored by the Ethiopian Institute of Agricultural Research.

More than 230 scientists representing all aspects of agricultural science from 21 countries attended the most recent meetings in Chiang Mai. These Proceedings include all of the general session papers, symposium discussions, and country reports from this highly successful conference. We earnestly hope that this volume and the conference from which it is taken will help agricultural scientists and political leaders in both the developing and the developed nations around the world deal creatively and successfully with the challenges of increasing world food production and improving human nutrition.

Adequate food production is one of the major problems facing mankind, and the problems that exist in tropical and subtropical areas are especially acute. Cooperation among those directly concerned with these problems is vital. To this end, the Chiang Mai conference concluded with a symposium on extension of research results to the village farmer. Extension work is an essential link between what we know or can learn and its application on the farm. The extension symposium was an eloquent statement of the importance of establishing an alliance between research workers, extension personnel, and farmers.

The sponsors wish to thank all who attended the conference. Those of us at INTSOY and AVRDC deeply appreciate the support and hard work of our colleagues in Thailand, whose arrangements and hospitality made the visit of so many international guests a pleasure. To the Governor of Chiang Mai Province and the Deputy Undersecretary of State for Agriculture and Cooperatives we owe a special debt of gratitude for attending the conference and setting the tone during the opening ceremonies.

The sponsors are deeply indebted to Sheila Ryan Wiley, who reviewed every paper in these Proceedings and assisted the editor in assuring the literary quality of the final versions published here. Arleah Dix, Vicki Toews, Sheila Welch, and Maralyn Chew in the office of the Department of Plant Pathology, University of Illinois, helped with the typing, and their assistance is gratefully acknowledged. We are also grateful to Peter Laramie of the Ford Foundation Multiple Cropping Project, Faculty of Agriculture, Chiang Mai University, who fluently translated the opening address of the Governor of Chiang Mai Province.

INTSOY, AVRDC, and the Government of Thailand are proud to have been associated with this effort. We look forward to continuing cooperation among the workers who attended the conference and the international agricultural research community in general.

Robert M. Goodman, Editor
Urbana, November 1976

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OPENING ADDRESSES

The Future of Soybeans in Asia

Adul Nyomphiphat

The Director, International Soybean Program of the University of Illinois; the Associate Director, Asian Vegetable Research and Development Center; distinguished delegate participants, ladies and gentlemen.

It is my great pleasure to have the opportunity to be here with you this morning and to participate in the opening ceremony of this regional soybean conference. It is especially an honor to welcome you, since this is the first time in the history of my country that international scientists have joined together in a group such as this to discuss the various aspects of soybeans. On behalf of the Thai Government, Ministry of Agriculture and Cooperatives, and on my own, I would like to welcome you to Thailand and to Chiang Mai. Even though your stay in Thailand will be of short duration, I hope it will be a happy and useful one.

The Thai Government for some time has recognized the importance of soybeans as a multiple purpose crop benefiting the Thai people in general and the Thai farmers in particular. The current national economic and social development plan for 1972 to 1976 considered the production, protection, utilization, and economics of soybeans as one of the major crop priorities for this five-year plan. Undoubtedly this priority will also be included in the five-year plan beginning next year. I trust that our involvement with soybeans will indicate to the delegates from other lands our willingness to cooperate with you in the various activities that will ultimately benefit all of the people in this region and that will perhaps have an impact in other parts of our world.

I personally find the objectives for this conference very appealing. If these goals can be realized, it will certainly be a highly successful conference of which all of us can be proud. Furthermore, this conference could make a significant contribution to the future success of soybeans in this part of the world. Even though this meeting cannot solve all of the problems of soybeans, I predict it will be valuable in many ways and that all of us will be more knowledgeable because of it.

Friendships established here will enable us to communicate and cooperate more easily on problems that need to be solved. In my opinion, the personal contacts established here with fellow workers will provide much better understanding, new ideas, and more willingness to work together. This could be one of the most valuable contributions of this meeting to soybean research.

I wish to convey my thanks to the organizing committee for selecting my country for this meeting. I trust that each of you will find new challenges for your work, and I wish each and every one of you success. I hope you will have fond memories of us and the people of Chiang Mai as you go about your duties.

Adul Nyomphiphat: Deputy Undersecretary of State for Agriculture and Cooperatives, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Welcoming Address by His Honor the Governor of Chiang Mai

Chalaw Tomasiri

Mr. Deputy Undersecretary of State, the Director of the International Soybean Program (INTSOY), Associate Director of the Asian Vegetable Research and Development Center, distinguished guests from Illinois, distinguished guests from Puerto Rico, and various delegates from around the world.

I wish to welcome you all in the name of the people of Chiang Mai Province. For those of you who have come to Thailand, but have not yet been able to listen to Thai, it is as though you have not yet arrived. You might think you are attending a conference in the United States of America. I have visited Puerto Rico and the United States; consequently, I am happy to hear that there are guests here from Puerto Rico, as well as from Illinois. We are happy and honored to welcome you all to our city for your conference. For the people of Chiang Mai always welcome guests enthusiastically.

In the past ten years the Province of Chiang Mai has changed considerably, just as the rest of the world is constantly changing. Within the Province many hotels have been built. We now have a variety of tourist attractions and many artifacts for sale, all of which indicate the development of the Province of Chiang Mai. Those of our guests here today who have returned after perhaps three or four years undoubtedly realize that there have been many changes.

Please allow me to do a little public relations before the meeting begins. Next year the city will have an international airport so that when you come again, you will be able to fly directly here. Also, Chiang Mai is planning to export a variety of agricultural products throughout the world, such as flowers, vegetables, fruits, and possibly soybeans. Because of its colder climate, Chiang Mai is one of the few provinces in Thailand that is able to plant many different types of crops. Up in the hills during the past year, the temperature got as low as 0° Centigrade. There was no snow, but there was ice. It seems to me this climate offers an advantage for developing our agriculture.

Here in Chiang Mai the Thai Government has established the Northern Agricultural Development Center, which covers an area of about ten provinces in the north. At the present time we are experimenting with various types of crops that can grow during the cold season. Quite possibly during your stay here you will have the opportunity to try some of our strawberries and vegetables, especially soybeans. The weather conditions and soil are quite favorable for planting soybeans; consequently, I am happy that the conference has chosen Chiang Mai as its base of operations.

There are many other things I would like to say, but your time is somewhat limited. If I tell you about everything, there will be nothing left to say. I hope you will have the opportunity to investigate various points of interest on your own. I know you will be taking a look at things related to your work, but if you go exploring points of interest not included in the program, you might not receive the right answers.

In the name of all the government officials and the people of Chiang Mai, please allow me once again to welcome you very heartily. I hope that you will have an enjoyable time during your stay here. If some things cause you discomfort, I apologize for them now. A small city such as ours receiving so many guests may not be able to do the job quite adequately. I also wisl to thank the translator for his efforts this morning. Excellent interpreter [in English]! Again, I wish you success, as well as happiness, during the conference. And when you return to your homes, please take back some souvenirs of Chiang Mai, specifically articles, not people.

Chalaw Tomasiri: Governor of Chiang Mai Province, Chiang Mai, Thailand.

The Role of AVRDC in Soybean Crop Improvement

James J. Riley

Deputy Undersecretary, Mr. Governor. Let me tell you how pleased we are to be in Thailand and especially in Chiang Mai. We want to welcome the participants of this conference on behalf of AVRDC. I do not think that I have ever attended a conference that was so well organized locally, including, I might say, the World Soybean Research conference this past summer at the University of Illinois in Urbana. Although that, too, was well organized, I think no one could do any better than what has been done here. AVRDC as an international center is proud to participate in this conference.

Smallest of the international agricultural research centers and located near Shanhua in southern Taiwan, AVRDC has devoted its limited resources to the improvement of six crops (soybean, mung bean, tomato, sweet potato, Chinese cabbage, and white potato) during the past three years.

These crops are some of man's richest sources of vitamins, minerals, and plant proteins. In tropical Asia, these nutrients are needed to supplement the staple diet of rice, which is high in starch and low in protein and vitamins. Current production of these six crops in most tropical and subtropical regions of the world is inadequate to meet dietary requirements on a year-round basis.

The principal research objective of AVRDC is to increase the yield potential and nutritional quality of crops that are particularly suited for supplementing the rice diet and increasing the income of the Asian rice farmer by diversifying his production activities.

AVRDC's research and training staff is led by 19 professionals representing seven nationalities and is organized into three multidisciplinary programs, namely, the Vegetable Legumes; Horticultural Crops; and Nutrition, Environment, and Management Programs. Thus, a coordinated effort is being made to solve the problems limiting both the quantity and the quality of vegetable production in the humid tropics.

Soybean is a major world crop; however, varieties suitable for the lowland tropics have not yet been developed. Given varieties better adapted to tropical conditions, soybean should become a high protein crop for local use and an important export crop for the developing countries of the tropics as well. A large soybean germ plasm collection (over 9,000 entries) has been assembled and is being screened to identify sources of tolerance to tropical conditions, diseases, and insects.

Mung bean has been a popular legume in Asia for centuries. It is an excellent source of easily digestible protein and is eaten in many forms, including bean sprouts, green beans, boiled dry beans, noodles, and bean curd. Mung bean has not received the kind of research attention that has been given to most other food crops. Yet, through a concerted large-scale research program, its yield potential is being increased considerably. This is being achieved by breeding varieties that not only make more efficient use of solar energy and soil nutrients, but that are also more resistant to insect and disease attack.

Tomato is a popular crop almost everywhere and is an excellent source of vitamins A and C. It is also an important cash crop for small farmers. Unfortunately, tomato production in the tropics is beset by many handicaps, principally those of disease susceptibility and of poor fruit set in hot rainy weather. AVRDC tomato breeding lines are being tested throughout the region and are performing very well.

More people can be fed from a hectare of sweet potato than from a hectare of rice. At AVRDC we are developing varieties that can produce roots containing high amounts of β-carotene and protein. We are also looking for varieties with high yield and earlier maturity in order to fit multiple cropping patterns. In addition, we are screening the sweet potato germ plasm and breeding lines for high yield when grown without fertilizer, pesticides, and irrigation. Results to date have been most promising.

The heading type of Chinese cabbage (*Brassica pekinensis*) is another popular crop that has seasonal difficulties in the lowland tropics. Although well adapted to higher altitudes and cooler seasons, it does not form

James J. Riley: Associate Director, AVRDC, Shanhua, Tainan, Taiwan.

heads in hot weather and is readily attacked by several serious diseases and many insect pests. AVRDC scientists are developing new heat-tolerant, disease-resistant varieties of Chinese cabbage.

Although the white potato is a staple food crop in many parts of the world, it does not do well at low elevations in the humid tropics. AVRDC, in cooperation with the International Potato Center (CIP) in Peru, is making an effort to develop a white potato that will form tubers under tropical conditions, particularly during the hot, rainy months. Summer yield trials of AVRDC's more promising selections did very well near Davao City, Philippines, in 1975.

Outreach programs have been established in Korea and the Philippines, and numerous "scientist-to-scientist" contacts have been made with colleagues around the world. Scientists from all over the world are encouraged to utilize AVRDC's research facilities for advanced studies, and to take advantage of the Vegetable Production Training courses begun in February 1976 with participants from the Philippines, Indonesia and Taiwan.

Those of you who are able to arrange your schedule to visit AVRDC are most welcome to do so. Those of you who have other commitments or are from Thailand and will be going no farther than Chiang Mai or Bangkok or Mae-Jo are welcome to pick up a copy of the AVRDC brochure or the annual report. Let me say again we are pleased to be here as cosponsors of this conference. The greater part of the preparations made here, however, have been carried out by the Thai representatives. Our part has been rather minor, but we are pleased to be associated with this conference.

Soybean Production and Utilization: A Cooperative Endeavor

W. N. Thompson

Honorable Deputy Undersecretary, Honorable Governor, our joint sponsors, soybean workers, both ladies and gentlemen.

It is a pleasure for INTSOY to be one of the sponsors of this conference. The theme, Expanding the Use of Soybeans, is especially significant because it expresses the mission of INTSOY and those with whom we work on a national and international scale. Those of you who are familiar with INTSOY know that it is a cooperative program between the University of Illinois and the University of Puerto Rico, Mayaguez Campus, serving in a leadership role in the network of organizations and individuals with interests in soybeans. The relationship between the two universities is very special because it has enabled us to establish a bridge between the temperate, tropical, and subtropical zones. Let me emphasize, however, the importance of the network of agricultural research, education, and development organizations working cooperatively to provide more and better food for the ever-increasing numbers of people of the world.

The process of planning for this conference and your presence are gratifying testimony to the cooperation within this soybean network. Planning has involved work with several organizations and many individuals in Thailand. As the week passes I know you will agree that the local arrangements committee has done a tremendous job, and I am also confident that you will be impressed with the hospitality and efficiency of the Thais as joint conference sponsors and hosts. The joint sponsorship with AVRDC is also significant because it indicates the degree of cooperation possible with an organization that is active both regionally and internationally.

This is the third conference of this type that INTSOY has sponsored in cooperation with other organizations. The first, held in February 1974 at the University of Puerto Rico, Mayaguez, was primarily for representatives from Central America, South America, and the Caribbean. The second, held in Addis Ababa, Ethiopia, in October 1974, was for scientists from Africa, the Middle East, and South Asia. Following that, we began immediately to plan for this conference, which promises to be the best of the three because of the experience gained from the previous two conferences and because of the expertise of soybean workers in this region of the world.

These conferences have been supported to a considerable extent through special grants from the United States Agency for International Development. Although the sum of money was not large enough to cover travel expenses for the many delegates, we are pleased that individuals and their sponsoring organizations have been willing to invest in the personnel and travel costs necessary for persons such as yourselves to participate.

Some of us come to Asia humbled by the fact that soybeans are an old, old crop in this part of the world. We have seen what the combination of research, education, enterprising farmers, business, industry, and the organizational infrastructure can do in adapting a crop to different production environments and consumer uses. We have seen, during less than one career time span, the development of soybeans from a very minor to a major crop. Concurrently, there have been important soybean developments at research stations, in farmers' fields and food laboratories, and within the homes of both temporate and tropical Asia.

We fully appreciate why the soybean has been named not only *Glycine max*, but also "the miracle crop" and "the Golden Bean." But the potential of soybeans as a human food is far from being fully exploited. There is much to be learned here as we anticipate being able to achieve a blend between what is known about soybean production in temperate areas and what is known about soybeans grown under tropical and subtropical conditions. Similarly, we expect to build on the wide range of uses of soybeans and soybean products, with emphasis on the most efficient ways of using soy foods to meet the compelling needs of large numbers of people who are less than adequately nourished. We hope this conference will enable us to discover new areas of research and development, so that soybeans might become a still more important means of improving human nutrition.

W. N. Thompson: Professor of Agricultural Economics and INTSOY Director, University of Illinois, Urbana, Illinois, U.S.A.

The focus of INTSOY and others in the soybean network is on all aspects of the crop — production, marketing, processing, and use. It should be emphasized, however, that we are interested in soybeans finding their proper place in the farming system of the producer and in the combination of food uses of the consumer. Soybean production and use are to be encouraged only where farmers and consumers feel that they have a place. As suggested by the conference theme, the special qualities of the soybean give us confidence that it has a major and increasing role to play in a world faced with expanding needs and demands for both protein and calories. Indeed, the problem is upon us right now. Your presence is an expression of both your interest in assisting with the problem and your confidence in soybeans as a significant part of the solution.

I hope you will find this conference enjoyable. More importantly, I hope you will find something professionally useful that can be of service to your people when you return home. The point that the Deputy Undersecretary made about developing friendships is well taken. Conferences such as this provide the opportunity to establish personal relationships, so that communication between soybean workers will be facilitated on both a regional and a worldwide basis. If the conference fosters that objective, it will have been a success.

GENERAL SESSIONS

Breeding Soybean Varieties for the Tropics

B. B. Singh

The origin, distribution, and production of soybeans indicate that the crop has been confined primarily to the temperate zone. Soybeans originated in northeastern China between 35° and 45° N. latitude, and even today most of the world acreage planted to soybeans is in this latitudinal range. Up to 1966 the area under soybeans in the tropics and subtropics accounted for only 4.5 percent of the world soybean acreage. Since that time it has increased only slightly, even though considerable efforts have been made to popularize soybean cultivation in the tropics. Interestingly, the small quantity of soybeans grown in this region is restricted mainly to hilly regions or similar areas having moderate temperatures and low humidity. For example, soybeans have been grown for centuries in the northern hills of India, but not in the plains. Probably the hot, humid climate and short days in the tropics have not been congenial to soybean cultivation, and apparently little effort was made in the past to develop soybean varieties specifically suited to tropical conditions.

Recent soybean adaptability trials, conducted in different tropical locations with introduced varieties from temperate regions, have revealed a number of production problems associated with soybean cultivation. The widespread occurrence of a number of diseases and pests, poor seed germination, less growth due to short-day conditions, and failure of nodulation due to varying soil conditions are some of the major factors limiting soybean development in this region. It is quite likely that the same problems might have frustrated any attempts made in the past to popularize soybean cultivation in the tropics and subtropics. Therefore, soybean breeding programmes undertaken in this region must aim at developing high yielding, disease-resistant varieties with good germinability and wider adaptability under tropical conditions.

This paper summarizes the progress made in identifying sources of desirable genes needed for solving the aforementioned problems, and also includes a few points on breeding methodology and selection criteria for developing soybean varieties for the tropics.

BREEDING FOR DISEASE RESISTANCE

The hot, humid climate of the tropics and the dense canopy of soybeans provide an ideal environment for the development of a number of diseases. Yellow mosaic, soybean mosaic, bud blight, rust, *Rhizoctonia,* stem canker, pod blight, bacterial blight, and bacterial pustule have been observed at several places. However, the most widespread and devastating of all, yellow mosaic and rust, cause yield losses up to 70 percent in severe cases. Some of the varieties from the southern United States, such as Hardee, Bragg, and Semmes, which yielded about 4 tons per hectare in 1967-68, yielded only 1.2 to 1.4 tons per hectare when severely affected by rust and yellow mosaic in 1970-71 at Pantnagar (Table 1). In contrast, the yield of Clark 63 in 1970-71 was not affected. Clark 63 flowers and matures earlier than the other varieties used in this study and therefore escaped the disease.

In 1970 systematic screening of soybean germ plasm was initiated at Pantnagar to identify sources of resistance to yellow mosaic and rust. In 1971 the entire soybean germ plasm obtained from the United States Department of Agriculture (USDA) was also screened. From a total of about 4,000 lines screened, only 2 lines were immune to yellow mosaic, 6 resistant to rust, and 15 moderately resistant to rust (Table 2) (Singh et al., 1974). In addition, a few lines tolerant to yellow mosaic have also been identified.

A number of segregating populations involving these resistant lines and varieties with agronomically superior characteristics have been produced. Performance of some advanced breeding lines derived from these populations is very encouraging (Table 3, Fig. 1). Populations involving sources resistant to yellow mosaic are now in F_6 and some of the progeny appear very good. Therefore, high yielding varieties combining resistance to yellow mosaic and rust may be available soon. Sources of resistance to other diseases have been summarized by Hartwig (1973) and these should be used wherever such problems exist.

B. B. Singh: Department of Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar, Dist. Nainital, U.P., India.

Table 1. Days Required for Maturity and Yield of Some Selected Varieties in Four Years at Pantnagar[a]

Variety	Maturity (days) and yield (kg/ha)							
	1967		1968		1970		1971	
	Maturity	Yield	Maturity	Yield	Maturity	Yield	Maturity	Yield
Hardee	127	4,518	129	4,050	116	2,333	107	1,429
Bragg	120	4,051	121	3,883	104	1,799	100	1,298
Semmes	121	4,601	121	3,287	106	1,599	102	1,211
Clárk 63	103	3,102	101	3,098	100	3,099	...[b]	...

[a] No rust in 1967 or 1968; severe rust in 1970 and 1971.
[b] Data not available.

BREEDING FOR INSECT RESISTANCE

A number of insects attack soybeans, but those causing noticeable damage are defoliators, such as the hairy caterpillar (*Dicrisia obliqua*), tobacco caterpillar (*Spodoptera littoralis*), indigo caterpillar (*Laphygma exigua*), and semilooper (*Plusia orichalsia*); the stem miner (*Melanogromyza sojae*), and whitefly (*Bemisia tabaci*) are also important. Chemical control measures are effective, but when the crop is grown in the rainy season, it becomes difficult to follow spray schedules.

Little work has been done to screen the soybean germ plasm to identify insect-resistant lines. However, the discovery of lines resistant to Mexican bean beetle (P.I. 171451, P.I. 227687, P.I. 229358) by Van Dyan et al. (1971) and potato leaf hoppers (dense pubescent lines) by Singh et al. (1971) indicates the possibility of obtaining lines resistant to other insects as well, provided proper screening is done. Preliminary field screening of the germ plasm lines maintained at Pantnagar has shown marked varietal differences with respect to damage due to defoliators. Twenty lines showed very little damage due to defoliators when adjacent rows were completely destroyed by the insects; UPSM-930 appeared to be the least affected. Further screening is in progress.

BREEDING FOR BETTER SEED QUALITY AND GERMINATION

Ensuring adequate plant stand is one of the major problems in soybean cultivation. The poor germinability of soybeans may be partly due to inherent factors and partly due to adverse environmental factors. The hot, humid climate in the tropics reduces the seed quality at the time of maturity and causes rapid loss of viability during storage.

Genetic variability for seed quality in soybeans has

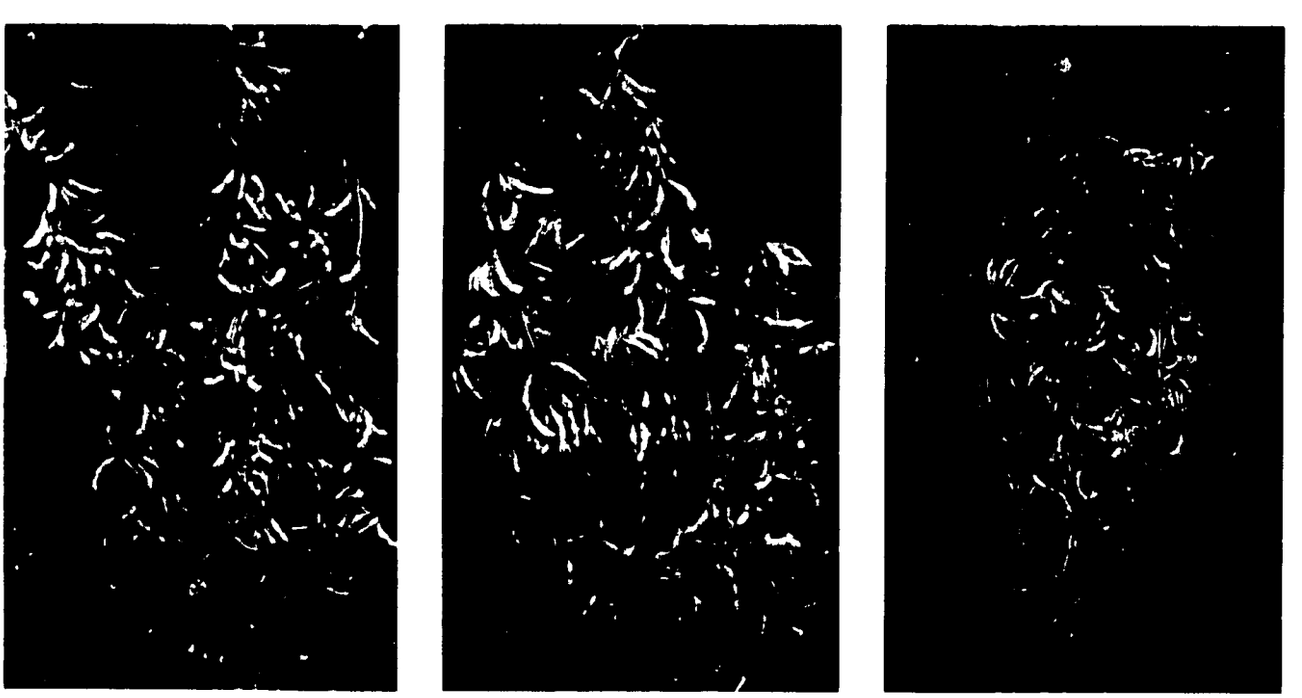

Fig. 1. Some promising breeding lines of soybeans. Left to right: PK-73-94 (resistant to rust, tolerant to yellow mosaic); PK-71-21 (resistant to yellow mosaic, tolerant to rust); Ankur (resistant to rust).

Table 2. Soybean Lines Showing Resistance to Yellow Mosaic and Rust

Introduction number	Variety	Original source
Resistant to yellow mosaic		
P.I. 171443	.....	China
G. formosana (a variety of *G. Soja*)	.....	China
Resistant to rust		
P.I. 200465	Fusanaridaizu	Shikoku, Japan
P.I. 200466	Gakubun	Shikoku, Japan
P.I. 200477	Hondadaizu	Shikoku, Japan
P.I. 200490	Keburi	Shikoku, Japan
P.I. 200492	Komata	Shikoku, Japan
P.I. 224268	.....	Hyogo, Japan
Moderately resistant to rust		
E.C. 11695	.....	.....
E.C. 50081	.....	.....
P.I. 88816-S	.....	Korea
P.I. 181567	.....	Japan
P.I. 200455	Aso No. 1	Shikoku, Japan
P.I. 200474	Hikagedaizu	Shikoku, Japan
P.I. 200476	Hitayoshu	Shikoku, Japan
P.I. 224270	Howgyoku	Sasayama, Japan
E.C. 26694	Variedale Alianca	Italy
E.C. 36956	Asomasari	Japan
P.I. 200487	Kinoshita	Shikoku, Japan
P.I. 285089	.....	Venezuela
P.I. 341352	.....	.....
Ankur	UPSS-38	U.S.A.
P.K. 71-39	.....	U.S.A.

been reported by Green and Pinnell (1968). In an attempt to identify lines maintaining better germinability during storage, freshly harvested seeds of 40 different soybean lines were kept at room temperature from harvest (December) until next planting season (July). Four samples of 50 seeds from each line were taken at monthly intervals and germinated on moist paper towels at 30°C. The two indigenous small-seeded varieties, Type-1 and Type-49, showed no significant reduction in germination. These varieties maintained above 90 percent germination. Seven lines, viz., Ankur, UPSM-215, PK-71-33, PK-71-39, UPSM-249, JS-3, and UPSL-85, maintained between 80 and 88 percent germination, 17 lines had 70 to 80 percent germination, and 13 lines, including Bragg, Hardee, and Lee, had less than 70 percent germination (Table 4). These data indicate considerable varietal differences with respect to loss of germinability during storage. In general, strains with small seeds maintained better germinability. In another experiment with isogenic lines in Lee background, we found that the small-seeded types maintained better germination (83.4 percent) than large-seeded types (57 percent). In separate studies on the rate of imbibition and the time taken for emergence of radicles, we found that in small-seeded types the requirement of water for complete imbibition was less, and the emergence of the radicles was much faster compared with the large-seeded types (Fig. 2). In all the small-seeded lines the radicles emerged within 20 to 24 hours, whereas it took between 36 and 48 hours for the large-seeded types.

Faster germination and a smaller water requirement for germination may be of considerable advantage in adverse conditions. Moreover, small seeds are less prone to mechanical damage during threshing and processing. Thus, small seed size appears to be a good index for selection for better germinability. However, reduction in seed size below 11 g per 100 seeds may reduce yield as well as oil content; therefore, the desirable range in seed size would be between 11 and 15 g per 100 seeds. Most of the promising breeding lines developed at Pantnagar have seed sizes in this range.

BREEDING FOR BETTER NODULATION

Failure of nodulation in soybeans has been observed in certain parts of India where soils are low in organic matter and where salinity or acidity is high. The U.S. varieties, such as Bragg and Lee, are more likely to show poor nodulation under these conditions. This has necessitated localized adaptation of the introduced varieties.

Considerable genetic variability has been observed in nodule-forming ability under different soil conditions for soybean varieties and *Rhizobium* strains alike (Damirgi et al., 1967; Caldwell and Vest, 1968; Ham et al.,

Table 3. Days to Maturity, Yield, and Disease Reactions of Some Promising Breeding Lines at Pantnagar, 1974

Line	Parentage	Days to maturity	Yield (kg/ha)	Disease reaction[a]	
				Rust	Yellow mosaic
PK-73-84	UPSL 85 x Hardee	132	4,335	R	L
PK-73-94	UPSL 85 x Hardee	135	4,181	R	L
PK-73-109	UPSL 85 x Hardee	135	4,279	R	L
PK-73-148	UPSS-3 x Clark 63	127	3,853	R	L
PK-73-156	UPSS-3 x Clark 63	125	4,129	R	L
Ankur	Singh plant selection from a composite	126	3,305	R	L
PK-71-21	D63-6094 x D61-4249	120	2,702	M	VL
Bragg	Jackson x D49-2491	111	2,261	S	S

[a] R = resistant; S = highly susceptible; M = moderately susceptible; L = light; VL = very light.

Table 4. Percentage Germination Before and After Storage at Room Temperature for 8 Months in Relation to Seed Size of Soybean Varieties

Variety	Initial germination (December)	Final germination (July)	100-seed weight (g)
Type-1	96.4	99.4	9.0
Type-49	96.4	92.4	9.7
Ankur	95.0	88.0	14.8
PK-71-39	97.0	81.4	15.5
UPSL-85	95.0	80.0	15.6
PK-71-21	96.0	77.4	16.0
UPSL-68	94.0	71.4	23.6
Hardee	95.4	68.0	15.4
Bragg	90.4	64.0	18.0
Lee	80.4	56.0	16.9

1967 and 1971), indicating that if soybean germ plasm is screened in problem soils with inoculation, lines with desirable nodulation could be identified. The results of preliminary studies at Pantnagar are encouraging. Local varieties, such as Type-1 and T-49, form more nodules than Bragg and Lee in soils with high as well as low organic matter. Bragg and Lee form few nodules in soils with 0.5 percent organic matter with normal inoculation (Table 5). Additional work is in progress.

DEVELOPMENT OF SOYBEAN VARIETIES FOR SHORT-DAY CONDITIONS

Most of the varieties being evaluated at present in the tropics have been introduced from the United States. When grown under the short-day conditions of the tropics, these varieties often flower and mature before adequate growth is obtained. This causes reductions in yield as well as seed quality.

We have, therefore, determined the days required for maturity of a few varieties at different locations (Table 6). As expected, all the varieties matured sooner at 10° N. than at 29° N. When these varieties were grown at different elevations but similar latitudes the number of days required for maturity increased with elevation, indicating their sensitivity to temperature. Thus, photosensitivity and thermosensitivity of soybean varieties must be considered for successful local adaptation.

Recent screening of the USDA world soybean germ plasm has revealed about 184 lines that mature later than Hardee and which may do well in the tropics. These lines have been classified in maturity groups IX and X (Hartwig and Edwards, 1975). Most of these were originally collected from tropical countries, such as Indonesia, Australia, Thailand, Malaysia, the Philippines, and India. Such lines should be used for tropical soybean breeding programmes.

Some of the soybean lines belonging to maturity groups 00 and 0 have been found to be insensitive to extended photoperiod (AVRDC, 1975). However, the mode of inheritance of this trait is still under investigation. There is also a need to screen the soybean germ plasm for thermoinsensitivity since photoinsensitivity alone will not ensure wider adaptability.

BREEDING METHODS AND SELECTION CRITERIA

Soybean variety improvement in different countries has followed the familiar route of introduction, selection, and hybridization. The methods used to handle segregating populations following hybridization have been bulk or pedigree, or slight modifications or combinations of these, or backcross breeding. The exact procedures vary, however, depending upon the parentage used and on the preference and objectives of the investigator.

The current objectives in tropical soybean programmes are to develop disease resistant varieties with better seed quality, better germinability, proper maturity, and high yield. Thus, the major emphasis has been on character improvement rather than breeding for higher yield per se. For this purpose, the pedigree method is more effective because it permits rigorous selection for height, maturity, disease and shattering resistance, plant type, and seed quality in F_2, thus cutting down undesirable selections from being carried to advanced generations. Further evaluation of individual progeny rows for these characters, along with seed quality and germination, and chemical composition and lodging in F_3 and F_4 generations, ensures the replicated testing of only those lines which are otherwise desirable. The modified pedigree method (Brim, 1966) would be equally effective if rigorous selection for the aforementioned characters is done in F_2 and later generations. Partial backcrossing

Fig. 2. Emergence of radicles in large-seeded and small-seeded isolines in Lee background under similar conditions.

followed by the pedigree method or the complete backcrossing methods could also be used, depending upon the agronomic characteristics of the donor parents.

While practicing selection for highly heritable traits in early generations, due consideration must also be given to the yielding ability of the plants. Correlation and path coefficient analyses of yield and yield-contributing characters in soybeans have revealed a predominant effect of pods per plant in determining the yield. Normally the variation for seed size and number of seeds per pod in elite populations is low, and at the same time these are negatively correlated with pods per plant. Therefore, the yield contribution of these characters is negligible. The direct contribution of height, nodes, and branches toward yield is negligible, but their indirect contribution through pods is quite substantial (Table 7). Thus, pods per plant is a good index for selection.

CONSIDERATION OF PLANT TYPE

The number of pods per plant depends upon the plant type. Some possible plant types in soybeans range from very tall (156 cm) to dwarf (43 cm), and from no branches to nine branches per plant (Fig. 3). As expected, the number of pods is greater in dwarf branching types than tall, nonbranching types. Moreover, the extra tall types are more susceptible to lodging. The medium-tall, nonbranching type (Fig. 3, No. 3) would be ideal, provided that a high plant population is maintained. However, ensuring high plant population in soybeans is always a problem because of loss in seed viability during storage and adverse weather at the time of sowing. A nonbranching type would give very poor yield if plant population is low. On the other hand, a dwarf branching type may compensate for poor germination by profuse

Table 5. Nodulation of Four Soybean Varieties Grown in Different Soils (Pot Culture) With and Without Inoculation[a]

Variety	Number of nodules per plant					
	Pantnagar soil		Aligarh soil		Bareilly soil	
	Inoculated	Uninoculated	Inoculated	Uninoculated	Inoculated	Uninoculated
Type-49	120	45	25	15	40	12
Kalitur	105	51	22	10	31	24
Bragg	68	20	0	0	2	0
Lee	73	25	10	0	2	0
Soil characteristics	pH = 7.07, O.M. 3.0%		pH = 7.8, O.M. 0.5%		pH = 7.2, O.M. 0.5%	

[a] In collaboration with Dr. K. V. B. R. Tilak, Soybean Microbiologist.

Table 6. Days Required for Maturity by Different Varieties at Various Elevations and Latitudes

Variety	Maturity group classification	Maturity (days) at four locations			
		30–75 m 6° S.–10° N.	1,210–1,800 m 7° N.–9° S.	262 m 29° N.	1,200 m 31°–34° N.
Hark	I	74	113	90	121
Clark 63	IV	83	120	101	139
Bragg	VII	87	134	120	150
Hardee	VIII	93	142	130	170

Source: adapted from Whigham, 1975.

Table 7. Direct and Indirect Effects of Factors Influencing Yield of Soybeans

Character	Effect on yield characters					Correlation
	Height	Nodes	Branches	Pods	100-seed count	
Height	−.22[a]	−.10	.05	1.87	−.67	.83
Nodes	−.20	−.10	.03	1.69	−.60	.72
Branches	−.06	−.02	.21	1.08	−.46	.64
Pods	−.20	−.08	.11	2.05	−.79	.91
100-seed wt.	.17	.07	−.11	−1.85	.88	−.63

[a] Underlined values are direct effects.

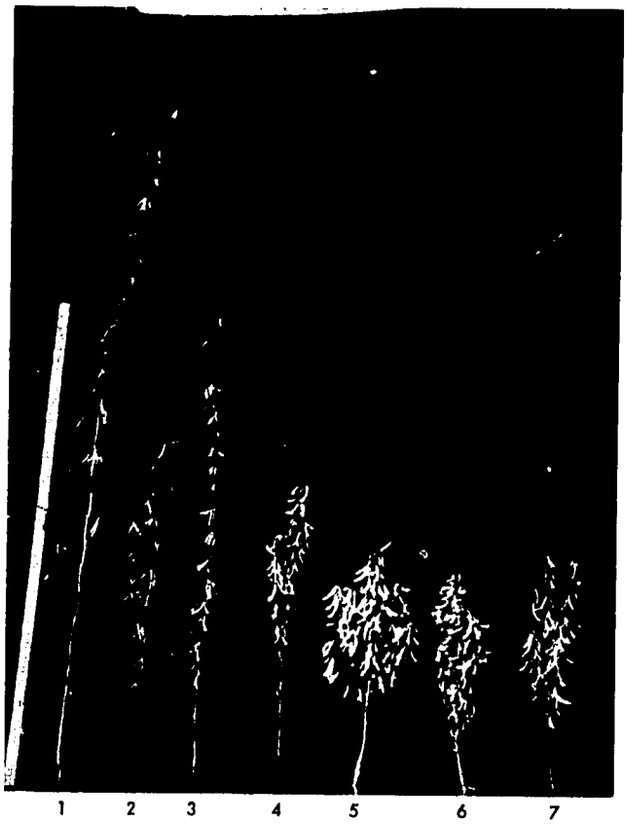

Fig. 3. Different soybean plant types.

branching and increased per plant yield. Therefore, under tropical conditions the dwarf plant type (50 to 70 cm) with branching would be more desirable. In order to reduce intra- and interplant competition due to dense foliage, narrow leaves should also be incorporated in the new breeding lines.

POPULATION IMPROVEMENT

Because soybeans are primarily self-pollinated, population improvement programmes in soybeans were not possible in the past. However, with the discovery of several male sterile mutants (Brim and Young, 1971; Singh et al., 1974a) it is now possible to undertake such programmes. Brim and Stuber (1973) have outlined a procedure for recurrent selection in soybeans. The initial populations may be synthesized by crossing a number of desirable parents in many ways, depending upon the objectives. Such composite populations could be continuously improved by recurrent selection, and new genes could be infused in them as and when available. This elite gene pool in the form of a multitude of recombinants would serve as a continuous source for deriving high yielding, pure lines to be used as varieties. Since soybeans are sensitive to photoperiod as well as temperature, it would be desirable to synthesize composite populations for specific adaptability zones, depending upon the latitude and altitude.

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Discussion

N. Vignarajah: Regarding the existence of two races of the rust pathogen, was the determination based on pathogenic reaction or on differential reactions on varieties?

B. B. Singh: I based my remarks about the races of rust on the observations made by plant pathologists at the

Asian Vegetable Research and Development Center, Taiwan. The determinations were based on pathogenic reactions.

T. Venkata Swamy: Have you conducted any studies on drought resistance in soybeans?

B. B. Singh: This is certainly an important aspect, but we have not screened the germplasm for drought resistance. The station where I work receives about 60 inches of rain evenly distributed throughout the entire growing season and therefore, even if we wish, we cannot undertake such studies.

Sumin Smutkupt: I would like you to summarize again your ideas on the ideal type of tropical soybean.

B. B. Singh: In the tropics, where the problem of germination is so widespread, I feel that a plant type with profuse branching habits may be more desirable because it would have an inherent capacity to give increased yields per plant in case of poor plant stand. We have observed that a plant 75 to 85 cm tall with 9 or 10 branches and seed size in the range of 11 to 15 g per 100 seeds may be ideal for tropical conditions.

Some Concepts of Soybean Improvement in the Lower Latitudes

D. E. Byth

Recent decades have revealed a rapid increase in the demand for protein, as is reflected in the expansion of soybean production worldwide. Efforts to increase production in many tropical and subtropical countries have stemmed from recognition of the important role played directly or indirectly by grain legumes, including soybeans, in human nutrition. In this context, various national research and development programmes exist, and the role of international groups such as INTSOY and AVRDC is well known.

GENERAL CONSIDERATIONS OF SOYBEAN IMPROVEMENT

In considering soybean improvement, it should be noted that *Glycine max* L.(Merr.) is a cultivated plant, not a native plant. Three points arise from this. First, the variability existing at any place or time does not reflect the full range of variability in the species, but rather only that portion collected or selected in that area. Second, although considerable genetic diversity is apparent worldwide, this has not been exploited to any extent in any one region; many programmes have a restricted germ plasm base. Third, most soybean breeding has occurred in temperate areas, so that the philosophies of improvement are biased towards the problems of temperate adaptation.

Much of the soybean research and technology in the temperate areas is relevant to the tropics, and adaptive research is justified. However, huge differences exist in the diversity of climate, growing seasons, rotations, cultural systems, and so forth; consequently, different objectives may be necessary in soybean improvement and adaptation.

Scientific knowledge is inadequate with regard to most aspects of soybean culture in the lower latitudes, including physiological response, canopy physiology, nutrition and soil fertility, nitrogen fixation, and pest and disease problems. Consequently, a pragmatic approach to soybean improvement is required through the development of problem-orientated regional programmes to obtain the necessary scientific knowledge and to identify the best available germ plasm and technology at the farm level. Plant improvement programmes, which by necessity are a multidisciplinary activity, require a long-term commitment. Breeding and selection of cultivars are of central importance, but must be conducted within the context of existing and possible cultural systems.

Clear definition of objectives is basic to the success of any programme. This paper will discuss some general concepts of soybean adaptation that may influence those objectives.

PHOTOPERIODIC RESPONSE AND ADAPTATION

Sensitivity to photoperiod is the most important single factor influencing adaptation of soybean genotypes to both latitude and planting date. Daylength influences the phenological and physiological development throughout growth. Other factors, such as temperature and moisture availability, also affect development, but cannot be dealt with here.

In practice, the most important influence of photoperiod involves the induction and initiation of flowering. Most soybean genotypes are quantitative short-day plants and will flower quickly if subjected to photoperiods shorter than a "critical" photoperiod characteristic of each genotype. Depending on temperature and environmental conditions, the minimum period from planting to flowering ranges upward from 25 days. Photoperiods longer than the "critical" level may delay flowering (Fig. 1), but most genotypes are facultative, short-day plants that will flower eventually under a range of photoperiods.

A complete spectrum of photoperiodic response, including day neutrality, exists in soybeans. A maturity group classification is used in North America as a broad basis for characterising differences among cultivars in floral induction and maturity. For example, group 00 cultivars will flower quickly in long days and are

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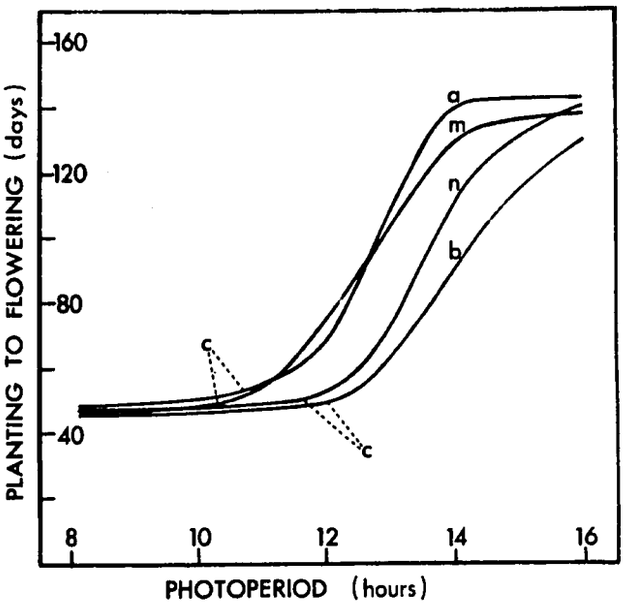

Fig. 1. Influence of photoperiod on time from planting to flowering for soybean cultivars under constant photoperiod: (a) Avoyelles, (b) Bienville, (m) Mamloxi, (n) Nanda, (c) critical photoperiod. Source: Byth, 1968.

therefore regarded as suitable for the higher latitudes (45° to 50°), while group VIII cultivars require relatively shorter daylengths to flower and are considered "adapted" to lower latitudes (25° to 30°). Cultivars adapted to even lower latitudes would require definition of more groups (e.g., IX, X, XI).

In general, culture of a particular group in latitudes higher or lower than its classified "adaptation" will delay or hasten maturity, respectively. Therefore, the terms "early" and "late" are relative only to the particular photoperiod and environment involved. As expected, these changes in phenology also result in large changes of growth and development; for example, most group I cultivars grown in group IV environments will be earlier maturing, shorter, and less vegetative than the vegetatively vigorous, "adapted" group IV cultivars. They will also have a different seasonal distribution of their growth phases, because they will be induced to flower and mature earlier than the "adapted" cultivars.

The phenological responses of various cultivars (groups III-XI) to a series of planting dates in subtropical Australia (27° S.) are shown in Fig. 2 for different stages of growth (Lawn and Byth, 1973). Clearly, group III cultivars were effectively insensitive to daylength throughout growth, in that flowering invariably occurred rapidly and resulted in short-season growth and rapid maturity. At the other extreme, the latest maturing cultivars were sufficiently sensitive that flowering of all plantings was delayed until the shorter days of autumn. In general, the length of a growth phase was extended most where that phase occurred during the longest days.

These general patterns of response may be expected to occur in most environments for that range of cultivars capable of successful reproductive growth. At latitudes lower than 27° S. with a smaller seasonal variation in daylength, most of these cultivars would mature comparatively early and would be less responsive to planting date. Very late cultivars at 27° S. would probably mature relatively late, but would be capable of reproductive growth at lower latitudes.

These responses have important implications regarding adaptation in the lower latitudes, particularly with respect to photoperiodic insensitivity and its use in soybean improvement. Clearly, group III material was effectively day-insensitive at 27° S., so that Group 00-III cultivars form, in general, a population insensitive to the daylength range at that latitude. At lower latitudes, higher groups are increasingly less responsive, so that at the equator much of the genetic material from the higher latitudes may be relatively insensitive to the range of daylength. Consequently, the lower latitudes are in a favourable position to obtain and use much of the improved genetic material produced in the higher latitudes. The potential germ plasm base for breeding is therefore very broad indeed, and responsiveness of genotypes to environmental factors other than photoperiod will assume major importance.

REGIONAL ADAPTATION AND AGRONOMIC USE

In North America particular maturity groups are recommended as "adapted" for narrow bands of latitude, depending on their ability to perform and yield in a defined cultural system involving spring planting, full-season growth, and wide rows (75 to 100 cm). Clearly, substantial vegetative growth is required; "adapted" groups correspond well with latitude and "nonadapted" groups must provide suboptimal performance.

This concept of adaptation has been simply applied, effective, and acceptable in the United States. However, change of the cultural system alters much of the meaning of the maturity group classification with respect to adaptation, while allowing for more flexible use of genotypes in production and breeding. It is debatable whether this change would be necessary or useful in the United States. Nevertheless, it seems certain to be necessary in the lower latitudes where the diversity of climate, growing seasons, rotations, and cultural systems make flexibility both possible and necessary. Such flexibility imposes additional demands in the choice of cultivars and complementary cultural systems, with the result that breeding strategies and objectives, and concepts of adaptation must be adjusted accordingly.

Experience in Australia suggests that three different general approaches to adaptation may be possible (Lawn and Byth, 1976):

1. Adoption of U.S. cultivars and full-season, wide-row U.S. technology for soybeans as the major summer crop. This is successful in the subtropics under irrigation, but has rather rigid cultivar and cultural requirements.

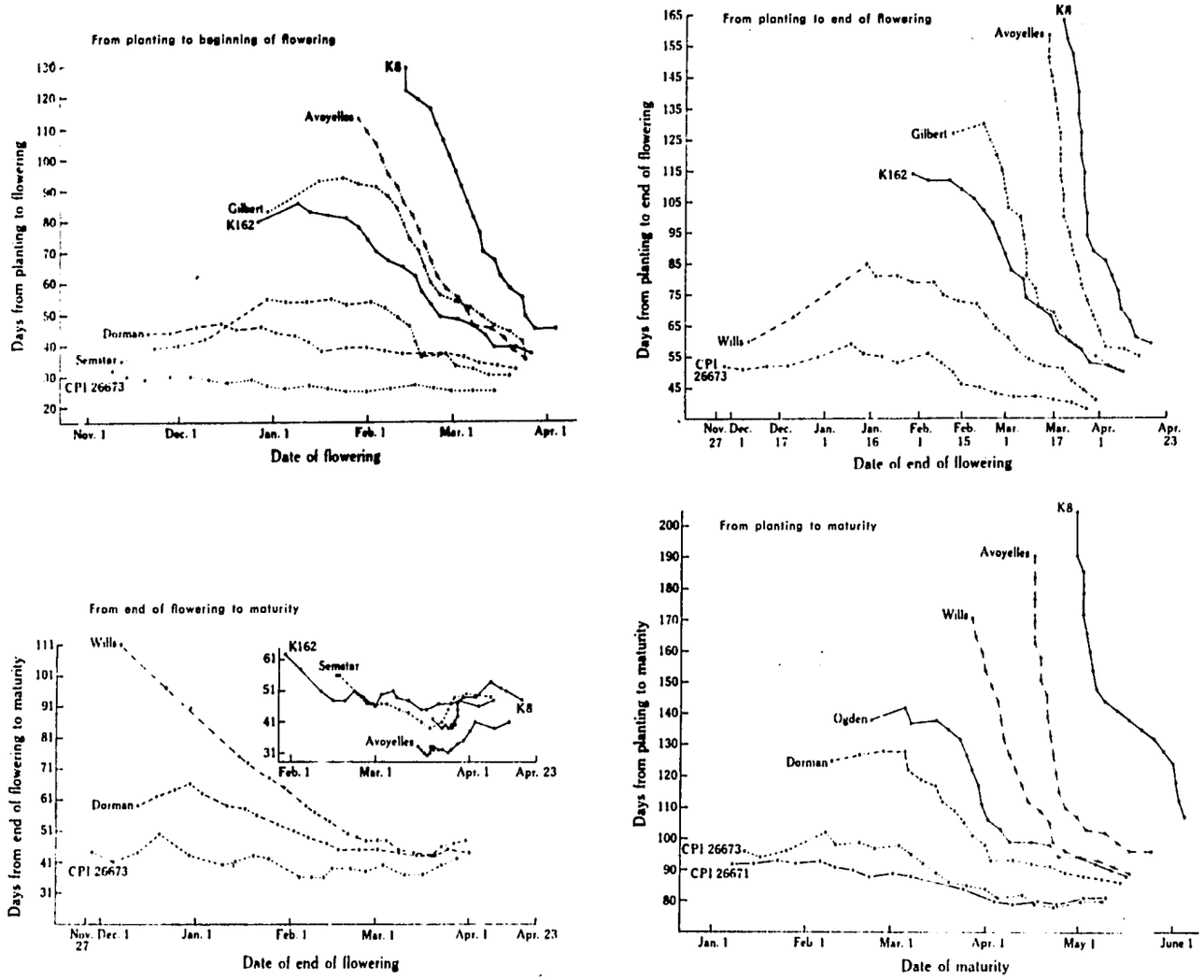

Fig. 2. Variation in phenological development for representative cultivars planted at weekly intervals from 8 October to 20 February at Redland Bay, Queensland (27° S.).

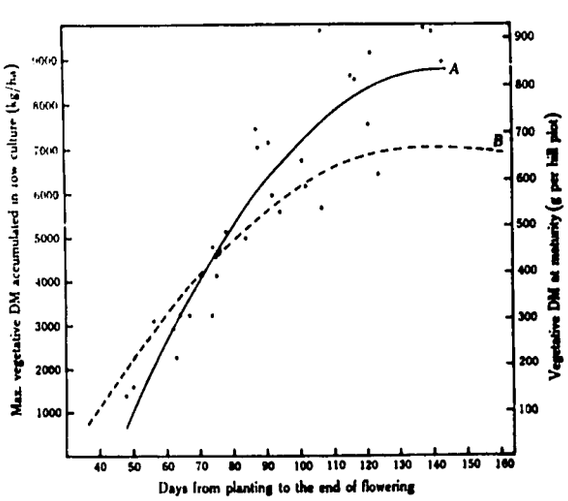

Fig. 3. Dry matter (DM) accumulation for various cultivar-planting date combinations (A — row culture; B — hillplot culture).

2. Flexible use of cultivars and planting dates by change of cultural system, with recommendations based on cultivar x planting date x plant density/arrangement interaction. Thus, soybeans complement existing rotations and climatic conditions, while yield is optimised for each usage.
3. Development of short-season cultivars, insensitive or nearly so to the daylengths of the region, which can be used flexibly over planting dates and latitude in uniform, high density culture.

These approaches involve contrasting concepts of adaptation, as well as substantial differences in phenology, growth and development patterns, and germ plasm base. Each has been used successfully in different situations, indicating the flexibility possible when necessary in soybean adaptation. Optimisation of yield will require adjustment of cultural practices. In subtropical Australia (27° S.), detailed studies of phenology, growth and development of a range of cultivars, and planting dates showed the following (Lawn and Byth, 1974):

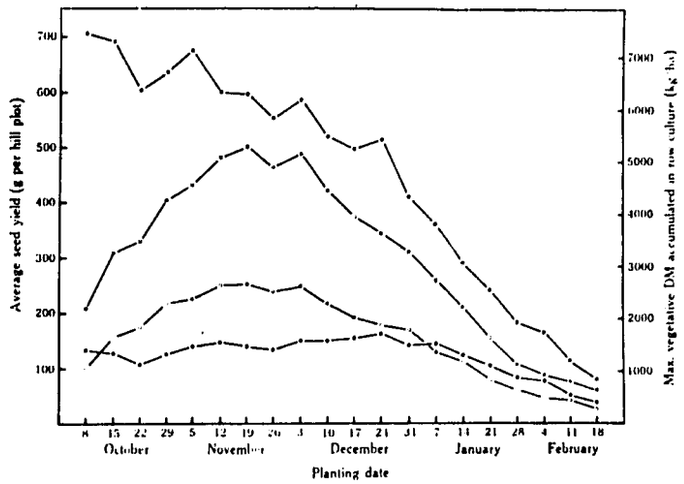

Fig. 4. Seed yield (closed and open circles) and dry matter (DM) yield at maturity (closed and open squares) across planting dates, for nine early and nine later maturing cultivars, respectively.

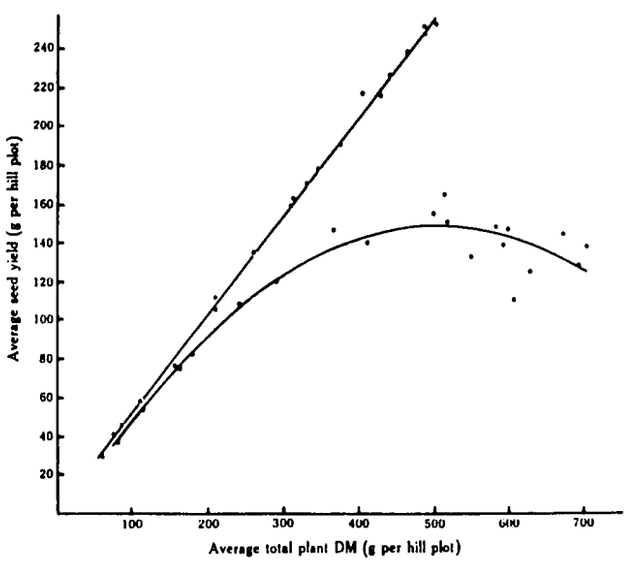

Fig. 5. Average seed yield versus average dry matter (DM) yield at maturity for nine early (open circles) and nine later (closed circles) maturing cultivars, respectively, in hillplots.

1. Vegetative growth was greatest for those cultivars and/or planting dates that resulted in the longest periods to the end of flowering (Fig. 3).
2. Percentage of leaf dry matter declined with increase in vegetative development.
3. Seed yield per unit area for each cultivar increased as the length of the growing period was extended, until vegetative growth was sufficient to form closed canopies in the row spacing used (Fig. 4, 5). Further increases in duration of vegetative growth merely sustained yield or reduced it. Different durations of vegetative growth were required for different row spacings.
4. Individual plant dry matter and seed yield declined with decrease in duration of vegetative growth.
5. Biological efficiency of seed production (harvest index) was greatest where early flowering, limited vegetative growth, and short-season growth occurred (Fig. 6).

Since biological efficiency was negatively associated with duration and extent of vegetative growth, maximisation of seed yield requires an optimum compromise of these factors. The optimum plant density and arrangement will vary, depending on the cultivar-planting date combination. We found (Lawn and Byth, in press) that seed yield was maximised in progressively narrower row (higher density) treatments as plantings were delayed beyond the longest days, and as shorter-season cultivars were used (Table 1). Also, seed yields from short-season growth in narrow rows were equivalent to, or greater than, the highest yields obtained from full-season growth. Clearly, the low dry matter production from short-season growth may be compensated by increased plant density and high harvest index, and high seed yields are feasible

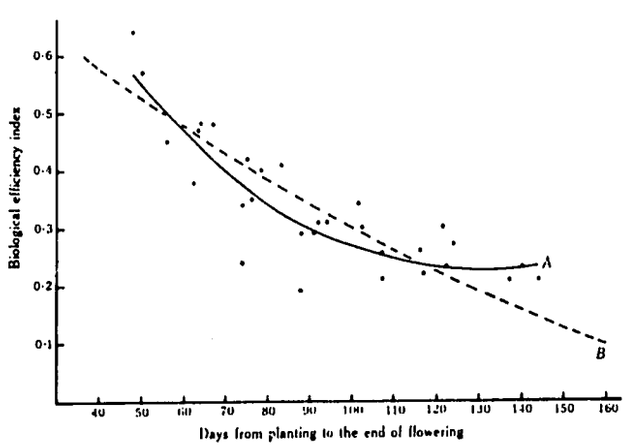

Fig. 6. Biological efficiency versus duration from planting to end of flowering, for various cultivar-planting date combinations (A — row culture; B — hillplot culture).

Table 1. Effect of Row Width on Soybean Yields at Two Sites in Subtropical Australia (27° S.)

Planting date	Soybean yields (ton/ha) at Lawes (1968-69)							
	Cultivar			Row width (cm)				Mean
	Wills	Avoyelles	Gilbert	101.5	50.8	25.4	12.7	
14 Dec.	2.09	1.69	1.59	1.72	1.92	1.81	1.70	1.79
11 Jan.	2.14	1.40	1.40	1.53	1.73	1.70	1.64	1.65
8 Feb.	1.53	1.54	1.60	1.26	1.66	1.86	1.46	1.56
Mean	1.92	1.54	1.53	1.50	1.77	1.78	1.60	1.66

Planting date	Soybean yields (ton/ha) at Redland Bay (1970-71)						
	Cultivar		Row width (cm)				Mean
	Wills	Bethel	101.5	50.8	25.4	12.7	
6 Dec.	2.84	2.59	2.59	2.79	2.89	2.58	2.71
29 Dec.	2.70	2.64	2.54	2.86	2.80	2.50	2.67
19 Jan.	2.34	2.35	1.49	2.58	2.70	2.60	2.34
Mean	2.63	2.52	2.20	2.74	2.79	2.56	2.58

Source: adapted from Lawn and Byth (in press).

from short-season culture. Similar results have been obtained at 22° S. and 17° S.

Preconception of what constitutes "adaptation" is likely to inhibit progress and bias development. Research should be directed to the solution of real problems, and concepts of adaptation adjusted accordingly. However, short-season culture of daylength insensitive (or nearly insensitive) cultivars may have application in low latitudes, particularly where soybeans are grown in erratic climates or as short-season, secondary crops following cereals in intense rotations. In these situations, the flexibility of rotational systems is likely to be enhanced. Definition of breeding objectives would be simpler, and breeding programmes could be centralised with extensive regional testing, thus accommodating a wider germ plasm base and encompassing a wider area of relevance. Where climatic constraints necessitate prolonged growing periods, cultivars sensitive to photoperiod or longer-season, insensitive cultivars may be identified.

As in all breeding exercises, difficulties in attaining these objectives undoubtedly exist. Some of the developmental problems with "nontraditional" seasonal culture of soybeans (Hinson, 1974) have occurred in subtropical Australia for particular cultivars or planting dates. However, in our experience adequate germ plasm exists to allow normal growth and development at reasonable yield levels for virtually any season of culture. As indicated previously, the lower latitudes are in a position favourable for gaining access to a great diversity of germ plasm.

PLANT HABIT

Considerable debate exists regarding the superiority or desirability of determinate and indeterminate forms for the lower latitudes. To a large extent the question is academic. Harvestable yield of a desirable product is the basic criterion regardless of plant habit. Furthermore, the question of determinacy is only a portion of the overall design of the plant.

Considerable flexibility of plant design exists. The Australian research described earlier primarily involved cultivars bred in the United States as photoperiodic responsive material for full-season culture in wide rows. Yet when tested in the tropics and subtropics, these lines maintained satisfactory yields in a wide variety of planting dates and drastic consequent changes in the pattern of plant development and crop duration, as long as appropriate adjustments in plant density or arrangement were made. Presumably, the results of these tests were suboptimal, since the cultivars were evaluated under circumstances in which plant habits differed grossly from those of their selection. It is doubtful that plant design considered desirable for yield accumulation in massive vegetative canopies will also be optimal for short-season culture with far less vegetative growth.

The "optimal" plant design for short-season culture is unknown and will be derived only by experimentation. However, certain aspects are clear. Short-season culture inevitably reduces plant height and the number of nodes, and predisposes to the occurrence of pods near ground level, high harvest losses, and reduction in the number of fruiting sites. The height of the first pod is adjustable by appropriate plant density or arrangement, and adequate genetic variability exists (Table 2). Terminal and axillary raceme development can be introduced genetically to condition prolificacy and the production of pods near the top of the plant.

Strong arguments can be made in favour of the determinate habit, particularly for short-season culture where a highly reproductive organism is required, and where efficiency dictates maximisation of the reproductive phase and avoidance of excessive overlap of the physiological stages. Raceme development is an additional associated objective. However, limited evidence suggests that

Table 2. Performance of Soybean Varieties When Planted in Rows 70 cm Apart at Two Sites in the Markham Valley, Papua New Guinea (7° S.)

Plant spacing in row	Cultivar	Site 1			Site 2		
		Plant height (cm)	Lowest pod (cm)	Yield (ton/ha)	Plant height (cm)	Lowest pod (cm)	Yield (ton/ha)
4 cm	Semstar	69	5.6	1.4	71	7.7	0.8
	Bragg	30	5.2	0.8	36	7.7	1.1
	Wills	30	3.1	1.6	31	4.1	2.3
	Davis	32	6.1	1.4	33	6.4	1.4
	Hampton	29	4.9	1.7	32	7.7	1.3
	Gilbert	42	6.4	2.4	41	8.7	2.8
	Daintree	53	9.2	2.3	49	9.0	2.7
	Ross	57	10.4	2.6	49	8.0	2.4
	Semstar	49	5.2	1.3	48	5.2	1.1
	Gilbert	44	7.6	3.6	..	...	...
	Daintree	..	...	...	54	12.9	1.9
	Wills	29	5.6	1.9	27	2.2	1.4
8 cm	Semstar	49	5.2	1.2	38	5.7	0.6
	Gilbert	35	4.4	3.1	..	...	...
	Daintree	..	...	...	40	8.4	1.8
	Wills	28	4.7	1.1	26	3.2	1.5
	Semstar	36	3.8	0.8	47	3.2	0.6
	Gilbert	32	2.2	2.3	..	...	...
	Daintree	..	...	...	33	4.0	1.5
	Wills	24	2.9	1.0	25	3.0	1.2

Source: J. S. Sumbak, personal communication.

many determinate cultivars may become excessively short in the lower latitudes, particularly during the shorter days. The reasons for this are not known. Harvestable yield is the main objective, and this may require an indeterminate plant habit under some circumstances. For this reason, other approaches for obtaining pod production near the top of the plant and high pod potential are necessary.

Shattering and lodging are problems common to all soybean programmes in every area. Shattering resistance is particularly necessary where hand harvesting requires multiple handling of plants. Attainment of shattering resistance presents little difficulty where an effective local breeding programme exists. Lodging has implications for harvestability, disease attack, and reduction of yield and seed quality. It is a complex problem requiring research into plant habit, rooting habit, response to waterlogging at establishment, and soil preparation.

GERM PLASM BASE

Only three aspects will be discussed, viz., restriction of the germ plasm base of individual programmes, genetic vulnerability, and collaboration in the exchange of breeding material.

Large germ plasm collections are held by various institutions, particularly the United States Department of Agriculture and AVRDC, and in general, material is freely available on request. However, only very limited use of the collections in quantitative plant improvement has occurred; consequently, many programmes have a narrow genetic base. Practical and logistical pressures encourage breeders to work within narrow genetic bases, and these may be greatest and most justifiable where a specific photoperiodic response is required and where a high yield level already exists. However, no clear justification exists in the lower latitudes where farm yields are low and a wide diversity of germ plasm is potentially relevant.

In subtropical Australia even extremely wide crosses (group III x group XI) have produced elite and different segregating populations. Improved plot techniques and breeding procedures, such as multiple crossing, bulk breeding methods, single-seed-descent, and hill-plot testing in early generations, can facilitate broadening of the genetic base.

Genetic similarity of cultivars creates uncertainty regarding the genetic vulnerability of the crop. In the United States relatively few cultivars occupy much of the total area, and particular cultivars dominate specific regions. In 1972 all of the major cultivars involved Mandarin parentage, with some 85 percent of the total area traced to only six maternal ancestors (National Academy of Sciences, 1972). The genetic base in Australia is qualitatively similar to that in the United States, so that a similar concern must exist regarding genetic vulnerability. Proliferation of U.S. cultivars has occurred or is occurring elsewhere, and constitutes a narrowing of the genetic base internationally. The implications are potentially serious, particularly in the low latitudes where quite different environments and challenges to the genetic material are likely. An example is the vulnerability of U.S. germ plasm to the rust pathogen, *Phakopsora*

pachyrhizi Syd. Deliberate broadening of the genetic base is justified on the basis of developing adaptation in "new" areas; potential genetic vulnerability is simply an additional justification.

Much of the exchange of germ plasm from collections involves a search for "instant" cultivars because few accessions are used in local hybridisation. Coincidentally, the majority of each breeding population is discarded by the breeder as "nonadapted," unsuitable, or simply not the best material locally. Numerous demonstrations of large genotype x environment interactions suggest the possibility that elite but unreleased selections from one programme may have value in other areas. Exchange of elite breeding lines for preliminary evaluation may provide rapid and inexpensive access to breeding investment elsewhere, in addition to providing some information on the potential value of particular parents in that area.

For a number of years, breeding lines identified at 27° S. as potentially useful at lower latitudes have been supplied by the author to a number of overseas and Australian locations. The results suggest that the exercise has been productive, particularly where local breeding is limited or absent. Regional exchange could broaden the genetic base, as well as provide inexpensive access to advanced breeding lines. A comprehensive programme of germ plasm exchange and genetic analysis using random single-seed-descent progenies has recently been suggested (K. S. McWhirter, personal communication).

RESPONSE TO ENVIRONMENTS

The low farm yields characterising much soybean culture in the tropics are the result of many interacting factors, including environmental, agronomic, and genetic. The impact of some environmental factors on breeding strategy will be discussed briefly.

Soils and Soil Fertility

Soybeans can be grown successfully on most soil types as long as adequate moisture and nutrients are available throughout growth. A wide range of pH can be tolerated, provided that micronutrient availability and nodulation are not upset. Ideally, fertilizer application and pH adjustment should be made as necessary if high yields are to be obtained.

In practice, however, most farmers in the tropics apply no fertilizer to soybeans, highly acid soils (pH 4.2 to 6.0) are common, and fertilization and pH adjustment are probably not generally feasible. Obviously, breeding should be directed to problems in the production environment, such as tolerance of aluminum toxicity and zinc deficiency, and to symbiotic combinations effective under low pH conditions. However, it is probable that selection for quantitative characters may be relatively ineffective under low fertility conditions. A dichotomous situation may be desirable, with selection and breeding in less limiting environments and rigorous testing subsequently under farm conditions. A similar argument exists regarding moisture stress.

Disease and Pest Resistance

Breeding for disease resistance has expanded rapidly in North America in recent years. Many of the diseases present in temperate regions occur commonly in low latitudes also and can be severe. Other diseases, such as rust (*P. pachyrhizi*) in Asia, are distinct regional problems. In the case of some diseases, prior study of the pathogen and disease elsewhere may have revealed sources of resistance effective in the tropics and in improved cultivars. Alternatively, resistance may be sought in tropical germ plasm. Collaboration between breeders and pathologists is necessary.

A wide range of insect pests exists in the tropics, and damage can be severe, varying with country, region, season, and year. Because there is relatively little knowledge of genetic resistance, collaborative research in biological control and integrated pest management should be developed regionally.

Environmental Adaptation

As in the case of most other crops, relatively few studies of environmental adaptation and responses of soybean cultivars have been made. Although numerous studies have demonstrated substantial cultivar x environment interaction, no detailed studies of the nature and causes of the differential responses have been reported. Such studies could provide clearer definition of breeding objectives and stimulate analysis of environmental limitations. An important component is a data base from a continuing uniform regional trial series, along with its detailed analysis and interpretation.

SEED QUALITY

Chemical Composition

In Asia the purpose of soybean production gives rise to contrasting demands for oil and protein contents. Thailand, for example, requires high oil (> 19 to 20 percent) for extraction or export, while Indonesia, on the other hand, requires high protein (> 41 to 42 percent) for human and animal food. The elasticity of these requirements is unknown; however, local demand must influence breeding objectives. Similarly, various consumer preferences for seed and hilum colour, seed size, flavour, and so forth must be considered.

In the United States large increases in protein and oil percentage have been achieved by selection. Studies suggest that similar advances are possible in subtropical Australia (27° S.). However, large genotype x environment interactions exist, and testing of quality in several environments may be necessary in selection. It is possible that certain environments predispose to high oil or high protein percentage. In view of the generally low farm yields in the tropics, breeding should emphasise yield

improvement initially, with chemical composition as a lower priority. The greatest improvement in protein and oil production initially is likely to result from improvement in seed yield.

Physical Quality

Poor plant stands, which are a major cause of low farm yields, can be alleviated, in part, by improved seed production and storage schemes at the local level. Genetic improvements in the physical quality of the seed, storability, and seedling vigour are also possible. It is clear that small seeds have superior storability and emergence. However, they may also be lower in oil percentage. Furthermore, the implications of seed size on seedling vigour are important, particularly for short-season crops in which early vigour is critical. The universality of preharvest damage to seed quality, and thus to storability and viability, justifies detailed investigation of this area by physiologists and breeders.

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Soybean Varieties for Southeast Asia

Ricardo M. Lantican

In Southeast Asia soybeans are grown under conditions ranging from those in upland areas to lowland paddies following rice cultivation. In upland areas soybeans are grown as an intercrop or alone, often in rotation with cereal crops, during a period of seven to eight months of natural rainfall. In countries north of the equator the first crop is planted at the onset of the southwest monsoon in May or June. This season, often referred to as the wet season when rainfall is normally high, coincides with the period when daylength exceeds 12 hours. The second crop is normally planted in October or November. This period, when precipitation is low, is called the dry season, except in the equatorial zone between 10° N. and the equator which receives greater amounts of rainfall. During these months the temperature is lower and daylength is less than 12 hours.

Soybeans grown after paddy rice are usually planted from December through January, and are usually accompanied with minimal tillage and by moisture stress in nonirrigated areas. Each of these three sets of growing conditions, i.e., (a) wet season upland, (b) dry season upland, and (c) dry paddy, requires soybean varieties with special adaptive features.

Observations indicate that certain varieties from high latitudes tend to mature early and produce an ideal plant structure of moderate stature and leafiness and, therefore, high seed-stover ratio when brought to the low latitudes. They appear better suited to the wet, long-day season than the Asian varieties, which tend to be overvegetative during this period. On the other hand, the late-maturing but fast-growing tropical types are better suited to conditions of the dry, short-day season and dry paddy cultivation. This contention is substantiated by data we have obtained under upland conditions at College, Laguna, Philippines (Table 1).

A number of such varieties originating in high latitudes, notably those from the U.S. Midwest and Gulf states, have been introduced and acclimatized in the Philippines and other Southeast Asian countries. These varieties have performed well under tropical growing conditions, and some have already been used in commercial plantings. Likewise, a number of varieties native to the low latitudes in Southeast Asia have been grown under varying conditions of the upland and paddy areas.

In 1971 a project was initiated to bring together elite soybean varieties grown in Southeast Asia for uniform trials at selected locations in the Philippines, Thailand, West Malaysia, Indonesia, Laos, and Khmer Republic. The objective of the project was twofold: to determine the range of adaptation of different varieties in Asia and to maximize the use of any one variety found to be widely adapted in the region.

This project was part of a larger project for uniform regional testing of a number of high-protein crops, conducted in cooperation with state universities and ministries of agriculture in Asia. The project was supported by the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) which is headquartered in College, Laguna, Philippines.

METHODS

Eleven elite, early-maturing varieties from the high latitudes and ten Asian types released by the different national breeding programs were used in the trials. The varieties were grouped according to the extent of vegetative development and period of maturity. Group I varieties consisted of the early-maturing, short-statured types to which most of the high latitudinal lines belong; Group II was composed of the late-maturing, tall-growing, predominantly Asian types. Each entry was planted in four rows, 6 meters in length. Each experiment was laid in randomized complete block design with four replications.

Row spacings of 50 cm and 75 cm were generally used for the dry and wet season plantings, respectively. Hill spacings were 10 cm with three plants per hill for Group I, and 20 cm with two plants per hill for Group II. Fertilizer applications were at 45-45-45 kg per hectare of nitrogen, phosphate, and potash, respectively. The

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Table 1. Maturity Period, Leaf Area Index, Harvest Index, and Yield per Hectare of Two Groups of Soybeans Grown Together During Wet Season (May) and Dry Season (October), Los Baños, Laguna, Philippines, 14° N., 1969

Maturity groups	Origin of varieties	No. of varieties tested	Av maturity period (days)		Av leaf area index		Av harvest index[a]		Av yield (kg/ha)	
			Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Early	High latitudes 32°–40° N.	29	87	77	1.62	1.85	46.4	46.1	1,226	1,126
Late	Low latitudes 2°–24° N.	25	124	83	7.57	4.86	24.5	39.8	955	1,843

[a] Proportion of total dry matter in the plant that went to seed development.
Source: Based on the master's thesis of C. D. Garaza, "Evaluation of soybean varieties on the basis of total dry matter and harvest index," July, 1971, University of the Philippines at Los Baños, College, Laguna.

Table 2. Average Bean Yield of Group I Soybean Varieties in Five Southeast Asian Countries, 1970-1974[a]

Variety entry	Varietal origin	Yield (ton/ha)					Average
		Philippines	Thailand	Khmer	Malaysia	Laos	
Clark 63	U.S.A.	1.75	1.66	2.48	1.19	2.82	1.98
TK-5	Taiwan	1.61	0.99	2.03	1.56	1.86	1.61
Wayne	U.S.A.	1.39	0.95	2.30	0.93	1.87	1.48
Lincoln	U.S.A.	1.65	1.08	1.90	0.82	1.71	1.43
CES 16-17	Philippines	1.42[b]	...	...	...	...	1.42
CES 16-103	Philippines	1.42[b]	...	...	...	...	1.42
Hill	U.S.A.	1.45	1.28	1.90	0.89	1.44	1.39
A2-5440	U.S.A.	1.56	1.07	1.81	1.00	1.47	1.38
Bethel	U.S.A.	1.50	1.11	1.17	...	1.57	1.34
SL-6	U.S.A.	1.32	...	1.85	0.66	1.49	1.33
Williams	U.S.A.	1.24[b]	...	...	...	...	1.24
CES 16-23	Philippines	1.23[b]	...	...	...	...	1.23
L-2A	U.S.A.	1.39	1.14	1.16	0.76	1.55	1.20
Multivar 80	U.S.A.	1.11[b]	...	...	...	...	1.11
SJ-1	Thailand	1.12	1.19	...	0.39	1.48	1.04
Bragg	U.S.A.	1.08	0.97	...	0.54	0.79	0.84
SJ-2	Thailand	...	1.42	...	0.39	...	0.90
Local variety		...	...	1.33	...	...	1.33

[a] Average of 2 to 4 seasons.
[b] New entry, grown for one season only.

Table 3. Average Bean Yield of Group II Soybean Varieties in Five Southeast Asian Countries, 1972-1974[a]

Variety entry	Varietal origin	Yield (ton/ha)					Average
		Philippines	Thailand	Khmer	Malaysia	Laos	
#29	Indonesia	2.33	...	...	...	...	2.33
SJ-2	Thailand	2.05	1.24	1.86	0.69	1.65	1.50
CES 434	Philippines	1.56	0.92	1.33	0.79	2.13	1.35
1248 (Davros)	Indonesia	1.29	1.46	1.74	0.58	1.61	1.34
945	Indonesia	1.81	1.37	1.45	0.83	1.36	1.36
KE-32	Taiwan	1.81	1.59	1.09	0.95	1.35	1.36
Local variety		...	...	1.23	...	...	1.23
L-114	Philippines	1.53	1.16	0.69	1.14	1.43	1.19
TK-5	Taiwan	1.45	0.93	1.34	0.88	1.67	1.25
Americana	S. America	1.86	1.11	1.45	0.80	1.00	1.24
Palmetto	U.S.A.	1.75	0.94	1.50	0.58	1.42	1.24
Jupiter[b]	U.S.A.	0.69[c]	...	...	...	...	0.69

[a] Average of 1 to 3 seasons.
[b] New entry.
[c] Average of only one season.

trials, which were accompanied by thorough land preparation and good soil granulation, were conducted primarily in the dry season and confined to the upland system of cultivation.

RESULTS

The summarized yield data for Group I and Group II varieties are presented in Tables 2 and 3, respectively. The data by individual country are appended in Tables 4 to 13.

Among the Group I varieties, Clark 63, an American variety acclimatized in the Philippines, showed a wide range of adaptation in the test locations. It consistently produced the best yields in the Philippines, Thailand, Khmer Republic, and Laos, and was second best in Malaysia. TK-5, a variety developed in Taiwan, also did well, ranking first in Malaysia, second in Laos, and third in the Philippines and Khmer Republic. It did not do too well in Thailand. Wayne and Lincoln, both of U.S. origin, performed fairly well, also.

Among the Group II varieties there was no clear indication of wide adaptation for any particular variety. Location specificity in yield response was more evident among the varieties. KE-32 from Taiwan ranked first in Thailand and second in Malaysia. Variety 1248 (Davros) from Indonesia was the second highest yielder in Khmer Republic and Thailand. SJ-2, originating in Thailand, yielded highest in Khmer Republic, second in the Philippines, and third in Laos. CES 434 and L-114, Philippine-bred varieties, were the best yielders in Laos and Malaysia, respectively.

DISCUSSION

Both groups of experiments were carried out once a year during the dry season under upland conditions. Planting took place from December through January, except in the Philippines, where Group I varieties were grown only during the wet season and Group II only in the dry season. There was, therefore, no way of comparing the relative merits of the two groups of varieties with the changing seasons, such as between wet and dry, or between upland and paddy conditions. Nevertheless, it is worth noting that some of the Group I varieties represented by those from high latitudinal sources did well and gave good yields during the dry season, at times surpassing those of the tropical varieties. In fact, current data and those we have accumulated in the Philippines indicate the versatility of Clark 63 in both wet and dry seasons. Clark 63, a Group IV or 136-day variety in the United States, was grown mainly in the Midwest during the mid-1960's. In Southeast Asia, Clark 63 matures in 80 to 94 days. It is now a Seed Board variety in the Philippines, recommended for wet and dry season plantings.

It should be pointed out, however, that the high latitude varieties used in this trial have had a period of about a decade of acclimatization and adjustment in the Philippines. Some, like Clark 63, have acquired the adaptive features of their tropical counterparts for fitness to dry season conditions, probably because of natural selection or genetic modification. It should be emphasized further that if seeds of these adapted varieties are to be planted immediately for dry season culture, they should not be imported directly from their place of origin. In our experience plants arising from such imported seeds find themselves alien to the new habitat and are easily and adversely affected by prevailing short photoperiods and moisture stress during the dry season. Consequently, they become unfit for commercial purposes. Use of directly imported seeds for wet season culture seems satisfactory in our observation.

The results of experiments have thus far been confined to upland growing conditions. We do not know how these varieties will behave under strictly controlled paddy conditions which are preceded by puddling operations associated with paddy rice cultivation. Very recently we have extended the soybean trials over a rice-based system, in cooperation with the outreach locations of the International Rice Research Institute's Cropping Systems program in several areas in the Philippines, Indonesia, Malaysia, Thailand, Burma, Sri Lanka, Pakistan, and Bangladesh. Now that we are coordinating our experiments with those of the INTSOY program, the varietal entries have changed somewhat, and will change more so in the future as new varieties evolve from our intensive screening, breeding, and selection program under paddy, shaded, and upland conditions at Los Baños, Laguna, Philippines.

We have made blends between the adaptive temperate and the tropical types. We have also incorporated genes for resistance to major diseases, such as bacterial pustule and rust, into our gene pool. AVRDC and other national programs are making similar efforts. With these combined efforts it is reasonable to expect stable yields and gradual increases of the yield potential of soybeans in Southeast Asia to more than 2 tons per hectare.

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Discussion

D. E. Byth: Do your tests involve true Clark 63? What is meant by "acclimatization"? Has a test been done on Clark 63 introduced from the United States?

R. M. Lantican: No. The tests have been conducted with plants selected or acclimatized in the Philippines and not with newly introduced Clark 63.

Table 4. Yield, Days to Flowering and Maturity, Plant Height, Protein Content, and Reaction to Disease of Group I Soybeans at Central Experiment Station, UPLB, College, Laguna, Philippines

Variety entry	Yield (ton/ha)					Average number of days to		Av plant height (cm)	Av crude protein content[b] (%)	Av disease rating[a]	
	June 1970	Nov. 1972	June 1973	July 1974	Average	flowering	maturity			Bacterial pustule	Rust
Clark 63	1.87	1.49	2.46	1.20	1.75	32	87	63	39.3	2.5	2.0
Lincoln	1.96	1.06	2.59	1.01	1.65	26	85	58	37.1	2.5	2.2
TK-5	2.60	0.80	2.07	0.98	1.61	34	87	57	39.0	3.8	3.1
A2-5440	2.05	1.00	2.24	0.96	1.56	24	84	54	37.5	2.5	2.8
Bethel	2.09	0.79	2.22	0.91	1.50	27	87	57	39.4	2.8	2.9
Hill	1.37	1.12	2.29	1.02	1.45	30	86	47	37.4	2.5	2.6
CES-16-17	...	...	...	1.42	1.42	36	89	80	...	..	1.0
CES-16-103	...	...	...	1.42	1.42	35	84	53	...	..	1.2
L-2A	1.59	0.98	2.01	0.97	1.39	26	82	63	38.9	4.0	2.2
Wayne	1.75	0.78	1.89	1.14	1.39	36	89	85	38.4	3.5	3.0
SL-6	1.33	0.90	2.35	0.81	1.32	25	84	56	40.1	2.5	3.1
Williams	...	...	...	1.24	1.24	33	89	54	...	..	1.0
CES-16-23	...	...	...	1.23	1.23	33	85	75	...	..	1.2
SJ-1	...	0.95	1.30	1.12	1.12	35	95	98	38.0	2.5	2.9
Multivar	...	...	...	1.11	1.11	30	90	58	...	..	1.0
Bragg	1.07	0.46	2.10	0.78	1.08	29	86	44	37.8	3.0	3.0
$LSD_{.05}$	0.51	0.15	0.22	0.23							
CV (%)	20.03	12.00	7.28	15.09							

[a] Rating system of 1-5, from resistant to susceptible.
[b] Percent N x 6.25 (DMB).

Table 5. Yield, Days to Flowering and Maturity, and Plant Height of Group I Soybeans in Thailand

Variety entry	Yield (ton/ha)					Average number of days to		Average plant height (cm)
	Jan. 1973 planting[a]	1974 planting[b]	1974 planting[b]	1974 planting[c]	Average	flowering	maturity	
Clark 63	1.81	1.52	1.85	1.44	1.66	38	92	57
SJ-2	1.41	1.12	1.50	1.66	1.42	48	92	49
Hill	1.44	1.19	1.37	1.12	1.28	42	89	49
SJ-1	0.98	1.01	1.57	1.19	1.19	41	91	50
L-2A	0.71	1.40	1.47	0.98	1.14	36	88	47
Bethel	0.74	1.39	1.28	1.03	1.11	36	91	37
Lincoln	0.89	1.21	0.96	1.25	1.08	35	91	40
A2-5440	0.99	1.04	1.41	0.82	1.07	34	89	54
TK-5	1.08	0.75	1.12	0.99	0.99	47	87	49
Bragg	0.88	1.10	0.99	0.91	0.97	36	91	23
Wayne	0.53	0.64	1.40	1.22	0.95	49	93	64
$LSD_{.05}$	0.45	...	...	...	...			
CV (%)	30.42	...	...	...	...			

[a] Mae-Jo Agricultural Experiment Station.
[b] Prabutharat Field Crops Experiment Station.
[c] Chainat Field Crop Experiment Station.

Table 6. Yield, Days to Flowering and Maturity, Plant Height, Weight of 100 Seeds, Protein Content, and Reaction to Insect and Diseases of Group I Soybeans at Prek Leap Agricultural High School, Khmer Republic

Variety entry	Yield (ton/ha)			Average number of days to		Average plant height	Weight of 100 seeds (gm)	Av crude protein content (%)	Av pest rating[a]	
	Jan. 1973 planting	Jan. 1974 planting	Average	flowering	maturity				Disease	Insect
Clark 63	2.29	2.67	2.48	28	82	52.4	18.5	37.8	2	2
Wayne	2.21	2.40	2.30	20	85	83.4	10.5	33.3	2	2
TK-5	1.82	2.24	2.03	27	79	46.1	17.0	29.9	3	2
Lincoln	1.92	1.89	1.90	16	83	36.9	15.0	33.7	3	3
Hill	1.64	2.16	1.90	22	80	28.7	18.0	33.5	..	..
SL-6	1.72	2.08	1.85	16	80	37.4	15.5	33.0	3	2
A2-5440	1.81	...	1.81	17	78	45.7	19.0	31.9	..	..
Bragg	0.72	2.12	1.42	17	83	19.8	18.0	38.6	2	2
Local (Check)	1.07	1.60	1.33	28	90	37.3	13.0	34.3	3	2
Bethel	1.30	1.24	1.17	21	84	35.0	20.5	36.2	3	4
L-2A	1.16	...	1.16	17	78	36.7	17.0	31.7	..	..
$LSD_{.05}$	0.48	0.45								
CV (%)	21.11	15.00								

[a] Rating system of 1 to 5, from resistant to susceptible.

Table 7. Yield, Days to Flowering and Maturity, Plant Height, Protein Content, and Reaction to Diseases of Group I Soybeans at Serdang, Selangor, Malaysia

Variety entry	Yield[a] (ton/ha)	Average number of days to		Average plant height (cm)	Av crude protein content[c] (%)	Average disease rating[b]	
		flowering	maturity			Rust	Bacterial pustule
TK-5	1.56	33	77	43.8	30.9	1.0	1.0
Clark 63	1.19	33	80	39.9	39.7	1.3	1.0
A2-5440	1.00	26	79	46.4	36.0	3.0	1.0
Wayne	0.93	33	80	77.5	31.7	1.0	1.0
Hill	0.89	30	78	29.1	34.4	2.8	1.0
Lincoln	0.82	28	84	43.8	34.5	1.5	1.5
L-2A	0.76	26	78	46.5	35.3	3.0	2.3
SL-6	0.66	26	82	47.6	32.8	3.3	1.0
Bragg	0.54	28	79	25.7	36.0	3.3	1.0
SJ-1	0.39	33	78	67.1	44.6	3.3	1.0
S2 (Check)	0.39	18	92	101.4	40.0	2.0	1.0
$LSD_{.05}$	0.30						
CV (%)	25.11						

[a] October 1972 planting.
[b] Rating system of 1 to 5, from resistant to susceptible.
[c] Percent N x 6.25 (DMB).

Table 8. Yield, Days to Flowering and Maturity, Plant Height, and Reaction to Diseases of Group I Soybeans at Hatdokkeo Pilot Project, Laos

Variety entry	Yield[a] (ton/ha)	Average number of days to		Average plant height (cm)	Average disease rating[b]
		flowering	maturity		
Clark 63	2.82	34	94	58.5	1.5
Wayne	1.87	47	96	65.4	1.0
TK-5	1.86	37	89	48.0	1.5
Lincoln	1.71	34	89	33.9	1.0
Bethel	1.57	34	89	32.8	1.0
L-2A	1.55	34	89	35.1	1.0
SL-6	1.49	34	89	33.9	1.0
SJ-1	1.48	37	93	54.1	2.0
A2-5440	1.47	34	89	32.8	1.0
Hill	1.44	37	89	37.2	1.5
Bragg	0.79	34	89	25.2	2.5
$LSD_{.05}$	0.32				
CV (%)	14.13				

[a] December 1972 planting.
[b] Rating system of 1 to 5, from resistant to susceptible.

Table 9. Yield, Days to Flowering and Maturity, Plant Height, Protein Content, and Reaction to Diseases of Group II Soybeans at Central Experiment Station, UPCA, Laguna, Philippines

Variety entry	Yield (ton/ha)				Average number of days to		Average plant height (cm)	Av crude protein content[b] (%)	Average disease rating[a]	
	Nov. 1972 planting	Jan. 1974 planting	Feb. 1975 planting	Average	flowering	maturity			Rust	Bacterial pustule
#29	...	2.03	2.64	2.33	33	85	50.6	33.3	..	2.5
SJ-2	0.98	2.36	2.81	2.05	34	92	53.7	38.0	3.3	1.8
Americana	1.15	2.19	2.26	1.86	31	89	65.2	41.4	2.0	2.0
945	1.06	2.01	2.35	1.81	33	85	80.4	38.3	4.3	2.3
KE-32	1.25	1.72	2.46	1.81	27	87	48.2	39.7	3.3	2.5
Palmetto	1.03	1.89	2.34	1.75	29	88	65.1	38.2	3.8	3.0
CES 434	0.85	2.61	1.23	1.56	36	93	79.1	39.3	2.5	1.5
L-114	0.95	2.37	1.28	1.53	37	95	67.1	42.3	2.0	1.8
TK-5	0.76	1.80	1.80	1.45	33	81	38.3	39.0	5.0	3.0
1248	1.01	1.80	1.05	1.29	29	93	52.5	39.9	4.0	1.8
Jupiter	...	...	0.69	0.69	36	..	36.9	...	..	..
$LSD_{.05}$	0.15	0.27	0.63							
CV (%)	10.00	8.93	7.40							

[a] Rating system of 1 to 5, from resistant to susceptible.
[b] Percent N x 6.25 (DMB).

Table 10. Yield, Days to Flowering and Maturity, Plant Height, and Reaction to Diseases of Group II Soybeans at Mae-Jo Agricultural Station, Thailand

Variety entry	Yield (ton/ha)[a]	Average number of days to		Average plant height (cm)	Average downy mildew rating[b]
		flowering	maturity		
KE-32	1.59	41	92	40.9	1.8
1248	1.46	43	90	43.4	1.8
945	1.37	40	90	56.2	2.0
SJ-2	1.24	42	96	58.9	1.0
L-114	1.16	43	103	50.1	2.0
Americana	1.11	38	98	38.0	1.0
SJ-1	0.99	40	93	62.5	1.8
Palmetto	0.94	40	92	65.9	1.3
TK-5	0.93	43	91	42.1	2.8
CES 434	0.92	62	105	82.9	1.0
$LSD_{.05}$	0.39				
CV (%)	23.07				

[a] January 1973 planting.
[b] Rating system of 1 to 5, from resistant to susceptible.

Table 11. Yield, Days to Flowering and Maturity, Plant Height, Weight of 100 Seeds, Crude Protein Content, and Reactions to Pests of Group II Soybeans at Prek Leap Agricultural High School, Khmer Republic

Variety entry	Yield (ton/ha)			Average number of days to		Average plant height (cm)	Weight 100 seeds (gm)	Av crude protein content[b] (%)	Av pest rating[a]	
	Jan. 1973 planting	Jan. 1974 planting	Average	flowering	maturity				Disease	Insect
SJ-2	1.97	1.75	1.86	28	88	57.7	14	41.5	2	3
1248 (Davros)	1.70	1.79	1.74	28	86	51.9	16	42.0	2	3
Palmetto	1.50	1.50	1.0	27	87	69.0	13	37.9	2	3
945	1.51	1.39	1.45	26	85	83.9	18	34.8	2	3
Americana	1.39	1.52	1.45	28	90	47.9	21	38.0	2	2
TK-5	1.36	1.33	1.34	28	81	39.2	22	39.4	2	3
CES 434	0.99	1.67	1.33	36	104	60.8	20	40.5	3	3
Local (Check)	1.20	1.27	1.23	28	88	52.8	18	33.8	3	2
KE-32	0.94	1.24	1.09	27	88	38.0	14	37.9	3	3
SJ-1	0.76	1.42	1.09	28	88	60.4	18	...	3	2
L-114	0.53	0.85	0.69	37	104	38.9	18	40.7	3	3
$LSD_{.05}$	0.38	0.49								
CV (%)	21.03	24.00								

[a] Rating system of 1 to 5, from resistant to susceptible.
[b] Percent N x 6.25 (DMB).

Table 12. Yield, Days to Flowering and Maturity, Plant Height, Protein Content, and Reaction to Diseases of Group II Soybeans at Serdang, Selangor, Malaysia

Variety entry	Yield[a] (ton/ha)	Average number of days to		Average plant height (cm)	Average crude protein content[c] (%)	Average rust rating[b]
		flowering	maturity			
L-114	1.14	40	93	54.6	38.3	1
KE-32	0.95	37	78	53.2	35.6	2
TK-5	0.88	33	78	44.0	30.9	1
945	0.33	37	78	76.3	33.5	2
Americana	0.80	36	88	49.2	36.5	2
CES-434	0.79	40	89	60.7	40.4	3
S2 (Check)	0.69	46	90	72.8	40.0	2
SJ-2	0.67	36	81	63.5	32.8	4
1248	0.58	38	79	59.1	41.4	3
Palmetto	0.58	38	79	61.7	38.4	3
$LSD_{.05}$	0.35					
CV (%)	34.72					

[a] November 1972 planting.
[b] Rating system of 1 to 5, from resistant to susceptible.
[c] Percent N x 6.25 (DMB).

Table 13. Yield, Days to Flowering and Maturity, Plant Height, and Reaction to Diseases of Group II Soybeans at Hatdokkeo Pilot Project, Laos

Variety entry	Yield[a] (ton/ha)	Average number of days to		Average plant height (cm)	Average disease rating[b]
		flowering	maturity		
CES 434	2.13	44	113	79.5	1.0
TK-5	1.67	41	92	39.0	1.0
SJ-2	1.65	41	97	43.0	1.8
1248	1.61	41	91	42.7	1.0
L-114	1.43	43	99	37.4	1.5
Palmetto	1.42	41	92	52.8	1.0
945	1.36	41	92	47.1	1.0
KE-32	1.35	41	98	31.0	1.0
E.G. Special	1.18	41	91	33.0	1.0
Americana	1.00	41	97	29.5	1.0
$LSD_{.05}$	0.36				
CV (%)	17.01				

[a] December 1972 planting.
[b] Rating system of 1 to 5, from resistant to susceptible.

Variety Performance in the Tropics and Subtropics

D. K. Whigham

The University of Illinois began testing soybeans in the subtropics about ten years ago. India was the first of ten countries with which the University cooperated before the establishment of the International Soybean Program (INTSOY) in 1973 (Development and Food Utilization of Soybeans, 1973). The International Soybean Variety Evaluation Experiment (ISVEX) was initiated in 1973 as a part of INTSOY, supported by the United States Agency for International Development. ISVEX is the first stage of a breeding program to identify adapted germ plasm and desirable plant characteristics for improving soybean production and utilization in the tropics and subtropics. Information from ISVEX is being utilized by the INTSOY plant breeding program for varietal improvement. The objectives of ISVEX are to: (a) test the adaptation of soybean cultivars under a wide range of environmental conditions; (b) provide research workers an opportunity to compare local and introduced cultivars; (c) provide a source of new germ plasm which cooperators may use directly or incorporate into breeding programs; (d) identify areas of the world that have a potential for soybean production; and (e) evaluate the responses of soybeans to different environments.

Data from the first ISVEX (Whigham, 1975) were received from 60 sites in 27 countries. The experiment included 20 soybean cultivars from various regions of the United States. The cultivars represented a wide range of genotypic and phenotypic characteristics and had some resistance to known pests. Because of the lack of a seed supply, uniform testing of cultivars from other countries was not possible, but local cooperators at many sites included one or more local cultivars in the experiment to compare their performance with that of the cultivars supplied by INTSOY. The second ISVEX (Whigham, 1976), in which 15 cultivars were tested, has produced data from 86 sites in 39 countries. Each site received the same set of cultivars for testing.

Communication between INTSOY and the cooperators is maintained by letters, on-site visits, and meetings. Numerous letters were exchanged with the cooperator to keep him informed about results from past experiments and plans for future cooperation. Whenever possible INTSOY staff visit the sites to become better acquainted with the cooperator, to observe the trial and other soybean research, to discuss the results of previous work and plans for the future, and to help solve any problems which have developed. International conferences and workshops also permit the cooperators to meet with INTSOY staff and discuss their work.

Because ISVEX is a cooperative program, the cooperator must request an experiment in order to participate and must be willing to provide the land (0.1 ha), labor, fertilizer, and management necessary. INTSOY provides the seed, inoculant, instructions, data book, and computer facilities for data analyses. Results from the experiment are returned to the cooperator for utilization.

ISVEX PROCEDURES

Commercially produced certified or foundation seeds of the cultivars were treated with a fungicide and micronutrients to improve stand establishment and plant development. Seeds were packaged for individual rows and randomized before shipment to the cooperator. Fresh inoculant was shipped with the seed. Detailed instructions for experiment management and data collection were provided with a field data book. Shipment of materials was made by air to reduce the loss of seed and inoculum viability and to assure delivery for optimum planting time.

The cultivars were evaluated in a randomized, complete block design with four replications. Each plot consisted of four rows spaced 60 cm apart. Rows were 6 m long in the first ISVEX, but were reduced to 5 m for the second experiment. Five meters of the two center rows were harvested in both experiments. A plant population of 400,000 plants per hectare was optimum.

The cooperator provided general information about the site and the experiment, including latitude, altitude, soil conditions, dates of planting and harvesting, amount of moisture, fertilizer used, local cultivars tested, and

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pests of the environment. In this paper I will use data from individual plots to discuss the following agronomic characteristics: yield (kg/ha), 100-seed weight, days to flower, days to maturity, plant height at maturity, and pods per plant.

EXPERIMENT SITES AND SOYBEAN CULTIVARS

The first ISVEX tested a wide range of environmental conditions representing latitudes from 30° S. to 35° N. and altitudes from 9 m to 1,803 m. The second ISVEX represented environments of 27° S. to 40° N. latitude and from 0 m to 1,850 m altitude. Local conditions dictated the optimum planting time at each site, and plantings were made throughout the testing zones during each month of the year. Each of several sites conducted the experiment during more than one season. Table 1 identifies the countries cooperating in ISVEX-1 and 2.

Table 1. Countries Where First and Second International Soybean Variety Evaluation Experiments Were Held

Region	Country	ISVEX number
Africa	Angola	2
	Cameroon	2
	Egypt	1 and 2
	Ethiopia	1 and 2
	Ghana	1 and 2
	Ivory Coast	2
	Lesotho	1
	Nigeria	2
	Rhodesia	2
	Sierra Leone	1 and 2
	Somalia	1
	Swaziland	2
	Tanzania	1
	Zambia	2
Asia	Afghanistan	1 and 2
	India	1 and 2
	Indonesia	1 and 2
	Malaysia	1 and 2
	Nepal	2
	Pakistan	1 and 2
	Philippines	1 and 2
	Sri Lanka	1 and 2
	Taiwan	1 and 2
	Thailand	1 and 2
	Vietnam	1
Europe	Spain	2
Mesoamerica	Belize	1
	Costa Rica	1 and 2
	Dominican Republic	2
	El Salvador	2
	Mexico	1 and 2
	Nicaragua	1
	Panama	2
	Puerto Rico	1 and 2
	Trinidad	2
Middle East	Iran	2
	Israel	2
	Jordan	1 and 2
	Lebanon	2
	Saudi Arabia	2
	Syria	1
South America	Bolivia	2
	Colombia	1 and 2
	Ecuador	1 and 2
	Guyana	2
	Venezuela	2

In order to set reasonable limits to the environmental range, the test sites were divided into zones determined by units of 10° latitude and 500 m altitude (Table 2). Within each zone there was considerable variation in temperature, moisture, and radiation. Results from zones I, IV, and VII will be discussed in this paper.

The first ISVEX included 20 cultivars (Table 3) representing U.S. maturity groups I through IX. The number of entries was reduced to 15 for the second ISVEX. Twelve cultivars were common to ISVEX-1 and 2.

RESULTS AND DISCUSSION

Table 4 presents the mean values for the major agronomic characteristics measured. Zones I, IV, and VII represent the tropics and subtropics at altitudes less than 500 m. Comparisons between zones and years were

Table 2. Environmental Zones for First and Second International Soybean Variety Evaluation Experiments

Zone	Latitude	Altitude
I	≤*10°59′	≤*500
II	≤*10°59′	501–1,000
III	≤*10°59′	>**1,000
IV	11°–20°59′	≤*500
V	11°–20°59′	501–1,000
VI	11°–20°59′	>**1,000
VII	21°–30°59′	≤*500
VIII	21°–30°59′	501–1,000
IX	21°–30°59′	>**1,000
X	31°–40°59′	≤*500
XI	31°–40°59′	501–1,000
XII	31°–40°59′	>**1,000

* ≤ = less than or equal to.
** > = greater than.

Table 3. Soybean Cultivars Tested in First and Second International Soybean Variety Evaluation Experiments

Cultivar	U.S. maturity group	ISVEX number
Jupiter	IX	1 and 2
Hampton 266A	VIII	1 and 2
Hardee	VIII	1 and 2
Hutton	VIII	1
Improved Pelican	VIII	1 and 2
Bossier	VII	2
Bragg	VII	1 and 2
Semmes	VII	1 and 2
Davis	VI	1 and 2
Lee 68	VI	1
Pickett 71	VI	1
Tracy	VI	2
Dare	V	1
Forrest	V	2
Hill	V	1 and 2
Bonus	IV	1 and 2
Clark 63	IV	1 and 2
Cutler 71	IV	1
Adelphia	III	1
Calland	III	1 and 2
Williams	III	1 and 2
Harosoy 63	II	1
Hark	I	1

Table 4. Mean Values for Agronomic Characteristics During First and Second International Soybean Variety Evaluation Experiments

Characteristic	ISVEX number	Agronomic data from three zones		
		I	IV	VII
Yield (kg/ha)	1	1,754	1,649	1,428
	2	2,260	1,928	1,221
100-seed weight (g)	1	17.6	15.6	13.5
	2	18.3	16.5	12.3
Days to flower	1	30	35	35
	2	30	34	42
Days to maturity	1	89	98	99
	2	94	98	114
Plant height (cm)	1	39	39	46
	2	45	48	67
Pods per plant	2	29	31	44

Table 5. Mean Maximum Yields for First and Second International Soybean Variety Evaluation Experiments

ISVEX number	Yield (kg/ha) in three zones		
	I	IV	VII
1	2,358	2,031	1,872
2	2,546	2,370	1,695

possible for all agronomic characteristics except pods per plant, which were not measured during the first ISVEX.

Grain yield. Yield was highest in zone I for both ISVEX-1 and 2, but decreased in both experiments as latitude increased. However, the yield differences varied more in ISVEX-2 from zones I to VII with a difference of 1,039 kg compared to 326 kg in ISVEX-1. The greatest difference occurred between zones IV and VII in ISVEX-2. In both experiments less favorable environments for soybean production were represented by sites in the subtropic areas. Yields were considerably higher for zones I and IV in ISVEX-2, but lower for zone VII because a few individual sites with unfavorable environmental conditions produced extremely low yields. Improved cultural management by the cooperators and the use of better adapted cultivars resulted in the increased yields in zones I and IV during ISVEX-2. Mean maximum yields across all sites within these three zones are shown in Table 5. Maximum yields showed the same trends as the mean yields (Table 4) but at a higher level. Mean maximum yields were a better indication of yield potential, since poorly adapted cultivars were also included for the mean value of all entries. Cultivars which produced the maximum yield varied from site to site.

Table 6 shows the maximum grain yields over 4,000 kg/ha reported during both experiments. Most of the high yields were produced in zone I. The two sites that produced yields greater than 5,000 kg/ha were in zone I in ISVEX-2. Of the 10 cultivars indicated in Table 6, Jupiter produced high yields most frequently. Yields of more than 4,000 kg/ha at so many sites indicate that many tropical and subtropical environments do have the potential for soybean production.

Seed weight. As latitude increased seed weight decreased. Compared with seeds produced during ISVEX-1, those produced during ISVEX-2 were larger in zones I and IV, but smaller in zone VII. Grain yield and seed weight trends were the same in both experiments. The highest mean seed weight of 18.3 g/100 was associated with the highest grain yield in zone I of ISVEX-2. The lowest mean seed weight of 12.3 g/100 occurred in zone VII of ISVEX-2, as did the lowest mean grain yield of 1,221 kg/ha (Table 4).

Days to flower. In zone I the number of days to flower was the same for ISVEX-1 and 2 even though the cultivar entries varied between experiments (Table 3). Daylength, which is determined by latitude, was the major factor that controlled flowering. Days to flower in zone IV differed by only one day between experiments. In zone VII the mean number of days to flower varied by one week between experiments because of changes in cultivars and testing sites. ISVEX-2 showed an increase in days to flower as latitude increased through 30°. The number of days to flower in ISVEX-1 increased only through 20° latitude.

Table 6. Maximum Grain Yields Over 4,000 kg/ha During First and Second International Soybean Variety Evaluation Experiments

Country	Site	Yield (kg/ha)	Cultivar	ISVEX number	Zone
Bolivia	Abapo-Izozog	4,392	Davis	2	IV
Colombia	Palmira	4,530	Jupiter	1	II
Ecuador	Boliche	4,621	Bossier	2	I
	Portoviejo	4,281	Hardee	1	I
Guyana	Mon Repos	4,140	Jupiter x F67-1533	2	I
Iran	Karaj	4,886	Calland	2	XII
Mexico	Chiapas	4,896	Hampton 266A	1	IV
Nepal	Khumaltar	4,300	bonus	2	IX
Pakistan	Mansehra	4,911	Jupiter	1	XII
	Swat	4,826	Lee 68	1	XII
	Swat	4,493	Williams	2	XI
Sri Lanka	Kilinochchi	5,392	Davis	2	I
	Maha Illuppallama	4,003	Williams	1	I
	Thirunelvely	4,428	Improved Pelican	2	I
Venezuela	Maracay	5,465	Jupiter	2	I

Days to maturity. In both experiments the number of days to maturity increased as latitude increased. Zone IV had the same number of days to maturity in both experiments. ISVEX-2 required more days to mature than ISVEX-1 in zones I and VII. Longer days at the higher latitudes resulted in later flowering and a corresponding delay in maturity.

Plant height. As latitude increased, plant height increased, with the exception of zones I and IV during ISVEX-1. The change of cultivars between experiments allowed the ISVEX-2 mean values to be greater in all three zones than during ISVEX-1. Plant height was affected by the longer days and the longer maturation period of the higher latitudes. However, more days to maturity and greater plant height did not have a positive effect on yield or seed weight.

Pods per plant. In ISVEX-1 the number of pods per plant was not determined, but results from ISVEX-2 showed an increase in the number of pods as latitude increased. Taller plants with more days in which to develop produced more pods. Nevertheless, in zone VII the larger number of pods did not compensate for the smaller seeds, because grain yield was less in this zone than in the other two zones. Seed number was not measured in either experiment; however, by assuming that the mean plant population was 400,000 plants per hectare (desired population), the number of seeds per pod was calculated to be 1.06, 0.94, and 0.56 for zones I, IV, and VII, respectively, for ISVEX-2. Therefore, seed number decreased as latitude increased, thus following the same trend as grain yield and seed weight.

Mean rank of the cultivars for high grain yield by zone and experiment is shown in Table 7. Hardee was the most consistent for high yield in zones I and IV during ISVEX-1, and was among the top six entries in all three zones during ISVEX-2. Bossier, a new entry in ISVEX-2, was the most consistent for high yield across zones I, IV, and VII. Williams, which appeared among the top six entries in zone VII, performed better during ISVEX-1 than ISVEX-2. Davis and Improved Pelican were consistent in all three zones during ISVEX-2, and in zones I and IV during ISVEX-1. Jupiter made a strong showing during ISVEX-2 in zones I and IV. Although cultivars responded differently to the environments of individual sites (Development and Food Utilization of Soybeans, 1973; Whigham, 1975 and 1976), preliminary evaluation of soybean cultivars could start with those listed in Table 7, provided that the testing site falls within the environmental limits of zones I, IV or VII.

Table 7. Mean Rank of High Yield Cultivars for First and Second International Soybean Variety Evaluation Experiments

First ISVEX		
Zone I (24 sites)	Zone IV (20 sites)	Zone VII (5 sites)
Hardee	Hardee	Williams
Williams	Clark 63	Pickett 71[a]
Davis	Improved Pelican	Lee 68[a]
Hampton 266A	Cutler 71[a]	Clark 63
Cutler 71[a]	Williams	Bragg
Improved Pelican	Davis	Harosoy 63[a]
Second ISVEX		
Zone I (37 sites)	Zone IV (21 sites)	Zone VII (6 sites)
Davis	Jupiter	Bossier[a]
Bossier[a]	Bossier[a]	Tracy[a]
Improved Pelican	Calland	Williams
Jupiter	Improved Pelican	Hardee
Hardee	Davis	Improved Pelican
Calland	Hardee	Davis

[a] Cultivars not tested in both experiments.

SUMMARY

Within the environmental limits of the experimental fields, i.e., from the equator to 30° latitude and less than 500 m altitude, the mean values for each designated experimental zone (10° latitude) indicate that yield and seed weight decreased as latitude increased. The number of days to flower and days to maturity increased as latitude increased. Plant height at maturity and pods per plant increased as latitude increased.

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Discussion

J. N. Sasser: Did you record whether or not root-knot nematodes and/or soybean cyst nematodes were present in the test plots? You included in your test some varieties that are root-knot resistant, some that are resistant to the soybean cyst nematode, and some apparently not resistant to either. Therefore, a consideration of whether or not the nematodes were present might be helpful in explaining the results that you observed in yield data.

D. K. Whigham: Root knot and cyst nematodes are included as diseases to be identified and rated by the cooperator. However, because of the lack of knowledge about nematodes and the difficulty of sampling soybean roots, we have received no information about these organisms from our cooperators. I have recommended that specific experiments be established to examine such problems.

K. R. Bromfield: There are reports of the presence of *Phakopsora pachyrhizi,* the soybean rust organism, in cowpeas in Africa. Has soybean rust been observed on soybeans in your INTSOY trials in Africa?

D. K. Whigham: We have not received any reports of soybean rust from our cooperators outside of Asia.

Seed Quality and Storage of Soybeans

J. C. Delouche and E. D. Rodda

Soybean farmers in the United States recognized early that soybean seed was somewhat different from the seed of almost all other crops, such as maize, wheat, cotton, and sorghum, with which they were familiar. Very often soybean seed germinated poorly even immediately after harvest. Germination further decreased during storage to the extent that by the next growing season the seed was worthless for planting. Ordinary seed-saving practices used by farmers for self-pollinating crops that require replacement of the seed only every three or four years did not, and still do not, work well for soybeans.

Some farmers did learn through experience how to produce and store soybean seed of satisfactory quality by installing basic facilities. These farmers have been able to save their own seed over several cropping seasons, but they always have the option of obtaining the necessary planting seed from commercial sources or a neighbor whenever their own seed production efforts fail, which is rather frequently. Other soybean farmers, perhaps the majority, have turned increasingly to the specialized, professional seed producers and companies, in other words, the seed industry, for their seed supply.

Production of quality soybean seed is not without problems and risks, even for the specialists and professionals. However, their experience, facilities, and other resources, as well as their concentration on the single task of producing quality seed, have permitted the development of a responsible soybean seed supply industry capable of delivering moderate to good quality seed in quantities ample enough to meet the needs of soybean farmers.

ATTRIBUTES OF SEED QUALITY

Soybean seed quality encompasses several important attributes:

1. **Genetic purity.** Cultivar purity is important from the standpoint of both total performance and uniformity, especially uniformity of maturity.
2. **Physical purity.** Soybean seed should contain a minimum amount of inert material and should not be contaminated with the seed of weeds and other crops.
3. **Germination.** High quality seed should have a germination rate of 85 percent or higher.
4. **Vigor.** The germinable seed in a lot should be vigorous enough to emerge rapidly and uniformly under a broad spectrum of seed bed conditions and to develop into rapidly growing, productive plants.

Although the most chronic and difficult seed quality problems in soybeans relate to germinability and vigor, serious problems can also arise in connection with cultivar and physical purity.

QUALITY OF SEED ENTERING STORAGE

The success of seed storage is largely influenced by the degree to which the seed has deteriorated prior to storage. Soybean seed subjected to weathering before harvest or severely damaged during harvest does not store well even though it may germinate moderately well after several months in storage.

Field Environment

The quality of soybean seed is very much affected by climatic conditions from the time seed moisture first drops below 25 percent during the postmaturation drying phase until harvest. Physiologically mature, the seeds are in effect stored in the field during this period. Frequent or prolonged precipitation during the postmaturation, preharvest period results in severe deterioration of the seed because of alternate wetting and drying. Conversely, a reduction in the physical and physiological quality of soybean seed has been associated with hot, dry weather during harvest.

Harvesting and Threshing

The harvesting and threshing process is probably the most critical phase in the overall soybean seed produc-

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tion and processing operation. Seed quality can be seriously affected during this phase in three respects. First, improper cleaning of the combine or threshing machine and incautious operation are major sources of cultivar contamination. Second, the timeliness of harvest is most important in minimizing field deterioration. Finally, mechanical abuse during harvesting and threshing, commonly referred to as mechanical damage, is the primary cause of injury to soybean seed.

The most favorable seed moisture content for soybeans at the time of harvest is controversial. Available evidence, however, suggests that the optimal range of seed moisture content for harvest is rather narrow, i.e., between approximately 13 and 15 percent. Seed cracking and splitting increase sharply as moisture content decreases below 13 percent, while seed bruising and other less visible, but no less detrimental, injuries increase at moisture contents above 15 percent.

DRYING AND STORAGE

Soybean seed harvested when the moisture content is above 14 percent must be dried to 13 percent or less to maintain viability in bulk storage. Natural air drying at flow rates of 3 to 5 cubic feet per minute per bushel (1.5 to 2.5 cubic centimeters per second per kg) is adequate for drying seed with about 16 percent moisture. For seed with moisture contents above 16 percent, supplemental heat and air flow rates, about twice those given above, are usually necessary for effective drying. In bulk storage the depth of the seed to be dried should not exceed 4 feet, and temperature of the drying air should not exceed 30°C.

In temperate climates, to maintain both germination and vigor from harvest to planting (about 8 to 9 months), soybean seed should be rapidly and properly conditioned to 12 to 13 percent moisture content after harvest. The seed should then be stored over the winter in a dry, ventilated storehouse. In tropical and subtropical areas, where the average annual temperature may be as high as 25°C, it may be necessary to air-condition a well-constructed storeroom so that temperatures of 20° to 22°C or less and relative humidity of 60 percent or less are maintained. Under these conditions soybean seed of reasonably good quality when placed in storage will remain viable for 8 or 9 months until planting. An alternative to air-conditioned storage is to dry the seed to about 9 percent moisture and then package it in moisture-vapor-proof packages. For this purpose polyethylene bags 10 mil (.26mm) thick or tightly sealed metal containers have proved satisfactory.

Seed-Borne Microorganisms and Their Control

James B. Sinclair

Since 1974 plant pathologists and soybean breeders have become increasingly aware that the single most important factor in the so-called "yield barrier" in soybean production in the United States is a pathological one. Among the pathogens attacking soybeans, those that cause root, stem, and seed diseases are of the greatest economic importance. Most of the important pathogens are seed borne. Only since 1975, however, has their widespread deleterious effect on seed quality, seedling vigor, and yield been appreciated.

SEED-BORNE MICROORGANISMS IN SOYBEANS

There are about 100 genera of fungi, nine species of bacteria, about 30 genera of nematodes, and 15 viruses reported to be associated with soybeans; about 100 microorganisms are associated with soybean seeds (Sinclair and Dhingra, 1975; Sinclair and Shurtleff, 1975). Most of the more common fungi associated with soybean seeds can cause distinctive symptoms on the seeds (Deutschmann, 1953; Sinclair and Dhingra, 1975; Sinclair and Shurtleff, 1975). These fungi include: *Cercospora* spp., *C. kikuchii, Colletotrichum dematium* var. *truncatum, Diaporthe phaseolorum* var. *sojae* (*Phomopsis* spp.) (Kmetz et al., 1974), and *Peronospora manshurica.*

The concept of microorganisms being internally seed borne in soybeans has heretofore suggested that the organism would primarily be found between the seed coat and the cotyledons or in the cotyledonary tissues. This concept has persisted in spite of Deutschmann (1953) illustrating the occurrence of *C. kikuchii* in the soybean seed coat.

The seed coat of a healthy soybean seed consists of a cuticle and three distinct cell layers: the palisade (exodermis), hourglass (hypodermis), and parenchyma (parenchyma and endosperm) (Schneider et al., 1974; Wilcox et al., 1974; Wolf and Baker, 1972). Schneider et al. (1974) suggested that the hourglass cell layer in part consists of an amorphous, starch-rich matrix, which could provide a nutrient source for microorganisms. When the seed coat cuticle and palisade layer are damaged, the hourglass cell layer is exposed with the parenchyma layer usually remaining intact. Wolf and Baker (1972) postulated that breaks in soybean seed coats, which may be genetically controlled (Liu, 1949), could provide potential sites for entrance and colonization by fungi.

The hourglass cell layer is the site of initial colonization by *C. kikuchii, C. dematium* var. *truncatum,* and *D. phaseolorum* var. *sojae* (*Phomopsis* spp.) (Deutschmann, 1953; Ilyas et al., 1975; Schneider et al., 1974) (Fig. 1A). Other fungi isolated from the seed coats of surface-sterilized soybean seeds are species of *Alternaria, Aspergillus, Cladosporium, Fusarium, Penicillium,* and *Rhizopus* (Dhingra et al., 1973; Ellis et al., 1974a; Nicholson and Sinclair, 1973; Sinclair and Dhingra, 1975; Sinclair and Shurtleff, 1975; Singh et al., 1973; Tenne et al., 1975).

Bacillus subtilis has been associated with the aerial parts of soybeans (Dunleavy et al., 1966) as well as with the seeds (Singh et al., 1973; Tenne et al., 1975). S. R. Foor, F. D. Tenne, and J. B. Sinclair (unpublished data) found *B. subtilis* in the parenchyma and hourglass cell layers of surface-sterilized soybean seeds (Fig. 1B).

CONTROL OF SEED-BORNE MICROORGANISMS

One of the factors that can reduce soybean seed germination and emergence is seed-borne fungi. Fungicide seed treatment of soybeans can reduce the effect of these fungi (Chamberlain and Gray, 1974; Johnson, 1958; Kirkpatrick and Sinclair, 1973; Mengistu et al., 1975; Nene et al., 1969; Prasartsee and Sinclair, 1974), thus increasing the emergence of low-quality seeds (Mengistu et al., 1975; Prasartsee and Sinclair, 1974). Such treatment, however, has little or no effect on high quality seeds (Table 1). Sinclair (1974) reviewed the use of systemic fungicides in seed treatments for soybeans. Kirkpatrick and Sinclair (1973) showed thiophanate-methyl, BD-18654, and methyl 2-benzimidazole carbamate (MBC) were absorbed by germinating soybean seeds within four hours.

Ellis et al. (1975) showed that the protectant, seed-treatment fungicides, captan and thiram, moved into

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Fig. 1 A and B. Cross sections of soybean seed coats, showing the location of (A) *Diaporthe phaseolorum* var. *sojae* (*Phomopsis* spp.) (arrows) in the palisade (p), hourglass (h), and parenchyma (pa) cell layers (approximately x 225); (B) *Bacillus subtilis* cells (arrows) within the hourglass (h) and parenchyma cell layers (x 600).

the seed coats of treated soybean seeds, but not into the embryo tissues, while benomyl, a systemic fungicide, was taken up by the seed coats and embryo tissues. Captan and thiram presumably moved by diffusion only into the seed coats of treated seeds, while benomyl moved into the seed coat and embryo. Several seed-borne fungi colonized the soybean seed coat (Deutschmann, 1953; Ilyas, 1975; Schneider et al., 1974). Thus, the quantity of fungicide moving into the seed coat could determine its effectiveness.

Dichloromethane (DCM) can be used as a carrier to introduce chemicals into seeds in the absence of water without apparent effects on germination and respiration (Ellis et al., 1976). DCM facilitated the movement of MBC and thiabendazole into dormant soybean seeds in the absence of water, but did not help in the case of captan, thiram or carboxin. Soybean seeds treated with MBC plus DCM and thiabendazole plus DCM had lower levels of internally borne total fungi and *D. phaseolorum* var. *sojae*, and had higher levels of germination *in vitro* and emergence in vermiculite and soil than untreated seeds or seeds treated with DCM alone (Table 2).

D. phaseolorum var. *sojae* (Kmetz et al., 1974) is seed borne in soybeans and causes pod and stem blight as well as seed deterioration (Ellis et al., 1974c, Prasartsee et al., 1975; Tenne et al., 1975; Wilcox et al., 1974). The amount of seed-borne *D. phaseolorum* var. *sojae* was significantly reduced below that on unsprayed plants when soybeans were sprayed in the field with one of the following fungicides or fungicide combinations: benomyl, benomyl plus zinc-ion, captafol, chlorothalonil, mancozeb, thiabendazole, and thiophanate-methyl (Ellis et al., 1974b; Ellis and Sinclair, 1975 and 1976; Prasartsee et al., 1975). The same authors also reported that *D. phaseolorum* var. *sojae* always occurred less in seeds from plants sprayed with benomyl than in seeds from plants sprayed with the other fungicides, and that soybean plants sprayed with benomyl remained green longer than unsprayed plants (Fig. 2).

Delayed harvest results in the increased occurrence of internally seed-borne *D. phaseolorum* var. *sojae* and other fungi (Ellis and Sinclair, 1976; Wilcox et al., 1974). Spraying of soybean plants before maturity with benomyl can significantly reduce seed-borne fungi, and even with a delay in harvest, the fungicide will control the amount of seed-borne fungi (Ellis et al., 1974b; Ellis and Sinclair, 1975 and 1976; Prasartsee et al., 1975) (Table 3).

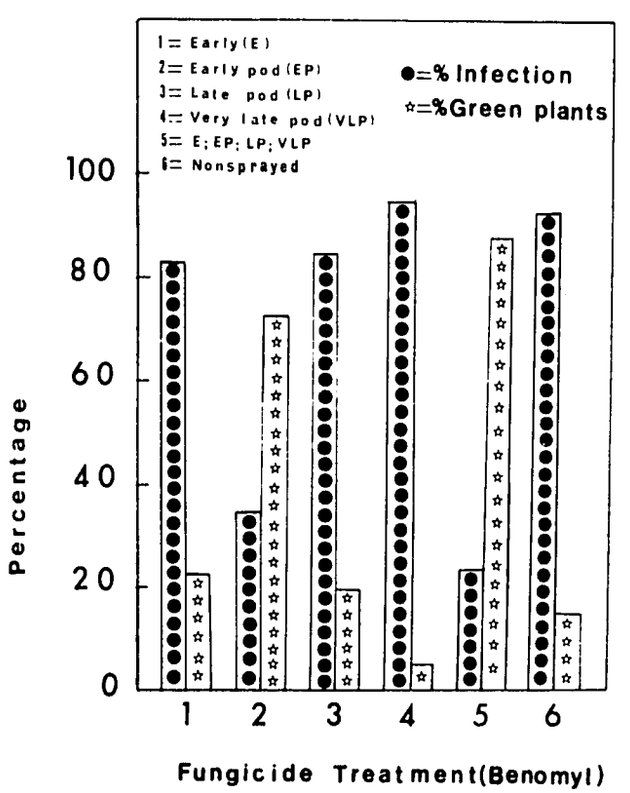

Fig. 2. Relationship between the percentage infection (Percentage) and percentage green plants of soybean (*Glycine max*) from field plots nonsprayed or sprayed with benomyl (1 lb formulated Benlate 65 WP/acre) at various stages of development.

Table 1. Effect of Fungicide Treatment on Stand Establishment with Poor Quality and Good Quality Soybean Seeds

Fungicide	Application rates	Mean stand counts[a]			
		Poor quality seed (Beeson)		Good quality seed (Amsoy 71)	
		15 days	30 days	15 days	30 days
Thylate 65 WP	1.23 oz/bu	88 a[b]	92 a	85 bc	85 a
Captan 80 WP	1.0 oz/bu	85 ab	87 ab	91 a	88 a
UniRoyal 1109	4.0 oz/bu	83 abc	85 abc	82 bcd	89 a
UniRoyal 1127	2.0 fl oz/100 lb	83 abc	85 abc	84 abcd	83 a
Demosan T	4.0 oz/bu	81 abc	84 abcd	87 abc	85 a
UniRoyal 1127	4.0 fl oz/100 lb	78 abcde	80 bcdef	81 cd	81 a
UniRoyal 1109	2.0 oz/bu	77 abcde	81 bcdefg	91 a	89 a
Vitavax SP	4.0 oz/bu	77 abcde	81 bcde	85 abc	85 a
UniRoyal H719	2.0 oz/100 lb	74 bcde	73 efgh	83 abcd	82 a
Nontreated (control)	.....	72 bcde	76 bcdefg	84 abcd	85 a
Celemerck 20EC	1.0 oz/bu	71 bcde	75 bcdefg	88 abc	87 a
Benlate 50 WP	4.0 oz/bu	68 cde	74 defgh	81 cd	86 a
UniRoyal P368	0.25 oz a.i./100 lb	65 de	69 gh	76 d	82 a
UniRoyal P368	0.50 oz a.i./100 lb	65 de	70 fgh	90 ab	86 a
UniRoyal H719 75%	4.0 oz/100 lb	64 de	69 gh	90 ab	86 a
Benlate 50 WP	2.0 oz/bu	64 de	64 h	80 cd	81 a

[a] Three replications of 100 seeds each. [b] Numbers followed by the same letter are not significantly different at the 5 percent level as determined by Duncan's New Multiple Range Test.

Table 2. Effect of Fungicide Treatment of Soybean Seeds on Germination, Emergence, and Prevalence of Seed-Borne Fungi

Treatment[b]	Mean percentage values for cultivar and character shown[a]									
	Hill					Wells				
	Germination	Total fungi	*D. phaseolorum* var. *sojae*	Emergence		Germination	Total fungi	*D. phaseolorum* var. *sojae*	Emergence	
				Vermiculite	Soil				Vermiculite	Soil
Methyl 2-benzimidizole carbamate	93	8	5	95	86	91	10	1	94	87
2-(4'-thiazoly)benzimidazole	93	10	5	96	83	91	8	1	92	86
Solvent alone	63	31	26	72	57	80	24	4	76	72
Untreated control	60	90	33	66	52	74	48	8	75	65
$LSD_{.05}$	8	6	6	7	6	3	10	3	9	6
$LSD_{.05}$	12	9	9	11	9	5	14	4	13	9

[a] Based on three replications of 100 seeds per replication and treatment.
[b] Fungicides applied by soaking seeds for 5 hours in 800 μg fungicide shown/ml dichloromethane.

Table 3. Effect of Fungicides and Harvest Date on Soybean Seed Germination, and Occurrence of Internally Seed-Borne *Diaporthe phaseolorum* var. *sojae*, and Total Fungi

Treatment[b]	Number of sprays	Mean percentage values for cultivar and character shown at two harvest dates[a]											
		Lee 68						Hill					
		Germination		*D. phaseolorum*		Total fungi		Germination		*D. phaseolorum*		Total fungi	
		1	2	1	2	1	2	1	2	1	2	1	2
Benomyl	1	92.5	96.0	1.5	1.0	2.5	2.5	85.5	31.0	14.0	64.0	15.5	86.0
	2	96.5	97.5	0.0	1.0	0.5	3.0	91.5	76.0	5.5	3.5	12.5	41.5
	3	92.5	94.5	1.0	0.5	1.0	1.5	95.5	77.0	3.5	1.0	13.5	40.0
Chlorothalonil	1	87.5	83.0	5.5	13.0	6.0	14.5	86.0	10.0	13.5	88.5	14.0	93.0
	2	91.0	81.0	5.0	14.5	7.3	16.0	89.5	11.0	9.0	82.5	9.5	87.0
	3	91.5	82.5	4.5	9.5	5.0	11.5	93.5	18.5	6.5	77.5	7.5	77.5
Captofol	1	90.0	87.5	6.0	7.0	6.5	12.0	53.5	14.5	46.0	74.5	47.0	78.0
	2	91.2	85.5	3.0	7.0	2.0	8.5	73.0	16.5	25.5	75.5	27.0	80.0
	3	86.5	85.0	4.0	7.5	5.5	9.0	78.0	4.0	21.0	94.0	22.0	94.0
Mancozeb	1	91.5	86.5	4.0	10.0	4.0	12.0	79.5	7.0	20.5	90.5	21.5	93.0
	2	86.0	82.5	6.0	9.5	6.2	14.0	71.0	8.5	28.5	81.0	30.0	84.5
	3	91.5	71.0	4.0	14.0	5.0	16.0	72.0	9.0	26.0	81.0	26.0	87.0
Control		90.5	75.5	3.5	19.0	6.0	26.0	75.5	6.0	24.0	87.5	25.5	88.5
$FLSD_{.05}$ (harvest)[c]		1.1		1.9		0.9		2.4		3.0		3.8	
$FLSD_{.01}$		2.1		3.6		1.8		4.3		7.2		7.1	
$FLSD_{.05}$		4.0		2.5		2.2		3.5		3.6		12.9	
$FLSD_{.01}$		5.4		3.3		2.9		4.7		4.7		17.1	

[a] Percentage based on 200 seeds from each first harvest (1) and delayed harvest (2). There were almost five weeks between harvests for 'Lee 68' and eight weeks for 'Hill.' [b] Applied at a rate of ½ pound formulated material per acre. [c] Carmer and Swanson, 1971.

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Discussion

John M. Yohe: Do you find cohabitation of *B. subtilis* and *Diaporthe* sp. in the seed coat at the same time, and how and when does the *B. subtilis* infect the pod or seed?

James B. Sinclair: Yes, we find cohabitation of various fungi and bacteria in soybean seeds. We do not have good experimental data on how and when *B. subtilis* infects the soybean seed.

D. K. Whigham: Have you observed seed coat thickness differences between large and small seeds? Might such differences affect the infestation of seed pathogens?

J. B. Sinclair: No, we have not looked for differences in seed coat thicknesses between cultivars. Yes, we might expect that seed coat thickness could be a factor in seed infestation.

S. Shanmugasundaram: Does the moisture content of the seed have any influence on the population and type of fungi and bacterial pathogens in the seeds?

J. B. Sinclair: This is a difficult question for which there is no simple answer. The microorganisms like moisture. If the moisture content is in excess of 13 percent, then there will be more pathogens, but if the moisture is regulated and the seed is stored under cool temperatures, then the seed-borne fungi and bacteria may be fairly well controlled.

M. C. Saxena: The purple stain pathogen reduces the quality of the seed. Should there be any standards provided for purple-stain-affected seeds? Is there any treatment to knock out the fungus on the seed?

J. B. Sinclair: Most research data show that the purple stain fungus (*Cercospora* spp.) is confined to the seed coat and has little effect on germination and emergence. There is no seed treatment that will completely control the fungi involved. An unpublished study in Puerto Rico shows that spraying with benomyl at about the mid-pod stage gives satisfactory control of the disease.

Soybean Inoculation

Lloyd R. Frederick

Soybeans are a high-protein crop requiring large amounts of nitrogen for satisfactory yields. Fortunately, soybeans are a legume that forms a partnership in root nodules with the bacterium, *Rhizobium japonicum*. These nodules allow the soybean plant to use elemental nitrogen (N_2) from the air. Inoculation is a way to provide adequate numbers of the proper bacteria in the soybean root zone so that excellent, effective nodulation takes place.

To use nitrogen from the air successfully, both the proper soybean plant and the proper bacteria are needed. Either fails without the other. The soybean plant has genetic capabilities for accepting or resisting the formation of nodules. The selection of soybean varieties that readily form effective nodules is very important because some lines of soybeans do not nodulate in the field. Also, certain Rhizobium strains are capable of infecting only certain soybean varieties. Therefore, selection of compatible combinations is important. Hardee soybeans, for example, do not nodulate effectively with C-1 and 122 serogroups of *R. japonicum*. Using an inoculant containing only a strain or strains in the C-1 serogroup resulted in nodulation failures and low yields. Using inoculant containing strains in the C-2 or C-3 serogroups, with or without C-1 strains, provided adequate nodulation (Vest et al., 1973).

In this paper the practical aspects of inoculation will be stressed. Particularly from the farmer's viewpoint, answers to the following questions are needed: (a) when and how often is it necessary to inoculate; (b) what is a high quality inoculum and where can it be obtained; and (c) how should the inoculum be used so as to get good results.

THE NEED FOR INOCULATION

When is inoculation needed? In any situation where soybeans respond to nitrogen fertilization, more effective nodulation is needed. Better nodulation can be achieved in many situations by better inoculation. Soybeans grown for the first time on a field usually respond to inoculation because few soybean Rhizobium bacteria are present in the soil. On soils low in nitrogen inoculated beans often yield 150 to 200 percent more than uninoculated beans (Nantakorn, personal communication). To obtain comparable yields with fertilizer requires large amounts of nitrogen per hectare. In fields where nodulated soybeans have been grown previously, soybean Rhizobium bacteria are often present, but their numbers may be high or low, and the Rhizobium present may form nodules of unknown effectiveness (Ham et al., 1971; Weaver et al., 1972).

Nodulation effectiveness can vary from one area of the field to another. Yield increases for soybeans are often small (5 to 10 percent) on fields where nodulated soybeans were previously grown. But farmers aiming for top yields often inoculate all soybeans planted because the cost of inoculation is usually less than the value of 60 kilograms of soybeans per hectare. More research is needed to determine the survival patterns of Rhizobium bacteria in different soils and cropping sequences, especially in acid or flood soils. The failure to use good inoculants can cost many kilograms of seeds because of nitrogen deficiency.

HIGH QUALITY INOCULANT

High quality inoculant provides effective, efficient living Rhizobium bacteria. Rhizobium strains need to be evaluated and selected for the crops and areas where they will be used. Mixing a few of the better strains of Rhizobium in an inoculant provides greater assurance of successful nodulation when used with different soybean varieties and soil conditions.

High quality inoculant also provides large numbers of effective, efficient living Rhizobium bacteria but Rhizobium numbers in the inoculant can be reduced quickly by unfavorable storage conditions. Drying is very detrimental. High temperatures (above 35°C) also decrease populations rapidly. Rhizobium numbers on inoculated

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seed exposed to a drying wind and sun can drop from a million (10^6) to less than a thousand (10^3) per seed in less than an hour. Placing the inoculant on the seed as a slurry or a dust is a convenient method of inoculation, but the drying is extremely hazardous to the Rhizobium bacteria, and the seed provides them very little protection. The use of seed protectant fungicides increases the hazards for the Rhizobium. Since the number of Rhizobium bacteria that can cling to and survive on a seed is limited, the inoculated seed should be protected and planted as quickly as possible after inoculation. Other methods of inoculation are needed to provide large numbers of Rhizobium bacteria as conveniently as possible. High quality inoculant can be assured only when adequate quality control is used and low quality inoculants discarded (Vincent, 1970).

USE OF INOCULANTS

Inoculation is a numbers game. At least one million Rhizobium bacteria per seed appear to be desirable for field application, although lower numbers sometimes give good results if conditions are favorable. Among other reasons, large numbers of Rhizobium bacteria tend to increase soybean yields (a) by promoting early nodulation and growth, (b) by ensuring greater survival of Rhizobium bacteria during adverse storage or growing conditions, and (c) by competing more successfully against the soil Rhizobium bacteria, which may be less desirable than those in the inoculant.

The location of nodules on the root system is an indicator of the time of infection and nodule development, and as such should be observed (Weaver and Frederick, 1972). Nodules on the upper tap root form early, usually within the first 14 days of seedling growth. The presence of large numbers of Rhizobium bacteria usually results in upper tap root nodulation and early nitrogen fixation. When most of the nodules are on the secondary roots or on the lower tap root, an indication of delayed nodule development, nitrogen deficiency may be prolonged, causing reduced yields. Delayed nodule development can be caused by low numbers of Rhizobium bacteria. When the numbers are low, the bacteria must colonize the root and proliferate, which often results in nodulation only on the secondary roots, especially when soil or climatic conditions are unfavorable. Thus, the pattern of nodulation on the root system is a rough indication of the abundance of Rhizobium bacteria present while the seedling was developing.

Improved methods of inoculation are needed, but until they are developed, the best methods currently available should be used. Proper use of inoculants has resulted in increased nodulation and yields in Thailand, in India, and in many other tropical areas. Education of the people who produce and distribute the inoculants and those who use them is essential. Because inoculants are cultures of living cells, they will be preserved best if handled like perishable produce such as meat or fresh vegetables.

Adding the inoculant in a thick layer around the seed to form a pellet has improved inoculation success with small-seeded legumes, but few data are available for this technique with large-seeded legumes. More studies of this inoculation technique for soybeans are needed.

Direct placement of the inoculant into the soil at the time of planting the soybeans has often improved inoculation (Scudder, 1975). Both liquid and solid (usually peat) carriers have been used with success. Placement in moist soil at or slightly below the seed has proved satisfactory. Either much larger amounts of inoculant or inoculants carrying much higher numbers of Rhizobium bacteria are desirable for this improved method of direct soil inoculation.

The proper use of soybean inoculants should be an integral part of the educational "package" of practices for good soybean production. Inoculants provide the Rhizobium bacteria, and good seed provides the soybean plants needed for this legume-Rhizobium symbiosis. These must be combined with proper planting, tillage, fertility, harvest, and storage practices, as well as with proper inoculation to provide adequate nitrogen without the use of fertilizer.

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Soybean Soil Fertility and Moisture Studies

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Although soybeans originated in China, it is only in comparatively recent years that the plant has been intensively managed in this part of the world. While plant scientists are engaged in many countries of the world, conducting research aimed to break the yield plateau barrier apparent in soybeans, much is known at present that can increase production throughout Asia.

From an edaphic viewpoint, soil fertility must be considered a key factor in successful soybean production in Asia. In this region many soils that could be planted to soybeans are naturally infertile. Leaching of bases, well weathered minerals, and low organic matter status combine to make both an acid soil complex and a diminished plant nutrient content common. While phosphorus and potassium are the two most common nutrient deficiencies, other deficiencies occur. Imbalances between nutrients may be readily induced, because many of these tropical and subtropical soils are weakly buffered.

No amount of applied phosphorus (P) or potassium (K) can increase soybean yields if other limiting factors prevail. Ineffective nodulation, drought, unfavorable soil pH, poor drainage or excess irrigation, and toxicities, singly or in combination, can preclude soybean response to added fertilizer.

The adoption of multiple cropping systems, many of which will include a legume such as soybeans, suggests that fertilizer programs should be designed more for the entire system than for an individual crop. Soybeans in this regard assume importance not only because of their known ability to efficiently utilize residual fertilizer, but also because of their potential to restore soil nitrogen (N) useful to succeeding crops.

The purpose of this paper is to review pertinent literature in soil fertility, soil water, and soybean production; to relate research findings from abroad to local problems; and to discuss recent fertilizer studies at Chiang Mai, using soybeans in cropping systems. It is interesting but unfortunate that most of the knowledge about fertility requirement and nutrition of soybeans has been gained in regions like North America, rather than in the Asian countries where soybeans originated. Much research needs to be done.

REVIEW OF LITERATURE

Nutrient Uptake

Hanway and Weber (1971) showed that unfertilized, effectively nodulated soybeans accumulated 247 kg N/ha, while non-nodulated soybeans, even with 263 kg N/ha accumulated only 198 kg N. An average of 60 percent N taken up by the plant was stored in the seed, compared with about 47 percent for P, and even less for K. Potassium fertilization (224 kg/ha) did increase total plant absorption from 74 to 121 kg K/ha.

In the southeastern United States Henderson and Kamprath (1970) described increasing nutrient absorption of determinate soybeans from early growth through blooming to seed formation. Maximum rates of accumulation were 7.7, 0.4, 4.6, 2.4, and 0.7 kg/ha/day for nitrogen, phosphorus, potassium, calcium, and magnesium, respectively. Nutrient absorption is rapid in relation to dry matter production during early stages, and as a result, nutrient concentrations are high.

Nitrogen

The use of ^{15}N-labeled fertilizers, the reduction of acetylene to ethylene, Kjeldahl N content of nodulated versus non-nodulated plants have all been used by numerous researchers (Norman, 1944; Weber, 1966; Koch and Evans, 1966) to determine whether soybeans can use more nitrogen than is provided by symbiosis. Generally, in situations where soybeans have been effectively nodulated, any increase of grain yield from applied N fertilizer has been uneconomical. Stewart (1966) reported 94 kg/ha fixed N, while Hardy et al. (1968) have calculated about 75 to 80 kg/ha of N fixed annually by soybeans. Several workers (Thornton, 1947; Norman, 1946; Weber, 1966; Ross, 1959) have reported that added fertilizer N linearly decreased the amount of N fixed biologically. Nodule number and size are usually

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reduced when the supply of soil or fertilizer N is increased. Moreover, Tanner and Anderson (1964) have suggested that nitrates exert an inhibitory effect on *Rhizobium* at the root infection stage. It would appear that urea has a less detrimental effect (perhaps slightly beneficial) on soybean yield than other forms of N studied (Uziak, 1960).

In summary, the N requirement of soybeans in the field is basically met by symbiosis and natural soil nitrogen mineralization. Low moisture or temperature, partially effective or noneffective nodules, or molybdenum deficiency could all account for the fact that sporadic soybean responses to added N fertilizers have been reported.

Phosphorus

The basic components of the cell nucleus, nucleoproteins, require P. Soybean plant absorption of P from fertilizers is generally high and continues to the end of the season, in contrast to corn, which has an early demand for P. Profitable yield responses from applied P depend on the P soil test level and the presence of available nutrients (Pierre, 1944; Miller et al., 1961; Ohlrogge and Kamprath, 1968). Very heavy applications of applied P may cause toxicities, especially among susceptible varieties.

Number, weight, and size of nodules have all been reported to increase following the addition of phosphate to soybeans (DeMooy and Pesek, 1966). Several researchers have also reported improved N fixation following P fertilization (Heltz and Whiting, 1928; Ludecke 1941), especially when ample available Ca is present (Erdman and Fife, 1928). Increases in dry weight of the various plant parts have been shown to accompany the P response in grain yield (Islam, 1964; Matrone et al., 1954).

Potassium

Soil mineralogy appears to have a significant effect on the soybean plant's ability to absorb K from exchangeable and nonexchangeable sites (Pesek, 1968; Graham and Turley, 1947). Fourfold increases in soybean production from added potash on soils with low soil test K have been reported (Nelson et al., 1946). It would seem that added phosphate tends to reduce the K content of leaves (DeMooy and Pesek, 1970), which suggests the particular need to apply potassium fertilizer in the presence of P fertilizer on soils testing low in K (Colwell, 1944; Weber and Caldwell, 1962). These authors also noted that potassium deficiency was accentuated by liming an acid, K-deficient soil.

Heltz and Whiting (1928) have noted an increase in nodule size following added K at 168 kg/ha but impaired nodulation at 336 kg/ha. The nodule response to added K appears related to the soil lime status (Perkins, 1924) and supply of P (Poschenrieder et al., 1940). Potassium application reduced the N content of nodules, but increased pods and seed size (Nelson, 1946).

Secondary and Minor Nutrients

Calcium appears to have an important role in soybean production apart from its role in raising soil pH (Moser, 1943). The role of Ca in symbiotic N fixation has been known for a long time. Magnesium, too, is needed in N fixation. Yield responses from Mg applications have been reported by Nelson et al. (1946), and Key and Kurtz (1960). Sulphur, another essential nutrient, is often supplied as a carrier in commercial fertilizer materials. With high analysis N and P materials, however, we might expect an increased need for added sulfate. Significant S fertilizer response on soybeans has been reported on strongly acid red latosols in Brasil (Mascarenhas et al., 1967).

Among the micronutrients, iron deficiency chlorosis appears most common. Chlorosis-susceptible soybean varieties are particularly vulnerable to iron deficiency commonly induced by high lime conditions (Weiss, 1943). At high concentrations, the combined effect of phosphorus and calcium may cause chlorosis even in iron-efficient varieties (Brown et al., 1959). Daylength apparently affects iron utilization by the soybean plant. Benedict et al. (1964) found that a short-day plant environment favored chlorosis.

Manganese and iron nutrition are related in soybeans. Alkali or excess lime induces manganese deficiency (Steckel, 1947). Strongly acid soils, especially if somewhat poorly drained, favor manganese toxicity (Parker et al., 1969). While manganese toxicity seems to be partially eliminated by added iron, soybeans grown on soils low in manganese may show manganese deficiency when iron is added.

Reduced soybean yields due to zinc deficiency have been reported (Weldon and Chesnin, 1959) and have been controlled by foliar application of zinc. Both high lime and high P conditions can induce zinc deficiency (Hutton and Fiskell, 1963; Keefer and Singh, 1969). Boron is another micronutrient whose availability decreases in high lime soils, although the relatively low boron requirement of soybeans accounts for few recorded responses to added borax.

Molybdenum deficiencies in acid soils seem to reduce N fixation. Symptoms of N deficiency have been controlled with added molybdenum (Parker and Harris, 1962). Researchers in Georgia found 70 g/ha of sodium molybdate as effective as 134 kg N/ha in raising soybean yields. While seed treatment with molybdenum salts has been at least equal to spraying on molybdenum as a foliar applicant, premixing inoculant with a molybdenum salt can be injurious to *Rhizobium* (Burton and Curley, 1966). Liming acid soils often reduces the need for molybdenum application.

Soil pH and Lime

While both the kind of soil and the soybean variety will determine optimum pH, it appears that for many conditions pH 6.2 approaches optimum (Ohlrogge, 1967). Good responses from liming have been obtained

on soil of low pH and low base status (Nelson, 1946; Johnson and Harris, 1967). Soybeans in Chinese cropping systems have performed best when soils were limed to about pH 6.5.

Soil Tests and Fertilizer Response

Soil test levels have been successfully correlated with response of effectively nodulated soybeans to both applied phosphorus and potash. Kamprath and Miller (1958), and Rouse (1968) showed that soybean yields approached maximum when P soil test values ranged between 40 and 50 ppm. Average responses of 340 kg/ha from 15 kg P and 28 kg K applied to soybeans in Iowa were consistent (Englehorn et al., 1947). Barber (1971) in Indiana and Miller et al. (1961 and 1964) in Iowa obtained yield responses approaching 2,000 kg/ha on soils testing low in P and K. Rouse (1961 and 1968) has shown that up to 67 kg K/ha may be needed for top soybean yield on low-testing soils.

Soybean response to residual fertilization has been shown on numerous occasions. Studies at Iowa State University in 1957 have shown a residual fertilizer efficiency of 0.6 following the application of 90 kg N, 47 kg P, and 237 kg K/ha applied to soybeans and measured on soybeans the following year. Anthony (1967), and DeMooy and Pesek (1971) observed an average efficiency of 0.5 and 0.3 two years after fertilization for P and K, respectively. Peterson (1967) has shown the residual value of superphosphate exceeding its direct effect. Thus, soybean yield increases of 350 and 570 kg/ha were obtained the first year from 101 kg/ha of applied P, and residual effects of 440 and 740 kg/ha were obtained the second year.

Methods of Fertilization

Band placement of P and K fertilizer 5 cm to the side and 5 cm below the seed have usually proven successful (Barber and Stivers, 1959; University of Minnesota, 1970 and 1971). Probst (1944) noted that placement of fertilizer 2 to 5 cm at the side and level with the seed was satisfactory, even up to rates of 450 kg/ha phosphate and potash. Drilling fertilizer near the seed can be harmful and reduces emergence (Rouse, 1961).

The magnitude of soybean response to applied fertilizer depends on soil nutrients and moisture, nodulation, pest control, row spacing, planting date, and variety.

SOIL WATER AND PLANT STRESS

Soil water content, hydraulic conductivity, and rate of transpiration control the level of internal plant water. Germination, grain yield, rate of photosynthesis, and N fixation of the soybean are influenced by the soil moisture status. The amount of water a soil holds is less important than the energy by which soil holds water and those factors which control its movement. This tenacity is expressed in terms of the potential energy of the water in the soil with respect to free water. Since the potential of soil water is usually less than that of free water or near saturation, water potential is usually negative and is expressed as suction or tension. Pressure units are used to describe this suction (negative pressure) and are referred to as bars or atmospheres. For example, as a soil dries, there is a decrease in potential energy, and suction (negative pressure) increases. Thus, the bar or atmosphere units increase from 0.1 near field capacity, to about 15 bars which is near wilting point. The rate of absorption of water by transpiring plants usually lags behind the rate of transpiration, resulting in leaf water deficits. The net effect of plant water stress is to impede the plant's physiological process, as will be discussed below.

Germination

Moisture, temperature, and oxygen primarily regulate germination. Hunter and Erickson (1952) concluded that the minimum seed moisture content required for germination was about 30 percent for corn and 50 percent for soybeans. They suggested that at 25°C the soil should have a moisture tension or potential of not more than 6.6 bars for soybean germination to occur in 5 to 8 days. They also pointed out that when soil moisture is high enough to enable seeds to imbibe some water but not high enough for germination within a week, the seeds are often attacked by fungi and will then decay.

High moisture content similarly may favor poor germination. Grable and Danielson (1965) indicated that pathogenic soil organisms developed on seeds and roots at 0.3 bars or less and stopped growth. Hanks and Thorp (1957) showed that soils with high crust strengths decreased emergence from 70 to 30 percent as soils dried from field capacity (0.3 bars) to 25 percent available water (approximately 1.0 bars).

Growth and Yield

According to Shaw and Laing (1966), maximum reduction in yield of soybeans due to moisture stress occurred during the last week of pod development and during the bean-filling stage. Even at flowering, moisture stress tended to lower yields, whereas earlier stress had minimal effect. As will be seen later, other physiological processes like N fixation may be unfavorably affected by water stress at other periods in the growth of the soybean. Dusek et al. (1971) showed that an optimum irrigation regime occurred when available water reached 40 percent, which coincided with the visible appearance of stress. Irrigation at 60 percent gave no yield increase, while irrigation at 20 percent available water lowered the yield. They also observed the greatest yield depression when moisture stress coincided with pod swelling.

Doss et al. (1974) examined the effect of soil water stress at various growth stages on soybean yield in a three-year experiment. Soil water regimes ranged from a limited supply (10 percent available water) to adequate water (50 percent available) during the entire growing season. More bean production was obtained from water applied after, rather than before, full bloom.

The pod-fill stage was the critical time for adequate water for maximum yields. Yields from adequately watered soybeans were 540 to 1040 kg/ha, or 24 to 55 percent, greater than where water was limited throughout the growing season. The highest yield obtained under the best water regime was 3,320 kg/ha.

Timing of irrigation water application is important in increasing soybean yields. Spooner (1961) found that irrigation applied before the first blooming did not significantly increase soybean yields. Grissom et al. (1955) reported that irrigation during the early stages of growth was not beneficial.

Mederski and Jeffers (1973) studied the yield response of soybean varieties grown at two soil moisture stress levels. Under high moisture stress conditions, the yield of most stress-resistant varieties was reduced about 20 percent, while the yield of the least stress-resistant varieties was reduced about 40 percent. The absolute reduction in yield for the most stress-sensitive varieties was approximately 1,000 kg/ha, while the yield of the least stress-sensitive varieties was reduced about 200 to 400 kg/ha.

Under conditions of optimum soil moisture, the difference in yield among varieties was large relative to the difference in yield produced under deficient moisture conditions. A low stress or nonstress soil moisture level permits greater genotypic expression, thereby increasing genotypic variance among varieties. A low soil moisture stress environment appears to be the optimum environment for selecting soybean yield attributes.

From the above data it may be concluded that soybeans do have a critical period of water stress that coincides with the pod-fill stage, that soybean varieties behave differently to soil moisture potential or tension, and that both excess or deficits of water can markedly reduce soybean yield.

Water Stress and Photosynthesis

Boyer (1970) has shown how moisture stress markedly influences leaf enlargement and rate of photosynthesis. At soil tensions higher than 4 bars, leaf enlargement declined rapidly and approached zero at 12 bars, as did photosynthesis. Plant water deficits probably decrease assimilation of carbon dioxide as well. However, while rewatering results in a rapid recovery of plant water content, CO_2 assimilation recovers slowly. This slow recovery of assimilation suggests that under field conditions the relief of high internal water stress following irrigation may not result in immediate resumption of maximum photosynthetic activity (Pallas et al., 1967).

Water Stress and N Fixation

Perhaps no physiological process affecting soybean yield is more sensitive to moisture stress than is N fixation associated with nodulated plants. Spent (1972) studied the effects of water stress on nitrogen-fixing root nodules and the effects on whole plants of *Vicia faba* L. and *Glycine max* (L.) Merr. Slow, natural drying of the soil over a 6-week period resulted in progressive reduction in N-fixing activity. Irrigation restored activity, and maximum N fixation occurred at about field capacity; above that level activity was reduced because of water logging. It was suggested that water stress affected nodule activity directly, but the effect might be aggravated by reduced supplies of photosynthate from wilted leaves.

In an experiment designed to evaluate the effect of soil temperature and soil water stress on the ability of soybeans to symbiotically fix nitrogen, Kuo and Boersma (1971) showed that both parameters are important and do not work independently of one another. Activity of nodule bacteria was very sensitive to water tension and root temperature. Relative rate of nitrogen fixation of 3-week-old soybean plants relative to soil temperature and soil tension is presented in Table 1.

Table 1. Effect of Soil Moisture and Temperature on Relative N Fixation in Soybeans

Soil temperature	Relative rate of nitrogen fixation at different values of soil water suction (bars)			
	0.35	0.70	1.50	2.50
10.0	43.2	30.7	17.0	13.1
23.9	100.0	83.5	76.1	58.5
32.2	88.1	76.1	72.7	55.7

Rates of nitrogen fixation decrease with increase in water suction, particularly at lower temperatures. It is interesting to note that the relatively large decrease in nodule N fixation occurred long before the soil tension approached wilting point. Nitrogen content of the 3-week-old soybean plant, as might be expected, decreased as the soil tension increased from 0.35 to 2.50 bars.

Sinclair and deWit (1975) have studied the mobilization and transfer of nitrogen from soybean leaves during seed formation. The pool of nitrogen and protein in vegetative tissues eventually loses physiological activity as the nitrogen levels decrease. The plant becomes self-destructive, leaves drop, and photosynthates to fuel the nitrogen fixation process disappear. The period of seed development depends on a readily available nitrogen supply to offset the self-destructive process. This N supply is terminated as N fixation is depressed during periods of soil moisture stress.

THAI STUDIES

Many methods exist for studying the efficiency of fertilizer use. Certainly, total plant response to different increments of added nutrients is one basis for determining fertilizer efficiency. But residual fertilizer effects on other crops in the system require monitoring. If a legume is included in the cropping system, the effects of symbiotic N fixation also deserve investigation. In 1974 three different cropping systems were initiated at the Multiple Cropping Experiment Station in Chiang Mai, Thailand.

The cropping systems under study were as follows:

System I: Field Corn — Soybean — Sweet Corn
System II: Rice — Soybean — Sweet Corn
System III: Soybean — Soybean — Sweet Corn

Each system shared three common elements:

1. Each cropping system included soybeans.
2. Three crops were included in each system.
3. Only the first crop was fertilized using a factorial N:P:K design.

Table 2 presents the chemical analysis of the surface soil taken from the Lampang sandy loam located on the Multiple Cropping Project Experiment Station site where system I was used.

System I

Field corn grain yield. Corn grain yield as influenced by nitrogen and phosphate fertilizer is presented in Table 3. Corn grain yields following nitrogen fertilization ranged from 1.07 to 5.35 tons/ha. The combination of 120 kg N/ha and 80 kg P_2O_5/ha produced the highest grain yield of 5.35 tons/ha, although this was not significantly greater than the yield produced by 180 kg N/ha without added phosphate (5.29 tons/ha).

Application of 60 kg N/ha of nitrogen fertilizer increased the average grain yield by 122 percent over the zero nitrogen treatment (1.42 to 3.16 tons/ha). The 120 kg N/ha rate resulted in a further 39 percent yield increase (3.16 to 4.45 tons/ha). Phosphate fertilizer had no influence on corn grain yield (Table 3).

Soybean yield. No difference was noted in soybean yields resulting from the residual effect of nitrogen and/or phosphate fertilizer applied to a prior corn crop (Table 4). Soil test results of samples taken from variously fertilized plots before the second crop of soybeans was planted indicated important differences. Soil phosphorus values showed an increase following phosphate fertilization (Table 5), while higher rates of applied nitrogen fertilizer decreased soil pH from 6.5, 5.9, 5.7 to 5.5 with 60, 120, and 180 kg N/ha. Moreover, N fertilizer had the effect of decreasing the amount of extractable soil P. This was particularly apparent in the absence of applied P fertilizer. Plant removal and increased soil acidity probably accounted for the lower soil P status.

Sweet corn yield. Neither the sweet corn yield nor the number of ears per hectare increased as a result of residual N and/or P fertilization. Apparently soil nitrogen not utilized by the initial field corn crop had been lost by leaching or volatilization. Soil phosphorus, on the other hand, remained adequate under the conditions of the experiment for both successive soybean and sweet corn crops.

System II

Rice yield. Rice, the first and only crop fertilized in the rice-soybean-sweet corn system, responded to both applied nitrogen and phosphate (Table 6). Rice yield increased as nitrogen fertilizer was added up to 80 kg

Table 2. Chemical Analysis of Surface Soil Sample (0-15 cm Depth)

pH[e]	Total N[a] (%)	Extractable elements: Phosphorus[b] (ppm)	Potassium[c] (ppm)	Calcium[d] (meq/100 g)	Magnesium[d] (meq/100 g)
7.2	0.0311	39.7	35.3	3.29	0.14

[a] Kjeldhal method.
[b] Bray II method.
[c] NH_4OAc, pH 7 extraction with flame photometer method.
[d] NH_4OAc, pH 7 extraction with atomic absorption method.
[e] Soil: H_2O = 1:1.

Table 3. Effect of Different Rates of N and P Fertilizers on Corn Grain Yields

Nitrogen (kg/ha)	Corn grain yields[a] (ton/ha) at three rates of phosphorus (kg/ha): 0	40	80	Average
0	1.07	1.50	1.69	1.42
60	2.98	3.33	3.16	3.16
120	3.99	3.87	5.35	4.40
180	5.29	4.44	3.62	4.45
Average	3.33	3.29	3.46	$\bar{X}$ = 3.36

% CV = 21.00

	For treatment	For N	For P_2O_5
$LSD_{.05}$	1.21	0.70	NS
$LSD_{.01}$	1.65	0.95	NS

[a] Data taken at 14% moisture content.

Table 4. Residual Effect on Soybean Grain Yields of N and P Fertilizers Applied to Previous Corn Crop

Nitrogen (kg/ha)	Soybean yields (ton/ha) at three rates of phosphorus (kg/ha): 0	40	80	Average
0	1.66	1.51	1.90	1.69
60	1.49	1.83	1.99	1.77
120	1.47	1.66	1.37	1.50
180	1.93	1.49	1.95	1.74
Average	1.64	1.62	1.80	$\bar{X}$ = 1.69

% CV = 24.32
$LSD_{.05}$ = NS for both N and P_2O_5
$LSD_{.01}$ = NS for both N and P_2O_5

Table 5. Effect of Nitrogen and Phosphorus Applied to First Crop on Extractable Phosphorus Levels Before Planting Second Crop

Nitrogen (kg/ha)	Extractable phosphorus (ppm) at three rates of phosphorus (kg/ha): 0	40	80	Average
0	26.3	31.3	33.8	30.5
60	23.8	22.5	30.0	25.4
120	15.0	18.8	45.0	26.3
180	17.5	23.8	30.0	23.8
Average	20.7	24.1	34.7	$\bar{X}$ = 26.5

N/ha. A small but nonsignificant response to 120 kg N/ha over the 80 kg rate was recorded. Rice yield was also significantly increased following P fertilization at a rate equivalent to 80 kg P_2O_5/ha, but only after N fertilization. Indeed, it would appear that, provided 80 kg N/ha was added, the soil P status was adequate without added P fertilizer.

Soybean yield. Residual fertilizer phosphate from the previous rice crop significantly increased soybean yield (Table 7) over that in controls in the plots that had previously received rates equivalent to 40 and 80 kg P_2O_5/ha. There was no significant difference between these two rates of added fertilizer phosphate. On the other hand, residual nitrogen from the previously nitrogen fertilized rice appeared to have no effect on soybean yield (Table 6). The increase in extractable P (Table 8) reflected a buildup in potentially available phosphate, and no doubt accounted for the soybean response. In this sense, P recovery, and thus efficiency of use, was improved by the growing of soybeans, the second crop in system II.

Sweet corn yield. Neither sweet corn fresh ear weight nor number of ears was influenced by residual fertilizer nitrogen and phosphate. It appeared that the phosphate fertilizer applied to paddy rice at 80 kg P_2O_5/ha had significantly increased soil residual phosphorus (Table 8). In fact, soil from the rice plots that originally received the high rate of P fertilizer appeared to increase in the amount of extractable P with time (Tables 8, 9).

Table 6. Effect of N and P Fertilizers on Rice Grain Yield

Nitrogen (kg/ha)	Yield (ton/ha)[a] at three levels of P_2O_5 (kg/ha)			
	0	40	80	Average
0	3.35	3.13	3.46	3.31
40	4.11	3.78	5.25	4.38
80	5.95	4.99	5.60	5.51
120	5.79	5.92	6.06	5.92
Average	4.80	4.46	5.09	4.78
% CV = 11.57				
		For treatment	For N	For P_2O_5
$LSD_{.05}$		0.94	0.54	0.47
$LSD_{.01}$		1.27	0.74	0.64

[a] Data taken at 13.2% moisture content.

Table 7. Residual Effect on Soybean Grain Yield Resulting from N and P Fertilizer Applied to Previous Rice Crop

Nitrogen (kg/ha)	Soybean yield (ton/ha)[a] at three levels of phosphate (kg/ha)			
	0	40	80	Average
0	1.94	2.31	2.89	2.38
40	1.96	2.38	2.23	2.19
80	2.23	2.30	2.89	2.47
120	1.83	2.39	1.91	2.04
Average	1.99	2.35	2.48	$\bar{X}$ = 2.27
% CV = 15.19				
		For treatment	For N	For P_2O_5
$LSD_{.05}$		0.58	NS	0.29
$LSD_{.01}$		0.80	NS	0.40

[a] Data taken at 14% moisture content.

Table 8. Effect of N and P Applied to a Previous Crop on Levels of Extractable P Before Planting a Succeeding Crop

Nitrogen (kg/ha)	Extractable phosphate (ppm) at three levels of applied phosphate (kg/ha)			
	0	40	80	Average
0	30.0	27.5	30.0	29.2
40	22.5	32.5	30.0	28.3
80	17.5	22.5	36.0	27.3
120	22.5	37.5	40.0	33.3
Average	23.1	30.0	35.0	$\bar{X}$ = 29.2

Table 9. Effect of N and P Applied to Two Previous Crops on Levels of Extractable Phosphorus Present Before Planting a Third Crop

Nitrogen (kg/ha)	Extractable phosphate (ppm) at three levels of applied phosphate (kg/ha)			
	0	40	80	Average
0	31.3	36.3	65.0	44.2
40	40.0	42.5	52.5	45.0
80	33.8	31.3	56.3	40.5
120	27.5	36.3	46.3	36.7
Average	32.2	36.6	55.0	41.6

System III

The growing of two soybean crops prior to planting sweet corn provided the opportunity to evaluate the initial and residual effect of applied phosphate and potash fertilizers on soybean yield and the residual effect on sweet corn resulting from soybeans so fertilized. Chemical analysis of surface soil taken at the initiation of system III is presented in Table 10.

First crop soybean yield. Soybean yield as influenced by phosphate and potash fertilizers is presented in Table 11. The application of 80 kg K_2O/ha increased the average grain yield by 18.4 percent (from 1.37 to 1.68 tons/ha) over zero potash treatment. Certainly, only 49.7 ppm extractable K (Table 10) might be considered low for the growth of soybeans in this soil. A gradual soybean yield increase was noted as potash fertilizer rates were increased. Soybeans showed no response to applied phosphate fertilizer (Table 11). The soil test extractable P of 43.2 ppm (Table 10) appeared adequate for the growth of soybeans on this soil.

Second crop soybean yield. Residual potash from previously applied fertilizer influenced the yield of the second cropping of soybeans (Table 12). An average of half a ton grain yield increase over the control (1.71 to 2.28 tons/ha) was obtained from the residual effects of potash fertilizer applied at a rate equivalent to 80 kg K_2O/ha. The residual effect on soybean yield from previously applied potash fertilizer appeared to be significantly greater at 80 kg K_2O/ha than at 40 kg K_2O/ha.

Table 10. Chemical Analysis of Surface Soil Sample (0-15 cm)

pH[e]	Total N[a] (%)	Extractable elements			
		Phosphorus[b] (ppm)	Potassium[c] (ppm)	Calcium[d] (meq/100 g)	Magnesium[d] (meq/100 g)
6.6	0.0343	43.2	49.7	1.76	0.11

[a] Kjeldhal method.
[b] Bray II method.
[c] NH_4OAc, pH 7 with flame photometry method.
[d] NH_4OAc, pH 7 with atomic absorption method.
[e] Soil: H_2O 1:1.

Table 11. Effect of P and K Fertilizers on Soybean Grain Yields

Phosphate as P_2O_5 (kg/ha)	Soybean yield (ton/ha)[a] at three levels of potassium as K_2O (kg/ha)			
	0	40	80	Average
0	1.31	1.38	1.67	1.45
30	1.48	1.61	1.67	1.59
60	1.44	1.51	1.70	1.55
90	1.25	1.54	1.67	1.44
Average	1.37	1.51	1.68	$\bar{\bar{X}} = 1.52$

	For P_2O_5	For K_2O
$LSD_{.05}$	NS	0.22
$LSD_{.01}$	NS	0.35

[a] Data taken at 14% moisture content.

Table 12. Effect of Phosphorus and Potassium Applied to a Previous Crop on Soybean Grain Yields from the Second Crop

Phosphorus (P_2O_5) (kg/ha)	Soybean yield (ton/ha) at three levels of potassium as K_2O (kg/ha)			
	0	40	80	Average
0	1.74	2.13	2.05	1.97
30	1.44	2.21	2.30	1.98
60	1.72	2.09	2.19	2.00
90	1.93	2.34	2.58	2.28
Average	1.71	2.19	2.28	$\bar{\bar{X}} = 2.06$

	For P_2O_5	For K_2O
$LSD_{.05}$	NS	0.333
$LSD_{.01}$	NS	0.452

Extractable soil K from soil samples taken after the first soybean crop is presented in Table 13. It is of interest to note that average extractable K (43.1 ppm) from the control plot was not much lower than the initial (49.7 ppm) soil K level (Table 10). However, the residual effect of 80 kg K_2O/ha applied potash increased the average extractable K to 63.3 ppm (Table 13). The increase in extractable K was associated with a significant second crop soybean grain response over the check.

As in the first soybean crop, no response to applied phosphate fertilizer was observed. Failure of the second soybean crop to respond to added phosphate supports the first crop results and thus confirms the hypothesis that a soil with more than 43 ppm extractable P provides adequate availability of this nutrient.

Sweet corn yield. Neither sweet corn yield nor ears per hectare appeared to be influenced by the previous fertilization of soybeans. These results suggest that previous phosphate and potash fertilization had not differentially affected the soybeans to fix atmospheric nitrogen in such a way that the succeeding sweet corn crop might benefit. It could have been hypothesized that soybean response to applied potash would result in increased residual soil N, which would be reflected in greater sweet corn yield. Soil extractable K appeared to be less affected following fertilization than soil extractable P. In other words, soil P status could be more readily increased by P fertilization than could soil K status be increased by potash fertilization.

COMPARISON OF THREE-CROPPING SYSTEM

General Comments

Since sweet corn was the last crop in each of the three cropping systems under study, comparative corn yields

Table 13. Effect of Phosphorus and Potassium Fertilizers Applied to First Soybean Crop on Extractable Potassium Levels Present After Harvest

Phosphorus (P_2O_5) (kg/ha)	Extractable soil potassium (ppm) at three levels of potassium as K_2O (kg/ha)			
	0	40	80	Average
0	33.9	47.3	69.1	50.1
30	56.9	43.4	56.9	52.4
60	40.8	50.0	61.0	50.6
90	40.8	39.3	66.3	48.8
Average	43.1	45.0	63.3	$\bar{\bar{X}} = 50.4$

Table 14. Sweet Corn Fresh Ear Weight Computed as Treatment Means for Each of Three Cropping Systems

Cropping system	Yield (ton/ha)			Treatment total	Treatment mean
Soybean-soybean-sweet corn	10.88	12.76	14.19	37.83	12.61
Field corn-soybean-sweet corn	10.11	8.38	8.44	26.93	8.98
Rice-soybean-sweet corn	10.10	10.33	8.58	29.01	9.67
Total and mean				93.77	10.42

LSD 5% = 2.47
1% = 3.74
CV = 11.91%

Table 15. Soybean Grain Yields from Three Cropping Systems Influenced by the First Crops

Cropping system	Yield[a] (ton/ha)			Treatment total	Treatment mean
Soybean-soybean-sweet corn	1.84	1.79	2.55	6.18	2.06
Field corn-soybean-sweet corn	1.77	1.64	1.65	5.06	1.69
Rice-soybean-sweet corn	1.18	2.33	2.31	6.82	2.27
Total and mean				18.06	2.01

CV = 13.16%

[a] Data taken at 14% moisture content.

provide one measure of comparing the different systems relative to residual and accrued soil fertility. The mean yield of sweet corn fresh ear weight was computed for each cropping system and compared (Table 14). It was found that the mean sweet corn ear weight from system III (soybean-soybean-sweet corn) was about 30 percent higher than in the other cropping patterns. Observations made during the study also revealed longer ears and a higher percentage of marketable sweet corn from system III.

Nitrogen fertilization is recognized as a critical factor in crop production, especially because of its recent elevated cost. Change in soil nitrogen supply resulting from different cropping systems suggests a re-evaluation of management techniques. Thus, the higher yields of sweet corn noted above might be interpreted as an increase in soil N brought about by two crops of soybeans. A soybean crop has been estimated to biologically fix about 75 kg N/ha annually (Hardy et al., 1971) and to remain unchanged by nitrogen fertilization (Stewart, 1966).

Fertilizer Efficiency

Our results from studies of various cropping systems show not only varying degrees of residual buildup in soil phosphorus and potash following fertilization, but also an increase in soil acidity due to N fertilization, and possibly even more important changes in soil productivity. It is interesting, for instance, that cropping system III (soybean-soybean-sweet corn), which received no application of N fertilizer (other cropping systems initially received from 120 to 180 kg N/ha), produced significantly higher yields and better quality sweet corn. It would appear that fertilizer use efficiency was different among the cropping systems under study and that fertilizer use was most efficient in system III.

Some investigators have reported reduced yields when certain legumes are planted in immediate sequence. Studies at the International Rice Research Institute (Herrara and Harwood, 1975) have indicated that a second mung bean crop gives depressed yields when planted immediately after a previous mung bean crop. Our results with soybeans do not show a similar effect. Indeed, soybean yields appeared a little higher when soybean followed soybean than when soybean followed corn (Table 15). It is also interesting to note that the highest soybean yield (2.27 tons/ha) was obtained in the rice-soybean-sweet corn cropping system in which soybeans were hand-planted directly into the rice stubble. In other words, in this treatment soybeans were unfertilized and received no tillage. A further reduction in production costs therefore was attained in this soybean-soybean-sweet corn system. An economic analysis of these data, examining the net farm income from the different cropping systems, deserves study.

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Discussion

D. E. Byth: It was suggested that moisture stress is less critical in the pre-flowering phases than it is later. While this is probably true for long season crops, it may not be so where shorter season crops are grown and where early vigor is crucial. Is there evidence of this in short season culture?

M. D. Dawson: Certainly most of the data on early stress has been derived from long season culture. However, there have been reports of differences among cultivars in response to stress, and these have been primarily in short season culture. I want to emphasize that the best way to show genetic differences in yield potential among cultivars is to conduct tests under minimal stress conditions.

Planting Date and Plant Spacing in Soybean Production

H. C. Minor

Soybean yields have increased gradually as the result of varietal improvement and better management. While varieties can be improved still more, much of the yield potential available in existing varieties remains unexploited as the result of improper management or untimely performance of appropriate practices. The magnitude of this unexploited potential is alluded to in a statement by Pendleton and Hartwig (1975): "The difference in average soybean yields from a community, state, or region and the yields from either research stations or outstanding growers therein is primarily due to management."

In this paper only two important aspects of soybean management are discussed: date of planting and plant spacing. However, these cultural practices, which interact with most other manipulations that influence the availability of factors required by the plant, can rarely be considered independently.

PLANTING DATE

Effects of Planting Date on Flowering and Maturation

Soybeans are believed to have originated in a temperate climate; hence most improvement of the crop has been oriented towards situations where it must fit into a more or less well defined summer season bounded by a cold spring and fall. In the changing seasons of a temperate zone, growth and reproduction must be synchronized with the changing weather. The "key" to the soybean's adaptation to this situation is its responsiveness to photoperiod. Because it is a short-day plant, the soybean flowers only when the photoperiod is sufficiently short. An adapted variety will be planted in temperate areas after the soil is warm, but before the maximum photoperiod is reached. It develops vegetatively until the photoperiod shortens to below a "critical duration" and then it flowers. Reproduction and maturation also take place when the photoperiod is decreasing in duration.

Under these conditions the response of a soybean variety to photoperiod determines the range of latitude over which it will be adapted. Soybean varieties have been divided into 12 maturity groups, 00 to X, based on their north-south zone of adaptation. As a variety is moved to a location closer to the equator, shorter photoperiods are encountered during the summer. Consequently, the variety flowers earlier than in its zone of adaptation, and vegetative growth is reduced. Conversely, as a variety is moved to a latitude higher than that to which it is adapted, longer photoperiods are encountered, and the plant remains vegetative until daylength shortens to less than the critical photoperiod of the variety. Flowering may occur so late that fall frost will not permit the variety to complete its reproductive cycle. Relative to a full-season variety adapted to an area, a variety from a higher latitude will flower earlier, and one from a lower latitude will flower later when all are grown at the same location. Varieties can always be moved to a location closer to the equator than that to which they are adapted where they will mature before the end of the growing season.

Data on the effects of moving a variety north or south were obtained at Beltsville, Maryland (39° N. latitude) by simulating the photoperiods of 36°, 32°, 20°, and 5° latitudes (Table 1). Each variety flowered and matured in fewer days as it was "moved" to lower latitudes. Conversely, as the varieties were "moved" to higher latitudes, flowering and maturity were delayed to such an extent in the case of Hardee that it did not mature before frost under the simulated 32° or 36° conditions.

Date of planting is one of the most critical cultural practices in soybean production. As planting is delayed during the summer season, time to maturity is shortened. Normally the life-cycle duration of late varieties is reduced more than that of early varieties. The reduction in number of days from emergence to maturity as planting is delayed represents an accumulation of differences from one or more stages of development of the plant.

Sufficiently early varieties will show no response to photoperiod during the pre-flowering stage. Variations in days to flower at different dates of planting occur largely in response to temperature differences during

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Table 1. Days to Flowering and Maturity Under Simulated Photoperiods from June 1 to September 30

Cultivar	Maturity group	Days to first flower				Days to maturity			
		36°	32°	20°	5°	36°	32°	20°	5°
Hill	V	36	33	36	28	105	98	91	71
Lee	VI	44	36	34	20	137	129	99	74
Bragg	VII	44	38	34	22	129	131	102	79
Hardee	VIII	68	51	42	24	...[a]	...[a]	101	81

[a] Indicates that variety did not mature.

Source: adapted from Hartwig, 1970.

the pre-flowering stage (Lawn and Byth, 1973). Abel (1961) reported that delayed planting reduced the time from 50 percent flowering to maturity in a very early variety. Subsequent research by Lawn and Byth (1973) showed that reductions take place primarily during the flowering phase.

The reduction in life cycle of late-maturing varieties as planting is delayed occurs primarily prior to flowering (Hartwig, 1954; Leffel, 1961; Mooers, 1908), although reductions in later stages are important in some variety-planting date combinations (Lawn and Byth, 1973). Pre-flower reductions are positively correlated with the genetic lateness of the variety. The later a variety, the greater the decrease in this stage of development as plantings are made under progressively shorter daylengths. The marked reduction in life cycle of late-maturing varieties results in their *date* of maturity being less influenced by date of planting than that of earlier varieties (Lawn and Byth, 1973; Hartwig, 1954; Leffel, 1961; Mooers, 1908).

The effects of planting date on flowering and maturity of five varieties at Mayaguez, Puerto Rico (18° N. latitude) are shown in Fig. 1. The varieties Williams, Clark 63, Hardee, Improved Pelican, and Jupiter, which are representatives in maturity groups III, IV, VII, VIII, and IX, respectively, were planted at intervals of approximately six weeks throughout the year. The number of days required for Williams and Clark 63 to flower and mature were not significantly affected by date of planting. However, the varieties Hardee, Improved Pelican, and Jupiter were sensitive to the seasonal change in daylength encountered at 18° latitude. Both the vegetative (pre-flowering) and reproductive (flowering plus post-flowering) stages were longest for planting dates that resulted in flowering during, or shortly after, the longest day of the year. These planting dates were May 20 for Hardee and Improved Pelican and April 7 to May 20 for Jupiter.

Maturation (Fig. 1) of Jupiter, when planted at dates that resulted in extended vegetative and reproductive stages, was abnormal. Stems and leaves remained green even after pods were fully ripened. Similar behavior has been noted for several varieties in Australia (28° S. latitude) when date of planting was such that flowering terminated during periods of long daylengths (Lawn and Byth, 1973) and in India (29° N. latitude) for late-maturing, determinate cultivars when planted between February 15 and March 15 (Saxena et al., 1971b). The type of behavior observed is characteristic of plants with a sink-source imbalance; too few fruiting bodies are present to fully utilize the photosynthate produced by the plant.

Effects of Planting Date on Yield

In northern areas of the United States planting date affects the yield of late varieties more than that of early varieties (Leffel, 1961; Osler and Cartter, 1954; Torrie and Briggs, 1955; Weiss et al., 1950). Their optimum planting date is early in the season. Torrie and Briggs (1955), and Weiss et al. (1950) reported steady declines in yield for late varieties planted after mid-May. Yield of early varieties was found to differ little as the result of delayed planting. In trials where yield was depressed in both early and late varieties because of late planting (Feaster, 1949; Leffel, 1961; Weiss et al., 1950), the optimum planting date for the early varieties was two to three weeks later than the optimum for the late varieties. Highest yields are generally obtained with varieties that use the full season, maturing just before autumn frost.

The effective growing season in southern soybean-producing areas of the United States is longer than in the north, and date of planting is more flexible. In Mississippi Hartwig (1954) found that adapted varieties

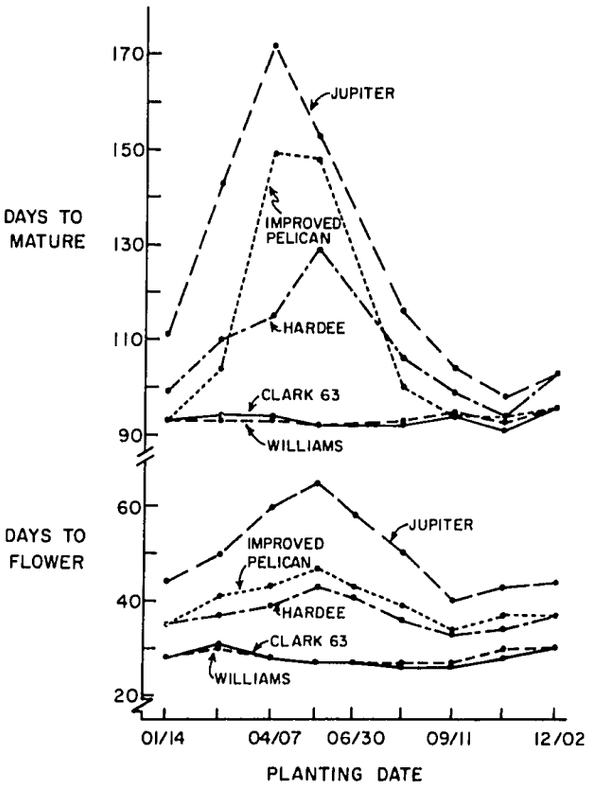

Fig. 1. Effects of planting date on flowering and maturity of five soybean varieties, Isabela, Puerto Rico (18° N.). Source: C. Nissly, unpublished.

could be planted over a considerable range of dates with little reduction in yield. Highest yields were obtained when plantings were made at daylengths of 14½ hours (early May), the critical photoperiod for most adapted southern varieties. Early flowering and reduced growth decreased the yield of full-season varieties planted three weeks before daylength increased to 14½ hours. The yields of early varieties declined steadily as planting was delayed. Farther south in Florida date of planting is frequently in early June (Hinson, 1967). Although earlier plantings produce higher yields under favorable conditions, soil moisture is often inadequate for establishment of the crop.

In northern and central India maximum summer yields are obtained when date of planting coincides with the beginning of the monsoon in mid-June (Jethmalani et al., 1969; Saxena et al., 1971a). Rainfall distribution in these areas, as at many tropical and subtropical locations, establishes limits on the growing season available for production of a nonirrigated soybean crop. The date of planting-variety combination that will produce maximum yield must fit within those limits. A variety that matures before the end of the rainy season may be difficult to harvest and will produce seed of low quality. Conversely, a variety that does not complete maturation before soil moisture is depleted may produce low yields as the result of moisture stress.

Similar logic can be applied when the restraint on cropping season length is another crop in the cropping system. The desirable date of planting-variety combination is the one that fully utilizes the time available for the soybean crop.

Dry season (winter) plantings in northern India (29° N.) produce highest yields when date of planting is in mid-February (Saxena et al., 1971b). Varieties of maturity groups I to III are more productive during this season than are varieties of maturity groups V to VIII.

PLANT POPULATION AND DISTRIBUTION

Response to either population or row spacing is closely correlated with the ability of the crop to intercept most of the incoming radiation without so much growth that lodging occurs. In the soybean-producing area of the midwestern United States, the yield of adapted soybean varieties is stable over a range of plant populations. Probst (1945) reported that maximum yields of well adapted varieties in 76-cm rows could be obtained with 13 to 20 plants per meter of row. Yield differences over the range of populations studied (8 to 39 plants per meter of row) averaged only 11 percent. Weber et al. (1966) studied populations from 64,000 to 516,000 plants per hectare in row widths of 12.7, 25.4, 50.8, and 101.6 cm. Maximum yields occurred at either 128,000 or 257,000 plants per hectare. Yield differences between plant populations were least in the widest rows.

Row-to-row spacings of 50 to 60 cm have frequently been demonstrated to result in higher yields than when wider spacings are used. Pendleton et al. (1960) reported that in Illinois 61-cm rows consistently gave about a 15 percent yield advantage over 102-cm rows. Yield advantages for even narrower row spacings have been reported. Timmons et al. (1967) reported that yields generally increased as row spacing decreased from 102 to 20 cm. Weber et al. (1966) found a significant

Table 2. Results from Coordinated Variety Trial, Boliche,[a] Ecuador, 1970

Variety	Maturity group	100,000 plants/ha		400,000 plants/ha		Yield increase (%)	Height increase (%)
		Yield (kg/ha)	Height at maturity (cm)	Yield (kg/ha)	Height at maturity (cm)		
Pelicano	...	1,796*[b]	95**[b]	1,939	98*	8	3
Abura	...	2,121**	63	2,140	93	−1	48
Mandarin	...	2,101*	94*	2,135	102**	2	9
Americana	...	1,995*	66	2,442	80	22	21
Improved Pelican	VIII	2,080*	82	2,539*	90	22	10
Hardee	VIII	1,930*	28	2,191	45	14	61
Bragg	VII	1,400	27	2,245	40	60	48
Semmes	VII	1,621	21	2,510	31	55	48
Lee 68	VI	1,500	19	2,275	32	52	68
Davis	VI	2,003*	30	2,999**	43	50	43
Dare	V	1,528	23	2,082	39	36	70
Hill	V	2,030*	28	2,717*	40	34	43
Clark 63	IV	1,695*	39	2,475	55	46	41
Adelphia	III	1,893*	34	2,705*	50	43	47
Corsoy	II	580	25	1,323	37	128	48
Hark	I	1,527	35	2,241	49	47	40
Mean		1,737	44	2,310	57		

	Yield	Height
$LSD_{.05}$ between population means	85 kg	1 cm
$LSD_{.05}$ between populations within a variety	342 kg	4 cm
$LSD_{.05}$ between varieties at the same population	462 kg	7 cm

[a] 3° S. latitude, 50 m altitude. Trial was conducted by Eduardo Calero, Chief of Oil Crops Investigation, Instituto Nacional de Investigaciones Agropecuris (INIAP).
[b] The top yielding or tallest variety at a location is designated by a double asterisk (**). Treatments not differing significantly from it are denoted by a single asterisk (*).

linear increase in yield as row spacing decreased from 102 to 13 cm. The yield advantage of row widths of 25 cm or less conflicts with early reports. Burlison et al. (1940), and Kiesselbach and Lyness (1942) found no yield advantage of close-drilled plantings spaced 61 cm apart over intertilled rows spaced 97 cm apart. The lack of weed control measures in close-drilled rows may have decreased yields in these early experiments.

As a rule of thumb, Hanway (1954) suggests that if a short, early variety is being grown or the fertility level is such that vegetative growth is limited, spacing rows as close as available equipment will handle will usually result in higher yields than for wider rows.

Trials in the southern United States have produced results similar to those in the Midwest with respect to population but not row spacing. Johnson and Harris (1967) found that for Bragg, an optimally adapted variety at their location, significant yield responses were not obtained for increases in population above 6.6 plants per meter in 91-cm rows. Two early and one late variety required 26 plants per meter of row to produce maximum yields. No yield reductions resulted from populations above the optimum.

Row spacing in the southern United States has traditionally been approximately one meter. Johnson et al. (1959) suggest that there is little advantage of rows closer than 91 to 107 cm for full-season varieties planted early. The advantage of narrow rows increases in late plantings.

Vegetative development of most soybean varieties, when grown in the tropics, is reduced as a consequence of hastened flowering. When vegetative development is curtailed, soybean yield can frequently be increased by increasing plant population. A measure of the response of soybean varieties to plant population at a tropical location was obtained in Ecuador (3° S.). The trial was similar to that of the International Soybean Variety Evaluation Experiment (ISVEX) in that it included a group of introduced varieties from the United States and several local entries (Pelicano, Abura, Mandarin, and Americana). Each was planted at populations of 100,000 and 400,000 plants per hectare and managed as currently recommended for the ISVEX. Date of planting was in September and the crop was irrigated (Table 2).

The yields of the local entry, Americana, and all varieties of the introduced group except Hardee were significantly higher at a plant population of 400,000 plants per hectare than at 100,000 plants per hectare. Varieties of maturity group VII or earlier tended to respond more to the increase in plant population than varieties of later maturity groups (Fig. 2). For the varieties of maturity groups I to VII, the mean yield at 400,000 plants per hectare was 55 percent (780 kg/ha) greater than at 100,000 plants per hectare.

The height of all varieties except Pelicano increased when plant population was increased. The mean increase in height was 13 cm. Pelicano and Mandarin were the tallest varieties at both plant populations (Table 2).

While the trial did not include a sufficient number of population levels to permit estimation of an optimum plant population, it did illustrate that the estimate of yield potential of each variety depended on the plant population at which it was grown. At the low population Abura was the top yielding variety. None of the other local entries or Improved Pelican, Hardee, Davis, Hill, Clark 63, and Adelphia, yielded significantly less than Abura. At the high population Davis was the highest yielding variety, and the yields from Hill, Adelphia, and Improved Pelican did not differ significantly from that of Davis. Davis produced significantly more than the highest yielding local entry. However, findings of Bastidas et al. (1971) in Colombia (3° N.) indicate that the optimum population for a tall, indeterminate

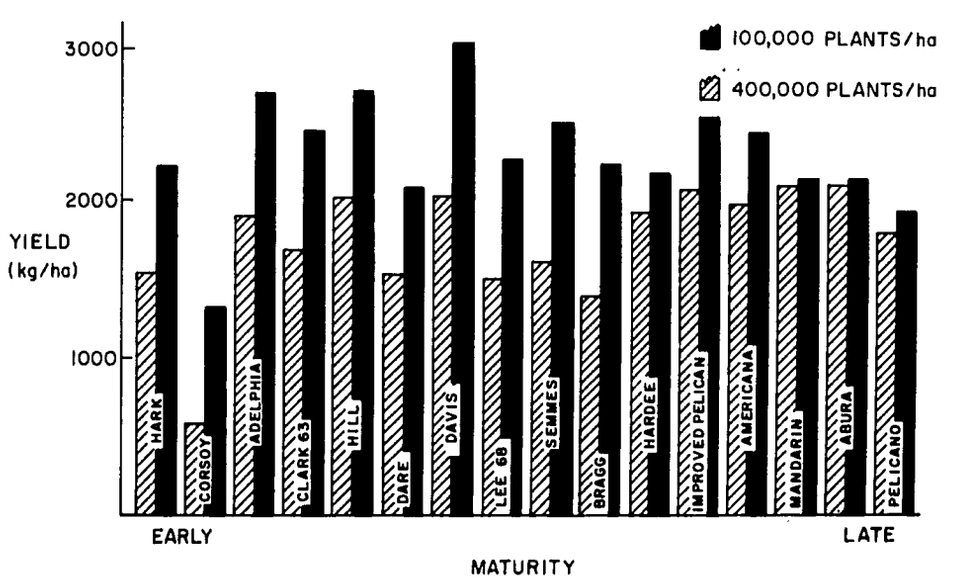

Fig. 2. Response of soybean varieties to plant population, Boliche (3° S.), Ecuador, 1970.

variety may be less than 400,000 plants per hectare and that this population level may result in a yield reduction. Conversely, varieties of the earliest maturity groups may not have produced their maximum yields at 400,000 plants per hectare.

The effects of plant distribution (row-to-row spacings) at tropical locations have been less thoroughly studied than the effects of plant population. Nevertheless, it is expected that the effects of plant distribution are also accentuated when varieties that make limited development are grown. In research conducted in central India, Minor (1971) found that the effects of row spacing increased as planting was delayed (Fig. 3). At the earliest planting date (June 10), no consistent differences in yield resulted from variations in row spacing. However, during the second (June 25) and last (July 20) dates of planting, there were linear declines in yields as row width was increased. The decrease at the second date was 223 kg per hectare, or 6 percent, over the range of row widths studied. At the last planting, the decrease was substantially greater. Soybeans in 30-cm rows outyielded those in the widest rows by 498 kg per hectare, a difference of 17 percent. The nature of the response to row width at these last two dates of planting suggests that rows less than 30 cm apart might further increase yield. Optimum plant population was largely independent of row spacing (Fig. 3).

In each of the last two trials reported, soil fertility was adequate. The environmental factor that reduced vegetative development was exposure to short photoperiods, either as a consequence of latitude or date of planting. However, other commonly encountered conditions, such as moisture stress or low soil fertility, can limit plant development. The possibility of compensating for reduced vegetative growth at low levels of soil fertility through the proper selection of cultural practices has recently been studied in Brasil (Neumaier and Minor, unpublished). Those cultural practices considered were date of planting, choice of either an early or late variety, and plant population. Dates chosen were October 15, the recommended date of planting for the region, and December 15, a late date, but one used by farmers planting soybeans after wheat. Varieties were IAS-2, an early variety for the location, and Santa Rosa, a late variety. Plant populations studied were 100,000, 250,000, 400,000, 550,000, and 700,000 plants per hectare. All combinations of planting date, variety, and plant population were studied with and without application of recommended amounts of lime and fertilizers.

Fertilization increased the yield of soybeans 660 kg per hectare (33 percent). The yield response to fertility was similar for each date of planting and variety. However, the response was greater at the lowest plant population studied than at higher levels. At a low level of fertility, plants at a population of only 100,000 plants per hectare could not compensate sufficiently to effectively use the area available (Fig. 4).

The recommended date of planting did not produce significantly higher yields than the date at the end of the planting season. This was true for all levels of fertility and variety. But, as in the case of yield response to fertility, the greatest difference between dates of planting was at the lowest plant population. As in the other trials discussed, the responsiveness of soybeans to population increased as planting was delayed past the optimum time. Greater responses were probably not obtained because even the early variety in this trial, IAS-2, required 42 days to flower and 104 days to mature at the late date of planting. A pre-flowering stage of this duration meets minimum requirements under favorable conditions (Hartwig, 1970).

Of the varieties studied, the early cultivar, IAS-2, yielded more than Santa Rosa, and was the only one of the two to respond significantly to increases in plant population. The yield of IAS-2 increased as plant population was increased to 250,000 plants per hectare, at which point it stabilized.

The failure of the two varieties to effectively use the area per plant available at low populations under conditions of native fertility and at the late date of planting was associated with their inability to maintain the number of pods produced per unit of area. Individually each

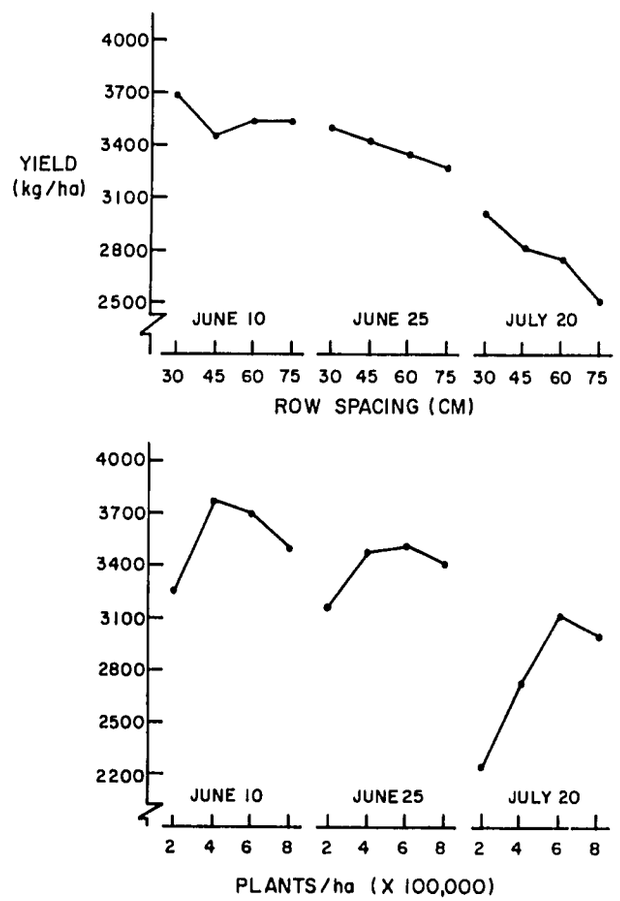

Fig. 3. Mean response of two soybean varieties (Clark 63 and Bragg) to row spacing and plant population for three planting dates, Jabalpur (23° N.) M.P., India, 1968.

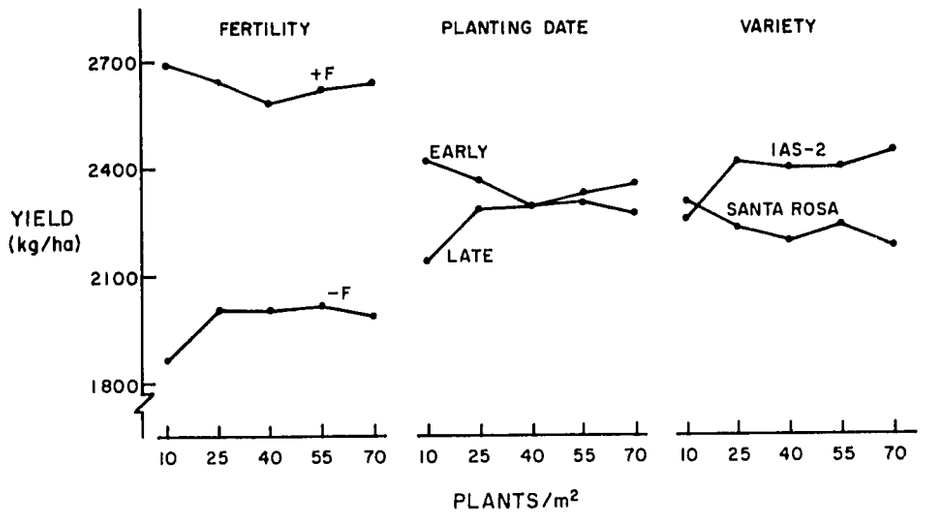

Fig. 4. Effects of soil fertility, date of planting, and plant population on yield of two soybean varieties (IAS-2 and Santa Rosa), Guaiba (30° S.), R.S., Brasil, 1974-75.

plant produced more pods than at higher plant populations, but as others have found (Weber et al., 1966), the spacing that produces the maximum number of pods per plant does not always produce the highest yield per hectare.

CONCLUSION

Photoperiodic control of soybean flowering and maturity is reasonably well understood and is an important determinant in the adaptation of a particular variety to a location or cropping system. In short-day environments, most improved varieties developed in the temperate zones show little response to the fluctuation in photoperiod encountered and have a relatively constant, although shortened, life cycle. The performance of these materials is markedly influenced by the management to which they are subjected. Later maturing and/or faster growing, improved varieties are becoming available in the tropics and should be less sensitive to management.

When vegetative development is curtailed, soybean yield can frequently be increased by increasing the number of plants per unit of land area and decreasing the spacing between rows. This appears to be true until enough plants are established to give complete ground cover during pod filling. Tall, late-maturing varieties require fewer plants per unit of land area to produce maximum yields than do short, early-maturing ones.

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Soybean Cropping Systems in the Tropics

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In the tropics and subtropics environmental conditions permit year-round cultivation and crop production. A variety of crops is found growing sequentially or interplanted on the same land in a single year (Harwood, 1975). As soybeans become more popular and economical to raise, farmers are including this crop in their cropping systems. This paper presents a few examples of the diversity of cropping patterns into which soybeans are integrated in Asia.

SOYBEAN-RICE

No-tillage, rice stubble culture is frequently used in southern Taiwan and northern Thailand in areas where soybeans are sown in paddy fields following rice harvest. The period between two rice crops may be limited to 100 days or less in some areas of Asia. Thus, time-saving techniques must be employed. In Taiwan the second rice crop is harvested at the end of the monsoon rainy season after which soybeans are planted. The practice has the same advantages of any zero tillage system, i.e., it saves time, avoids soil crusting, and minimizes soil moisture loss (Scott and Aldrich, 1970).

Farmers using this method sow soybean seeds in the paddy field by making an opening (about 2 cm deep) close to the rice stubble with a small hand trowel. Two to four seeds are dropped into each opening. Most farmers do not cover the seeds. One person can sow from 0.1 to 0.2 hectare per day. By using the no-tillage, rice stubble technique the soil is not disturbed, weed growth is reduced, and soil moisture is retained in the entire soil profile.

The seeds are sown close to the rice stubble so that soybean roots will penetrate the puddled soil and grow into the decomposing root channels of the rice plant. Also, additional nutrients may be available to the soybean plants from the decaying rice roots.

In southern Taiwan rice is planted at a density of 180,000 to 200,000 hills per hectare. In these fields the spacing between the rows of rice stubble ranges from 22.5 cm to 25.0 cm. The close row spacing precludes intertillage and weeding operations. Some farmers apply a preplant contact herbicide or preemergence herbicides, or a combination of both. Larger weeds are removed by hand about the time the soybean canopy closes.

Soon after planting, rice straw is spread over the field and pressed close to the soil surface using the rice row marker. If this is not done, the straw will shade the soybean seedlings, which will become etiolated. The rice straw mulch conserves soil moisture, suppresses weed growth, and eventually adds organic matter to the soil. Some farmers burn the straw after placing it on the field, whereas other farmers remove it from the field and use it for other purposes. When applied, fertilizer is broadcast or banded near the soybean plants 10 to 15 days after emergence. During the crop cycle both insecticides and fungicides may be applied.

The cultivars Shih-Shih, Wakajima, and Palmetto are planted in southern Taiwan. These varieties reach maturity in less than 100 days. At harvest the plants are usually threshed by machine in the field, and the land is prepared for rice planting. The average soybean yield in southern Taiwan is 1.7 metric ton per hectare (Cheng, 1972). In northern Thailand, where the cultivars SJ-1 and SJ-2 are generally used, the soybean yield is approximately 1.0 ton per hectare (FAO, 1973).

Intercropping of rice and soybeans is used when the period between rice crops is too short for a full season soybean crop. Farmers using this technique plant soybeans in rows before the rice is harvested. Green pods are harvested and sold as a vegetable crop. Grain soybeans can also be cultivated using this method if sufficient time is available for the pods to mature. Here again, precious time is saved by planting before the rice harvest. Generally, no significant reduction in rice yield is encountered if soybeans are planted 15 days before the rice harvest. However, in Indonesia farmers broadcast the soybeans in the rice field before the harvest of the rice crop. Because of poor germination and the use of poor cultural practices, yields are only 0.5 ton per hectare (Somaatmadja, 1972).

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SOYBEANS AND OTHER CEREAL CROPS

Soybeans are sometimes cropped following or interplanted with other cereal crops, such as corn and barley (Dalrymple, 1971), oats (Pendleton and Hartwig, 1973), and sorghum (Cheng, 1972). In one system used in Taiwan, one row of corn or sorghum is planted for every four rows of soybeans. In southern Taiwan the combination of corn and soybeans netted the highest returns even though the soybean yield was 35 to 65 percent below pure stand yields (Chao, 1975).

SOYBEAN-PLANTATION CROPS

Soybeans minimize weed growth, provide additional income, and reduce soil erosion. Four rows of soybeans can be planted between the newly planted banana stalks during the first year (Hung, 1974). In the Philippines and Sri Lanka soybeans are being interplanted experimentally in mature coconut plantations (Herath, 1975). In Malaysia trial plantings are being made between young rubber and oil palm trees.

SOYBEAN-SUGAR CANE

In Taiwan several legume crops, including soybean, peanut, and mung bean, are sown between rows of newly planted or recently ratooned sugar cane. Intercropping soybeans in sugar cane reduces the sugar cane yield by about 6 percent (Hung, 1974). A similar planting system is being tried on an experimental scale at the Philippines Sugar Research Institute.

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Importance of Weed Control in Tropical Soybeans

Guillermo Riveros

The reduction of yield is, in general, the most serious and common kind of damage associated with competition between weeds and crops. Any factor that enhances the degree of competition or reduces the competitive ability of the crop will result in greater crop yield losses.

Some important factors affecting the degree of competition between weeds and crops are weed population density, type of weed, and growth conditions. Competition tends to be greater in the tropics and subtropics than in the temperate zone because weed population densities are greater, weed species are more numerous, and weeds are more vigorous. Furthermore, the tropical environment is better suited to the growth and reproduction of weeds (Furtick, 1967; Holm, 1969). Because competition is greater under tropical and subtropical conditions than in the temperate zone, yield reductions tend to be higher, and for this reason weed control becomes more important. Removing weeds can increase yields by as much as 25 percent in the temperate zone and by 100 percent or more in the tropics and subtropics (Ashby and Pfeiffer, 1956).

LOSSES CAUSED BY WEEDS

Weeds cause considerable losses in soybean yields in the temperate zone. From 15 experiments performed over several years, Staniforth and Weber (1956) reported an average yield reduction of 10 percent due to full-season competition of weeds. More recently the overall losses caused by weeds to soybeans in the United States have been estimated at 17 percent of the potential crop yield (USDA, 1965). However, the same publication indicates that weeds are a more serious problem in the southern states. This may be caused by the presence of more troublesome weeds favored by the high rainfall and long growing season of this region (Wax, 1973). Since the flora of the warmer areas of the world are more abundant in species than those of the colder zones (Billings, 1966), the probability of existing troublesome weed species is higher in those states and higher still in the tropics.

Information on the nature and magnitude of losses caused by weeds in soybeans, as well as in other crops, under tropical and subtropical conditions is relatively scarce or difficult to obtain. However, when the available data on yields from weeded and unweeded plots from different types of studies are compared, the reductions are approximately 50 to 60 percent, although greater reductions are encountered when certain highly competitive species predominate. Most authors consider that the average yield loss of soybeans in the tropics and subtropics due to weed competition is about 50 percent (Hammerton, 1974; Bhan, 1974).

Data from different studies conducted in Colombia during five years (Table 1) show that the average soybean yield reduction caused by common annual weeds was 60 percent (Pulver, 1974). The same author reports results of other studies showing yield reductions of more than 80 percent when the dominant weed was *Cyperus rotundus*.

FACTORS AFFECTING LOSSES

The degree of yield reduction varies with the type of weed. Staniforth (1965) studied the effects of three species of *Setaria* on soybean yields, and observed variations that were related to differences in mature plant yield of the species.

Types of Weeds and Weed Population Densities

Studying the effects of competition of specific weeds on cotton yield, Buchanan and Burns (1971a, b) found in one study that *Xanthium pensylvanicum* was more competitive than *Amaranthus retroflexus*. In a second study they found that *Ipomea purpurea* was more competitive than *Cassia obtusifolia*. A comparison of the two studies showed that *Xanthium* seems to be the most competitive of the four species, *Amaranthus* the second, and *Cassia* the least. McWhorter and Hartwig (1972) found that *Xanthium* is more competitive with soybeans than is Johnson grass (*Sorghum halepense*).

Several studies have demonstrated that the degree of

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Table 1. Effect of Weed Competition on Soybean Yield, Palmira, Colombia

Year	Yield (kg/ha)		Yield reduction (%)
	Hand weeded	Weedy	
1968	1.551	409	74
1969	1.464	613	58
1970	1.937	606	69
1971	1.159	262	77
1972	2.282	1,565	32
1973	2.111	1,013	52
Average of 6 years			60

Prevalent weeds: *Leptochloa filiformis; Echinochloa colonum; Eleusine indica; Digitaria sanguinalis; Ipomoea* spp.: *Amaranthus* spp.: *Portulaca oleracea.*

Source: Pulver, 1974.

competition and yield reduction is influenced by weed population density. Thurlow and Buchanan (1972) studied the effects of competition of *C. obtusifolia* on soybeans, and observed yield reductions up to 35 percent at an average density of 7.7 plants per m^2. They also found that the higher the weed weight at harvest time, the lower the soybean yield.

Full-season competition of *X. pensylvanicum* at a density of 26,000 plants per hectare reduced soybean yields by 52 percent, while at a population of 100,000 plants per hectare, competition for only 12 weeks resulted in 80 percent less yield (Barrentine, 1974). Wilson and Cole (1966) observed yield reductions up to 25 percent with increasing populations of two species of *Ipomea.*

Amaranthus hybridus with a population density of one plant per meter of row of soybeans caused a yield reduction of 18 percent; 40 plants per meter caused a 51 percent yield reduction in comparison with the weeded control plot (Moolani et al., 1964). Eaton et al. (1973) reported greater soybean yield reductions with increased populations of *Hibiscus trionum.* Knake and Slife (1962) noted similar reductions with increasing populations of *Setaria faberii.*

The preceding examples, taken from the temperate zones, illustrate the degree of yield reduction that may be expected with high population densities of certain weeds likely to occur in the tropics. These examples also illustrate the need for similar studies to identify weed problems in tropical and subtropical areas potentially suitable for soybean production.

Growth Conditions

The optimal growing conditions of a plant are very similar to those prevailing in its native habitat. A native of the temperate zone, the soybean plant will be less able to compete with more adapted species when grown in the tropics and subtropics. Furthermore, the degree of weed competition during a growing season depends on environmental conditions. When temperature, soil fertility, and moisture level are more favorable to plant growth, competition of certain weeds is greater, because the degree of competition is related to the amount of weed growth (Burnside and Colville, 1964).

Minerals. Although competition for minerals between weeds and crops is important at low fertility levels, yield reductions may also be high in fertile soils or when adequate fertilizer is supplied, because many weeds may respond better than some crop plants to fertilizers. If responsive weeds are not controlled, they not only reduce the amount of minerals available for crop plants, but they may also grow more vigorously and compete with the crop plants for water or light. Soybean yield reductions due to noncontrolled weeds were greater in fertilized plots than in unfertilized plots (Staniforth, 1962).

When radioactive phosphate was injected into a soil in which *Phaseolus vulgaris* was growing with *A. retroflexus* and *Setaria viridis,* the two weed species absorbed P from the same zone as the beans. Furthermore, *Amaranthus* contained seven times more P than the beans (Chambers and Holm, 1965). The ability of weeds to accumulate large quantities of minerals at the expense of crop plants has also been demonstrated by Vengris et al. (1953, 1955).

Water. Water availability affects competition through its effects on the germination and growth of both weeds and crop. When water is limited, some weed species will germinate and become established sooner than soybeans (Hooveland and Buchanan, 1973), thus obtaining an early competitive advantage that will cause great yield reductions (Dawson, 1964). Moreover, in areas or periods of limited rainfall weed control is also essential to increase water use efficiency, since weeds utilize large amounts of water (Pendleton, 1966).

Competition is greater when rainfall is abundant, especially after sowing (Weber and Staniforth, 1957; Eaton et al., 1973). Studies of weed control in soybeans were conducted in Palmira, Colombia, during the first and second semesters of several years which differed in the amount of rainfall. Data from these studies show that during the season with higher rainfall there were more weeds, more vigorous weed growth, and greater yield reductions due to weed competition (ICA, 1968-1974). Since soybeans are planted in many areas when rainfall is more available for plant growth, weed control is especially important because the more competitive species tend to grow abundantly in wet soils (Wiese and Vandiver, 1970).

After the establishment of crop and weeds, the degree of competition will be influenced by the amount of rainfall during the rest of the growing season. Staniforth (1958) observed smaller yield reductions when moisture was either adequate or limited throughout the growing season than when adequate in the first part and limited during the second part. In most cases, because rainfall distribution during the growth period is variable and unpredictable, opportune weed control will reduce the adverse effects of a water shortage later in the season.

Crop Characteristics

Certain growth characteristics of soybeans limit their competitive ability, even with temperate zone weeds. Frazee and Stoller (1974) compared the growth of seedlings of corn, which is usually considered a competitive crop, soybeans, and seven weed species at various temperatures. They observed that while corn grew faster than all the weed species studied, soybeans after reaching a height of 15 cm had a slower growth rate than the weeds. Evetts and Burnside (1973) studied the root and shoot development of nine species, including soybeans, and seven dicotyledonous weeds, and found that soybeans had the highest ratio of shoots to roots. These findings indicate that soybeans would be at a competitive disadvantage in times of water shortage when weeds, such as *Amaranthus* spp, with better shoot to root balance are present.

Black et al. (1969) proposed that differences in photosynthetic efficiency may play an important role in plant competition. Since plant growth is a function of carbon assimilation rate, rapidly growing, efficient plants have an advantage over inefficient species, especially in the tropics and subtropics. Among other characteristics, inefficient plants have the C_3 pathway of CO_2 fixation and possess photorespiration, which is evident from their high CO_2 compensation concentrations and from the inhibition of their rates of photosynthesis by oxygen (Table 2). In general, at high light intensities in normal air and warm temperatures, C_4 species have faster rates of net photosynthesis than do C_3 species (Zelitch, 1975).

Forrester et al. (1966) found that the rate of apparent photosynthesis of soybean leaves was inhibited by O_2, caused in part by an increase in photorespiration. Similar results were obtained by Tregunna et al. (1966). Curtis et al. (1969) studied photosynthetic rates of 36 soybean varieties, finding that the CO_2 compensation concentration was high (about 40 ppm) for all varieties tested. Since soybeans have the characteristics of inefficient plants, they will be less competitive than photosynthetic efficient weeds.

Chen et al. (1970) surveyed a number of plant species for their photosynthetic efficiency, finding that most of the widely distributed or highly competitive weeds had high photosynthetic capacity. Laetsch (1974) in his review lists the following families in which C_4 species have been found: Amaranthaceae, Aizoaceae, Chenopodiaceae, Compositae, Euphorbiaceae, Nyctaginaceae, Portulacaceae, Zygophyllaceae, Cyperaceae, and Gramineae. The majority of troublesome weeds belong to these families.

One common feature of C_4 photosynthetic efficient plants is that they evolved in the tropics and are adapted to habitats where dry periods alternate with periods of abundant rainfall (Black, 1973; Laetsch, 1974; Chollet and Ogren, 1975). C_4 plants use water more efficiently, an advantage when soil moisture is limited (Table 2). Furthermore, their rapid growth enables them to compete with mesophytes when water is abundant (Laetsch, 1974).

Photosynthetic efficient plants are more competitive than inefficient species under tropical conditions, because they have higher optimum temperature for CO_2 fixation and growth (Black, 1973). This is probably because photorespiration of inefficient plants increases with light intensity, high temperature, and water stress (Jackson and Volk, 1970; Chollet and Ogren, 1975).

One of the plant groups studied extensively in relation to photosynthetic efficiency is the grasses. Most grasses of tropical origin are efficient in photosynthesis, while those originating in the temperate zone are inefficient (Downton and Tregunna, 1968; Krenzer and Moss, 1969). This may explain why so many grasses in the tropics are as much of a nuisance as weeds.

In the tropics the high competitive ability and predominance of troublesome weeds, such as *Sorghum halepense, Echinochloa colonum, Eleusine indica, Cyperus rotundus, Amaranthus* sp., and *Portulaca oleraceae* can be explained on the basis of characteristics associated with their photosynthetic efficiency (Tregunna and Downton, 1967; Black et al., 1969). The climatic conditions of the tropics and subtropics favor the establishment of dense populations of highly competitive weeds, and at the same time are unfavorable to soybean growth. Since soybeans are at a competitive disadvantage in these

Table 2. Some Characteristics Distinguishing Two Groups of Higher Plants

Photosynthetic efficiency	Low	High
Primary type of CO_2 fixation	Pentose	C^4
CO_2 compensation (concentration ppm)	30–70	0–10
Transpiration ratio (g H_2O/g dry weight)	450–950	250–350
Maximum rate of net photosynthesis (mg CO_2/dm² of leaf surface/hr)	15–40	40–80
Photosynthesis sensitivity to O_2	Yes	No
Photorespiration	High	Low
Optimum temperature for net CO_2 fixation	15°–25° C	30° to 47° C
Maximum growth rate: (g of dry weight/dm² leaf area/day)	0.5–2	4–5
Optimum day temperature for growth (dry matter production)	20°–25° C	30°–35° C
Net photosynthesis vs. light intensity	Saturation at ¼ to ⅓ full sunlight	Proportional or only tending to saturate at full sunlight
Crop examples	Soybeans	Corn

Source: adapted from Black, 1973.

environments, elimination of weed competition is essential to obtain a successful crop.

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Weed Control in Asian Soybeans

Keith Moody

Weeds are misfits and are ever present throughout the agricultural calendar. They are one of the major limiting factors of soybean production throughout the world. The losses caused by weeds and the cost of weed control are among the most expensive items in crop production.

In most tropical countries losses due to uncontrolled weed growth in soybeans range from 50 to 60 percent (Bhan, 1975; Hammerton, 1974; Moody, 1973; Vega et al., 1970). However, higher yield losses have occurred in Thailand (Waranyuwat and Kotama, 1973) and Nigeria (Table 1). In one instance, complete crop loss has been reported (Vega et al., 1970). Losses in Taiwan are much lower. Chan and Tsaur (1973) reported an average yield loss due to weeds of only 17 percent for two crops.

Competition between crops and weeds generally does not begin at the early stages after emergence of the crop. Most crops can tolerate weed competition for two to three weeks after emergence with little adverse effect on their yields. Soybeans could possibly be a notable exception. Moody (1974) observed that if weeds were left growing in association with soybeans for just 10 days following emergence, a 10 percent yield reduction resulted. For the duration of growth of this crop, reduction in yield due to weeds was approximately 1 percent per day. Vega et al. (1970) reported an average yield decline of 17 percent due to weeds between the 10th and 20th day after planting (Table 2). Bhan (1975), however, found little yield decline due to weeds in the first fifteen days after planting (Table 3).

The greatest competition between crops and weeds for water, nutrients, and light occurs during the first 25 to 33 percent of the life cycle of the crop. Several research workers (Bhan, 1975; Moody, 1974; Vega et al., 1970) have reported that only a 30- to 40-day weed-free period immediately after planting is needed for soybeans to give a yield equal to that obtained under weed-free conditions (Tables 2, 4). In Nigeria two weedings, one and four weeks after the emergence of the crop, were such that an average yield depression of only 6 percent for three soybean varieties at two row spacings occurred (Table 1). In this trial one weeding, no matter how well timed, could not produce yields better than 78 percent of the weed-free check. In Taiwan, however, where yield losses due to weeds are less than in Nigeria, Chan and Tsaur (1973) reported that one timely weeding was all that was required to give high yields, provided that the correct row spacing was used.

WEED CONTROL METHODS

Throughout the centuries the farmer has employed complex combinations of practices to control these "plants out of place." Unfortunately he may not have known the correct way to use these methods to obtain the greatest benefit from his efforts.

At present the farmer has many options available for weed control (Fig. 1). These methods should not be thought of as mutually exclusive, because quite often the best results are obtained if several practices are used concurrently. When the farmer is given the choice of weed control practices, he will choose only those that are feasible and economical.

Chemical

Except in the case of estate crops, virtually no chemicals are used for weed control in upland crops in tropical Asia. The reluctance of farmers to use herbicides is probably related to cost, the unavailability of suitable compounds, inconsistent results, problems associated with application, and the supposed availability of cheap labor.

Biological

Spectacular results have been achieved in some instances with biological control on large infestations of a single weed species in rangeland situations. However, this technique is probably not applicable in field crops, because in most cases many species of weeds, some of which may be closely related to the crop plant, have to be controlled.

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Crop Competition

Crop competition is one of the cheapest and most useful methods of weed control available to the farmer. Crop production practices, including factors such as the variety grown, planting density, time of planting, and time of fertilizer application, need to be designed or manipulated so that conditions favor crop growth.

Variety. The evidence is sufficient to indicate that there are significant differences in the ability of soybean cultivars to compete with weeds. McWhorter and Hartwig (1972) found that yield reduction caused by *Sorghum halepense* (L.) Pers. in hand-harvested soybeans ranged from 23 to 42 percent for six soybean cultivars (Table 5). Hardee, the latest maturing and the tallest growing variety, had the lowest yield reduction. Semmes had the lowest yield reduction from *Xanthium pensylvanicum* Wallr. competition, while Lee, the shortest variety and one of the earliest to mature, had the highest

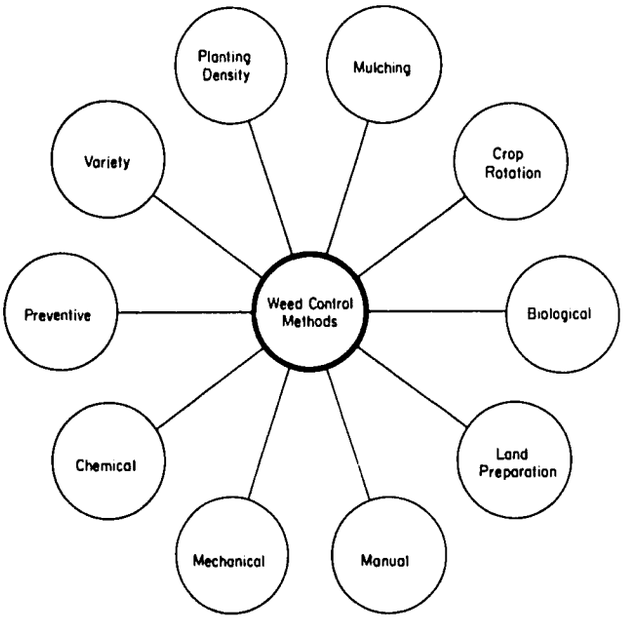

Fig. 1. Various weed control methods that can be used for suppression of weeds.

Table 1. Effect of Time of Weeding and Row Spacing on Yield of Three Soybean Varieties in Nigeria

Weeding treatment (weeks after emergence)	Soybean yield (kg/ha)					
	CES 407		Hardee		Kent	
	50 cm	75 cm	50 cm	75 cm	50 cm	75 cm
As needed	1,014	648	2,873	1,788	1,344	719
1 + 4	1,119	490	2,565	1,450	1,403	816
1 + 3	771	574	2,836	636	1,381	989
4	1,160	338	2,132	1,145	1,244	530
3	848	679	2,487	332	945	499
No weeding	152	241	387	95	556	104

Table 2. Effect of Duration of Weed Competition on Soybean Yield in the Philippines

Duration of weed competition (days after planting)	Soybean yield (kg/ha)	
	Dry season	Wet season
10	857	826
20	606	787
30	596	598
40	614	386
50	491	444
60	461	337
Unweeded	375	0

Source: adapted from Vega et al., 1970.

Table 3. Effect of Duration of Weed Control and Weed Competition on Soybean Yield in India

Weed control duration (days after planting)	Yield[a] (kg/ha)	Weed competition duration (days after planting)	Yield[a] (kg/ha)
Unweeded	1,250	Weed free	2,910
15	2,480	15	2,870
30	2,900	30	2,390
45	2,870	45	1,870
60	3,120	60	1,010
Weed free	2,920	Unweeded	1,270

[a] Average of three crops.

Source: adapted from Bhan, 1975.

Table 4. Effect of Duration of Weed Control on Soybean Yield in the Philippines

Duration of weed control (days after planting)	Soybean yield (kg/ha)	
	Dry season	Wet season
Unweeded	375	0
10	482	558
20	691	801
30	644	1,097
40	862	1,259
50	767	1,206
60	765	1,435

Source: adapted from Vega et al., 1970.

Table 5. Effect of Soybean Cultivar and *Sorghum halepense* Competition on Yields from Hand-Harvested Soybeans in the United States

Cultivar	Weeding treatment	Yield (kg/ha)	Yield reduction (%)
Hardee	None	1,010	23
	Weed free	1,310	
Semmes	None	1,210	28
	Weed free	1,680	
Bragg	None	1,390	32
	Weed free	2,040	
Davis	None	1,210	35
	Weed free	1,850	
Lee	None	1,040	41
	Weed free	1,760	
Jackson	None	910	42
	Weed free	1,310	

Source: adapted from McWhorter and Hartwig, 1972.

yield reduction when the crop was hand harvested (McWhorter and Hartwig, 1972). In a later trial (McWhorter and Barrentine, 1975), Hill was the most competitive cultivar against *X. pensylvanicum,* while Semmes and Lee were the poorest competitors (Table 6).

Burnside (1972) reported that yield reduction due to uncontrolled weed growth ranged from 41 to 52 percent for ten soybean cultivars. The lowest yield reduction occurred with Amsoy and Ford, the highest with Lindarin 63. Philippine data (Table 7) illustrate that soybean varieties vary in their ability to suppress weeds, but reduction in weight of weeds competing with the crop does not necessarily mean a corresponding reduction in yield loss.

Despite the fact that soybean varieties vary in their competitive ability against weeds, little emphasis has been placed on this line of research. Cultivars are generally selected under weed-free conditions without paying attention to their ability to compete with weeds. Varieties that perform best under weed-free conditions may yield poorly when weeds are not controlled. For example, in Nigeria Hardee, which far outyielded Kent under weed-free conditions, yielded less than Kent when weeds were not controlled (Table 1). Are plant breeders unaware of the importance of plant competition as a means of weed control, or has the weed scientist failed to present them with suitable criteria with which to evaluate their breeding lines for their competitive ability? This extremely interesting area of research needs to be investigated further.

Planting density. According to numerous authors, soybeans planted at narrow row spacings yield more and are much more effective in suppressing weed growth than soybeans planted at wide row spacings (Burnside and Colville, 1964; Hammerton, 1972; Kust and Smith, 1969; Wax and Pendleton, 1968). This is probably because of increased competition and faster shading of the soil surface. Nigerian and Philippine data confirm these findings (Tables 1, 8). Chan and Tsaur (1973) examined the effect of row spacing on weed control in soybeans in two crops. In the spring crop the degree of weed control increased as the distance between rows decreased. In the summer crop no correlation between row spacing and weed control was observed.

Fewer interrow cultivations (Burnside and Colville, 1964) and lower rates of herbicide (Burnside and Colville, 1964; Kust and Smith, 1969) are needed to achieve comparable weed control as row spacing decreases. Care has to be taken that the distance between rows does not become too narrow; otherwise, interrow cultivation as a weed control method could become impractical, forcing the farmer to use manual weeding or herbicides. In addition, soybeans planted in narrow rows often grow taller and lodge more readily than soybeans planted in wide rows.

Spacing within the row is also important with respect to competition. Weber and Staniforth (1957) reported that yield reductions due to weed competition were considerably greater (23 percent versus 17 percent) when five to six soybean plants, compared with double this planting rate, were grown per 30-cm row. They also observed that unweeded soybeans with three plants per 30-cm row yielded 18 percent less than unweeded stands of nine or fifteen plants per 30-cm row. The yield reduction in weed-free plots was only 9 percent.

Staniforth (1962) reported lower yield reductions due to weed competition for four soybean varieties when there were thirteen to fifteen plants per 30-cm row than when there were seven to nine plants per 30-cm row. Weed weights were also lower at the higher plant density (Table 9).

In Thailand Waranyuwat and Kotama (1973) observed that a doubling in plant population from 200,000 to 400,000 plants per hectare while maintaining row spacing constant at 50 cm resulted in superior weed control. In Taiwan Chan and Tsaur (1973) observed that

Table 6. Effect of Soybean Cultivar Population and *Xanthium pensylvanicum* Wallr. Competition on Soybean Yields in the United States

Cultivar	Treatment	Soybean stand (1,000 plants/ha)	Yield (kg/ha)	Yield reduction (%)
Hill	None	260	1,370	32
	Weed free	280	2,010	
Bragg	None	420	1,080	39
	Weed free	440	1,760	
Forrest	None	460	1,110	44
	Weed free	480	1,980	
Lee	None	350	930	51
	Weed free	370	1,890	
Semmes	None	450	910	52
	Weed free	510	1,910	

Source: adapted from McWhorter and Barrentine, 1975.

Table 7. Effect of Several Soybean Cultivars on Weed Growth in the Philippines

Cultivar	Height (cm)	Leaf area index	Weed weight (kg/ha)
TK 5	55.1	1.53	950
CES 16-23P	44.4	1.09	1,700
CES 16-103	49.0	1.50	1,795
Hsih-Hsih	50.7	1.27	2,225
Kailua	42.7	1.36	2,455
Multivar 80	49.9	1.04	2,725
EG Special	43.8	2.26	3,640

Table 8. Effect of Row Spacing on Weed Weight and Soybean Yield in the Philippines

Spacing (cm)	Yield (kg/ha)		Yield reduction (%)	Weed weight (kg/ha)
	Weed free	Unweeded		
33.3	694	593	14.6	826
50.0	673	494	26.6	997
100.0	524	298	43.1	1,812

the effectiveness of weed control was inversely proportional to spacing for the spring crop. In the summer crop, however, for the wider row spacings (50 and 45 cm) weed control was most effective with narrow plant spacing (10 cm), but for narrow row spacings (40 and 30 cm) weed control was most effective at wide plant spacing (20 cm). The reason for this was not explained.

Land Preparation

In parts of the Philippines and Indonesia, soybeans are broadcast into rice stubble or relay planted into the maturing rice crop without any land preparation. The soybeans have to compete with the rice or its ratoon and the weeds that may have started to develop in the rice crop. As a rule, no weeding is done in the soybean crop, and yields are low. This method is not recommended, but yields could probably be improved considerably if high seeding rates of highly competitive varieties adapted to these conditions are used.

Generally, though, most farmers do some land preparation. The major objective of land preparation, irrespective of the method used, is to provide weed-free conditions at planting. Throughout the tropics, however, numerous farmers plant into seedbeds that have been poorly prepared. Quite often weeds are present or have started to germinate by the time the crop is sown. The crop is at a competitive disadvantage from the start. It is therefore essential that the crop be sown as soon as possible after land preparation into a weed-free seedbed.

Manual and Mechanical Weeding

One of the most important reasons for growing crops in rows instead of broadcasting is to permit ease of weeding. When the crop has been broadcast, interrow cultivation is impossible; consequently, time-consuming and laborious hand-weeding must be done. Although very effective in controlling weeds, manual weeding methods rely on a supply of cheap labor, which may not be available when needed. Delayed weeding can result in appreciable yield reductions.

Hand-weeding, still common throughout the world, is used mainly for removal of weeds within the crop row where cultivating implements cannot reach. In developing countries the use of the hoe is widespread. Frequently a man with a hoe can accomplish results not obtained as effectively and cheaply by other means.

Interrow cultivation cannot completely control weeds within the crop row, where weeds need to be removed by alternative methods to prevent substantial yield losses (Knake and Slife, 1962; Moody, 1976; Moolani et al., 1964). Timely cultivation, however, is sometimes impossible because of adverse soil or weather conditions. Moist soils or rainfall soon after tillage may allow weeds to reestablish themselves quickly with little or no apparent injury. Moreover, if tillage is too close to the row, crops may be damaged, thus reducing yields. It should be noted, though, that soybean varieties do differ in their tolerance to cultivation injury (Russel et al., 1971).

Mulching

In Java, rice straw is often used as a mulch in soybean cultivation, the soybean seeds being dibbled after the rice straw has been scattered on the surface of the soil. Dahro (1953) reported that mulching caused lower soil temperatures, increased moisture availability, and decreased weed growth resulting in higher yields (Table 10).

Reduced weed growth due to mulching of soybeans with rice straw has also been observed in the Philippines (Table 11). The use of mulch in unweeded plots leads to a sixfold increase in yield and a 40 percent reduction in weed weight, compared with unweeded, unmulched

Table 9. Effect of Within-row Spacing on Yield Reduction Due to Weeds in Soybeans in the United States

Cultivar	Plant no./30 cm	Weed weight (kg/ha)	Yield reduction (kg/ha)
Hawkeye	7– 9	896	339
	13–15	616	263
Chippewa	7– 9	728	477
	13–15	560	201
Bavender Sp.	7– 9	824	452
	13–15	627	163
Ford	7– 9	862	464
	13–15	582	326

Source: adapted from Staniforth, 1962.

Table 10. Effect of Rice Straw, Incorporated, Burnt or Used as Mulch, on Soybean Yield in Indonesia

Treatment	Straw used (ton/ha)	Yield (kg/ha)	
		1951	1952
Straw as mulch	20	4.7	8.1
	40	4.4	6.8
Straw incorporated	40	3.5	6.4
Straw burnt	20	3.3	4.5
	40	3.0	4.4
Straw incorporated	20	2.5	4.9
Control	..	3.1	4.1

Source: adapted from Dahro, 1953.

Table 11. Effect of Mulching, Row Spacing, and Weeding Regime on Soybean Yield and Weed Weight in the Philippines

Time of weeding (weeks after emergence)	Soybean yield (kg/ha)		Weed weight (kg/ha)	
	With mulch	Without mulch	With mulch	Without mulch
	50-cm row spacing			
None	481	79	689	1,404
3	588	467	490	288
1 + 4	541	630	343	97
	75-cm row spacing			
None	324	43	1,100	1,647
3	510	341	593	588
1 + 4	532	527	317	220

plots. In fact, the mulched, unweeded plots yielded as well as the unmulched plots that had been weeded once.

Mulching also reduced the number of weedings required. Mulched soybeans weeded once yielded as well as those that had been weeded twice, but in unmulched plots those weeded once yielded 30 percent less than those weeded twice. Weed control by mulching appears to have considerable potential, provided that residues from previous crops are used in situ. Transportation of mulch from another area is not recommended, as this is time-consuming and can add considerably to the cost of growing the crop.

CONCLUSIONS

Weeds can and do cause appreciable losses in soybeans if left growing in association with the crop during the first 30 to 40 days after emergence. Frequently the farmer is unaware that in order to maximize yields it is important to weed early in the growth of the crop. Late developing weeds cause little yield reduction, but can harbor pests and cause problems with harvesting.

The farmer has available to him many methods by which he can control weeds. Not only does he have the nonchemical methods described in this paper, but he also has a most powerful tool with chemical weed control. Chemicals, though, should not be regarded as replacing nonchemical methods, but rather as supplementing them. In this way, the farmer increases the options available to him for controlling weeds.

Weed control methods chosen by the farmer will depend largely on economics and feasibility. However, the options given to the farmer should be such that the weed population is subjected to a variety of pressures and no weed or group of weeds is allowed to develop undisturbed. Otherwise, the farmer may end up with a worse weed problem than when he started.

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Discussion

James J. Riley: In your measurement of leaf area index, did you measure it for the soybeans, the weeds, or both?

Keith Moody: We have measured only the leaf area index of soybeans. We have observed that the soybean leaf area index increased with an increased number of weeds. We cannot explain this at the moment; however, these studies have just begun. In the future, we shall look at the leaf area index of the weeds to see if it is important.

Edi Guhardja: Does weeding within the rows after one week of emergence do more harm than good to young soybean plants?

Keith Moody: We need more research on when weeding should be done within the rows.

Use of Herbicides for Weed Control in Tropical Soybean Production

R. D. William and M. Y. Chiang

Whether soybeans are monocropped, intercropped, relay planted after rice, wheat, or barley, or planted along paddy bunds in Asia, effective and economical weed control must be considered an integral part of any soybean production scheme. Effective weed control systems must include all combinations of cultural practices, such as crop rotation, proper fertilization, appropriate plant population, row spacing, selection of competitive varieties, dry season weed control practices, and combinations of hand, mechanical, and chemical weed control techniques. Thus, our task of developing appropriate weed management strategies involves more than merely selecting suitable herbicides, but is also one of integrating all available technology into various production schemes to meet the needs of local soybean producers at costs below the value of the increase in production.

As discussed by Riveros and Moody during this conference, appropriate weed control strategies are essential if maximum or even average yields are to be expected. When considered as another tool that must be employed in the total system, herbicides can be an extremely valuable component, offering both biological and economic benefits. In this paper we shall present specific information related to the use of herbicides in Asian soybean production, and wherever possible we will emphasize their use in the entire production scheme.

RATIONAL USE OF HERBICIDES

Because of the cost and added risks involved with the use of herbicides, many people assume that chemical weed control is impracticable for use by small farmers. Certainly the farmer will not accept the practice if it does not offer an advantage he can clearly understand, such as increased soybean yield, significantly better weed control, or increased income from a stable market, enabling him to recover the herbicide cost plus an incentive for applying the chemical. Herbicides must therefore be used rationally.

At present there are many agronomic situations in which herbicides should be considered an effective and potentially economical means of controlling weeds in soybeans. For example, soybeans are often planted during the final stages of the wet season when weed competition can seriously reduce crop productivity, especially if the competition occurs during the initial stages of soybean growth. Timely hand or mechanical weedings are sometimes postponed because the fields are too wet. Even if weeding were attempted, many of the weeds would merely be transplanted, not effectively controlled, because most weed implements are designed to cultivate soils having ideal moisture conditions. When tardy, weeding may further reduce crop productivity by breaking leaves, pruning roots, and reducing the effectiveness of the crop canopy.

In other cases, because the farmer must stop planting to weed the crop, weeds limit the total area that can be planted to soybeans. In Brasil, for example, the senior author noted that the production of several upland crops could be greatly increased by simply planting more land to the crop, but weed growth inevitably required the farmer to turn his attention to weeding. In addition, timely plantings of soybeans could be achieved during periods when planting conditions are optimum, such as after the rice harvest in many parts of Asia. Cultural practices, such as spraying, drainage or irrigation, and fertilization, could also be completed at timely intervals if the peak use of labor required for weeding were better distributed throughout the cropping cycle. Crop productivity could be further increased with the use of modern cultural practices and management systems, such as closely spaced rows and high plant populations.

HERBICIDES FOR TROPICAL SOYBEAN SYSTEMS

The use of herbicides in Asian soybean production is in the infancy stages. At present only a few herbicides are used by soybean growers on a commercial scale. As soybean yields and markets stabilize to meet the demands for increased soybean production, more efficient management systems that include the use of herbicidal weed control as part of an integrated approach will, of course,

R. D. William and M. Y. Chiang: AVRDC, Shanhua, Tainan, Taiwan.

become more common in tropical growing areas. One might wonder, however, how production specialists will meet the challenge of developing various approaches to more efficiently control weeds in soybean production.

Selection Criteria

Because the climate, cropping systems, equipment, and methods of planting soybeans in Asia differ from those in other regions, the criteria used to select herbicides must also differ. Many factors must be considered, such as predominant weed species, herbicide application and incorporation equipment, soil types, and herbicide placement, persistence, and seasonal activity.

Naturally we want to choose herbicides that selectively control many of the major weed species found growing among soybeans. When herbicides are first used in a field, however, a major shift to predominantly resistant species usually occurs within a few years. In the tropics this shift is generally towards perennial sedges and grasses. Romanowski and Nakagawa (1967) reported a dramatic shift to *Cyperus rotundus* L. after several preemergence herbicides were applied to a native population of weeds in Hawaii. In this case, *C. rotundus* increased from 1.3 plants per 0.1 m^2 to as many as 29 plants in just 50 days!

Many herbicides require specific types of application equipment or must be incorporated into the soil for maximum results. Although knapsack sprayers are common in the tropics, power equipment for successful herbicide incorporation is rare. In Brasil, for example, weed control recommendations involving the herbicide EPTC (see Table 2) ranged from 1 to 10 kg/ha (William et al., 1976). Most of the variation was due to uneven soil incorporation of the herbicide, which resulted in poor weed control; therefore, the situation required that higher rates be recommended. Consequently, the use of herbicides that require elaborate equipment for application, or simply require soil incorporation, may have to be restricted to countries where mechanized agriculture exists or can be introduced.

Where soil moisture is adequate, crops are usually planted in various multiple cropping schemes throughout the year in Asia. Combinations of warm or cool, and dry or wet climatic conditions generally prevail. Some herbicides respond differently under these conditions, thereby increasing the chances for failure. For example, during the warm-wet season in Brasil, nitrofen was more active when applied after emergence to *C. rotundus* foliage, whereas EPTC was less active when incorporated in the soil (Table 1). Both compounds exhibited moderate to high vapor pressures which enhanced the penetration and activity of the nitrofen when applied directly to the *C. rotundus* foliage, whereas the EPTC concentration and activity was reduced near the tubers in the soil by dilution and volatilization from the moist soil surface. Herbicides that perform differently under varying climatic and environmental conditions should certainly be recommended with considerable caution.

Table 1. Seasonal Activity of Nitrofen and EPTC Herbicides Under Cool-Dry and Warm-Wet Conditions in Brasil

Herbicide name and dose (kg/ha)		Seasonal herbicide activity (% suppression of *C. rotundus* foliage)	
		Cool-dry	Warm-wet
Nitrofen[a]	0	0	0
	1	0	50
	2	20	70
	4	20	60
EPTC[b]	0	0	0
	2	90	20
	4	100	30
	8	100	55

[a] Night applications of nitrofen (emulsifiable concentrate formulation) were applied in water to *C. rotundus* foliage at 3 and 6 weeks after carrot (*Daucus carota* L.) was planted. *C. rotundus* foliage was weighed one week after the second application.
[b] EPTC was incorporated into dry or wet soil with a power tiller immediately after application. *C. rotundus* foliage was weighed 6 weeks after application.

Source: adapted from William and Warren, 1975; William et al., 1976.

Because many herbicides persist in the soil for periods longer than the soybean crop cycle, we must also consider the crop that follows soybeans. Where sensitive crops may be planted, herbicides having a short residual life should be recommended.

Finally, specific recommendations of herbicide doses must be amended according to soil texture and organic matter content. Many herbicides are adsorbed by soil colloids, thereby requiring larger doses as the organic matter increases. Some herbicides become completely inactive when the organic matter content exceeds 8 to 10 percent in the soil (Warren, 1962). Under such conditions, herbicides that perform well within a broad range of soil organic matter contents must be used. Soil testing laboratories will thus be necessary in key agricultural regions to test soil samples so that appropriate herbicides and correct doses can be recommended.

Herbicide selection must ultimately be accomplished on a regional basis by local production or weed specialists. To make successful recommendations, these specialists must consider the environmental, physical, biological, and managerial variations that influence the performance of a herbicide and integrate these aspects into the total production system. Results from other regions of the world where similar climates exist can, of course, serve as guidelines for testing under local conditions.

Herbicides for Asian Soybean Production

Since the advent of chemical weed control, considerable emphasis has been placed on developing selective herbicides for soybeans. For discussion purposes, a partial listing of either successful or potentially successful herbicides is presented in Table 2. This table was compiled from extension bulletins and popular magazines from

Table 2. Some Promising Herbicides for Use in Soybean Production

Common name (trade name)	Chemical name	Area of world where promising
Preplant (non-selective)		
dalapon (Dowpon)	2,2-dichloropropionic acid	USA
glyphosate (Roundup)	*N*-(phosphonomethyl)glycine	.....
paraquat (Gramoxone)	1,1′-dimethyl-4,4′-bipyridinium ion	USA, Brasil
Preplant (selective)		
A-820 (Amex 820)	*N*-*sec*-butyl-4-*tert*-butyl-2,6-dinitroaniline	USA
dinitramine (Cobex)	N^3,N^1-diethyl-*a,a,a*-trifluoro-3,5-dinitrotoluene-2,4-diamine	USA
eptam (EPTC)	*S*-ethyl-n,n-dipropylthlocarbamate	USA, Brasil
fluchloralin (Basalin)	*N*-(2-chloroethyl)-2,6-dinitro-*N*-propyl-4-trifluoromethyl aniline	USA, Brasil
nitralin (Planavin)	4-(methylsulfonyl)-2,6-dinitro-*N*,*N*-dipropylaniline	USA, Brasil
penoxalin (Prowl)	*N*-(1-Ethylpropyl)3,4-dimethyl-2,6-dinitro benzenamine	USA
profluralin (Tolban)	*N*-(cyclopropylmethyl)-*a,a,a*-trifluoro-2,6-dinitro-*N*-propyl-*p*-toluidine	USA
trifluralin (Treflan)	*a,a,a*-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine	USA, Brasil
vernolate (Vernam)	*S*-propyl dipropylthiocarbamate	USA, Brasil
Preemergence		
alachlor (Lasso)	2-chloro-2′,6′-diethyl-*N*-(methoxymethyl)acetanilide	Asia, USA, Brasil
butachlor (Machete)	2-chloro-2′,6′-diethyl-*N*-(butoxymethyl)acetanilide	Asia
chloramben (Amiben)	3-amino-2,5-dichlorobenzoic acid	USA, Brasil
chlorbromuron (Maloram)	3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea	USA, Brasil
chlorpropham (Furloe)	isopropyl *m*-chlorocarbanilate	USA
DCPA (Dacthal)	dimethyl tetrachloroterephthalate	USA, Brasil
diphenamid (Dymid, Enide)	*N*,*N*-dimethyl-2,2-diphenylacetamide	USA
fluorodifen (Preforan)	*p*-nitrophenyl *a,a,a*-trifluoro-2-nitro-*p*-tolyl ether	USA, Brasil
linuron (Afalon, Lorox)	3,(3,4-dichlorophenyl)-1-methoxy-1-methylurea	Asia, USA, Brasil
metribuzin (Lexone, Sencor)	4-amino-6-*tert*-butyl-3-(methylthio)-as-triazin-5(4*H*)one	USA, Brasil
naptalam (Alanap)	*N*-1-naphthylphthalamic acid	USA, Brasil
propachlor (Ramrod)	2-chloro-*N*-isopropylacetanilide	USA
Postemergence		
2,4-DB (Butyrac)	4-(2,4-dichlorophenoxy)butyric acid	USA
bentazon (Basagran)	3-isopropyl-1*H*-2,1,3-benzothiadiazin-4-(3*H*)-one 2,2-dioxide	USA, Brasil
chloroxuron (Tenoran)	3-[p-(p-chlorophenoxy)phenyl]-1,1-dimethylurea	USA, Brasil
dinoseb (Premerge)	2-*sec*-butyl-4,6-dinitrophenol	USA, Brasil

Asia, the United States, and Brasil; scientific journals; and personal communication from scientists and commercial representatives in Asia.

The herbicides in Table 2 are grouped according to the method of application that provides the most uniform results, which depends in part on the physical and chemical properties of the herbicides. For example, dalapon is not selective for soybeans; however, it can be used to control many perennial grasses if applied to actively growing vegetation a few weeks before soybeans are planted. Another new chemical that may be similarly used is glyphosate, which has a broader spectrum of weed control activity, including control of many broadleaf weeds.

The second group of preplant herbicides usually requires soil incorporation for optimum results, although slightly higher doses sometimes offer good control when applied before emergence to the crop. In tests at AVRDC, however, three of these dinitroanaline herbicides applied to the soil surface without soil incorporation exhibited poor weed control (Table 3), and penoxalin appeared to inhibit soybean growth and reduce grain yield. Therefore, when compared to other preemergence herbicides (Table 4), these compounds may be used only on a limited scale in areas where appropriate soil incorporation equipment is available or where local weed problems and soil types permit their effective use.

Both the pre- and postemergence herbicides listed in Table 2 may be applied with locally available pesticide application equipment. Although we have tested many of these compounds at AVRDC, only alachlor, chloramben, and linuron have selectively controlled the major weed species growing in these experiments (Table 4). Alachlor, which controls many of the weed species for two to three months at AVRDC, has shown the most consistent results, probably because it requires only moderate moisture as a result of its relatively high solubility in water. Many of the other preemergence herbicides tested in these experiments performed poorly, especially during the warm-wet period, or persisted in the soil longer than the duration of the soybean crop cycle.

According to M. Sandaru (personal communication), the use of preemergence herbicides for weed control in cultivated upland soils is only in the experimental stages in Indonesia. Sandaru reported promising results in one experiment in which alachlor (1.9 kg/ha), metribuzin (1.0 kg/ha), nitrofen (3 kg/ha), and several other numbered compounds were applied before emergence. In another experiment, however, weed control by herbicides was poor, and soybean yields were not significantly higher than in the weedy control plots. In Indonesia weed control is usually accomplished by hand at three and six weeks after planting. Herbicides are not commonly used because of the low cost and abundance of

hand labor, the small land holdings (approximately 0.5 ha/farmer), the cost of the chemicals, and because of problems with selectivity of herbicides in cropping systems, such as interplanting corn and soybeans.

In Korea the introduction of herbicides has been fairly recent and much of the work is still experimental. However, K. U. Kim (personal communication) states that butachlor (2 to 3 kg/ha) is recommended as a preemergence herbicide for control of some annual and broadleaf weeds in soybeans. In Taiwan butachlor also performs well, but costs considerably more than alachlor because of the limited use of butachlor as an emulsifiable formulation.

Bhan (1974) in India reported that alachlor (2 to 3 kg/ha) is currently recommended, and metribuzin, nitrofen, and fluchoralin show considerable promise for use

Table 3. Effect of Dinitroanaline Herbicides Applied to Soil Surface the Day After Soybeans Were Planted, AVRDC, Spring and Fall, 1975

Herbicide common name (trade name)	Dose (kg/ha)	Soybean grain yield[a] (ton/ha)		Grass control[b] (no./500 cm²)	Final weed fresh wt[b] (g/m²)	Estimated residue[c] (months)
		Spring	Fall			
Weedy check	...	0.84	0.26	180	972	...
Hand weeded check	...	1.65	0.98	...	239	...
Nitralin	0.75	1.60	...	...	...	>4
(Planavin)	1.0	1.44	...	...	...	>4
	1.5	1.38	...	...	...	>4
A-820	1.0	1.40	0.70	134	994	2 to 4
(Amex 820)	2.0	1.48	0.88	141	422	2 to 4
Penoxalin	0.5 (0.75)[d]	1.51	0.56	79	389	2 to 4
(Prowl, AC-92553)	1.0 (1.5)[d]	1.10	0.31	85	561	2 to 4
LSD 5%	...	0.35	0.34	10.4	...	...

[a] Part of two experiments planted on March 3 (spring) and October 2 (fall) with the soybean cultivar Shih-Shih. Grain yields are corrected to 13 percent moisture. Low yields in the fall experiment are due to planting late after the rains ceased.
[b] Weed data presented are from the fall experiment and included: *Eleusine indica, Echinochloa colonum, Amaranthus spinosus* and *A. viridus, Portulaca oleracea, Solanum nigrum,* and *Ageratum conyzoides.*
[c] Estimates are averages of all herbicide residue trials conducted at AVRDC during 1975.
[d] Herbicide doses for fall in parenthesis.

Table 4. Effect of Preemergence Herbicides Applied to Soil Surface the Day After Soybeans Were Planted, AVRDC, Spring and Fall, 1975

Herbicide common name (trade name)	Dose (kg/ha)	Soybean grain yield[b] (ton/ha)		Estimate of maturity delay (days)	Weed control[a]			Estimated residue[c] (months)
		Spring	Fall		*Eleusine* + *Echinochloa* (no./100 cm²)	*Amaranthus* (no./100 cm²)	Final weed wt (g/m²)	
Weedy check	...	0.84	0.26	+4	45	10	972	...
Hand weeded check	...	1.65	0.98	0	..	..	239	...
Alachlor	1.0	...	0.96	−1	4	8	144	<2
(Lasso)	2.0	1.61	1.02	−1	0	4	56	<2
	4.0	1.72	0.84	−1	1	1	22	<2
Chloramben	2.0 (1.5)[d]	1.74	0.85	+1	9	2	366	2 to 4
	4.0 (3.0)[d]	1.40	0.86	+2	4	1	61	2 to 4
Linuron	0.25	1.58	0.98	−1	39	6	322	2 to 4
(Lorox or Afalon)	0.50	1.41	0.82	0	30	1	300	2 to 4
	1.00	0.94	...	..	..	..	...	2 to 4
Nitrofen	3.0 (2.0)[d]	1.61	0.84	−1	37	12	367	<2
(TOK-WP)	6.0 (4.0)[d]	1.19	0.72	0	32	7	533	<2
LSD 5%	...	0.35	0.34	..	10.4	6.8	...	

[a] Weed data presented are from the fall experiment and included *Eleusine indica, Echinochloa colonum, Amaranthus spinosus* and *A. viridus, Portulaca oleracea, Solanum nigrum,* and *Ageratum conyzoides.*
[b] Part of two experiments planted on March 3 (spring) and October 3 (fall) with the soybean cultivar Shih-Shih. Grain yields are corrected to 13 percent moisture. Low yields in the fall experiment are due to planting late after the rains ceased. Soil organic matter was 1.5 to 1.7 percent.
[c] Estimates are averages of all herbicide residue trials conducted at AVRDC during 1975, except for linuron which are estimates from the literature.
[d] Herbicide doses for fall in parenthesis.

in soybeans. Alachlor costs approximately Rs 200 (US $24) per hectare in India and is applied with backpack or power sprayers. According to K. L. Rathod (personal communication), alachlor is applied to extensive soybean plantings grown for seed purposes near Pantnagar, India.

The use of paraquat as a preplant, nonselective compound has become popular, especially in the United States, where it is used to control weeds in the "stale seedbed" or "no till" methods of planting soybeans. The "stale seedbed" method consists of applying a preplant herbicide when the field is prepared for planting. A dinitroanaline herbicide that primarily controls annual grasses is the type most frequently used. Planting is delayed, however, two to three weeks until many of the broadleaf weeds have germinated and emerged. Contact herbicides, such as paraquat, are applied alone or in combinations at planting to control the emerged broadleaf weeds. The "no till" system involves the use of a contact herbicide that controls all existing vegetation before soybeans are planted into any previous crop, such as corn, wheat stubble, or pasture.

Before these methods are introduced to the tropics, thorough testing by local agronomists or weed specialists must occur. The senior author visited several progressive farmers who had experimented with the "stale seedbed" method of controlling weeds in Brasil. The method failed completely because perennial grasses could not be adequately controlled.

Another approach to weed control in tropical regions is the use of paraquat directed between the rows of upright and fast growing crops, such as legumes. Because paraquat is absorbed by the foliage within a few minutes after application, it is especially useful during the warm-wet season, when weeds grow rapidly and traditional weed control methods are ineffective. To apply paraquat, we designed a funnel-shaped shield over a nozzle, and instructed the applicator to drag the shield over the weed foliage. When careful application procedures are followed, weeds can be successfully controlled in approximately one-third of the time required to control the weeds by hand hoeing (William, 1973).

Weed Control in Rice Stubble Soybean Culture

When soybeans follow rice according to the rice stubble culture method, an entirely different weed problem confronts the soybean grower. The infestation is usually reduced, because the few weeds found growing in rice at harvest time die when the soil is no longer flooded. Also, fewer viable weed seeds remain exposed to the soil surface under proper conditions for germination since no additional cultivation is accomplished. However, because soybean seeds are planted throughout the field at the base of the rice stubble at spacings of approximately 22.5 cm by 25 cm, there is limited space for weeding with traditional implements or by animal cultivation. In addition, many soybean growers either burn rice straw or place rice straw over the seed after planting to conserve soil moisture and partially control weeds.

In Taiwan approximately 67 percent of all soybean hectarage in 1974 was planted during the winter season in the Pingtung-Kaohsiung area (Taiwan Agr. Yearbook, 1975). Results of a random sample survey of 104 soybean growers in Taiwan showed that 96 percent planted soybeans after rice, using the rice stubble culture method; 78 percent of this group used herbicides (Table 5). Paraquat alone or herbicide combinations with paraquat were the most popular. Most herbicides were applied as preplant applications, although a few farmers in Kaohsiung applied the herbicides after sowing. The herbicide rates that farmers mentioned in the survey, however, appear to be rather low compared to rates that are normally recommended.

We therefore tested combinations of the cultural and

Table 5. Factors Related to Herbicide Use by Soybean Growers in Taiwan, 1974-1975

Factor surveyed	Percent of herbicide users at three locations		
	Pintung (N = 83)	Kaohsiung (N = 29)	Hualien (N = 28)
Herbicide name			
paraquat	38	3	4
alachlor	6	10	6
butachlor	4	0	0
paraquat + alachlor	12	3	4
paraquat + other herbicide	5	0	0
other and unknown herbicides[a]	17	24	4
no herbicide used	18	60	82
Herbicide application method	preplant	preplant and preemergence	preemergence
Soybean planting method	rice stubble (87%) + tillage (13%)	rice stubble (97%) + tillage (3%)	tillage (100%)
Season planted	cool-dry	cool-dry	warm-wet

[a] Several farmers could not recall or did not know what herbicide they applied, only that they applied a chemical to control weeds.

Source: adapted from K. R. Huang and M. R. Menegay. Soybean production situation in Taiwan. AVRDC, Shanhua, Taiwan (in preparation).

chemical methods of weed control in rice stubble soybean culture at AVRDC this past season. Soybeans ('Shih-Shih') were planted a few days after rice harvest at the base of the rice stubble, and combinations of herbicides were applied, or rice straw was mulched on the soil surface or burned. Because the short-strawed rice varieties planted in southern Taiwan do not produce sufficient straw to adequately mulch soybeans, the quantity of rice straw used was 1.5 and 2.0 times more than the amount originally grown per unit area in the rice straw mulch and burned rice straw treatments, respectively. No additional rain fell after planting, although the experiment was planted almost one month late because of an extended rainy season in 1975.

Results from this single experiment suggest that both the rice straw mulch and burned rice straw provided better general weed control than the no mulch check with herbicides (Table 6). Both mulching materials reduced the light often required for weed seed germination, and the burned rice straw treatment controlled all weed vegetation at planting time. The use of herbicides improved the control of annual grasses in both the rice straw mulch and the no mulch check, but did not substantially improve weed control in the burned rice straw treatment (Table 7). Combinations of hand weeding or paraquat with alachlor also improved weed control slightly, compared with the treatments using only one weed operation. Soybean yields were low because of the late planting, but were generally improved with increasing levels of weed control (Table 8).

Table 6. Effect of Traditional Mulching Treatments in Combination with Herbicides for Weed Control in Rice Stubble Soybean Culture

Mulching treatment	Weed counts[a] (no./6 m²)		Weed fresh weight[a] (kg/6 m²)	
	No herbicide	Herbicide[b]	No herbicide	Herbicide[b]
No mulch	169	93	4.01	0.71
Burned rice straw	33	34	0.50	0.34
Rice straw mulch	80	42	0.91	0.45

[a] According to the F-test, the main plot (cultural), subplot (chemical) and the interaction were significantly different at the 5 percent level. *Eleusine indica* and *Echinochloa colonum* were counted from a 6 m² area. *Cynodon dactylon* was included in the fresh weight data.
[b] Data are averages of all herbicide treatments.

Table 7. Control of Annual Grasses Using Cultural and Chemical Methods in Soybean Rice Stubble Culture at AVRDC, 1975

Chemical weed treatment (dose kg/ha)	Annual grass count[a] (no./6 m²)			Fresh wt all grass weeds[a] (kg/6 m²)		
	No mulch	Burned rice straw	Rice straw mulch	No mulch	Burned rice straw	Rice straw mulch
Weedy check	169	33	80	4.01	0.50	0.91
Hand weeded check	42	39	57	0.03	0.41	0.61
Paraquat (0.75)	106	53	54	0.77	0.77	0.29
Alachlor (1.5)	93	34	54	0.95	0.38	0.83
Butachlor (1.5)	97	25	48	1.06	0.29	0.82
Alachlor + hand weeded	110	33	40	0.39	0.10	0.21
Paraquat + alachlor	85	27	14	0.40	0.15	0.10

[a] According to the F-test, the main plot (cultural), subplot (chemical) and the interaction were significantly different at the 5 percent level. Annual grass count data include only *Eleusine indica* and *Echinochloa colonum*, whereas fresh weights also include *Cynodon dactylon*.

Table 8. Effect of Cultural and Chemical Weed Control Methods on Yield of Soybeans Grown After Rice, Using Soybean Rice Stubble Culture Method

Chemical weed treatment (dose kg/ha)	Soybean grain yield[a] (kg/10 m²)			
	No mulch	Burned rice straw	Rice straw mulch	Mean chemical treatment
Weedy check	0.60	0.78	0.73	0.70
Hand weeded check	0.80	0.74	0.78	0.77
Paraquat (0.75)	0.68	0.75	0.86	0.76
Alachlor (1.5)	0.70	0.80	0.75	0.75
Butachlor (1.5)	0.75	0.76	0.95	0.82
Alachlor + hand weeded	0.70	0.87	0.80	0.86
Paraquat + alchlor	0.85	0.76	0.97	0.86
Mean cultural method	0.72	0.78	0.84	

[a] According to the F-test, the subplot treatments (chemicals) and interaction were significant at the 5 percent level. LSD 5 percent for chemical treatment was 0.1 kg/10 m² and 0.16 kg/10 m² for any level of chemical within the same level of mulch.

It is often difficult to assess the biological or economic effect of continual maintenance of a weed-free field during continued crop production throughout an entire year. We have noticed many soybean growers in southern Taiwan who repeatedly weed soybeans when no apparent economic or biological response is expected, but because *Echinochloa colonum* in particular is considered a serious pest in rice, these farmers maintain a low population level of this weed.

FUTURE OUTLOOK AND SUMMARY

The potential for increasing soybean production on a world basis is indeed great, but must be considered from a "total systems" point of view. For example, we must consider the social, economic, and biological implications of our research work and improvement programs. At times these barriers may seem great in certain countries, but at some point there ought to be an economic advantage gained with the use of improved technology. We must therefore understand and appreciate these factors and develop systems that meet the requirements of local growing conditions and economic situations in the various countries.

The development of weed control technologies must also be considered an integral part of the "total system." Only recently have we begun to understand the role herbicides must play in any production system. Recent work from the southern United States (Dowler et al., 1974; Hauser et al., 1974), the Philippines (Harwood and Bantilan, 1974), and Colombia (Doll and Piedrahita, 1975) has suggested that cropping systems or crop rotations and the use of mechanical plus chemical weed control have provided the best means of weed control over a two- to four-year period. Harwood and Bantilan (1974), for example, showed that most grasses and sedges were virtually eliminated after four seasons when a low level of chemical treatment (butachlor at 0.6 kg/ha) was followed by a single hand weeding in combination with one or more high leaf area index crops, such as corn, interplanted with mung bean.

We are only beginning to appreciate the dynamics of the total systems approach to weed and crop management or improved crop production technologies. It is certainly worthwhile to note the initial work in Asia, but it is even more important to consider the challenge of improving the entire production, marketing, and utilization scheme for soybeans. An integrated and efficient system of weed control will be a vital segment of the scheme, and the use of herbicides will most likely play a significant role when used as a part of the total system.

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Discussion

N. Vignarajah: Will the practice of burning plant debris and so forth in the highlands be as effective, in terms of weed control and weed weight, as in rice stubble soybean culture? Will not such practices break the dormancy of weed seeds?

R. D. William: Burning rice straw or plant debris will enhance the germination of certain weed seeds, but I doubt that significant numbers or fresh weight of weeds will be affected in upland soybean production systems. Under upland conditions, weed seeds are randomly mixed in the soil, and if proper soil preparation is practiced, few or no weeds should be growing at planting time when burning would occur.

Ricarte Abejuela: Do you have economic data to show when to use mulch with a herbicide or when not to use a herbicide?

R. D. William: We do not have the specific economic data that you requested, but we do have some comparisons. In Taiwan, rice straw is used to mulch various crops, to feed livestock, to burn for fuel, and to produce mushroom compost, rope, bags, and paper. The value of straw after rice harvest is approximately US$40 per hectare.

In the experiment, 1.5 and 2.0 times more rice straw were required to adequately mulch or burn, respectively. Therefore, the value of the rice straw would be $60 and $80 for the rice straw mulch and burned

rice straw treatments, respectively. Of course, these figures do not include the cost of transportation for the extra straw, nor the cost of labor to spread the straw. Current market costs per hectare for herbicides such as alachlor, butachlor, and paraquat are $30, $40, and $10, respectively. At present we lack accurate estimates of farm labor costs for applying these herbicides. However, in Taiwan it certainly appears that herbicides are competitive, in terms of cost, with the rice straw mulch.

Also, please note that there are other benefits from rice straw mulch that are difficult to evaluate without elaborate studies. These benefits include the conservation of soil moisture after the rains cease and enhanced soybean seed emergence or modifications in nutrient availability after the rice straw is burned.

Foliar Diseases of Soybeans

Charles Y. Yang

About fifty diseases are known to attack soybeans, approximately twenty of which are found in East and Southeast Asia. The diseases are caused by fungi, bacteria, viruses, nematodes, and occasionally mycoplasmas (Athow, 1973; Dunleavy et al., 1966; Kennedy and Tachibana, 1973; Kitajima and Kagihara, 1972). In any given year some diseases may be found wherever soybeans are grown. Others are not so widespread, and still others require a rather specific environment before they can develop.

All soybean diseases cause plant damage, but some, such as *Phakopsora* rust, yellow mosaic, and soybean mosaic, are especially serious. The use of resistant varieties is the most practical and economical means of controlling soybean diseases. Many of the foliar diseases attacking soybeans can also be controlled by the application of chemicals. An assessment of soybean yield losses due to foliar diseases in the field has not yet been done in Southeast Asia. Information on economic thresholds is necessary for the development of effective, economical control measures against these diseases.

The most destructive of the foliar fungal diseases is soybean rust, caused by *Phakopsora pachyrhizi*. It is widespread in Asia and Australia and can be regarded as a potential threat to other soybean production regions. Probably the most common bacterial diseases throughout the world are bacterial blight, caused by *Pseudomonas glycinea*, and bacterial pustule, caused by *Xanthomonas phaseoli* var. *sojensis*. Although bacterial pathogens are common on soybeans, they apparently do not seriously limit production (Kennedy and Tachibana, 1973). Wilt symptoms have been reported in certain areas, but leaf spots are the more prevalent symptoms found. Most bacterial pathogens are seed borne, which may account for their wide distribution. Reports of crop loss due to bacterial diseases are rarely found in the literature, but yield losses of 30 to 95 percent were reported by Russian investigators. Recently, blight and pustule were found to be the most prevalent bacterial diseases in Brasil (Kennedy and Tachibana, 1973).

SOYBEAN RUST

Soybean rust, caused by *P. pachyrhizi*, is one of the more common but least studied diseases of soybeans grown in Asia and Australia. It occurs in the Far East, from Korea and Japan, south to Australia, and in China, India, and Southeast Asia. Annual losses up to 50 percent have been reported (AVRDC, 1975).

Soybean rust occurs primarily on the leaves, but may also be found on the petioles and stems of soybeans in a severely infected field. Small, grayish-brown spots first appear on infected leaves of the lower parts of the soybean plant. At later stages of soybean development, these spots become larger or sometimes coalesce, and the leaf becomes a dark brown color. Generally found on the underside of the leaf, the spots erupt into pustules, which contain the powdery brown or pink uredospores characteristic of this rust. If the soybean plants are heavily infected, premature defoliation occurs.

The rust-inducing fungus was first described by Hennings in 1903 as *Uredo sojae*. Since that time it has been known by a number of synonyms. In 1932 Hiratsuka finalized the name of the soybean rust pathogen as *Phakopsora pachyrhizi*. Information on the life cycle of this fungus is incomplete. Only the uredospores and teliospores have been described (Kitani and Inoue, 1960). Uredospores are hyaline to yellow-brown, oval with fine echinulation, and 21 to 42 x 15 to 29 μ in size. Teliospores are one-celled, elliptic to polygonal, 19 to 30 x 4 to 13 μ in size (Kitajima and Kagihara, 1972; Kitani and Inoue, 1960).

The soybean rust pathogen, *P. pachyrhizi*, can attack a number of legume crops and has a wide range of hosts. It is not understood how the fungus survives from season to season in nature. However, perennial hosts, such as wild soybeans, yam beans, and other legumes, are suspected to be its hosts between seasons.

No truly resistant variety of soybean has yet been identified. Screenings of the soybean germ plasm collection at AVRDC have determined that certain soybean

Charles Y. Yang: AVRDC, Shanhua, Tainan, Taiwan.

varieties, such as PI 200492, PI 200490, TK5, and Tainung 4, formerly considered rust-resistant, were susceptible. However, a small number of soybean cultivars, screened under the same epiphytotic conditions, showed moderate resistance to rust. They are being tested further. The soybean rust pathogen is not transmitted through seeds (AVRDC, 1976). Rust damage can be reduced by the application of fungicides if chemical spray schedules are started on a regular basis at an early stage of soybean growth (AVRDC, 1976).

DOWNY MILDEW

Downy mildew on soybeans was first described by Miura in 1914. This disease has been found wherever soybeans are grown. Tests have shown that downy mildew, *Peronospora manshurica,* can reduce yield as much as 8 percent (Dunleavy et al., 1966).

If the environmental conditions are right, downy mildew usually occurs prior to the flowering stage of soybean growth. Yellowish-green areas varying in size and shape on the leaf's upper surface are produced in the initial stages of infection. The diseased areas later become grayish-brown to dark brown necrotic lesions that are commonly surrounded by chlorotic, yellow-green margins. A fluffy, gray or faintly purple, mycelial growth develops in the lesions on the undersurface of the leaf. Severely diseased leaves become dry, curl at the edges, and fall prematurely. Plants that are systemically infected remain small throughout the soybean growing season. The fungus sporulates abundantly on conidiophores that make up the fluffy, mycelial growth on the underside of the leaf. Conidia are ovoid to subglobose, 15 to 28 x 16 to 22 μ in size, and faintly grayish. Light brown, smooth-walled oospores are 24 to 40 μ in size. Infected seeds have a powdery, dull white encrustation on the seed coat. The entire seed, or only portions of it, may be infected. The seed encrustation is composed of oospore masses.

Many physiological races of *P. manshurica* have been reported. The following cultivars can be used as race differentials: Pridesoy, Norchief, Mukden, Richland, Roanoke, Illini, S-100, Palmetto, Dorman, Kabott, and Ogden (Dunleavy et al., 1966). A physiological race of *P. manshurica* closely resembling Dunleavy's race 20 has been identified at AVRDC (AVRDC, 1976).

The fungus survives from season to season on diseased crop residues and on the seed. A small percentage of the infected seed produces systemically infected plants that serve as sources of infection. Chemical seed treatment can eliminate the incidence of systemically infected plants. The cultivars Mendota, Kanrich, and Shih-Shih appear to be resistant to the races in Taiwan.

PURPLE SEED STAIN

Purple seed stain, caused by *Cercospora kikuchii,* is the most prevalent and widely distributed disease of soybean seed. The disease has been observed in most countries where soybeans are grown. Seed discoloration varies from pink to light or dark purple. The discolored area may be the size of a small spot or may cover the entire seed coat. Cracks often occur in the discolored areas, giving the seed a rough, dull appearance. Although the symptoms of purple stain are most conspicuous on the seed, the causal organism also attacks leaves, stems, and pods. Foliar symptoms become most evident during the latter part of the growing season as the plants approach maturity. Individual lesions are angular, reddish-brown spots approximately 2 mm in diameter. They frequently coalesce to form large areas of dead tissue that have a crusted appearance and that are noticeably thickened. Weather conditions during the time of flowering and plant maturity have a pronounced influence on the percentage of discolored seeds that develop. More than 50 percent of the seeds of some varieties may be discolored.

Matsumoto and Tomoyasu in 1925 described the causal fungus as *Cercosporina kikuchii.* In 1953 Chupp changed the name to *Cercospora kikuchii.* The pathogen overwinters on diseased leaves and stems as well as in infected seeds. Seeds infected with *C. kikuchii* have slightly lower germination rates than noninfected seeds. The fungus produces abundant filiform, hyaline conidiospores that have 0 to 22 septa and that are 70 to 165 x 4 to 5 μ in size on the diseased seedlings. The spores are both wind borne and rain splashed onto other leaves.

Varietal differences with regard to susceptibility have been observed, and PI 80837 appears to be immune to purple seed stain. Recently, 25 soybean accessions screened from 1,874 of the germ plasm collection at AVRDC have been found resistant to purple seed stain (AVRDC, 1975 and 1976).

TARGET SPOT

Target spot, caused by *Corynespora cassiicola,* occurs in Taiwan, People's Republic of China, Japan, Cambodia, Nicaragua, and the United States. An 18 to 32 percent yield loss from target spot was measured by Hartwig in the Mississippi Delta area during a five-year period when the August and September rainfall was above normal (Athow, 1973).

Target spot occurs primarily on the leaves, but may also be found on the petioles, stems, pods, and seeds. The lesions on the leaves are reddish-brown, circular to irregular, and vary from pinpoint size when young to 10 to 15 mm or more when mature. The larger lesions sometimes have concentric rings of dead tissue. The lesions are frequently surrounded by a dull green or yellowish-green halo. Premature defoliation may follow lesion development.

The fungus attacks plants of several genera, and there appears to be some pathogenic variability among isolates. All isolates were morphologically similar. The conidia were of an inverted club shape, hyaline to light olive in color, with 2 to 20 septa. In size they ranged from 5 to

20 μ wide and 26 to 219 μ long. Most of the soybean cultivars grown in the southeastern United States are resistant to the fungus.

FROGEYE LEAF SPOT

The fungus causing frogeye leaf spot was first described as *Cercospora sojina* in Japan in 1915. The disease has been reported on soybeans grown in Taiwan, People's Republic of China, Thailand, Japan, the Philippines, India, Australia, Canada, southern United States, Venezuela, Guatemala, Brasil, Germany, and the U.S.S.R.

Frogeye leaf spot is primarily a disease of the leaves, but stems, pods, and seeds may also be infected. Lesions on the leaves vary in both size and shape, and have a gray or light tan central area with a narrow, reddish-brown border. When the lesions are numerous, the leaf becomes dry and drops. Infection on stems and pods is not distinctive. Moderately heavy infection can reduce seed yield 12 to 15 percent.

The fungus survives from season to season in diseased leaves, stems, and seeds. The hyaline spores are of an inverted club shape, 4 to 12 x 14 to 79 μ in size, and have 0 to 10 septa. The spores, which are produced on diseased crop residues, are a prime source of inoculum. Infected seeds are a means of long-distance dissemination of this pathogen. Physiological specialization of this fungus has been reported. Frogeye leaf spot can be effectively controlled by using resistant soybean cultivars. Davis, Ogden, and Kanrich are resistant to all four races of the frogeye pathogen (Athow, 1973).

BROWN SPOT

Brown spot, caused by *Septoria glycines,* was first described in Japan in 1915. It has been reported in Taiwan, People's Republic of China, Japan, Korea, U.S.S.R., Yugoslavia, Germany, Italy, Canada, the United States, and southern Brasil.

It is primarily a leaf spot disease causing severe defoliation. The first symptom of the disease is the appearance of irregular, dark brown patches on the cotyledons. Next, reddish-brown, angular spots, 2 to 3 mm in diameter, develop on the primary leaves, which quickly turn yellow and drop. The disease progresses upward on the plant from the lower leaves. The lesions frequently coalesce. The disease may appear on the stems and pods of plants approaching maturity. Brown pycnidia form in mature lesions, which are found primarily on the upper side of the leaves. Pycnidiospores are hyaline, filiform, curved, and have one to four septa. They range from 1.4 to 2.1 x 21 to 53 μ in size.

Conidia overwinter on diseased leaves and stems. The fungi enter the leaves through stomata and grow intercellularly. They are seed borne. This disease is more prevalent when soybeans are grown on the same land in consecutive years, because the inoculum for initial infection arises mainly from infected plant debris. No resistant cultivars have been identified.

BACTERIAL BLIGHT

Bacterial blight, caused by *Pseudomonas glycinea,* is present throughout soybean production areas in the United States, U.S.S.R., Japan, Taiwan, the Philippines, and People's Republic of China.

Symptoms of bacterial blight are particularly conspicuous on leaves and consist of small angular lesions, usually water-soaked at the center and surrounded by a yellow-green halo. Spots later become brown or black as tissues die, and eventually shredding of the foliage occurs. The disease is not restricted to leaves, lesions frequently being found on stems, petioles, and pods. Stunting and chlorosis occur in young leaves and are caused by a toxin produced by the pathogen. Torn leaves are almost always present on infected plants. Seeds are infected via the pod. The spread of this disease is facilitated primarily by splashing rain. The pathogen can survive for at least seven years in dried leaves at 5 to 7°C, but it is especially vulnerable to antibiotic activity of soil microorganisms (Kennedy and Tachibana, 1973).

The causal bacterium, *P. glycinea,* is a Gram-negative rod with rounded ends, and is motile, having one to several polar flagella. There are different races of this pathogen in nature. Variability in host resistance to *P. glycinea* has been noted (Kennedy and Tachibana, 1973). Flambeau and Hawkeye are less susceptible than most soybean cultivars, while PI 68708 is highly resistant.

BACTERIAL PUSTULE

Bacterial pustule, caused by *X. phaseoli* var. *sojensis,* has been found throughout soybean-growing areas of the United States and many countries in Southeast Asia.

The bacteria enter through stomata and cause hyperplasia and hypertrophy of mesophyll leaf cells, resulting in the formation of pustules. Bacteria are present throughout the pustule, and host cells become partly suberized. An early symptom of this disease is the formation of small, pale green spots with elevated centers. The spots are usually confined to the lower leaf surface, where they are most conspicuous. They are seldom more than 1 mm in diameter, yet they may become confluent and cause large brown patches of dead leaf tissue. These spots do not produce the conspicuous water-soaked appearance characteristic of blight. Yellowing is a readily noticeable symptom, but is not a universal symptom of pustule. When found, it occurs around the periphery of each individual lesion.

The causal organism was named *Xanthomonas phaseoli* var. *sojense* by Hedges in 1924. The bacterium can overwinter in the rhizosphere of wheat roots and may infect weed hosts. The effect of bacterial pustule on yield and chemical composition of soybeans has been studied (Hartwig and Johnson, 1953). In resistant lines the protein content was higher and the iodine number in the oil was lower than in susceptible lines. A reduction in seed number, as well as other factors, accounts for yield losses. A yield loss of 4.3 percent was reported to be

caused by bacterial pustule, primarily because of the reduction in both seed number and size (Weber et al., 1966).

At present the use of resistant varieties is the only form of control. A high degree of resistance was found in the variety CNS. Crosses made with this variety indicated that the inheritance of resistance is a simple recessive trait conditioned by a single major gene pair (Kennedy and Tachibana, 1973).

OTHER FOLIAR DISEASES

Minor foliar diseases, such as soybean sleeping blight, caused by *Septogloeum sojae,* and soybean scab, caused by *Elsinoe glycines,* have been reported only in Japan. The sleeping blight pathogen produces superficial, brown, obscure spots or streaks on leaves, petioles, stems, and pods. The pathogen is spread by rain, and produces conidia (hyaline, club-shaped or long spindle-shaped) with two to seven septa (3.5 to 5 x 22 to 47 μ in size); the conidia are borne on top of a 30 to 100 μ stroma. Sphere-shaped chlamydospores are also produced.

Soybean scab is a foliar disease that was discovered in Japan after World War II. This disease also attacks stems and pods. Scab-resistant varieties of soybeans have been developed in Japan.

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Root and Stem Diseases of Soybeans

F. C. Quebral

Root and stem diseases of soybeans in Southeast Asia and the Pacific are considered of minor importance; consequently, very little attention has been given these diseases. This is reflected in the scarcity of available published materials devoted to them. Another possible explanation for the dearth of materials is that soybeans were not widely cultivated until recently. Thus they had low priority in terms of research activities.

Investigations of root and stem diseases are based primarily on surveys, reports on their occurrence, and descriptions of their symptoms and causes. The most commonly reported root diseases in the region are Rhizoctonia root rot, Sclerotium wilt, charcoal rot, basal stem rot, collar rot, and wilt (Table 1).

At present Rhizoctonia root rot and Sclerotium wilt are considered the most prevalent root diseases in the region. Rhizoctonia root rot is caused by the pathogen *Rhizoctonia solani* Kuehn (Syn.: *Pellicularia filamentosa* (Pat.) Rogers; *Corticium solani* (Prill and Delacr.) Bourd. and Galz.). Sclerotium wilt is caused by *Sclerotium rolfsii* Sacc. (Syn.: *Corticum centrifugum* (Lev.) Bres.; *Hypochnus centrifugus* (Lev.) Tul.). They have been discussed by the following researchers: Agrawal and Katasheane (1971), Chandrasrikul (1962), Chu and Chuang-Yang (1961), Daculla (1969), Dumbleton (1954), Endo (1963), Fujioka (1951), Geh and Lim (1975), Han (1959), Hanson (1963), Johnston (1960), Kurata (1960), Litsenberger et al. (1962), Mathur (1954), Morwood (1956), Oei-Dharma (1969), Rodrigo (1947), Sangawongse (1975), Shivanathan (1975), Thompson and Johnston (1953), Uichanco (1962), Uppal et al. (1935), and Anon. (1974). Both pathogens, which are worldwide in distribution, have similar life cycles and attack many species of plants (Brien, 1932; Daculla, 1969; Pruss, 1973; Sangawongse, 1975; Uichanco, 1962).

RHIZOCTONIA ROOT ROT

Rhizoctonia root rot, also known as Rhizoctonia blight and collar rot, causes a high percentage of seedling loss in close plantings during the wet season, when the soil is extremely moist (Rodrigo, 1947; Sangawongse, 1975; Uichanco, 1962). In Uttar Pradesh, India, heavy losses have been observed among soybeans grown at an altitude of 4,000 to 7,000 feet, as well as among those grown in the plains. The plants were affected during the *Kharif* season, especially in August (Mathur, 1954).

In Sri Lanka, where soybean cultivation started recently, collar rot is estimated to have damaged 10 percent of the plants. Continuing surveys indicate that the disease is becoming widespread (Shivanathan, 1975). Both Queensland, Australia, and Taiwan have experienced difficulty attaining a good plant establishment due to *Rhizoctonia* (Chu and Chuang-Yang, 1961; Pruss, 1973). *R. solani,* a soil-borne pathogen, has been found to be more aggressive when supplied with an external source of nitrogen (Geronimo, 1972). Kahn (1954) reported it as highly pathogenic to soybeans at pH 4-6.

SCLEROTIUM WILT

In Taiwan a survey conducted over a two-year period (1956-1958) revealed that Sclerotium wilt, also known as sclerotial blight, southern blight, and foot rot, was present in most of the soybean-producing areas on the island (Hanson, 1963). A high incidence of the disease was reported in the sugar cane-soybean interplanted fields of Taiwan (Chu and Chuang-Yang, 1961). In 1964 Sutakaria of Indonesia surveyed the important diseases of soybeans in his country and remarked that relatively little was known about soybean diseases (Sutakaria, personal communication). Among the diseases mentioned, Sclerotium blight was reported as the most serious soybean disease in Indonesia (Oei-Dharma, 1969). In Thailand, where the disease is known as basal stem rot, the pathogen attacks seedlings, causing as much as 25 percent seedling loss (Sangawongse, 1975). Scattered areas of dead seedlings are commonly seen in irrigated fields. In Madhya Pradesh, India, Sclerotium blight has been reported to kill soybean seedlings at pre- as well as postemergence stages of their growth

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Table 1. Root and Stem Diseases of Soybeans

Disease	Pathogen	Distribution
Wilt, Sclerotium blight, southern blight, foot rot	*Sclerotium* sp.; *Sclerotium rolfsii; Corticium centrifugum; Hypochnus centrifugus*	Malaysia, Thailand, Cambodia, Indonesia, Sarawak, Japan, Fiji, Philippines, China, Taiwan, India
Sclerotinia rot, stem rot	*Sclerotinia sclerotiorum*	Taiwan, Japan, Australia, New Zealand
Rhizoctonia blight, Rhizoctonia root rot, collar rot	*Rhizoctonia solani; Pellicularia filamentosa; Corticium solani*	Malaysia, Japan, Thailand, Australia, Sarawak, Sri Lanka, Taiwan, Philippines, India
Charcoal rot, dry root rot	*Sclerotium bataticola; Rhizoctonia bataticola; Macrophomina phaseoli; M. phaseolina*	Thailand, Philippines, Taiwan, Sri Lanka, Indonesia, India, Australia
Basal stem rot	*Ophionectria sojae*	Taiwan, Japan
Wilt	*Fusarium oxysporum; Fusarium* sp.	Japan, Laos, India, Philippines
Bacterial wilt	*Pseudomonas solanacearum*	Indonesia
Phytophthora rot	*Phytophthora megasperma* var. *sojae*	India

(Agrawal and Katasthane, 1971). Other countries that reported the presence of this disease are West Malaysia, Fiji, Japan, Cambodia, Sarawak, the Philippines, and the People's Republic of China.

CHARCOAL ROT

Charcoal rot, caused by *Macrophomina phaseoli* (Maubl.) Ashby, is another root disease becoming more important in the region. Much of the Queensland soybean crop in 1973 suffered from a condition commonly described as "sudden wilt." This disease was unusually severe, affecting large patches of soybeans, mostly 'Wills,' as they approached maturity. In every case, *M. phaseoli* was associated with the condition. The disease has been reported to be especially bad where crops grow in heavy black soils (Pruss, 1973). Observations in India and Thailand indicate that charcoal rot may cause extensive damage to soybeans under stress conditions, such as excessive heat or drought (Sangwongse, 1975; Singh and Mital, 1970). The disease causes smaller seeds and reduced yield. Both the seed and soil from various soybean planting areas usually contain the charcoal rot pathogen.

OTHER ROOT DISEASES

Other root diseases occurring in the region are Sclerotinia rot (*Sclerotinia sclerotiorum* (Lib) de Bary), Fusarium wilt (*Fusarium oxysporum* Schlecht, *Fusarium* sp.), basal stem rot (*Ophionectria sojae* Hare), and bacterial wilt (*Pseudomonas solanacearum* E.F.S.).

Exotic varieties, as well as existing local soybean cultivars, are susceptible to one or more of the root diseases under favorable conditions. Attempts to control the diseases have been directed toward breeding and screening varieties for resistance. Inoculation screening tests have shown some varieties to be resistant. In Madhya Pradesh the resistant varieties are IC216, Taichung E 32, Improved Pelican, Monetta, Shelby, Palmetto, Hood, Jackson, Hill, Clark 63, Harosoy, Shih-Shih, and Hardee (Agrawal and Katasthane, 1971). Varieties that have shown some degree of resistance in the Philippines are L-114, CES 276, CES 16-21 PD, CES 16-26, PI 200492, L-2A, Tainung No. 4, Tainung No. 3, Kaoshung No. 3, and I-346.

Other means of controlling the diseases include the use of chemicals applied either to the seed or into the soil. Some of these chemicals are PCNB, formaldehyde, and captan and thiram fungicides (Barraquio, 1969; Oei-Dharma, 1969; Oka, 1975; Sangawongse, 1975). Proper cultural management, including time of planting, crop rotation, and application of soil amendments, such as rice hull and sawdust (Geronimo, 1972; Oei-Dharma, 1969; Rodrigo, 1947; Uichanco, 1962), is another means of controlling the disease. But in most cases, control measures have generally not been justified.

Now that many of the countries in the region have joined the "soybean race" and have plans to expand substantially the areas to be planted to soybeans, it is expected that diseases, including root diseases, will become more prevalent. Because this can be a limiting factor for soybean production, it is time that the root rot complex of pathogens affecting soybeans be given greater attention by pathologists. More in-depth studies on etiology and epidemiology should be carried out, for without such information rational and effective control measures are unlikely to be developed. In addition, information on the effects of the different root and basal stem pathogens on yield and quality is lacking. These kinds of data are essential in determining the economic significance of the diseases and in establishing priorities for further intensive research.

With regard to regional and international cooperation, there is a need to embark on a program of interchange of genetic material and information on resistant cultivars useful for disease resistance programs. Resistant materials should be freely exchanged among countries. INTSOY and AVRDC can contribute significantly in this regard.

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Nematode Diseases of Soybeans and Their Control

J. N. Sasser

Plant-pathogenic nematodes, which are worldwide in distribution, constitute a major threat to the production of most crops. Soybeans can be severely damaged by nematodes, especially in the sandy soils of warmer climates. My remarks will center around the following: (a) the need to reduce nematode densities below damaging levels in fields planted to soybeans, (b) the kinds of nematodes that limit soybean production, (c) the problems encountered in devising effective control measures, and (d) the application of available knowledge to control nematodes.

NEED TO REDUCE NEMATODE DENSITIES

All nematodes that attack soybeans feed on the root system, resulting in different kinds of damage, such as galls, lesions, general cessation of growth, root pruning, destruction or alteration of nodules, and general root deterioration. In addition to causing substantial damage by themselves, nematodes predispose the soybean plant to attack by fungi and bacteria, many of which are not normally pathogenic. This root damage is manifested in poor shoot growth and lower yields. In most cases, the aboveground (or shoot) growth and the subsequent yield are directly correlated with the growth and vigor of the root system, and inversely correlated with the plant-parasitic nematode density. Thus, control of these pests is essential for profitable yields.

KINDS OF NEMATODES THAT ATTACK SOYBEANS

The following nematodes are known to be important pathogens of soybeans: root-knot (*Meloidogyne* spp.), soybean cyst (*Heterodera glycines*), lesion (*Pratylenchus* spp.), reniform (*Rotylenchulus reniformis*), sting (*Belonolaimus* spp.), stubby root (*Trichodorus* spp.), dagger (*Xiphinema* spp.), lance (*Hoplolaimus* spp.), spiral (*Helicotylenchus,* spp., *Rotylenchus,* spp.), and stunt (*Tylenchorhynchus* spp.). Others of lesser importance include pin (*Paratylenchus* spp.) and ring (*Criconemoides* spp.).

The aboveground symptoms of nematode diseases are quite similar for all of the above species. There may be stunting of the entire plant, yellowing of the foliage, wilting at midday under dry conditions, irregular growth, and poor stands. The peculiar feeding and reproductive habits of individual species may be related to symptom expression in the root zone. Some are more destructive than others, which may be related to the type of physiological changes in the plant, resulting from the feeding by the nematode. For example, root galls, caused by *Meloidogyne* spp., are quite complex compared with the almost imperceptible changes in the root tissues, resulting from feeding by *Helicotylenchus digonicus.* The amount of damage in soybeans due to plant-parasitic nematodes is correlated with initial densities at planting time. The subsequent yield loss is dependent on the environmental factors throughout the growing season.

PROBLEMS ENCOUNTERED

Most fields are infested with many species of pathogenic nematodes capable of causing serious losses. Numbers required to cause damage vary with the nematode species, age of the plant, and environmental conditions during the growing season. Generally, if population densities are moderate to high at the time of planting, and growing conditions are not especially favorable, serious damage will occur. The initial population density is important because few secondary roots of the soybean plant have developed, and the loss of just a few roots at this time can retard plant growth to such an extent that recovery or compensation cannot occur. When initial populations of the nematodes are lower, the soybean plant can produce considerable root and shoot tissue before nematode populations have increased to large numbers. Plant damage is less when large populations occur late in season than when they occur early. When an effective control program has been followed and the population density reduced to a trace prior to planting, the crop has an excellent chance to grow to maturity

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and produce respectable yields. The chances of high yields are enhanced if good cultural practices are followed and growing conditions are favorable. Without this low initial population, however, serious crop losses are likely to occur.

The question then becomes one of determining how to insure low initial population densities so that the plant will develop a healthy root system and produce a good crop. It should be kept in mind that most fields are infested with several genera and species, and while certain crops are nonhosts for some species of the nematode, they may be good to excellent hosts for others present. Sometimes a *target* species is present toward which control efforts are directed. For example, crop rotation or use of resistant varieties can effectively control the soybean cyst nematode, *H. glycines,* or a single species of the southern root-knot nematode, *Meloidogyne incognita.* The presence of a dominant species, such as those mentioned above, often suppresses development of other parasitic forms, and they cause no appreciable damage the first year. Continuous planting of nonhosts, however, can result in a buildup of nontarget species to a density capable of causing as much damage as the target species. Lesion nematodes (*Pratylenchus* spp.), for example, could increase on rotation crops to a level that would cause serious yield reduction in soybeans. Another perhaps even more serious problem associated with such crops would be the overuse of resistant varieties in the same field. In such cases, new pathogenic strains of the target nematode capable of attacking the resistant variety could emerge. This phenomenon has been called genetic vulnerability. Once this occurs, the grower has lost one of his best weapons to control nematodes, viz., the resistant variety.

In addition to the polyspecific nature of our fields with reference to parasitic nematodes, another hindrance to control is locked into the biological makeup of the nematodes. For example, many species can live in the soil for several years in the absence of a host. While the planting of nonhost or resistant varieties will greatly reduce the population density in the soil, there are always a few survivors ready to bounce back rapidly when susceptible hosts are planted.

What then can growers do to alleviate damage caused by nematodes? This brings us to a consideration of how to most effectively make use of available information in the development of control strategies.

APPLICATION OF AVAILABLE KNOWLEDGE

In spite of the complex nature of nematode diseases of soybeans and the problems associated with their control, much can be done to alleviate damage. Making the right choice of available control methods and optimum use of each method is dependent upon a correct diagnosis of the nematode involved and an understanding of its biology. For example, if rotation with nonhost crops is the control method selected, the grower must know the nematode involved and its host range, so as to select the right crops to use in the rotation. He must also know its ability to survive in the soil for long periods in the absence of suitable hosts, and if possible, its pathogenic variation. With this knowledge, or even part of it, the grower can employ intelligent cropping systems that will greatly reduce the population density of target species. Control of the soybean cyst nematode through crop rotation is a good example. Corn is a nonhost, and when soybeans follow two or three years of corn, population densities are greatly reduced and yields are quite good.

Equally effective is the use of resistant varieties when available. These, however, should be used in combination with nonhost crops and never planted in the same field for more than one year. Growing of a susceptible variety about every four years will make it difficult for new pathogenic strains, should they develop, to compete by perpetuating the original population. With the continuous planting of resistant varieties, new pathogenic races capable of attacking the resistant variety may develop.

Finally, in some instances the use of a nematocide may be practical. For certain nematodes, such as the sting nematode, there are no known sources of resistance. Furthermore, in those areas where corn, cotton, and peanuts are used in rotation with soybeans, all of which are susceptible to this nematode, there is little the grower can do except reduce the population density through the use of nematocides.

Ideally, growers should seek to use a combination of control methods in an integrated program designed to give maximum benefits from the use of each control practice. This is not always easy, but at least attempts should be made to take advantage of the good points in each method and mesh them into a total, long-range control program aimed at keeping damage to a minimum.

Discussion

Ricarte Abejuela: What is the nematode population index you recommend to warrant the use of a nematocide, such as Furadan?

J. M. Sasser: This will vary with the nematode species, crop, soil type, and growing conditions. For most regions, it is best to try nematocides in a small area, and assay the soil about 60 days after treatment to determine the population densities of various species in the treated and nontreated plots. Then, based on general crop growth and the final yield that results from treatment versus no treatment, decide on population levels which are capable of damaging a specific crop.

Virus Diseases of Soybeans

Robert M. Goodman and Y. L. Nene

Among the more than 50 viruses that infect soybeans, about 20 have been reported to occur in natural infections. Virus diseases constitute the most serious disease threat to soybean production in many tropical areas.

In general, all soybean varieties in use today are susceptible to the important viruses. Most important viruses are spread in the field by invertebrate vectors, such as aphids, whiteflies, and beetles. Three important soybean viruses are seed-transmitted, and so are readily spread from season to season, as well as from country to country. Many soybean viruses have other plant hosts, either weeds or other crop plants, that serve as sources of inoculum for spread to soybeans. The importance of these factors is amplified in tropical areas by the usual absence of a killing drought or winter season that keeps weed reservoirs and vector populations low in temperate areas. Also, the prevalence of other legumes, both as crops and as weeds, contributes to the importance of viruses as factors that will affect the success of soybeans in the tropics.

Freedom from apparent virus disease during the first few years of growing a new crop, as soybeans are in certain tropical areas, should not be taken as an assurance that virus diseases will be unimportant in the future. Newly introduced crops are often free of significant diseases for a few years. Only after a source of inoculum builds up or after the potential vectors of a virus begin to adjust to the presence of the new crop does disease incidence increase (Ford and Goodman, 1976). The increase may then be explosive, especially when larger areas are planted at the same time with a uniformly susceptible variety.

Several virus diseases of soybeans have similar symptoms, and the symptoms of other virus diseases are easily confused with symptoms induced by other causes, such as mineral deficiency or chemical residue toxicity. Accurate diagnosis of soybean virus diseases requires host range and serological tests by a knowledgeable plant pathologist. As with other diseases, accurate diagnosis is extremely important, especially because a correct identification of the virus causing a disease will also usually lead to the identification of the important vector.

The purpose of this paper is to review basic information on the soybean viruses that are of present or potential consequence to soybean production in tropical and subtropical areas of the world. The discussion can be divided conveniently into two parts. In the first, we deal with diseases caused by known viruses, which include those transmitted by aphids, nematodes, beetles, and possibly thrips. Among these viruses, three important ones are also seed-transmitted in soybeans. In the second part, we will discuss the viruslike pathogens that cause yellow or yellow mosaic diseases in soybeans. These pathogens, which are probably viruses but which have not been fully characterized, are transmitted by the whitefly (*Bemisia tabaci* Genn.). Viruslike pathogens transmitted by *B. tabaci* are known in both Asia and the New World. The disease caused by one such pathogen prevalent in the humid areas of India is the limiting factor of soybean production in the areas where it occurs.

SOYBEAN MOSAIC

Probably the most common virus of soybeans around the world is soybean mosaic virus (SMV). It is transmitted nonpersistently by several species of aphid, and it is also transmitted through the seed. Moreover, it can be readily transmitted mechanically. The symptoms of infection by SMV vary widely, depending upon soybean varieties, weather, time of inoculation, and the strain or isolate of the virus (Ross, 1969). Mild strains of SMV in tolerant varieties growing under ideal conditions cause little loss of yield, although maturity of the plants may be delayed. In warm climates (above 30°C) infected plants may even grow normally with few or no foliar symptoms. Highly susceptible or moderately susceptible varieties infected with severe strains of SMV show a yellow veinclearing symptom in the first system-

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ically infected leaves. This is followed by a characteristic mosaic and rugosity. Severely affected plants may be stunted with short internodes and downwardly curled leaves, and the pods may contain fewer than the normal number of seeds.

Yield reductions of 50 percent or more have been reported from experiments in which all plants in the field were artificially inoculated. Losses of 80 percent occurred when plants were doubly infected with SMV and bean pod mottle virus (Ross, 1968). In temperate areas where soybeans have been grown for many years, it is unusual for symptoms to appear on all of the plants in a field, and little loss in yield has been attributed to SMV in the past. What losses may have occurred have never been documented. However, in tropical areas where aphid vectors are plentiful and seed-borne virus is available as primary inoculum, rapid spread of the virus can be expected. It is conceivable, and in some cases has already been found, that 100 percent infection by SMV can occur. In such cases, significant yield losses are expected. Soybean mosaic virus is seed-transmitted and is therefore known in every country where soybeans are grown (Dunleavy, 1973). Most commercial seed lots of soybeans contain some SMV-infected seeds; some varieties have a very high level of seed transmission (Dunleavy et al., 1970; Smith, 1957). The host range of SMV is relatively narrow compared with other legume viruses, but a number of varieties of *Phaseolus vulgaris* L. and *Lespedeza* sp. are systemically infected and are potential sources for spread of the virus in areas where soybeans are grown near these other legumes.

In addition to possible deleterious effects on plant growth and yield, SMV can also cause other problems. SMV-infected soybeans of many varieties produce a high proportion of mottled seeds, i.e., seed with an irregularly pigmented seed coat. This is an undesirable character in the soybean seed industry and can result in discounting on domestic and world markets. Also, some investigators have reported reduced germinability of seeds from SMV-infected plants compared with seeds of the same variety from healthy plants (Quiniones et al., 1971; but also see Galvez, 1963).

It is theoretically possible to control SMV by planting noninfected seeds of resistant varieties and also by controlling insect vectors, but in practice, control of insect vectors is not effective. No agronomically suitable varieties resistant to SMV have been put into wide use, and even the cleanest seed lots of soybeans available on commercial markets can contain a low percentage of virus-infected seed. In addition to searching for virus-resistant lines to use in breeding programs to produce virus-resistant varieties, research at the International Soybean Program is directed toward finding lines that do not transmit the virus to their seed. If a nontransmission character were found in the soybean germ plasm, it could be used to create new varieties which, while they may be infected with the virus, do not produce seeds that are infected. Since the major source of inoculum for spread within the field is believed to be infected seedlings arising from infected seed, the elimination of infected seed should provide a successful means of controlling SMV infection.

BUD BLIGHT

Two viruses can cause bud blight disease of soybeans. Tobacco streak virus (TSV) causes a severe bud blight disease in Brasil (Costa and Carvalho, 1961) and the United States. (Fagbenle and Ford, 1970; Ghanekar and Schwenk, 1974). The more common bud blight disease in the United States is caused by tobacco ringspot virus (TRSV). Both TSV and TRSV have wide host ranges. No insect vector is known for TSV, and the means of spread of this virus in soybeans is so far unknown. Field spread of TRSV usually occurs in a pattern suggesting spread of the virus from outside the field by an aerial vector. TRSV is known to be transmitted by thrips (Messieha, 1969), grasshoppers (Dunleavy, 1957), and nematodes of the genus *Xiphinema* (Bergeson et al., 1964), although in no case is the transmission of TRSV to soybeans very efficient. Transmission by thrips is the most likely means of spread in soybeans, but laboratory studies show that only the relatively sedentary thrip larvae are capable of transmitting the virus (Messieha, 1969). Therefore, the effective vector of TRSV in soybean fields is also unknown. Both TSV and TRSV are seed-transmitted in soybeans (Ghanekar and Schwenk, 1974; Athow and Bancroft, 1959; Athow and Laviolette, 1962). One hundred percent transmission of TRSV to soybean seeds was reported in one study in which the plants became infected with the virus before flowering (Athow and Bancroft, 1959).

Symptoms of TSV and TRSV infection in soybeans are identical. The growing tip in young, infected plants curves downward, becomes brown, and dies. The plants are stunted and produce little or no seed. Leaves of the infected plants often show a red flecking symptom. Plants that became infected by TRSV during or after flowering produce poorly developed pods that often show dark, irregular markings. As with soybean mosaic virus, TRSV causes infected soybeans to mature later than healthy plants so that at the end of the growing season, when healthy plants lose their leaves, virus-infected plants remain green.

BEAN YELLOW MOSAIC

Another legume virus that has been reported as a pathogen of soybeans in several countries is bean yellow mosaic virus (BYMV). The English terminology in current use for various yellow mosaic virus diseases of beans is confusing. Yellow mosaic diseases that are not caused by BYMV, but by a whitefly-transmitted, viruslike pathogen, have been reported in India, Brasil, and Puerto Rico. Bean yellow mosaic virus is a flexuous, rod-shaped virus that can be readily purified. It is transmitted in the fields by aphids and can also be easily transmitted

mechanically, but it is not seed-transmitted in soybeans. BYMV has been reported to infect soybeans in the United States (Zaumeyer and Thomas, 1957) and Japan (Koshimizu and Iizuka, 1963). The virus is widespread in legumes, especially in species of *Phaseolus,* and will undoubtedly appear in soybeans in areas where its other hosts are grown.

Soybeans infected by BYMV have yellow mottled foliage or chlorotic veinbanding. Red necrotic areas occur on mature leaves. There are no records on yield loss caused by BYMV, and usually infected plants are not significantly stunted. However, various strains of BYMV are known, and the potential for a more severe disease of soybeans caused by BYMV should not be ignored.

BEETLE-TRANSMITTED VIRUSES

Bean pod mottle virus (BPMV) and cowpea mosaic virus (CPMV) are transmitted to soybeans by leaf beetles (Patel and Pitre, 1971; Ross, 1963; Walters, 1964). Soybeans singly infected by BPMV are usually not seriously affected, but double infection with BPMV and SMV can result in severe losses (Ross, 1968). In addition to yield losses, seed size may be reduced in plants affected by BPMV. The foliar symptoms of BPMV include mild chlorotic mottle, which may be more severe at higher temperatures. The virus has a narrow host range, but it includes several other useful bean crops in the genus *Phaseolus.* Isolates of CPMV from Trinidad, Puerto Rico, and the United States can cause a very serious disease in soybeans (Goodman, R. M., and Thongmeearkom, P., unpublished observations). The symptoms include transient vein chlorosis, followed by an intense yellow-green mosaic. Leaves are distorted, often assuming a cuplike shape during the acute stage of the disease. During the chronic stage of the disease the leaves tend to be narrowed, occasionally straplike, and show a pronounced mosaic pattern. CPMV-infected soybeans produce few or no flowers. Occasionally flower buds and even vegetative buds turn brown and die, and the plants do not mature. There are no reports of CPMV causing diseases of soybeans in Africa, and some isolates of CPMV from Africa do not apparently infect soybeans systemically. Some consideration is now being given to the possibility that the beetle-transmitted CPMV common in Africa is related to, but distinct from, that found in the western hemisphere (VanKammen, 1971).

SOYBEAN DWARF

Yet another soybean virus of importance in some areas is soybean dwarf virus (SDV). The disease caused by this virus was first reported from Japan (Tamada, 1970). The known host range of the virus is restricted to legumes. SDV is transmitted by aphids in a persistent manner but has not yet been transmitted mechanically and is apparently not seed borne. There is evidence that SDV may be a phloem-restricted virus. All 45 soybean varieties tested by Tamada (1970) were susceptible to SDV. The complete range of the virus in Asia is not yet known.

OTHER DISEASES

Alfalfa mosaic virus, cowpea chlorotic mottle virus, peanut mottle virus, southern bean mosaic virus, and broad bean mosaic virus are other naturally occurring soybean viruses that may become important in new soybean growing areas but are of no known consequence in soybeans today. Alfalfa mosaic virus (AMV), for example, has been reported naturally infecting soybeans in Japan, South Africa, and the United States (Dunleavy, 1973), but the symptoms are generally very mild. AMV has a wide host range among legumes (Klesser, 1961) and is probably a common virus in tropical areas where legumes may become an important crop. Since AMV is transmitted by aphids, there is a real possibility that in certain tropical areas a severe strain of AMV may become widespread in soybeans.

SOYBEAN YELLOWS

Perhaps the greatest threat to soybean production in the tropics is the group of viruslike pathogens of legumes that are transmitted by whiteflies. Unlike the viruses discussed above, the whitefly-transmitted, viruslike agents have not been fully characterized, but they are serious. For the rest of this discussion, we shall concentrate on work done in India on the infection of soybeans by mung bean yellow mosaic virus, which is one of the whitefly-transmitted viruses.

Soybean cultivation in India and neighboring countries was confined until recently to the cooler mountainous regions. Through the efforts of the United States Agency for International Development, University of Illinois, and G. B. Pant University of Agriculture, Pantnagar, India, the possibilities of expanding soybean cultivation to other regions of India were explored. As a result of these efforts initiated in 1965 at Pantnagar, it became evident that high yielding soybean cultivars, e.g., Bragg, could be successfully grown in several areas of India. In the initial years the crop looked almost totally disease free. However, in subsequent years disease problems started becoming evident. By 1969 yellow mosaic was regarded as the most serious problem and was considered a threat to the crop. In fact, the efforts of extension workers to popularize the crop in north India received a serious setback because of the widespread incidence of yellow mosaic.

Nariani (1960) described a yellow mosaic disease of mung bean (*Phaseolus aureus* L. Roxb.). In his host range studies he reported soybeans to be one of the species susceptible to the mung bean yellow mosaic virus (MYMV). Subsequently at Pantnagar yellow mosaic caused by MYMV was found occurring in soybeans. This was reported by Nene (1969), and since then has been

confirmed by Suteri (1974). Although systematic surveys have not been conducted specifically to study the prevalence of this disease in different parts of India, it is evident through personal communication, observations, and reports made at annual soybean conferences that the disease is prevalent in all areas of India from north to south wherever soybean cultivation has been undertaken. The prevalence is high, even to the extent of 100 percent, in areas where, during the growing season, the weather is warm and humid. In cool and/or drier regions the prevalence is very low. To be more specific, in mountainous regions of northern India where weather is cooler, and in parts of central India where humidity is low, the prevalence is negligible. When the commercial farm at Pantnagar was planted for extensive seed multiplication in 1970, almost 600 acres out of 2,500 had to be plowed in because of the devastation due to yellow mosaic.

Losses caused by yellow mosaic in soybeans depend upon the time of infection (Nene, 1971). When the plants of the cultivar Bragg became infected within the first month after planting, the average loss in yield on a per plant basis was 80.2 percent. If the plants became infected during the second month, the loss varied between 35.4 to 64.6 percent, whereas there was no significant loss if the plants became infected beyond 60 days after sowing. The trend was more or less similar in the cultivar Clark 63. No efforts have so far been made in India to estimate annual losses in soybeans due to the yellow mosaic.

Under field conditions the infected plants can be seen within 20 days of sowing. The initial symptoms consist of mild, scattered yellow specks or spots. Subsequently emerging trifoliolate leaves show irregular alternating yellow and green patches. The leaf size is generally not affected, and affected plants keep on growing with the healthy ones. The affected plants show reduction in growth only if these are infected within the first three weeks or so. Subsequently emerging leaves show more yellow patches, and at a later stage most leaves of the plant turn completely yellow. This type of symptom was described by Nene (1972) as "yellow mottle." The other type, in which the yellow spots on leaves do not enlarge but remain restricted and turn necrotic, was described as "necrotic mottle." A good deal of leaf area remains green until maturity in the case of the "necrotic mottle" reaction of certain varieties. Diseased plants have fewer flowers and pods, and pod size is reduced.

Nariani (1960) reported that the whitefly (*B. tabaci*) is the vector of MYMV and transmits the virus to other hosts including soybeans. This was confirmed by Nene (1969) and Suteri (1974). Graft transmission is possible, but the virus is not transmitted through seed or mechanically. The spread of the disease under field conditions is mainly by the adult whiteflies.

Nene (1972) has reported detailed studies on the MYMV-whitefly relationship. The minimum acquisition feeding and inoculation feeding times for soybean ('Bragg') were more than 60 minutes. This is in contrast to results with mung bean or urd bean (*Phaseolus mungo* L.), for which these periods vary from 10 to 15 minutes. In soybeans the symptoms usually appear from 10 to 14 days after inoculation. The whitefly becomes viruliferous 4 hours after the end of acquisition feeding. Results of studies on urd bean (*P. mungo*) revealed that a single whitefly adult was sufficient to transmit the virus successfully to at least 25 percent of the plants on which it subsequently fed, whereas 10 whiteflies transmitted the virus to 100 percent of the plants. Male adults retained their ability to transmit the virus for 3 days if they had no access to diseased plants again; female adults could transmit the virus for 10 days under similar conditions. No evidence of transovarial transmission was obtained. Preadult stages can acquire the virus and transmit it.

The whitefly adults do not seem to cause much damage as pests on soybeans. The host range of the whitefly is fairly wide, with more than 70 plant species in the Pantnagar area serving as hosts (Nene, 1972). The adults can be seen year-round, but their population is very low in cooler months in northern India.

The whitefly adults, unlike apterous aphids, are constantly moving around. No definite field pattern of the disease spread is observed. However, the pathogen can be spread very rapidly under warm and humid conditions, apparently because of the rapid buildup in the population of whiteflies. Heavy monsoon showers reduce the population of whiteflies drastically; a rain drop can knock an adult dead. In fact, in years when monsoon rainfall is frequent, i.e., when the interval between showers is less than three days and the showers continue for a month or so, the incidence of yellow mosaic is quite low. It is presumed that the frequent showers continue to kill whitefly adults, thus keeping their population low, which in turn results in low disease incidence.

The studies carried out by Nariani (1960) and Nene (1972) indicate that the following hosts are susceptible to MYMV: *Brachiaria ramosa, Cajanus cajan, Cosmos bipinnatus, Dolichos biflorus, Eclipta alba, Glycine max, P. aconitifolius, P. acutifolius, Phaseolus aureus, P. lathyroides, P. mungo, Phaseolus vulgaris* 'Manitou,' *Xanthium strumarium*. Out of 25 varieties of *P. vulgaris* tried, only 'Manitou' was susceptible. *Brachiaria ramosa, Eclipta alba,* and *Xanthium strumarium* are common weeds growing around fields. The host range includes plants in the Compositae, Graminae and Leguminosae.

Nene (1972) has described in detail techniques for artificial screening of the germ plasm for resistance, using viruliferous whiteflies under both glasshouse and field conditions. A large collection of soybean germ plasm obtained by soybean breeders at Pantnagar through the United States Department of Agriculture, as well as from other sources, was screened. Whichever lines appeared promising in the field were checked further under

glasshouse conditions. As a result of the intensive screening done during 1971 through 1973, the following lines were identified as resistant (no infection) or tolerant (necrotic mottle reaction):

Resistant: E-721, E-14448, UPSM-534
Tolerant: PK 71-21 and PK 71-24

It is understood through personal communication with Dr. B. B. Singh at Pantnagar that UPSM-534 has been extensively used in his program and that a number of F_5 and F_6 progenies look promising. PK 71-21, a tolerant line, has done well in the All India Coordinated Soybean Trials.

Many insecticides and other materials were screened to find the ones that would kill whitefly adults quickly (Nene, 1972). A nonphytotoxic grade of emulsifiable mineral oil, when sprayed (2 percent) on leaves, immobilizes the whitefly adults in 3 to 9 seconds and is most effective in killing whitefly adults quickly. However, the high cost of oil limits its use on a large scale. As a result of several trials, a spray schedule has been recommended for seed production plots at Pantnagar with excellent results over the last four years. A mixture of endosulfan (0.025 percent) and oxydemeton-methyl (0.05 percent) is recommended for sprays. The first spray is given when plants are about 20 days old and then three more sprays at 10-day intervals are recommended. This not only keeps the incidence of yellow mosaic to less than one percent (as compared to more than 50 percent in unsprayed plots in the area), but also controls other serious pests. Both insecticidal sprays and granular insecticides have been used successfully by other workers also (Rataul and Singh, 1973; Singh et al., 1971).

Nene (1972, 1973) reported the occurrence of a fungus parasite on *B. tabaci*. The fungus was identified as *Paecilomyces farinosus* (Dick. ex Fr.) Brown and Smith. Balakrishnan (1974) explored the possibility of using the fungus for biological control of the whitefly. He found that all stages, i.e., larval, pupal, and adult, were susceptible to the fungus. The fungus spores germinated only when the humidity was above 80 percent. The optimum temperature for the growth and sporulation of *P. farinosus* and infection of *B. tabaci* was found to be 25°C, with a functioning range of between 20° and 30°C. The ability of fungus-infected whitefly adults to transmit yellow mosaic virus in *P. mungo* was significantly reduced after they were exposed to the fungus for 2 to 4 hours and kept under high humidity conditions. Considerable work is needed to fully explore the possibility of using this fungus against *B. tabaci*.

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Discussion

Salih M. Damirgi: Have you ever observed double infection, such as yellow mosaic virus and soybean mosaic virus, on the same plant?

R. M. Goodman: I have not seen published reports of the mixed infection that you mentioned. But the general question you raise is quite important. Undoubtedly, mixed infections are common in the field. Some mixed infections result in synergistic effects on the plant; that is, the result of double infection is greater than the additive effects of single infections. The double infection of bean pod mottle virus and soybean mosaic virus is an example. In other cases, mixed infections may not affect the plant so severely, but they can compound the difficulty of reliably diagnosing a virus disease using symptoms alone.

Insect Pest Diversity and Succession in Asian Soybeans

Romeo S. Rejesus

Soybeans are a major part of many Asian diets and are a strong candidate to bridge the protein gap in many nations throughout the world. Shortage of this commodity in 1973 elicited mild political and commercial friction among consumer and producer countries (Smith et al., 1974). The crop is cultivated in practically all Asian countries, and in most there is one or more significant insect pest that reduces yields. Although the level of insecticide use is still low in this region (Smith and Huffaker, 1973; Smith et al. 1974), insecticides are so far the only material employed for insect pest control. Often, however, they are used indiscriminately without due consideration given to the agro-ecosystem. Complete reliance on chemical pesticides in this area is inevitable unless the inadequate understanding of the crop ecosystem can be overcome and replaced with more systematic methods of control. Pressures to increase production, as well as the absence of alternative pest control measures in the region, force the farmer to rely primarily on chemical pesticides. Furthermore, the relentless campaign of the pesticide industry, whose representatives are often the only extension workers reaching the farmers, overwhelms the effort to achieve a more rational means of crop protection. Because of the high cost of pesticides and the growing worldwide concern for a clean environment, the need for alternative controls is critical.

Efforts must be redirected from a purely chemical to an integrated method of control. Turnipseed (1972), Smith and Huffaker (1973), and Napompeth (1975) emphasized the necessity for immediate implementation of component studies of the agro-ecosystem in order to evolve an integrated control scheme in soybeans before it is too late. It appears that certain Asian countries have already passed the stage of solving immediate problems of crop protection. Therefore, it is now appropriate to shift efforts to the analytical stage, which includes the initiation of fundamental studies of tropical agro-ecosystems. Only by a thorough understanding of tropical ecology can we start to formulate a multifaceted approach to crop protection. This paper attempts to rationalize the need for analyzing the soybean pest complex within the context of an ecological foundation of pest problems as a means of evolving a pest management scheme. This discussion will be limited to the following: (a) determination of the arthropod and insect pest component of soybeans in the Philippines and some Asian countries, (b) the infestation succession and plant growth relation, and (c) future work needed.

PEST DIVERSITY

The concept of insect diversity in the agro-ecosystem was recently reviewed extensively by van Emden and Williams (1974). They emphasized the stabilizing role of diversity in a complex system, but cautioned against a general application of the principles, noting that contrary to the usual generalizations "certain diverse systems can be very unstable and some monocultures are quite stable." In this paper diversity is treated simply as richness of species (pests, potential pests, parasites, predators, and other arthropods). The interpretation of the data is purely empirical and perhaps should be subjected to critical analysis at a later date.

Insects and Other Arthropods in Philippine Soybeans

The soybean ecosystem is very rich and complex (Turnipseed, 1972; Smith et al., 1974). The arthropods may be grouped into four categories: (a) sheltering (migrant) species, (b) soybean-feeding species, (c) weed-feeding species, and (d) parasite and predator species, including spiders. This is perhaps the first deliberate attempt to establish the diversity of insects and other arthropods associated with the soybean ecosystem in the Philippines.

About 208 insects and 141 other arthropod species were collected during the wet and dry seasons from pesticide-free soybeans. Sweep net samples were taken from the various quadrants in the early morning or late afternoon twice a week from the seedling stage to maturity. Samples were stored in 70 percent ethanol and sorted

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Table 1. Number of Species of Insects and Other Arthropods in Soybean Ecosystem in the Philippines

Order	Number of species			
	Wet season	Percentage of species	Dry season	Percentage of species
Araneae (spiders)	9	4.3	8	5.7
Coleoptera	27	13.0	31	22.0
Diptera	51	24.5	25	17.7
Hemiptera	20	9.6	17	12.1
Homoptera	18	8.7	13	9.2
Hymenoptera	39	18.8	31	22.0
Lepidoptera	32	15.4	7	5.0
Odonata	2	1.0	3	2.1
Orthoptera	10	4.8	6	4.3
Total	208		141	

for identification. Unidentified specimens were number coded, presumably as separate species for future identification.

Species were grouped by their order and the number per season (Table 1). The numerically dominant orders during the wet season were Hymenoptera and Diptera, constituting 18.8 and 24.5 percent of the species, respectively. This is rather interesting, since most of the parasitic species belong to these orders. Lepidoptera constituted 15.4 percent of the species, followed by Coleoptera, 13.0 percent; Hemiptera, 9.6 percent; Homoptera, 8.7 percent; Orthoptera, 4.8 percent; and Odonata, 1.0 percent. The predatory Araneae (spiders) comprised 4.3 percent of the arthropods collected.

The number of species collected during the dry season was relatively smaller, but was dominated by Hymenoptera and Coleoptera, followed by Diptera, Hemiptera, Homoptera, Lepidoptera, Orthoptera, and Odonata. The proportion of spider species to the various insect orders increased during the dry season. Likewise, the most numerically dominant species belong to those orders with a large number of predatory and parasitic species. Of the total species at least six insect predators, viz., Nabidae, *Geocoris* sp., *Nysius venitor* Bergroth, syrphid fly, *Mecraspis crocea,* and *Menochilus sexmaculatus,* and eight or nine spiders of the families Oxyopidae, Thomicidae, Salticidae, Thericidae, and Angiopidae were identified. Coccinellids and oxyopid spiders were present in considerable numbers during both the dry and the wet seasons, whereas large numbers of nabids were present only in the dry season. The community of parasitic species is complex, especially considering the abundance of specimens from the orders Hymenoptera and Diptera. At present the parasites and their specific hosts have not yet been determined.

The phytophagous species comprise the bulk of the insect fauna, but a number of these migrate from adjacent crops to seek shelter in the soybean canopy. Certain insect species are abundant only during a specific growth stage of the soybean, while others persist throughout the growth period. In spite of the number of phytophagous species, key pests were not recognized. The relative damage was primarily the result of the combined action of several species, especially the defoliators. The dreaded bean fly, *Ophiomyia* (*Melanagromyza*) *phaseoli* Tryon, did not damage soybeans, despite the high adult population during the seedling stage. Leafhoppers, Lepidoptera defoliators, and pod borers are potentially dangerous as key pests. The same species of soybean insects were observed in surveys of selected regions in the Philippines (J. Litsinger, personal communication). Obviously many more species will be found associated with soybeans as the sampling technique is improved.

Insect Diversity in Other Asian Countries

Much of the literature on insects in Asian soybeans consists primarily of insect pest listings. In Japan, Kobayashi (1972) reported 218 pest species (61 families and 9 orders) classified according to plant parts attacked (Table 2). Thirty species, principally stink bugs, Lepidoptera, pod borers, and some Diptera, caused severe damage.

Napompeth (1975) mentioned 15 major soybean pests in Thailand (Appendix 1). There is little doubt that insect diversity in Thailand approximates every tropical area of Asia. Napompeth (1975) strongly argues for the development of a pest management scheme based on a better understanding of the ecological components of pest occurrence.

Evidence from scattered available literature indicates that soybean insect fauna in India are as diverse as in most other parts of Asia. Twenty-nine species (Appendix 1) are listed as soypean pests (Maxwell, 1971; Srivatsava et al., 1963; Kashap and Adlakhi, 1963; Shashi Verma et al., 1972; Srivatsava, 1964; Gujarati et al., 1971 and 1973). The number of species associated with soybeans will undoubtedly increase, considering the extremely varied geographical divisions of the subcontinent and the climatic conditions.

Stapley (1972) listed *Maruca testulalis* and *Hymenia recurvalis* as the most important soybean pests in the

Table 2. Number of Insect Pest Species Classified by Orders and Soybean Parts Attacked

Order	Attacked part				
	Root[a]	Stem[b]	Leaf[c]	Flower[d]	Pod[e]
Collembola	1	..	2	..	..
Orthoptera	1	7	13	..	4
Dermaptera	..	..	1	..	..
Thysanoptera	..	1	8	4	..
Hemiptera	3	49	40	..	24
Lepidoptera	..	9	73	1	7
Coleoptera	8	8	35	1	..
Hymenoptera	..	..	2	..	..
Diptera	4	3	8	..	1
Total	17	77	182	6	36

[a] Roots, root tubercles, and subterranean parts of stems.
[b] Most parts of stems and petioles.
[c] Cotyledons and young and developed leaves.
[d] Flowers and flower buds.
[e] Pods and seeds.

Source: adapted from Kobayashi, 1972.

Solomon Islands. In Micronesia Gressitt (1954) recorded 14 species on soybeans (Appendix 1). In Indonesia a key pest, soybean leaf beetle, *Phaedonia inclusa* Stal., has been identified, although the overall pest community is as diverse as that recorded elsewhere (M. Iman, personal communication; Kalshoven et al., 1951). There are 12 known pests found in different parts of the Indonesian archipelago. Three species of bean flies, *Ophiomyia phaseoli* Tryon, *O. sojae* Zn., and *O. dolichostigma* De Meij., are recorded.

On the basis of available records it appears that there is an urgent need to intensify the effort to catalogue and classify the insects associated with soybeans in Asia. The initiation of any pest management scheme will be greatly protracted in the absence of adequate biological and ecological information on the insect fauna. Currently there is a strong consensus among developing countries to employ pest management schemes instead of relying completely on chemical pesticides, but the basic foundation needed is not available.

PEST SUCCESSION

An understanding of the sequential dominance of insect pests in relation to soybean growth stages could provide the immediate impetus for developing a simple integrated control program based on minimum insecticide application. By delineating the succession of the major pests at different stages of soybean growth, the frequency, timing, and dosage of insecticide application could be synchronized, hence avoiding the calendar method. The spray program could then be based on expected population peaks at any given growth stage.

The following discussion will treat only the more important pests with a view toward formulating control strategies that involve minimum use of insecticides. Strict adoption of the standard concept of pest management is extremely difficult in most Asian countries for want of a better understanding of the agro-ecosystem. Nevertheless, there is strong indication for successful pest management because of the temporal and spatial diversity of the tropical ecosystem.

Thirteen pest species found on Philippine soybeans are considered in the successional analysis (Fig. 1). The sequence is based on growth stages or the number of weeks after seedling emergence (WASE). We employed Fehr's description of soybean stage development (Fehr et al., 1971) in establishing succession, with the exception of the last stage. Generally, population peaks of the various pest species occurred in the mid-vegetative or early reproductive stages during both the dry and the wet seasons. During the wet season the population peak (mainly larvae) generally occurred in the early vegetative stage, whereas during the dry season the peak was delayed until the early reproductive stage. Minor peaks occurred in

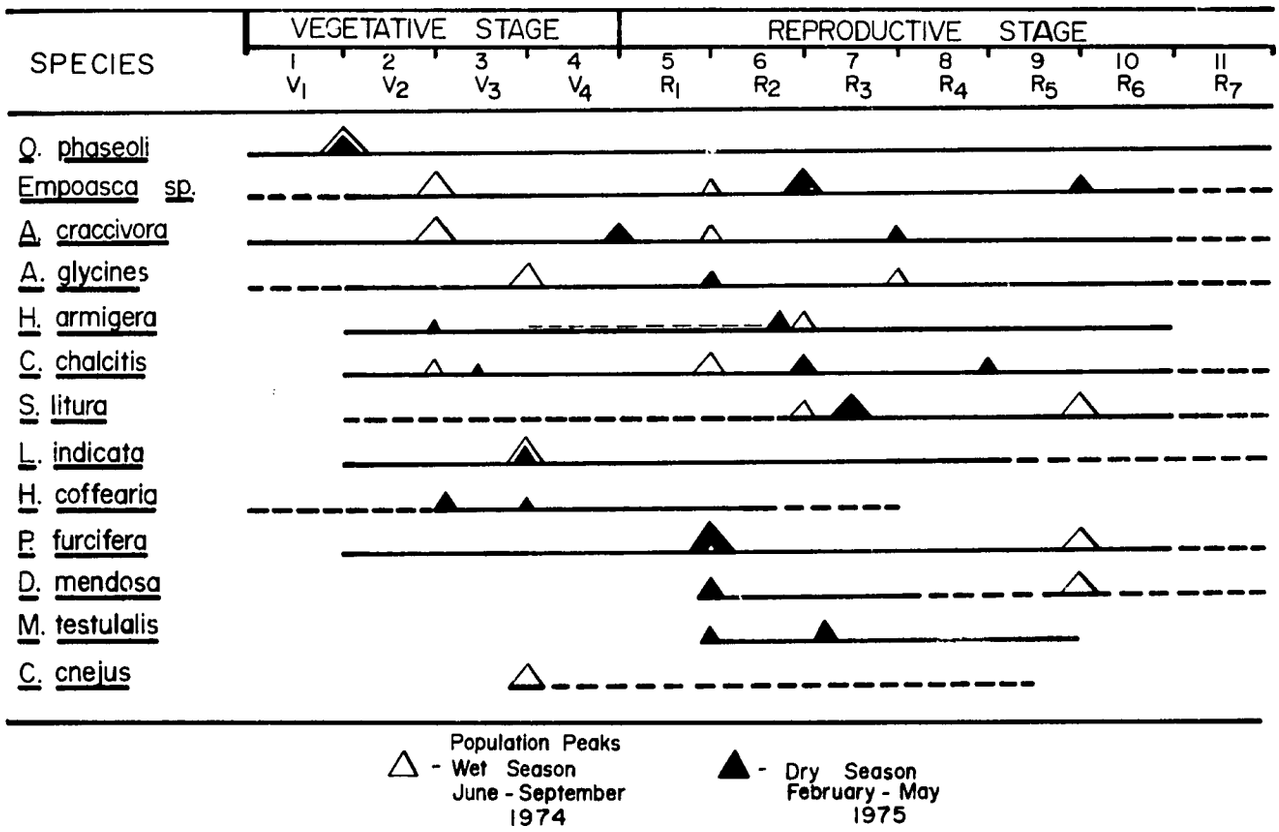


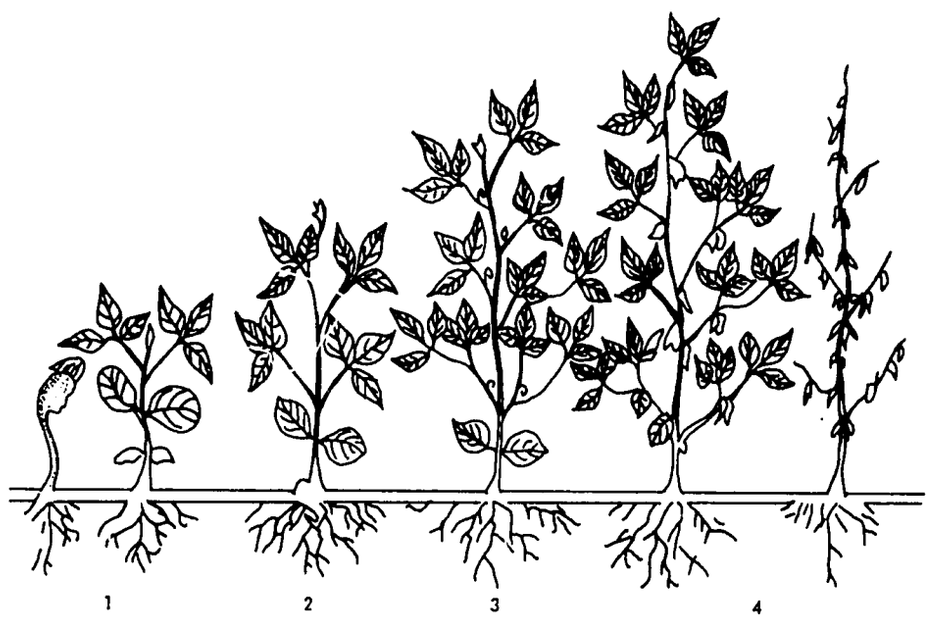
Fig. 1. The growth stages of soybean plants and successional occurrence of major insect pests.

either the vegetative or the reproductive stage, depending upon the season, i.e., some species were present during only one season or the other, but not during both (Fig. 2, 3). Furthermore, the soybean growth cycle was relatively longer during the wet season; consequently, the duration of a high insect population density was prolonged.

Wet season. *Ophiomyia phaseoli* peaked during the early vegetative stage at about 10 days after plant emergence, but persisted at a relatively low density until the mid-reproductive stage, although they did not seem to cause any damage. *Empoasca* sp., *Aphis craccivora, Aphis glycines,* and *Lamprosema indicata* peaked during the 2nd or 3rd WASE, with small peaks occurring during the 5th and 7th WASE (R_1 and R_3), i.e., when flowers and small pods began to appear. *Heliothis armigera* (Hubn.), *Chrysodiexis chalcitis,* and *Spodoptera litura* were abundant in either the early or middle reproductive stages. *C. chalcitis* appeared at the beginning of the 3rd WASE; *S. litura* during the 6th, with a peak during the 9th WASE, or mid-reproductive stage. *L. indicata* peaked at the mid-vegetative stage, while *Dasychira mendosa* reached a high point during the late reproductive stage, or about the 9th WASE. *Catochrysop cnejus* was abundant in the 3rd WASE, and maintained this level until the 9th WASE, but was not present during the dry season. *Phaneroptera furcifera* was most abundant during the 9th WASE (R_5), but began to appear during the early reproductive stage.

Dry season. The peak population of the various pest species was generally delayed until the early reproductive stage, but the growth-stage-specific pests, i.e., *O. phaseoli* and *L. indicata,* peaked during the early and mid-reproductive stages, as in the wet season (Fig. 1). *H. coffearia* and *Maruca testulalis* peaked during the 3rd and 6th WASE, but were rather sparse. The aphid population and most of the Lepidoptera species, with the exception of the growth-stage-specific pests, reached the high point in the early reproductive stage. Climatic factors, particularly rainfall and temperature, appeared to have a pronounced influence on population growth.

The known predatory species were more abundant during the dry season than during the wet season. Population densities of predators generally followed that of



1	2	3	4
bean flies	bean flies	bean flies	bean flies
leafhoppers	leafhoppers	leafhoppers	leafhoppers
aphids	aphids	aphids	aphids
corn earworm	corn earworm	corn earworm	corn earworm
corn semiloopers	corn semiloopers	corn semiloopers	corn semiloopers
		tussock moth	
	leaf folders	leaf folders	
		pod borers	pod borers
		coreid bug	
common katydid	common katydid	common katydid	common katydid
		slant-faced grasshoppers	
		tortoise beetles	tortoise beetles
	loopers	loopers	loopers

Fig. 2. Schematic diagram of the sequential pest occurrence and growth stages of soybeans during the dry season (24 February to 2 May 1975). Source: adapted from Kogan, 1974.

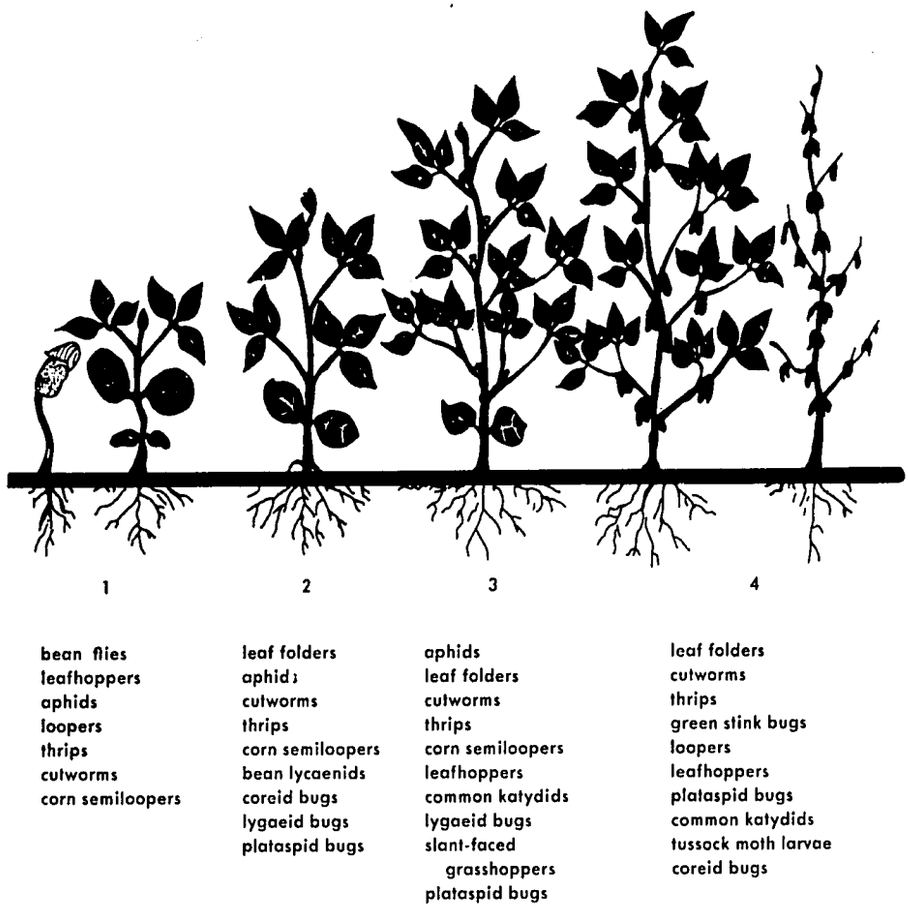


Fig. 3. Schematic diagram of the sequential pest occurrence and growth stages of soybeans during the wet season (June to September 1974). Source: adapted from Kogan, 1974.

the suspected hosts, e.g., the abundance of coccinellid beetles occurred at times when many aphids were present also. Spiders, particularly Oxyopidae, were abundant from the 3rd WASE to the mid-vegetative stage. There is evidence that beneficial insects play an important role in the regulation of host populations.

These observations show that synchronized insecticidal application can be substituted for the usual calendar method. The technique is simple enough for ordinary farmers to use.

DEVELOPMENTAL APPROACH

Our crop protection research program is integrated so as to provide solutions to immediate problems and to gather basic ecological information for formulating future comprehensive pest management schemes. Developing countries are quite obviously more concerned with short-term impact research than long-term ecological planning. At present crop protection is generally regarded as essential to a given commodity or crop rather than as an area for independent research. Hence, with insecticides readily available, very often we create instant entomologists out of agronomists. But it should be emphasized that the basic aspects of pest management must now be investigated before we reach the point of no return with complete reliance on chemical pesticides.

The proposed approach is graphically illustrated in Fig. 4. The concept, which is by no means new, allows for a strategy that can be adopted by countries with limited resources. It is important to recognize that many countries can ill-afford the luxury of expensive and lengthy ecological investigations to develop more sophisticated pest management schemes.

This approach emphasizes minimum insecticide treatment through careful regulation of timing, frequency, and dosage. The bold arrows in Fig. 6 represent the degree of emphasis placed on the indicated criteria, as well as their interrelationship during implementation. In effect, any fundable research program on crop protection must have a built-in component that includes both cultural and biological controls and ecological studies without excluding the development of rational chemical controls. Since the collection of information is quite simple, it will not require highly trained personnel, thus eliminating one of the main obstacles in many developing countries. The proposal is still tentative and hence is open for additional suggestions.

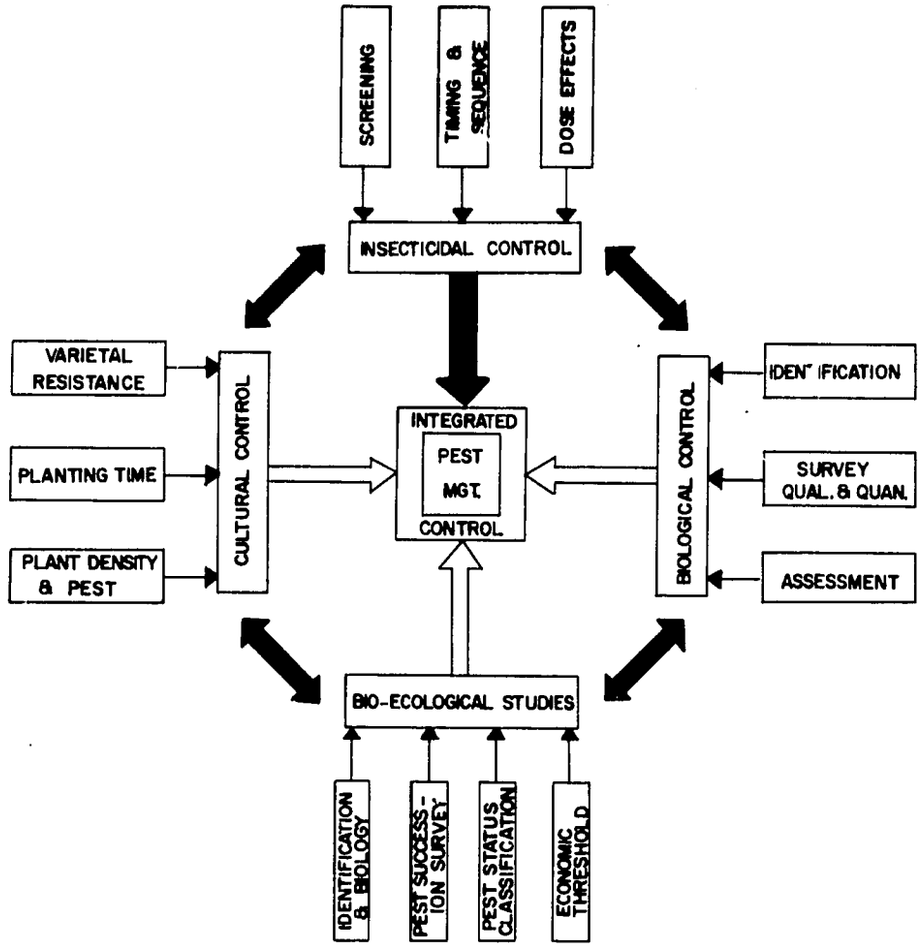


Fig. 4. Proposed model of an integrated research program for an expanding interim pest management scheme in devoloping countries.

APPENDIX I. PARTIAL LIST OF SOYBEAN INSECT PESTS IN ASIAN COUNTRIES

Indonesia (Kalshoven et al., 1951)

Riptortus linearis (F.) (HEMIPTERA:Alydidae)
Nezara viridula (L.) (HEMIPTERA:Pentatomidae)
Stomopteryx subsecivella (Zeller) (LEPIDOPTERA: Gelechiidae)
Chrysodeixis chalcites (Esper) (LEPIDOPTERA:Noctuidae)
Spodoptera litura (F.) (LEPIDOPTERA:Noctuidae)
Etiella zinckenella (Treitschke) (LEPIDOPTERA:Pyralidae)
Lamprosema indicata (F.) (LEPIDOPTERA: Pyralidae)
Phaedonia inclusa (Stal.) (COLEOPTERA:Chrysomelidae)
Holotrichia hellery Brsk. (COLEOPTERA:Scarabaeidae)
Melanagromyza dolichostigma de Meijere (DIPTERA: Agromyzidae)
M. sojae (Zehntner) (DIPTERA:Agromyzidae)
Ophiomyia phaseoli (Tryon) (DIPTERA:Agromyzidae)

India (Srivatsava, 1964; Srivatsava et al., 1963; Gujarati et al., 1971 and 1973; Kashap and Adlahki, 1963)

Riptortus linearis (F.) (HEMIPTERA:Alydidae)
R. pedestris (F.) (HEMIPTERA:Alydidae)
Chauliops fallax Scott (HEMIPTERA:Lygaeidae)
Diacrisia obliqua Walker (LEPIDOPTERA:Arctiidae)
Anarsia ephippias Meyer (LEPIDOPTERA:Gelechiidae)
Stomopteryx sp. (LEPIDOPTERA:Gelechiidae)
Scopula remotata Guenee (LEPIDOPTERA:Geometridae)
Spodoptera exigua (Hubner) (LEPIDOPTERA:Noctuidae)
S. litura (F.) (LEPIDOPTERA:Noctuidae)
Nacoleia sp. (LEPIDOPTERA: Pyralidae)
Nupserha bicolor Thomson (COLEOPTERA:Cerambycidae)
Oberea brevis Swederus (COLEOPTERA:Cerambycidae)
Myllocerus sp. (COLEOPTERA:Curculionidae)
Epicauta mannerheim Maklin (COLEOPTERA:Meloidae)
Zonabris pustulata (Thunberg) (COLEOPTERA: Meloidae)
Popillia gemma Newman (COLEOPTERA:Scarabaeidae)
Melanagromyza sp. (DIPTERA:Agromyzidae)
Hylemya cilicrura Rondani (DIPTERA:Anthomyiidae)

Solomon Islands (Stapley, 1972)

Hymenia recurvalis (F.) (LEPIDOPTERA:Pyralidae)
Maruca testulalis Geyer (LEPIDOPTERA:Pyralidae)

Micronesia (Gressitt, 1954)

Aphis laburni (Kalt.) (HOMOPTERA:Aphididae)
A. melicogeuis (HOMOPTERA:Aphididae)
Empoasca sp. (HOMOPTERA:Cicadellidae)
Leptoglossus membranicus (F.) (HEMIPTERA:Coreidae)
Halticus tibialis (Reuter) (HEMIPTERA:Miridae)
Nezara viridula (L.) (HEMIPTERA:Pentatomidae)
Acrocercops sp. (LEPIDOPTERA:Gracillariidae)
Chrysodeixis chalcites (Esper) LEPIDOPTERA:Noctuidae)
Etiella zinckenella (Treitschke) (LEPIDOPTERA:Pyralidae)
Maruca testulalis Geyer (LEPIDOPTERA:Pyralidae)
Cryptophlebia carpophaga (Lower) (LEPIDOPTERA: Tortricidae)
Adoretus sinensis Burmeister (COLEOPTERA:Scarabaeidae)
Pagria sp. (COLEOPTERA:Chrysomelidae)
Ophiomyia phaseoli (Tryon) (DIPTERA:Agromyzidae)

Thailand (Napompeth, 1975)

Patanga succincta (L.) (ORTHOPTERA:Acrididae)
Aphis glycines Mats. (HOMOPTERA:Aphididae)
Empoasca sp. (HOMOPTERA: Cicadellidae)
Stomopteryx subsecivella (Zeller) (LEPIDOPTERA:Noctuidae)
Heliothis armigera Hubner (LEPIDOPTERA: Noctuidae)
Spodoptera litura (F.) (LEPIDOPTERA:Noctuidae)
Bradina adhaesalis Walker (LEPIDOPTERA:Pyralidae)
Lamprosema diemenalis Guenee (LEPIDOPTERA:Pyralidae)
L. indicata (F.) (LEPIDOPTERA:Pyralidae)
Cacoecia micuceana Walker (LEPIDOPTERA:Tortricidae)
Homona sp. nr. *mermerodes* Oreyer (LEPIDOPTERA: Tortricidae)
Epicauta maklini Haag (COLEOPTERA:Meloidae)
Ophiomyia phaseoli (Tryon) (DIPTERA:Agromyzidae)

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Discussion

M. Z. Hoque: Do you have information on how insect diversity in soybeans is influenced by the absence or presence of other crops surrounding the soybean field? Can you tell us how the insect diversity data can help you in your pest management program for soybeans?

R. S. Rejesus: We do not have enough data on this aspect, but as mentioned earlier, the species are host specific. Regarding the use of data in developing the pest management program for soybeans, the data can be useful when the total pest management program is considered. Component analysis of the total program may be needed to employ the diversity data.

Control of Soybean Insect Pests in Thailand

Pisit Sepswasdi

Because of their potential economic importance, soybeans were included in the five-year plan (1972-1976) of Thailand's national economic development program. The goal of the program is to produce approximately 300,000 tons of soybeans in 1976. Production has gradually risen from 72,000 tons in 1972 to 252,400 tons in 1974. This increase was due in large part to a greater number of acres being planted to soybeans. The yield, about 150 kg per rai (937 kg per hectare), however, remains poor.

Many factors limit soybean yield, but insect pests are one of the most important factors causing significant reductions. Of the more than 30 species of insects found in soybean fields, only 10 are considered to be of serious economic consequences in soybean production. These pests include the bean fly (*Melanagromyza phaseoli* Tryon), leaf miner (*Stomopteryx subsecivella* Zeller), leaf roller (*Lamprosema* spp. and *Cacoecia micaceana* Wkr.), aphid (*Aphis glycines* Mats.), leafhopper (*Empoasca* spp.), cutworm (*Agrotis ypsilon* Rott.), cutworm (*Spodoptera litura* Fabr.), pod borer (*Heliothis armigera* Hubn.), and termite (*Odentotermes* spp.).

These insects are indigenous to soybean plantations and recur from season to season, although population densities vary from place to place. Since several of these pests appear at the same time, methods suitable for controlling them in particular environments have been studied carefully, including planting dates in relation to yield and the number of insect pests during a given period. Studies were conducted for two successive years at the Mae-Jo Experiment Station, Chiang Mai Province, and the Galasin Experiment Station, Galasin Province.

Immediately after the rice harvest, on or about December 15 in the dry season and June 1 in the rainy season, five plantings of soybeans were made at 15-day intervals during the two years of the experiment. The soybeans planted early in these periods, i.e., from December 15 to mid-January and throughout June, had significantly higher yields than those planted later. Several insect pests occurred in substantially larger numbers the later the planting date. Therefore, soybean farmers in the areas surrounding these two experiment stations have been advised to plant from December 15 to mid-January during the dry season and throughout the month of June during the rainy season.

In response to the urgent need of farmers to control the pests mentioned above, screening for effective insecticides was carried out during the two years of the experiment. The nature of the damage, the particular pests involved, and their control will be discussed in detail in this paper.

BEAN FLY (*MELANAGROMYZA PHASEOLI* TRYON)

The bean fly, which occurs year-round, is a serious pest that infests soybeans, mung beans, and stringbeans. When climatic conditions are favorable, the fly causes severe damage resulting in 90 percent seedling loss.

Nature of damage. The damage caused is of three types. First, in the seedling stage the tiny maggot bores into the stem at ground level and feeds on the stem tissue. As a result, the tissue becomes rotten, the seedling withers, and finally dies. Second, in the later seedling stage and the branching stage the maggot tunnels into the central part of the stem and feeds upward into the branches. An infested plant is easily recognized because the internode above the infested portion gradually withers and the shoot becomes stunted, thus causing more than a 50 percent reduction in yield. Third, in the leaf stage the adult fly can cause damage by puncturing the leaf with its ovipositor and feeding on the oozing cell sap. Dark brown spots appear on the leaves if damage is heavy.

Life history. The female lays from 200 to 300 eggs one at a time on the leaves. The egg stage lasts 2 to 3 days, while the larval period varies from 10 to 18 days. Pupation, which takes place in the soil surrounding the infested plant or within the stem at ground level, varies from 3 to 5 days. The adult lives for 7 to 10 days.

Pisit Sepswasdi: Division of Entomology and Zoology, Department of Agriculture, Bangkhen, Bangkok, Thailand.

Control measures. Carbofuran 3 G and Phorate 10 G, each applied at the rate of 1 pound active ingredient per acre in the furrow at the time of planting, provide adequate protection for about 40 days. Four sprayings with 0.03 percent dimethoate and 0.05 percent Metasystox R at weekly intervals, starting 5 days after germination, have also proved very effective in controlling the beanfly.

LEAF MINER (*STOMOPTERYX SUBSECIVELLA* ZELLER)

The leaf miner, a serious pest of both soybeans and groundnuts in Thailand, is found year-round wherever these crops are grown. The tiny caterpillar attacks soybeans any time from the seedling stage on. If the outbreak occurs during the seedling stage, it is usually very severe and can reduce the number of plant stands by 80 percent.

Nature of damage. The newly hatched caterpillar immediately mines into the leaf, where it feeds on the leaf tissue until the caterpillar is full-grown. The wound at the point where the caterpillar entered becomes dark brown, and hence is easily observed. As the caterpillar continues to feed, the remaining epidermis dries up and turns a whitish color. When the damage is severe, the leaves curl, shrivel, and often fall off, resulting in a significant yield reduction.

Life history. The eggs, which are an off-white, are laid singly, usually on the under surface of the leaf. The duration of the egg stage varies from 2 to 4 days with an average of about 3 days. The caterpillar passes through three successive molts and becomes full-grown within 15 to 18 days. Pupation takes place in a whitish cocoon inside the curled leaf. The pupal stage varies from 2 to 7 days with an average of 4.4 days. The adult lives for 3 to 12 days, or an average of about 6 days, and can lay from 3 to 100 eggs.

Control measures. Granular insecticides, viz., Carbofuran 3 G, Phorate 10 G, and Disulfoton 10 G, have proved very effective in controlling leaf miner when applied in the furrow during planting at the rate of 1 pound active ingredient per acre. Later spray applications of 0.02 percent Azodrin and 0.03 percent dimethoate were also very effective.

LEAF ROLLERS (*LAMPROSEMA* SPP. AND *CACOECIA MICACEANA* WKR.)

This pest has many host plants and is indigenous to soybean plantations throughout Thailand. The damage it causes from the seedling to the flowering stage is very serious because the infested plant becomes stunted, thus reducing the soybean yield.

Nature of damage. The caterpillar gathers several leaves together, rolls them, then lives inside one of the rolled leaves. When it has eaten all but the midrib of one leaf, it enters another rolled leaf and continues to feed.

Life history of *Lamprosema* spp. The pale green eggs, which are laid in batches of 10 to 20 eggs, take 3 to 5 days to hatch. The caterpillar then passes through four instars and becomes full-grown within 15 to 23 days. Pupation, which takes place inside the rolled up leaves, lasts 8 to 12 days. Laying an average of 260 eggs, the female lives from 7 to 28 days, or an average of 16 days.

Life history of *C. micaceana*. The eggs, which are laid in batches, change from pale white at the beginning of the egg stage to yellow toward the end of the 6 to 8 day period. The caterpillar passes through five or six instars and becomes full-grown in 22 to 28 days. The pupal stage takes place inside the rolled up leaves and varies in duration from 6 to 10 days. The adult mates 2 to 3 days after emergence and lives 5 to 11 days. One female can lay as many as 400 eggs.

Control measures. Because the caterpillar remains inside the rolled leaf, removal and destruction of the leaves is a practical means of control. If the damage is severe, however, two to three sprayings with 0.2 percent EPN, 0.1 percent Gusathion A, 0.1 percent Azodrin, 0.1 percent Folidol E 605, or 0.1 percent Tamaron at weekly intervals are recommended.

APHIDS (*APHIS GLYCINES* MATS.)

This group of relatively small, winged and unwinged insects infests several crops throughout Thailand in different seasons. By means of their sucking activity, the insects in this group act as vectors of many diseases, especially the disease commonly known as soybean mosaic virus.

Nature of damage. Both nymphs and adults suck the cell sap from the tender parts of the plant, such as the young leaves and shoots. In order to suck, they thrust their stylet into the plant tissue and remain in this position for long periods of time. The infested plant can be recognized by the rolling, discoloration, and etiolation of the leaves, and by the stunted growth of the plant.

Life history. Both alate and apterous aphids can reproduce parthenogenetically and viviparously. A single apterous female gives birth to between 10 and 20 young daily.

Control measures. Effective control of the pest can be achieved by spraying with systemic insecticides, such as dimethoate (0.03 percent), Tamaron (0.05 percent), or Metasystox R (0.05 percent). In order to eradicate aphids, however, two to three applications at weekly intervals are required. Other soil systemic insecticides, such as Carbofuran 3 G and Phorate 10 G applied in the furrow during planting at the rate of 1 pound active ingredient per acre, provide adequate protection for about 40 days.

LEAFHOPPERS (*EMPOASCA* SPP.)

Like aphids, leafhoppers are found on several crops and are a serious pest because they reduce the vitality and yield by sucking cell sap.

Nature of damage. Both nymphs and adults suck cell sap primarily on the under surface of the leaf. Yellowing of the leaf margins is an initial indication of damage, but if the damage is severe, the leaf curls and dries up, and finally the plant dies.

Control measures. Spraying with 0.2 percent Sevin, 0.03 percent dimethoate, 0.7 percent Dursban, or 0.05 percent Lannate effectively controlled leafhoppers for about 10 days. Additional treatment is recommended if reinfestation occurs.

CUTWORM (*AGROTIS YPSILON* ROTT.)

In 1974 this cutworm, which usually infests tobacco, vegetables, and corn, was found on soybeans in Chiang Mai Province in the northern part of Thailand.

Nature of damage. The caterpillar is active during the night, while during the day it hides in crevices of the soil or under heaps of plant debris. After cutting the young plant at ground level, the caterpillar feeds on the leaves and shoots. Sometimes it carries the plant into the soil crevice, where it continues to feed.

Life history. Detailed laboratory studies have not been made. However, field observations of the cutworm's life history indicate that pupation takes place in the soil in an earthen cocoon. The pupal stage lasts from 10 to 16 days.

Control measures. These pests can be successfully controlled by irrigation, which brings them to the surface, where they can easily be collected and destroyed. As an added measure of control, spraying with any one of several insecticides is recommended. These insecticides include a Toxaphine-DDT mixture (40:20) at 100 cc per 20 liters of water, 0.1 percent Gusathion, 0.1 percent Dursban, or 0.05 percent Lannate.

CUTWORM (*SPODOPTERA LITURA* FABR.)

This cutworm is a serious pest that attacks soybeans, vegetables of various kinds, castor beans, and sunflowers. Its activity causes damage in soybeans from the seedling stage on through maturity.

Nature of damage. The damage is easy to observe because the newly hatched caterpillars live together and feed on the under surface of the leaves. They remain only on the upper epidermis, which later dries up and turns white. During the second instar, when the caterpillars are bigger, they spread and feed on the leaves of adjacent plants.

Life history. A single female lays between 200 and 300 eggs in batches on the under surface of the leaves. The egg stage lasts 3 to 7 days. The caterpillar becomes full-grown in about 14 to 21 days. It molts four times and pupates for 7 to 12 days in the soil or in refuse. The adult lives approximately 7 to 10 days.

Control measures. As soon as the damage caused by the newly hatched caterpillars is observed, the infested leaves should be removed and destroyed. Chemical control can be achieved by the application 0.05 percent Lannate, 0.1 percent Gusathion A, 0.1 percent Dursban, or 0.1 percent Folidol E 605.

POD BORER (*HELIOTHIS ARMIGERA* HUBN.)

From the economic point of view the pod borer is considered the most serious pest, attacking soybeans, corn, cotton, tomatoes, tobacco, sorghum, and sunflowers. It is widespread and is found year-round. During the 1973 dry season in Chiang Mai Province, an outbreak of the pod borer completely destroyed nearly 10,000 acres of soybeans. Subsequently it was found that soybeans planted from December 15 to January 15 were not infested, but crops planted after January 15 were totally destroyed. The reason is that after the rice harvest farmers usually grow not only soybeans, but also many other crops, such as tobacco, groundnuts, and cotton, which serve as hosts. When the tobacco is harvested, the pest moves to adjacent soybean fields, where it attacks the soybeans, which by that time are bearing flowers and forming young pods, thus providing good food for the pest. It is therefore recommended that soybean and tobacco fields adjacent to one another be inspected regularly. In this way if the pest is found on the tobacco, control measures can be taken to protect the soybeans.

Nature of damage. After the pod bears seed, the larva bores into the pod and feeds on the seed. If the seed has not yet formed, the larva feeds on the young pod, primarily at the base of the pod, which is eaten away and often completely falls off. The pest then feeds on the flowers and finally the leaves.

Life history. On the average, one female can lay as many as 1,100 eggs. The shiny, greenish-yellow eggs are laid singly on the leaves and shoots, and hatch in 2 to 3 days. The newly hatched larva feeds on the young leaf until the third instar. Then it begins to feed on the pod, taking 15 to 18 days to become full-grown. Pupation, which takes place in the soil, lasts 8 to 12 days. The adult lives 8 to 10 days.

Control measures. The pest can be effectively controlled by three or four applications of Toxaphene-DDT (40:20) at 100 cc per 20 liters of water, 0.05 Lannate, or 0.1 percent Azodrin at weekly intervals. Treatment should begin as soon as the pest is observed, usually during the flowering stage.

TERMITE (*ODONTOTERMES* SPP.)

To date, the termite has attacked soybeans grown only in Chainat Province in the central part of Thailand, where soybeans are raised on Rendzinas and Brown

Forest soil. Damage is caused from the seedling to the harvesting stages and can result in the loss of over 5 percent of the plant.

Nature of damage. The termite is subterranean and feeds continuously upward from the tap root into the stem. The infested plant withers, although even after the plant finally dies, the termite remains inside the stem. As many as 10 to 15 termites have been counted in an uprooted plant.

Control measures. Aldrin (40 percent wettable powder) applied at the rate of 2 pounds active ingredient per acre in the furrow during planting provides adequate protection for the season.

Discussion

Dandi Soekarna: With regard to different parts of plants that are attacked by the bean fly, in Indonesia there are three species of bean fly attacking different parts of the plant. *M. phaseoli* attacks early stages of the plant, *M. sojae* attacks the shoots of more mature plants, and yet another species attacks the branches of the plant.

Entomophagous Insects in a Soybean Pest Control Strategy

Michael E. Irwin and Peter W. Price

Little has been recorded about the entomophagous insects (predators and parasitoids) of soybean pests in Asia and Oceania. A large portion of the literature that does exist on this topic deals with egg parasitoids and predators of the cosmopolitan and polyphagous pentatomid pest, *Nezara viridula* (L.). The following researchers, among others, have written on the topic: Cumber (1951, 1953, 1964), Ganesalingam (1966), Hokyo and Kiritani (1963, 1966a, 1966b), Kiritani (1964), Nakasuji et al. (1966), Nishida (1966), Singh (1973), Singh et al. (1973), and Valentine (1964). A smaller portion deals with natural enemies of *Heliothis armigera* (Hubn.). Gangrade (1963 and 1964), Manjunath (1972), Manjunath et al. (1970), Mathur (1967), and Mathur and Dharmadhikari (1970), among others, have contributed information. In general, however, information on insect species found in soybean fields throughout the world is inadequate.

Although knowledge is increasing rapidly, there is still much to learn. The International Reference Collection of Soybean Arthropods (IRCSA) at the Illinois Natural History Survey, which contains approximately 1,700 species of insects collected from soybean fields in the Americas, primarily from the United States, Brasil, Colombia, and Mexico, demonstrates this need in two ways. First, fewer than half these species have definitely been associated with soybeans, either as herbivores (including pollinators), saprophytes, predators, or parasitoids. The remainder, approximately 900 species, can be divided into three categories: incidental species that fly through soybean fields, species associated with weeds within soybean fields, and species associated with soybeans but for which evidence of association is lacking. The lack of biological information about the majority of species in the soybean ecosystem makes assessment of natural control difficult.

Second, of those IRCSA species known to be associated with soybeans, 33 percent (including pollinators) are herbivores, 46 percent predators, 17 percent parasitoids, and 4 percent saprophytes (Fig. 1). Comparisons between these statistics and those for species collected from soybean fields in areas where intensive field collecting has occurred show considerable variation among the number of species occupying various ecological roles. For example, of 622 species collected from soybean fields in Illinois, 55 percent (including pollinators) are herbivores, 18 percent predators, 18 percent parasitoids, and 9 percent saprophytes (Fig. 2). The 333 species collected from soybean fields in Colombia gave a similar picture: 50 percent herbivores, 32 percent predators, 11 percent parasitoids, 7 percent saprophytes.

Two things seem apparent: sampling methods have skewed collections in favor of larger, less active species (mainly herbivores); and parasitoids were poorly represented in most of these collections, while predators seem well represented in all the collections. An overall ratio of about 8:3:1 of herbivores, predators, and parasitoids, respectively, was obtained from the IRCSA collections. The ratio of herbivores to predators is not only consistent between sampled areas, but also seems reasonable in terms of ecological relationships. The ratio of herbivores to parasitoids, on the other hand, varies considerably between sampled areas and does not seem reasonable in terms of ecological relationships. Most herbivores when studied in detail have several parasitoids (egg, larval, adult), some of which are host specific. Thus, one would expect the ratio of herbivores to parasitoids to favor parasitoids, not herbivores.

Therefore, we feel more research must be done before the potential of entomophagous insects can be realistically evaluated for control strategies. This is especially true in Asia and Oceania, as well as in Africa and Latin America, where biologies of fewer species are known. In addition, an ecological understanding of soybean fields must be gained before the role of entomophagous insects can be placed in proper perspective.

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ECOLOGY OF SOYBEAN FIELDS

In terms of space and time, the physical setting greatly influences the soybean crop, partly because it directly affects the pests and their associated, natural enemies. One component of the physical setting is climate, i.e., the prevailing meteorological events that change with the season in a predictable and progressive manner. Growing seasons, for example, generally lengthen as one approaches the equator. Even at a single location, however, weather conditions vary predictably, and crop production systems usually take advantage of this. The effect of climate on the dynamics of pest and natural enemy populations operates independently of population levels.

Throughout a growing season the crop changes composition in terms of its ground cover, volume, and maturity characteristics. As the crop develops, the soybean field changes from open and sunny to covered and shady, hot and dry to warm and humid. In effect, the microenvironment becomes milder and more complex in structure with time. Crop growth is therefore a dynamic component of the ecosystem; it is also a successional component, and it helps to think in these terms when investigating aspects of pest control. The successional component, including climate, crop growth, and other factors, is of prime importance because it is a measure of available habitat space for organisms. Price (1976), who recently measured habitat space in a soybean field in Illinois (Fig. 3), found that this space increased rapidly during the middle of the growing season and only began to decrease with senescence.

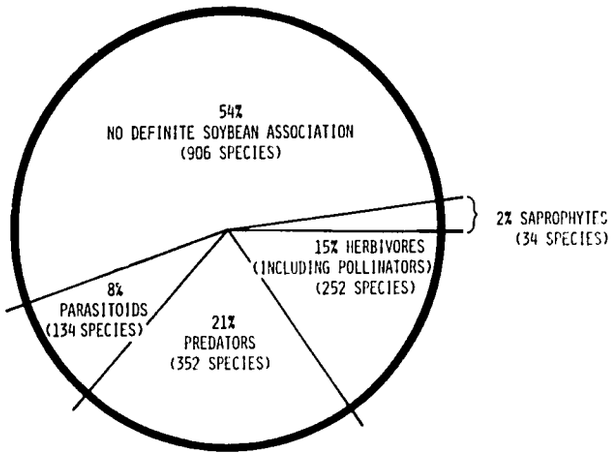

Fig. 1. Species of insects collected in soybean fields from various parts of the Americas and contained in the International Reference Collection of Soybean Arthropods (IRCSA), Illinois Natural History Survey. Percentages of species with different ecological roles.

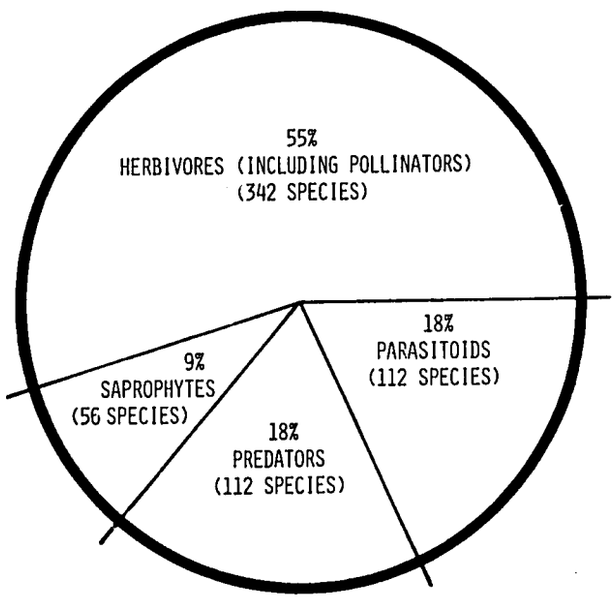

Fig. 2. Species of insects collected in soybean fields from various parts of Illinois and contained in the International Reference Collection of Soybean Arthropods (IRCSA), Illinois Natural History Survey. Percentage of total species with different ecological roles.

COLONIZATION BY ARTHROPODS

Most colonization of soybean fields takes place after seed germination. As soon as cotyledons appear in the field, certain herbivores colonize. In the United States most of these early colonists (leafhoppers, thrips, aphids) are part of the aerial plankton and drift in from great distances on wind currents (Huff, 1963). This might also occur in the temperate soybean growing zones of other countries where these arthropods are unable to overwinter successfully.

Density of ground cover does not seem to be an important factor in successful early colonization by small herbivores, probably because several generations can develop on a single young plant. As an early colonist locates a suitable host plant, it simply settles down and begins feeding.

Increased ground cover coincides with a volumetric

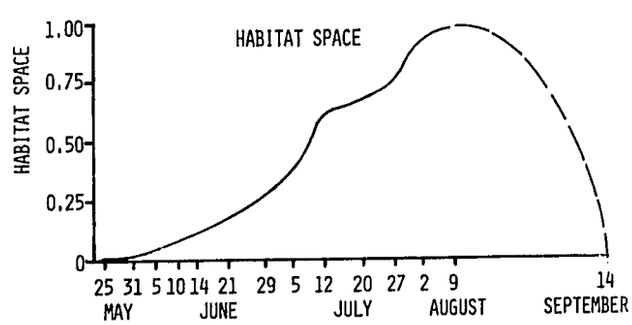

Fig. 3. Habitat space in an Illinois soybean field (Price, 1976). Measure takes into consideration number of leaves, length of average-sized leaf, and height of plant. Broken line indicates a trend rather than data taken from direct measurement.

increase in the amount of habitat space. With the expansion of habitat space comes an increase in diversity of herbivorous colonists. This is partly caused by the increased habitat space, but is also the result of successional maturity levels of the crop. As flowers develop, pollinators are attracted to the fields; as pods develop, pod borers, stink bugs, and other seed eaters colonize. The number of herbivorous species colonizing a soybean field in Illinois increases with time until the crop becomes senescent (Fig. 4).

Entomophagous species are unable to colonize an annual crop as early or rapidly as herbivores because they depend directly upon herbivores, saprophytes, or other carnivores as a food source. These sources of food must be present in the habitat before an entomophagous species can colonize successfully.

The intrinsic, host-searching patterns of entomophagous species also discourage early colonization. Predators must continuously search for subsistence, while parasitoids must seek hosts on which to deposit their eggs. Most entomophagous insects prefer microclimates that are warm and humid. The terrain surrounding newly emerged soybeans in a field is relatively harsh, i.e., usually hot and dry, or occasionally cold and damp. When ground cover is meager and habitat space small, searching must extend over large distances of rather hostile terrain. As the season progresses and habitat space increases, a warmer and more humid microclimate prevails, and the number and diversity of entomophagous species in soybean fields begin to increase rapidly (Fig. 5).

Lack of nourishment sources near or within a field also discourages colonization by entomophagous species. Many species of parasitoids and predators require nectar or some other form of nourishment to remain active and, in many cases, to oviposit. Furthermore, population buildups of these entomophagous species are greatly influenced by the availability and abundance of nourishment sources that provide nectar, honeydew, and so forth. For instance, the parasitizing efficiency and distribution of a tachinid parasitoid (*Lixophaga sphenophori* (Villeneuva)) of the New Guinea sugarcane weevil were greatly reduced when the edge weeds (*Euphorbia* spp.) that were its nectar sources near sugar cane fields in Hawaii were eliminated. Elimination of these weeds led to a buildup of weevil populations (Topham and Beardsley, 1975).

Clearly, the establishment and growth of herbivore populations is favored over those of entomophagous species in the early part of the growing season. As the crop reaches full height and the canopy closes, however, food webs and energy flows in soybean fields undoubtedly become much more complex and at this point entomophagous activity is great.

Another aspect of colonization that influences species composition is proximity of potential colonists to areas of colonization. Some herbivores, as mentioned earlier, drift in on jet winds and currents from as far as hun-

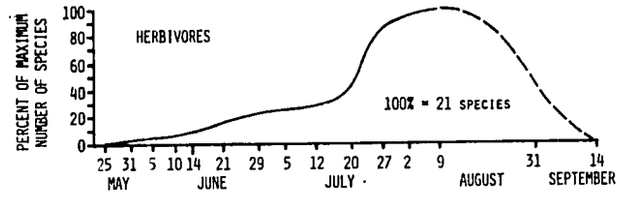

Fig. 4. Percent of total herbivorous insects found within a soybean field in Illinois throughout the growing season. Broken line indicates a trend rather than data taken from direct measurement.

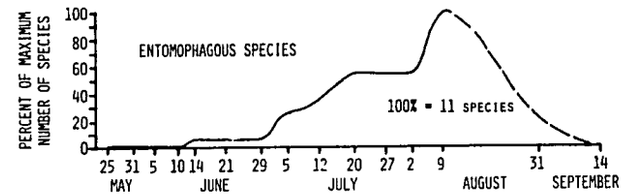

Fig. 5. Percent of total entomophagous insects found within a soybean field in Illinois throughout the growing season. Broken line indicates a trend rather than data taken from direct measurement.

dreds of miles away (Huff, 1963). In soybean fields in North America this is true for some early colonists, e.g., the potato leafhopper (*Empoasca fabae* (Harris)) and soybean thrips (*Sericothrips variabilis* (Beach)), that drift northward from warmer climates where they are able to overwinter. We feel this phenomenon may occur in other temperate soybean growing areas, but we do not know if this is important in the colonization of soybean fields in tropical and subtropical areas where dry seasons might act as barriers to year-round survival of some potential colonists. We feel it is probably unimportant in many tropical and subtropical areas where colonists are able to survive from year to year.

Many herbivores and most entomophagous species colonize soybean fields from surrounding areas, such as weedy patches, natural areas, and other crops. When these colonists enter a soybean field, they often take up residence initially along the margins of a field. Our data suggest that many species in a soybean field migrate into field margins and back out, and some of these species do not take up permanent residence deep within the field (Price, 1976). This results in a higher number of species existing in the margins of soybean fields and is often termed an edge effect. The edge effect, then, is a result of an ecotone, a zone where two environments meet.

The margins of soybean fields closely interface with vegetational zones proximal to the fields. Many insect species can subsist in these proximal zones prior to the emergence of soybean seedlings and from there spread into soybean fields early in the growing season. The proximal zones can harbor pests and entomophagous species alike. They can provide alternate host plants for

insect pests, viruses, and virus vectors. They can also provide shelter and alternate food sources for predators, parasitoids, and insect pathogens during the early growing season when the field environment is especially harsh. Careful analysis of individual situations is needed to determine whether the potential advantages derived from proximal zones that harbor beneficial species outweigh potential disadvantages from pest species harbored there. Very little has been published on this topic and we think it would prove useful to conduct research in this general area.

ENCOURAGEMENT OF ENTOMOPHAGOUS SPECIES

If entomophagous species could be attracted to the crop earlier in the growing season, and if they could be encouraged to remain in the fields, they would certainly exert more pressure on pests. This could be accomplished in many ways. First, pesticides that have little effect on parasitoids and predators should be used in preference to those that are broad spectrum, or they should be applied prior to major colonization by entomophagous species. Dosages should be at an absolute minimum to knock down target pests. These insecticides should be used judiciously only when target pests reach levels that can have an impact on yield (as discussed in this conference by Kogan and Heinrichs). Second, available habitat space should be increased early in the season by one of several methods: using shorter distances between soybean rows, using small field plots (or larger plots if edge effect is detrimental), employing strip cropping and intercropping systems, or allowing hedge rows and weedy areas to remain around the field. Third, the soybean environment should be stabilized as much as possible by crop rotation and intercropping schemes. Fourth, the prerequisites of entomophagous species in a particular area should be studied so that requisites can be made available, e.g., nesting sites and certain types of nectar sources.

Other methods of improving the impact of biological control agents in a system include importation of beneficial species and their artificial augmentation by inundative releases. Biological control, including the importation, rearing, releasing, and evaluation of entomophagous insects, has been successful for some pests of almost every major crop. The presence of sceleonid parasitoids, *Trissolcus basalis* (Woll.), on the eggs of *Nezara viridula* is a case in point. These tiny egg parasitoids were first introduced from Egypt into Australia in 1933 and periodically released thereafter in different areas over several seasons. Before the introduction of the egg parasitoid, *N. viridula* was an important pest in all areas it occupied in eastern Australia. A few years after releases of the egg parasitoids, the pest was held in check in most areas, i.e., population levels were kept below economic injury levels. Only in the interior where temperatures dropped very low during the winter months did *N. viridula* remain a pest (Wilson, 1963). This example illustrates two points. First, the parasitoid was able to control the pest in most areas and it was able to do so on a permanent basis; second, in some cases the requirements of the parasitoid did not exactly match those of the pest and as a consequence the pest remained unchecked in a few areas.

Inundative releases of an effective parasitoid during key times of the season have successfully lowered population levels of a target pest. For example, *Pediobius foveolatus* (Crawford), a gregarious larval parasitoid of the Mexican bean beetle (*Epilachna varivestis* Mulsant), was recently imported into the southeastern United States from India (Angalet et al., 1968). Even though this parasitoid is unable to overwinter in Maryland, yearly releases have greatly lowered population densities of the host during the latter part of each season (Stevens et al., 1975).

Augmentation of natural enemies, especially entomophagous insects, has not been employed to its full potential even though the benefits could be substantial. One promising aspect of augmentation is the use of supplementary foods to sustain entomophagous species. By spraying a yeast hydrolysate and sugar food source onto a cotton crop, Hagen and Hale (1974) were able to attract quantities of an entomophagous species, *Chrysopa carnea,* to the site. They found that they were able to move these predators from area to area by attracting them to food-sprayed areas, provided that the new sources were up-wind of the predators and the quantity of honeydew in the areas where the predators were residing was low. They also found that the predators could live on the food source for up to two weeks and, after feeding, were able to lay viable eggs. The searching time of the predators was increased because their life spans were increased. Moreover, because of induced oviposition, the predator-prey ratio was increased. This type of augmentation could effectively lower certain prey populations below economic injury levels.

A similar type of augmentation made use of chemical attractors (kairomones) to move egg and larval parasitoids from area to area. Lewis et al. (1975) and Gross et al. (1975) were able to manipulate egg parasitoids (*Trichogramma* spp.) and larval parasitoids (*Microplitis croceipes*) by attracting them to and holding them in areas in soybean fields that contained high densities of the pest *Heliothis zea.* To accomplish this they used tricosane, an extract of moths' scales or larval frass. They found that they were able to greatly increase the effectiveness of these parasitoids by the use of chemical attractors. Such inventive methods of augmenting entomophagous species should be employed with greater frequency in our fight to control soybean pests.

These two examples of augmentation may well pave the way for future manipulations. Both methods employed chemical substances to move entomophagous species from area to area. In both cases the effectiveness of the manipulated species was increased. The strategy seems obvious: to begin herding entomophagous species to areas where pest outbreaks occur; to herd these valued

species away from areas where pesticides must be used and then herd them back into the sprayed area after the chemical deteriorates and is no longer toxic. The idea of conserving and maximizing the usefulness of entomophagous insects is a dream today, but may become a reality tomorrow.

CONCLUSION

In ecological terms, the soybean system reaches equilibrium during middle pod set, and shortly thereafter begins to fall out of equilibrium because of plant senescence. Equilibrium timing may differ if determinate or indeterminate soybean varieties are used. Habitat succession due to climate, ground cover, plant volume, maturity, and other factors counteracts equilibrium and therefore suppresses the establishment of entomophagous insects. If entomophagous species are to successfully control pest species, we must help reduce these successional elements by every possible means, including the management and manipulation of crops, timely inundative releases of entomophagous species, establishment of biological control measures, and careful augmentation of natural enemies.

It is our considered opinion that the effort required to establish pest management by incorporating the efficient use of entomophagous species will, in the long run, pay handsomely. We strongly urge that this component be incorporated into future and existing soybean programs.

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Discussion

R. S. Rejesus: If biomass were analyzed with respect to different trophic levels, would you expect a more definitive picture to emerge?

M. E. Irwin: Very much so. The picture we have attempted to paint is very simplistic. In this paper we have not attempted to address the questions of species dynamics nor have we dealt with predator-predator interactions, hyperparasitism, and so forth. The real world of the soybean field is complex. In this paper we attempted to simplify the picture as much as possible in order to stress the ecological aspects of a soybean field and how they directly affect herbivores and entomophagous species.

R. S. Rejesus: Would you speculate about the possibility of allowing weeds to remain in a soybean field in order to increase habitat space?

M. E. Irwin: There are many confounding factors to consider when analyzing a soybean field. It is true that by leaving weeds in a field one increases habitat space and consequently diversity. These factors should tend to stabilize the soybean field and give entomophagous species a better foothold in it. On the other hand, weeds within a soybean field can compete with soybeans for space, light, water, and nutrients. Weeds can also harbor diseases and insect pests that can spread to soybean plants. These factors need to be studied in detail so that the system which provides the most benefit for the farmer can be adopted. Again, we are talking of a complex system and we really do not yet know the answers to these questions.

Soybean Disease and Insect Pest Management

Marcos Kogan

Since the concept of "protective management of populations" was formulated by Geier and Clark in 1961, many symposia, books, and collections of papers were dedicated to the subject, among them, FAO (1966), USDA (1966), Kilgore and Doutt (1967), National Academy of Sciences (1969), Tall Timber Research Station (1969), Rabb and Guthrie (1970), Pedigo (1970), Huffaker (1971), Geier et al. (1973), Shepard (1973), Stark and Gittins (1973), Glass (1975), Maxwell and Harris (1974), and Metcalf and Luckmann (1975). The terms "integrated control," "pest management," and "integrated pest management" (IPM) coined by various authors, probably with rather narrower definitions, are now used interchangeably. These terms generally define a system in which pest population regulation and control techniques are harmoniously integrated with one another, the crop production system, and the environment for the purpose of maintaining pest populations and diseases below the economic injury level. Since all crop protection sciences now tend to adopt the conceptual framework of IPM (Good, 1972; Tachibana, 1975), this definition encompasses both insect pests and diseases.

However popular the IPM concept became in the 1970's, practical implementation has lagged behind theoretical progress. Only a few examples of complex IPM systems exist for any field, vegetable, or fruit crop, primarily because the biological and economic data necessary to devise and implement IPM systems are inadequate.

Recent advances in management systems for soybean insect pests in the United States are the result of intensive multidisciplinary and interinstitutional cooperative research. At present these systems incorporate some of the following features: (a) rigorous correlations between phenology of the main pests and the growth cycle of the crop; (b) better understanding of behavioral and ecological characteristics of pests and their natural enemies; (c) improved sampling procedures, including development of sequential sampling models; (d) more accurate economic damage thresholds; (e) use of more selective or minimal rates of broader spectrum pesticides; (f) use of cultural control practices, such as trap crop methods; (g) breeding of varieties with multiple pest resistance; (h) avoidance of conflicting control measures through closer cooperation among researchers in entomology, plant pathology, nematology, and weed science; and finally (i) extensive use of dynamic simulation models and techniques of systems analysis as aids in the formulation of control strategies.

I shall first briefly discuss the main features of current soybean pest management systems. I shall consider then a hypothetical situation based on the occurrence of four key pests of soybeans in the Orient, viz., stem flies, soybean rust, a complex of leaf feeders, and stink bugs. Based on available information, steps leading to the development of management systems for these pests are suggested. Although pest problems differ quite markedly from region to region, techniques developed and tested in one area may serve as a basis for interim pest management systems in other regions. In time, research on local problems will allow adjustment of these systems to the unique nature of those problems.

Under most soybean growing conditions the greatest economic impact of pests occurs first from weeds, then from diseases, and finally from insects. By virtue of the chemicals most frequently used to control these pests, however, greater environmental contamination and ecological imbalances are more likely to result from mismanagement of insect pests, then weeds, and diseases. Therefore, I shall give greater emphasis to management of insect pests.

MAIN FEATURES OF CURRENT SOYBEAN PEST MANAGEMENT SYSTEMS

Pest management systems are being developed or are already in use in several North American states, viz., Florida (Strayer and Greene, 1974), Louisiana (Newsom et al., 1975), North Carolina (Anon., 1975), Arkansas (Lincoln et al., 1975), and Illinois (Kogan and

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Luckmann, 1974), as well as in Brasil (Turnipseed, 1975; Kogan et al., 1976). These systems basically consist in defining economic damage thresholds for the main potential pests; establishing sampling procedures for pest populations, their main diseases and other natural enemies, and defoliation levels where defoliating pest populations are concerned; and recommending physiologically or ecologically selective pesticides whenever these are available.

Correlation between Crop and Pest Phenologies

Particular types of injury to soybeans are more damaging when inflicted at certain stages of plant development. Furthermore, peaks of different populations may occur at more or less sensitive growth stages of the plant. If the peak of a given pest population coincides with a critical stage of plant development, there is a greater risk of economic damage. For instance, if stink bugs are pod feeders, their occasional appearance in fields before pod development should be no cause for alarm. Damage only results from direct injury to the pods (Kobayashi et al., 1972).

When plant and pest phenologies are superimposed, it is possible to identify periods in the crop cycle during which a pest population peak may coincide with a more sensitive stage of plant growth. During these critical periods sampling procedures should be intensified to monitor trends in pest populations. Fig. 1 describes when populations of some common soybean pests are expected to peak in central Illinois. Efforts to detect populations of defoliating pests are concentrated between periods 4 and 6, which are indicated in circles at the bottom of the figure.

Establishment of Economic Damage Thresholds

One of the key parameters in pest management is the correct definition of the pest population and the damage levels at which control measures should be undertaken. This parameter is designated the economic damage threshold (Turnipseed and Kogan, 1976). Usually at those levels the value of the probable yield reduction, which could be prevented by a control action, should more than offset the cost of application of this control action. Examples of economic damage thresholds adopted in the United States are presented in Table 1 for foliage feeders and in Table 2 for pod feeders.

Considerable progress in the evaluation of economic damage thresholds for defoliators was possible because information was available on the correlation between yield reduction and defoliation. Under most experimental conditions plants are most sensitive to defoliation at the pod-set/pod-fill stage. At this stage 30 percent defoliation of indeterminate varieties may cause an 8 to 10 percent yield loss (Kalton et al., 1949). Models using these data and data on the rates of foliage consumed by defoliating pest species were proposed (Stone and Pedigo, 1972; Ruesink, 1975). A detailed analysis of the components of one such model was presented by Kogan (1976). Development of IPM systems for the Orient will depend to a large extent on information on economic damage thresholds for stem flies, leaf-sucking arthropods, and pod borers. Also, the interaction between foliar diseases and insect attacks must be understood before the established economic damage thresholds can be applied with confidence under most growing conditions. James (1974) reviewed the information on assessment of losses due to plant diseases; there is practically nothing on soybean.

Improvement of Sampling Procedures

Since the backbone of current pest management programs is the correct assessment of pest population levels (scouting), much emphasis is placed on accuracy of sampling procedures. Only a relative estimate of populations is needed for most practical applications. In this regard the beat or drop cloth is perhaps the most versatile method for sampling lepidopterous caterpillars, stink bugs, and most predatory bugs. The sweep net is used for leaf beetles, but may also produce adequate results for certain lepidopterous caterpillars. Special techniques must be developed to sample soil-inhabiting, stem- and

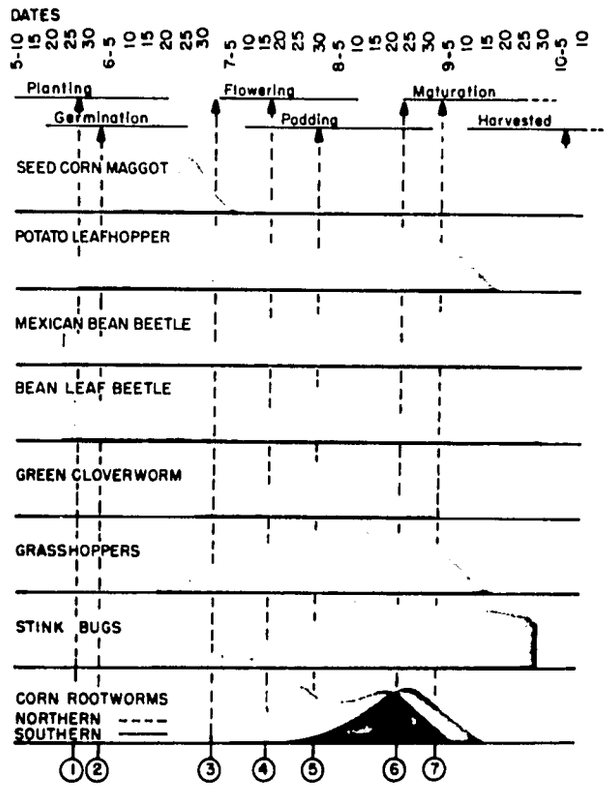

Fig. 1. Phenology of nine soybean insect species in Central Illinois superimposed on a chart describing the crop growth cycle. Crop growth stages are indicated beneath the calendar dates. The arrows indicate when 50 percent of the crop in the state is expected to be at given stages of development as indicated by the circled numbers. Source: Kogan and Luckmann, 1974.

Table 1. Economic Thresholds for Some Defoliating Pest Species in the United States at the Pod-Set/Pod-Fill Stage

Species	Thresholds	State
Bean leaf beetle	40% defoliation	Louisiana
	20 beetles/m row + 20% defoliation	Illinois
Mexican bean beetle	15% defoliation	S. Carolina
	15 adults or larvae/m row	Virginia
Velvetbean caterpillar	24 worms (> 1.2 cm)/m row	Louisiana
	12 worms (> 1.2 cm)/m row	Florida
	28 worms (> 1.2 cm)/m row + 15% defoliation	S. Carolina
Green cloverworm	21 worms/m row or 6% defoliation	Missouri
	24 worms (> 1.2 cm)/m row + 15% defoliation	Illinois
	24 worms (> 1.2 cm)/m row	Louisiana
	30–45 worms/m row	Iowa
Soybean looper	24 worms (> 1.2 cm)/m row	Louisiana
	24 worms (> 1.2 cm)/m row + 15% defoliation	S. Carolina

Table 2. Economic Thresholds for Some Soybean Pod Feeders in the United States

Species	Threshold	State
Corn earworm	9 worms/m row	Louisiana, S. Carolina
Corn earworm	6 worms/m row	Arkansas
Stink bugs	3/m row	Louisiana, Arkansas, and S. Carolina
Bean leaf beetle	10% pod feeding	Louisiana

pod-boring arthropods. Comparative studies on sampling methods for soybean arthropods were made by Shepard et al. (1974), and Hillhouse and Pitre (1974). For most pest management purposes it is sufficient to determine whether a pest population is below or above a tolerable level. Sequential sampling plans allow one to reach this decision with the least possible number of samples, given accuracy and risk levels adopted in the plan. Sequential sampling models are available for only a few soybean pests, e.g., *A. gemmatalis* and *Nezara viridula* (N.S.F., 1974).

Understanding Behavioral and Ecological Characteristics of Pests and Their Natural Enemies

Detailed ecological and behavioral studies of insect pests and their natural enemies often reveal conditions that may be used to advantage in both cultural and biological control techniques. For example, the corn earworm, *Heliothis zea,* is more serious on soybeans when the canopy is not closed at pod-set stage. If open canopy is observed at that stage an outbreak of the pest can be expected. The southern green stink bug (*N. viridula*) in India infests, in sequence, a series of host plants following the appearance of fruiting parts on each plant. Certain control techniques may be developed to disrupt migration from one crop to another (Singh, 1973). The manipulation of natural enemies also offers great possibilities (as discussed by Irwin and Price in this conference).

Use of Selective Pesticides

Most current soybean IPM programs rely on well-timed applications of insecticides if pest populations reach economic damage thresholds. Some insecticides widely used on soybeans destroy most beneficial insects together with the pests and frequently cause resurgence of the pest a short time after the treatment. Ecological selectivity was achieved with minimal dosages of insecticides used against various soybean pests (Turnipseed et al., 1974). Table 3 lists some of the insecticides and rates recommended to control some pests of soybeans in North and South America.

Newly introduced insecticides have great potential for physiological selectivity. One such insecticide, TH 6040, is an inhibitor of chitin synthesis and disrupts molting processes of certain lepidopterous defoliators. It has been used successfully on soybeans (Turnipseed et al., 1974; see also discussion by Heinrichs in this conference).

Use of Cultural Control Practices

Kobayashi et al. (1972) recommended several cultural practices to control pod borers in Japan. These included earlier planting to promote early maturation, interplanting with corn, and crop rotation. A trap crop system was used with success to control the bean leaf beetle, *Cerotoma trifurcata,* in Louisiana. A few rows of an early-maturing variety, planted 10 days to two weeks before the rest of the field, served as a trap for most of the colonizing adults, which could then be destroyed with insecticides (Newsom, 1976). Entomologists can devise cultural control schemes based on knowledge of the ecology and behavior of main pests. These schemes, however, are adopted only if they do not interfere with

Table 3. Minimal Insecticide Dosage Recommended for Control of Main Soybean Pests in North and South America

Insect	Preferred insecticide	Active ingredient (g/ha)	Alternate insecticides	Active ingredient (g/ha)
A. gemmatalis	Carbaryl	300	Methyl parathion	300
			Methomyl	200
			Monocrotophos	200
Plusia spp.	Methomyl	500	Monocrotophos	500
Stink bugs	Methyl parathion	600	Monocrotophos	500

established agronomic practices. These practices are developed to maximize yields, and sometimes they conflict with proposed cultural control schemes. Only careful experimentation and cooperation between agronomists and protection specialists can determine the feasibility of proposed cultural control schemes.

Use of Varieties with Multiple Pest Resistance

At present many widely used commercial varieties incorporate resistance to some of the most serious diseases and nematodes. The greatest success was achieved in the control of Phytophthora rot and the cyst nematode (Hartwig, 1973). Resistance to insect pests is now under intensive research in the United States (Turnipseed and Kogan, 1976; see also discussion by Kogan in this conference). Plant resistance is certainly one of the most desirable techniques to control soybean disease and insect pests.

Avoidance of Conflicting Actions in Pest Control

Some of the most effective natural control agents of lepidopterous defoliators are entomopathogenic fungi, such as *Nomuraea rileyi* (Farlow) Samson, *Entomophthora* spp., and *Metarrhisium* spp. Recent research has shown that certain fungicides used to control foliar and seed diseases of soybeans may adversely affect infectivity of beneficial fungi (Soper et al., 1974; Ignoffo et al., 1975). Following preliminary reports of higher yields in treated soybean fields, the use of benomyl and other systemic fungicides on soybeans is apparently increasing (Horn et al., 1975). The potential conflict between this disease control action and the natural control of lepidopterous larvae by entomopathogenic fungi was suggested by results reported by researchers in Louisiana and South Carolina. These researchers observed that velvetbean caterpillar populations were higher and the percent of infected caterpillars was lower in benomyl-treated plots (Herzog et al., 1975). Whether the differences observed will permit populations to increase above economic injury levels is still questionable. These potential conflicts, however, should be borne in mind when establishing total pest management strategies.

Use of Dynamic Simulation Models

The integrated pest management systems envisioned by crop protection scientists have been steadily mounting in complexity. In view of the inherent difficulties in testing alternative control strategies of such complex systems, attempts are being made to use dynamic simulation modeling. Main pest population dynamics are being modeled and preliminary soybean plant models are being developed. A systems approach is being used to produce decision-making algorithms for the farmer or the extension specialist. Besides permitting simulation of control strategies, the approach has been useful in indicating major gaps in our knowledge of the population dynamics of the main pests. Furthermore, a model is a valuable teaching tool that can be used to demonstrate the advantages or disadvantages of certain practices and can sometimes save years of painstaking field experimentation (Ruesink, 1976).

MAIN SOYBEAN INSECT PESTS IN THE ORIENT AND AUSTRALIA

A recent review of soybean entomology compared the main insect pests in the Orient and in North, Central, and South America (Turnipseed and Kogan, 1976). Table 4 uses a similar niche differentiation to compare the faunas of India, Japan, Thailand, and Australia.

It is apparent from Table 4 that some insect species or a complex of closely related species play a similar role in soybean ecosystems throughout these vast regions. Early in the season stem flies and seed flies seem to be ubiquitous in the Orient. Several species of lepidopterous caterpillars are the main defoliators. Stink bugs are the most serious pod feeders, but the soybean pod borer, *Grapholitha glycinivorella,* is uniquely damaging

Table 4. Some Important Insect Pests in the Orient and Australia

Plant part attacked	Australia[a]	India[b]	Japan[c]	Thailand[d]
Root nodules, germinating seeds, and seedlings	.....	*Hylemia platura*	*H. platura*	.....
	.....	*Melanagromyza* spp.	*Melanagromyza dolichostigma*	*Melanagromyza* spp.
Stalks and stems	*Corrhenes paula*	*Oberea brevis*	.....	.....
Leaves	*Heliothis armigera*	*H. armigera*	*H. viriplaca*	*H. armigera*
	Plusia spp.	*Plusia* spp.	.....	.....
	Spodoptera litura	*S. litura*	*S. litura*	*S. litura*
	.....	*Diacrisia obliqua*	*Spilosoma* spp.	.....
	.....	*Lamprosema indicata*	*L. indicata*	*Lamprosema* spp.
	Stomopterix simplexella	*S. subsecivella*	.....	*S. subsecivella*
Pods and seeds	*Nezara viridula*	*N. viridula*	*N. viridula, N. antennata*	*N. viridula*
	Riptortus serripes	*R. linearis*	*R. clavatus*	.....
	Etiella behrii	.....	*E. zinckenella*	.....
			Grapholitha glyciniverella	.....

[a] R. M. Watts, personal communication; Goodyer, 1974.
[b] Gangrade, 1974.
[c] Kuwayama, 1953; Kobayashi et al., 1972.
[d] Napompeth, 1975.

to soybeans in Japan and Korea (see discussion by Kobayashi in this conference). Many other species reported in these regions are of economic consequence only in more restricted areas.

A HYPOTHETICAL PEST MANAGEMENT PROBLEM

A sequence of pest problems conceivably important in many soybean-growing areas in the Orient involves the following components: (a) stem flies (*Melanagromyza* spp.), which attack seedlings early in the season; (b) fungal diseases affecting the foliage throughout the entire period of vegetative growth, soybean rust (*Phakopsora pachyrhizi*) probably being the main disease; (c) lepidopterous defoliators (a complex of species), which combine with foliar diseases to destroy leaf tissue and reduce photosynthetic activity of plants; and (d) stink bugs (*Nezara viridula, Riptortus* spp.), which attack pods later in the season.

A three-phase plan is outlined to initially alleviate the problem and to lead later to optimization of control procedures. A timetable for the implementation of such a plan will necessarily depend on available resources for development of local research programs.

PHASES OF AN INTEGRATED PEST MANAGEMENT PROGRAM

Phase I: Transplantation of Existing Technology

Considerable progress in crop protection can be made in new production areas with techniques developed elsewhere carefully being adopted as interim solutions to many local problems. Once the main pest problems are identified, this phase consists primarily of three major components.

Key pest phenologies described and superimposed on chronology of crop growth cycle. Fig. 2 shows hypothetical phenologies of a succession of the four pests during the crop cycle. Existing records are used to outline such graphs. Sampling programs carried out in conjunction with the scouting plans should provide data necessary to increase accuracy of preliminary phenological graphs.

Scouting and decision-making plans established. Before accurate data on pest phenologies are gathered during the first phase of the IPM program, it may be necessary to visit fields at fixed time intervals, e.g., weekly or biweekly. Samples of the main pests are taken and damage levels are estimated. This, however, is more easily said than done. There are good sampling methods for lepidopterous defoliators and stink bugs, the ground or beat cloth generally being used with reasonable success. Estimation of stem fly populations, on the other hand, is not easy. Adult flies can be sampled with a sweep net (Gangrade, 1976), but correlations between adult fly populations and larval populations have not been established. As a starting point, 20 plants picked randomly in the field can be removed and the number of

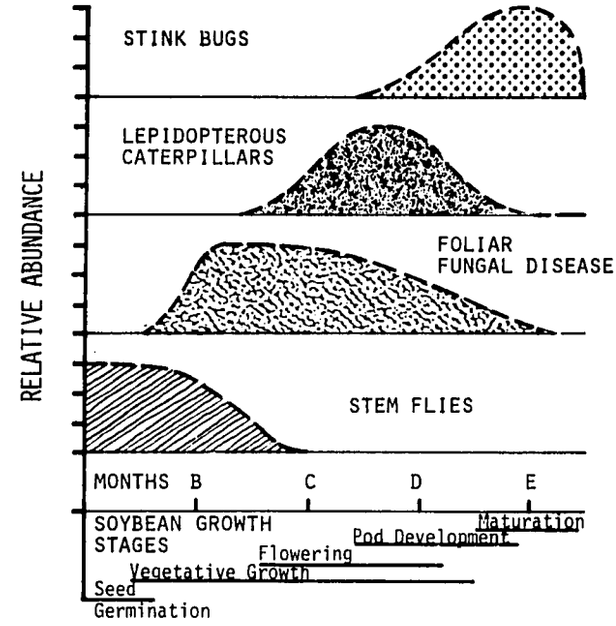

Fig. 2. Phenological relationship of four soybean pests and the crop growth cycle (hypothetical). Months are represented by letters since growing seasons vary considerably within the regions under discussion.

mined stems counted after dissection (see discussion by Rose et al. in this conference).

Defoliation levels are determined on the basis of visual estimates. Whole plants or leaflets are picked at random and the percentage of leaf area destroyed is determined by comparison with known standards (Kogan and Luckmann, 1974). With practice, scouts can be trained to visually estimate defoliation in the stand to within 5 to 10 percent of actual defoliation levels.

Control decisions are based on the combined results of population samples and damage estimates. Sampling is continued if a pest population is present but reduction of foliage area falls below established upper limits of tolerance for each growth stage of the crop. If the pest population is growing, samples should be taken at closer intervals.

It is also possible that foliage area reduction approaches a tolerance limit even though the causal pest population has disappeared. In this case no treatment is needed. In short, a decision to treat pests affecting the foliage should be based on a combined assessment of pest population and damage level. An example of some of the options available is shown in Table 5.

Establishment of economic injury levels for key pests is thus essential even in the early phases of the IPM program. Such levels are as yet unavailable for stem flies, but there is enough evidence to suggest that they cause serious problems only when they attack young plants.

Economic damage levels for defoliators have been established for several lepidopterous species. Up to the pod-set/pod-fill stage and during seed maturation it is

Table 5. Treatment Options and Loss Expectations in a Management Program for Insect Pests Affecting Soybean Foliage

Damage level	Pest population level		
	Low	Threshold	High
Low	Continue sampling at regular intervals	Continue sampling at closer intervals	Preventive spray Low probability of loss
Threshold	Continue sampling at closer intervals	Spray No loss	Spray overdue Loss expected
High	Spray overdue High probability of loss	Spray overdue Loss expected	Spray overdue Loss expected

generally accepted that 30 percent defoliation can be tolerated with no effect on yield. During the pod-set/pod-fill stage 20 percent defoliation may cause some yield reduction. These levels were established using both determinate and indeterminate varieties, but usually using plants grown under favorable agronomic conditions. There is no information on tolerance to defoliation in plants under suboptimal growing conditions. In most current IPM programs, defoliation levels in economic damage thresholds are set at 20 percent and 15 percent up to and at the pod-set/pod-fill stage, respectively. In addition, population levels greater than 20 lepidopterous caterpillars for every 1.5 cm per meter of row at normal row spacing (50 to 70 cm) are accepted thresholds for loopers (Noctuidae: Plusiinae). Armyworm and *Heliothis* spp. thresholds are reduced to 10 per meter of row (Kogan et al., 1976).

The occurrence of foliar diseases greatly complicates the picture. The leaf area destroyed by pathogens should be computed in the assessment of the total leaf area destroyed. Apparently no established economic thresholds are available for fungal pathogens, a deficiency that greatly hampers development of more comprehensive IPM programs for soybeans.

Economic thresholds for stink bugs have been established at 3 per meter of row at 75-cm rows or 2 per meter of row at less than 50-cm rows (Todd, 1976; Kogan et al., 1976). If seed quality is a major concern, as is the case in production of certified seed, these thresholds may have to be lowered.

Control actions selected. In this stage control practices are generally limited to well-timed applications of pesticides. In most IPM programs the preventive application of pesticides is ruled out, except perhaps for the control of stem flies with soil application of granular, systemic pesticides. Programs prescribing treatments at preestablished schedules are generally contrary to the ecological and economic foundations of pest management. Insecticides should be selected from among those least detrimental to natural enemies and applied at minimal, effective rates (Turnipseed et al., 1974). Control of fungal diseases should be considered only if epiphytotics are of economic proportions. The selection of fungicides should also be made carefully, since certain compounds may adversely affect entomopathogenic fungi, thus reducing the effectiveness of these natural control agents against many insect pests.

Control of stink bugs is also accomplished with well-timed, low dosage applications of organophosphate compounds. Table 6 gives an example of compounds and rates that may be adequate under most soybean growing conditions to control pests in the complex under consideration.

Phase II: Expansion of Local Data Base

With an interim control program underway, efforts should be concentrated on refining control techniques to better adapt them to local conditions. The following is an enumeration of possible areas of concentration. Local needs and available research capabilities should dictate priority areas.

1. Expansion of the biological data base with studies on the population dynamics of key pests, pest and crop life tables. Scouting at this time should be limited to critical times when potential pest outbreaks are likely to occur. Intensive scouting at the proper time makes the scouting program more economical and more apt to detect population trends.

Table 6. Compounds and Rates Considered Adequate for Control of Some Key Soybean Insect Pests[a]

Pest	Pesticides	Active ingredient (g/ha)
Early season stem flies	Monocrotophos[b]	500[b]
Mid-season lepidopterous caterpillars: (*Heliothis*, *Spodoptera*, Arctiids)	Carbaryl	500[c]
Plusiinae	Methomyl	500[c]
Late season stink bugs	Methyl parathion Monocrotophos	600[d] 600[d]

[a] Chemical control of foliar diseases is not included. See Sinclair and Dhingra (1975) for literature on the subject.
[b] No economic thresholds or control recommendations found in the literature. The stem fly seems to be a problem only when attacking seedlings. Monocrotophos is suggested on the basis of its mode of action and reported efficacy against similar pests on other crop plants. Preliminary results on chemical control by means of soil applications of systemic insecticides are found in Gangrade (1976).
[c] Turnipseed et al., 1974.
[d] Kogan et al., 1976.

2. Improvement of information on economic damage thresholds. It is apparent that such information is especially needed for stem flies and for soybean diseases.

3. Assessment of occurrence and effectiveness of natural control agents. Predators, parasites, and diseases should be identified, protected and, if possible, manipulated to maximize their effectiveness (see discussion by Irwin and Price in this conference).

4. Screening of germ plasm collections for sources of resistance to the main pests. There is evidence that expression of resistance may vary quite substantially under diverse environmental conditions. Screening programs may be necessary on a regional basis, because identification of a resistant line in one region is no assurance that the same line is going to maintain its characteristics of resistance when planted in another region. Furthermore, even if the same pest species is present in various regions, it is possible that local races are more virulent than others. A line resistant to a species in one region may be susceptible to local populations of the same species in another region (see discussion by Kogan in this conference).

5. Consideration of cultural practices suitable to local cropping systems. Early or late planting may allow escape from attack by stem flies. Certain cropping patterns and rotation sequences may favor or suppress particular pests.

6. Continuation of pesticide screening at minimal rates not only for their effectiveness against pests but also for their selectivity regarding beneficial species.

7. Improvement of the decision-making scheme adopted in phase I.

Phase III: Integration

Accumulation of biological and economic data through phases I and II of the program should permit development of a comprehensive pest management system. Such a system is dynamic. As new detection methods and control tactics become available, they are incorporated into increasingly improved programs. A situation may be envisioned in the future in which: (a) varieties with multiple pest resistance are available and capable of favorably competing with other varieties in yield and quality of grain; (b) actions are taken to maximize the role of natural control agents; (c) cultural control methods and selective pesticides are regularly adopted and used in accordance with needs established by conveniently monitoring pest and damage levels; and (d) pest control actions are in harmony with the total crop system and with the environment as a whole.

CONCLUSION

A program for development of pest management systems for soybean-producing areas of the Orient is proposed. The program includes three phases: (a) transplantation of technology, (b) expansion of the local data base, and (c) integration. Such a program should be considered as soon as expansion of the crop is contemplated.

Evidence from other soybean-growing regions (Kogan et al., 1976) suggests that technology currently available can be quickly and rather safely adapted in interim programs for solving regional pest problems of soybeans. Results are particularly encouraging regarding lepidopterous defoliators and stink bugs. As more information on specific pest problems becomes available, such interim programs can be improved and adjusted to produce pest management schemes capable of attending more effectively to regional needs. The dire need for additional research on stem flies, pod borers, and certain fungal diseases is quite evident for soybeans in the Orient.

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Small-Scale Equipment for Oil Extraction

Chalermsri Vajragupta

Soybeans have a wide range of uses. In addition to serving as animal feed and human food, they are also used for industrial application. The two major components of soybeans, protein and oil, make up nearly 60 percent of the seed, and are found in proportions of approximately 40 percent and 20 percent, respectively. Both the protein and oil serve as excellent bases for fabricated foods.

Soybean meal, which is a relatively low-cost by-product of cooking oil manufacture, is increasingly important in poultry and swine production. During the last decade, however, problems arose because of the use of low-quality grain, which adversely affects the quality of the oil produced. Therefore, an oil-seed laboratory, including an oil-seed pilot plant, was established in 1972 as a part of the Thai-Japanese Soybean Project. Research was initiated for the study of oil-seed chemistry and processing with a view toward solving production problems. Using a good quality grain processed by the method outlined in this paper, research workers at the oil-seed laboratory obtained a high quality cooking oil (Table 1).

Oil-seed processing can be grouped into three major steps: (a) the pretreatment process, (b) the solvent extraction process, and (c) the refining process. A flow chart for each of these steps is shown in Fig. 1, 2, and 3.

PRETREATMENT PROCESS

Raw Materials

The raw materials are received at the laboratory pilot plant and are kept in a small silo with a capacity of 5 tons (Fig. 4). Oil-seed quality is checked upon arrival. Analysis of the soybeans shows the following: a seed index of 10.48 grams per 100 seeds; foreign matter, 0.09 percent; damaged seed, 4.39 percent; moisture content, 13.53 percent; and oil content, 20.32 percent.

The raw material is conveyed from the hopper to the sifter by means of a screw conveyor unit. In the sifter dirt and other foreign matter are separated from the raw material. Normally when soybeans are the raw material to be processed, sifter screens with openings of 0.7 to 1.0 cm^2 are used.

Cooker

Cooking of the oil-seeds is carried out in a cooker, which consists of two closed, cylindrical steel kettles placed one above the other. The oil-seeds are delivered at a constant rate to the top kettle by means of a conveyor. After cooking for a while in the top kettle, the cooked seed is dropped to the kettle below, where cooking continues. The total cooking time in the two kettles is 20 to 40 minutes at 80° to 90°C. This treatment coagulates the protein and coalesces oil droplets making the seed permeable to oil flow, decreases the affinity of the oil for the solid surfaces of the seed, and results in an adjustment of seed moisture content to 8 to 10 percent.

Flake Roller

To facilitate the extraction of oil, the seed is reduced to small particles by means of a flake roller assembly. Two pairs of rollers are provided, the clearance between rolls being adjusted according to the desired thickness of

Table 1. Comparison of Properties of Cooking Oil Produced at Oil-Seed Laboratory with General Standard Cooking Oil[a]

Properties	Values for properties of soybean cooking oil	
	Oil-seed lab.	Standard (JAS)
Acid value	0.06 – 0.09	<0.2
Soap content (ppm)	10 – 45	<50
Color (Lovibond)	20 – 30 Y ; 2 – 5 R	< 20 Y ; 2.5 R
Iodine value	129 – 132	123 – 142
Sponification value	191 – 204	188 – 195
Peroxide value	0.7 – 14	<10
Specific gravity (28°/25°C)	0.920 – 0.922	0.916 – 0.922
Refractive index (25°C)	1.473 – 1.474	1.471 – 1.475

[a] Specified by the Japanese Agricultural Standard (JAS).

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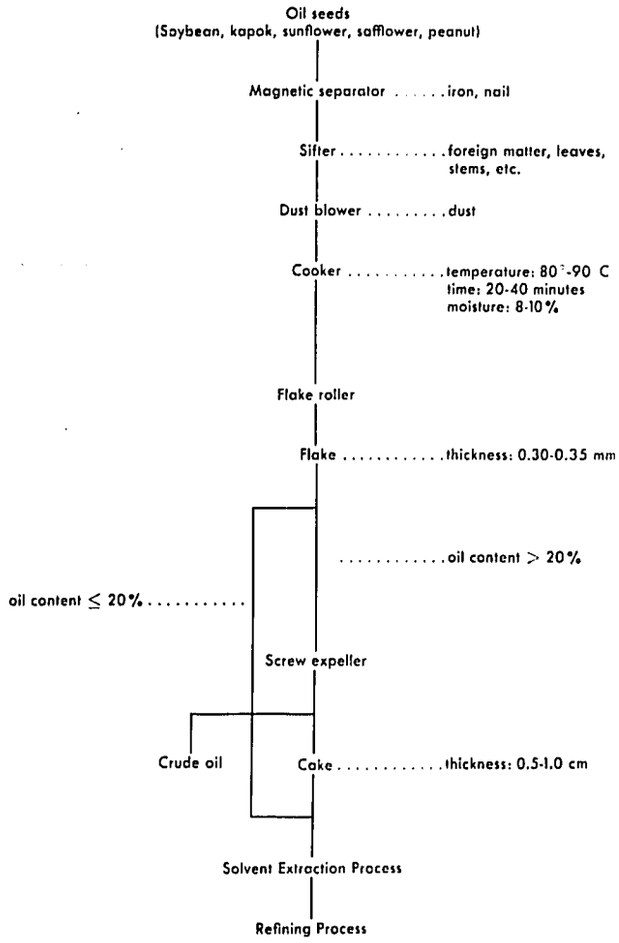
Fig. 1. Pretreatment process.



the flakes. A small flake roller unit can accommodate 100 kilograms per hour of soybean seeds.

A reasonably high moisture content is required for oil-seeds that are to be rolled into thin flakes. Very dry seeds do not flake well. For solvent extraction, soybean particles are adjusted to a moisture content of 10 to 11 percent and flaked while still hot. At the end of this stage the soybeans have a moisture content of 11.41 percent, a thickness of 0.35 mm, and contain 38.19 percent soluble protein.

In the preparation of oil-seeds for expression in the expeller, the particles need not be as thin as those used in a hydraulic press. The reason for this is that the heat which is generated causes the seed particles to break up as a result of the intense shearing stress developed in the expeller.

Expeller

This unit operates on the oil-seed flakes, using a pressure of 5 to 10 tons per square inch to force the oil out of the flakes. The oil is expressed by means of rotating screw expellers that produce the controlled cake thickness. Generally this unit is used for seeds that have an oil content of more than 20 percent, e.g., peanuts and kapok. Therefore, this step is omitted during the processing of soybean seeds.

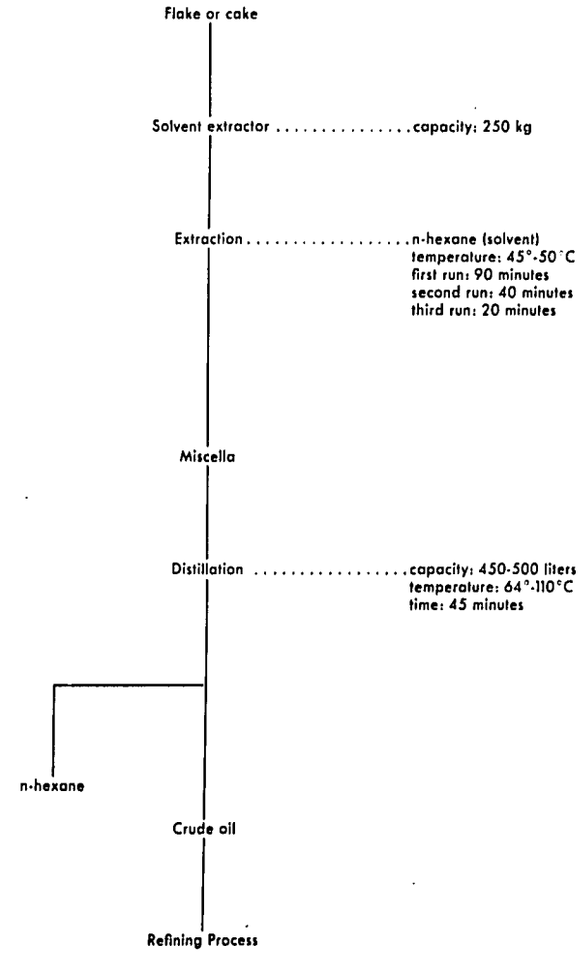
SOLVENT EXTRACTION PROCESS

In the solvent extraction process the pure solvent is delivered continuously to the layer of material from which oil is to be extracted and is percolated through the mass by gravity until the removal of oil is complete. Complete extraction can be accomplished only by the use of a large volume of solvent relative to the volume of oil extracted. The solvent is then recovered from the oil by distillation.

In the case of soybeans, the extractor holds 250 kilograms of soybean flakes. Pure solvent (hexane) is delivered to the top of the soybean flakes and is pumped through the mass until the removal is complete. The solvent extraction unit operates at temperatures of 45° to 50°C. The circulating time and the quantity of hexane used during each recycling step are as follows:

First extraction — 90 minutes, 900 liters
Second extraction — 40 minutes, 700 liters
Third extraction — 20 minutes, 700 liters

Fig. 2. Solvent extraction process.



The first, second, and third miscellas (crude oil plus solvent) are drained off to miscella tanks. Recovery of the solvent from the miscella is done by distillation. The loss of the solvent (hexane) during the solvent extraction process was about 7 percent. Crude oil concentrations in each of the three miscellas are: first extraction, 12.11 percent; second extraction, 5.61 percent; third extraction, 2.21 percent.

The crude oil obtained at the end of this process has the following composition: acid value, 2.32; moisture, 0.09 percent; neutral oil, 94.73 percent; and gum matter, 4.02 percent. The components of the soybean meal include moisture, 13.59 percent; oil, 0.90 percent; protein, 35.29 percent; and soluble protein, 15.32 percent.

REFINING PROCESS

Degumming and Neutralization

The degumming and neutralization treatment is designed to remove free fatty acids, phosphatides, gum matter, and other impurities in the crude oil. This unit, which consists of an open tank with a conical bottom, is equipped with an agitator and a steam coil for heating. The agitator is comprised of a central, vertical shaft to which a series of blades are attached. The agitator rotates at a speed of about 60 rpm. The cone of the kettle is steam jacketed to assist in melting and discharging materials after the treatment is completed.

Degumming is carried out in two steps. During the first step, 4 percent water is added to the crude oil. The mixture is then heated to 60°C and agitated for 30 minutes. It is allowed to settle for at least 24 hours. In the second step, 10 percent water and 1 percent oxalic acid are added, the mixture heated to 40°C, and agitated for 20 minutes. Again it is allowed to settle for at least 24 hours. Finally, the degummed crude oil is neutralized by the addition of sodium hydroxide. The amount of base required is calculated by multiplying the sum of the acid value plus one by 1.5 or 2.0 (to obtain a NaOH concentration of 20° to 25° Baumé). The neutralized oil is agitated for one hour at 35° to 60°C, and then allowed to settle for 24 hours.

Water Washing Treatment

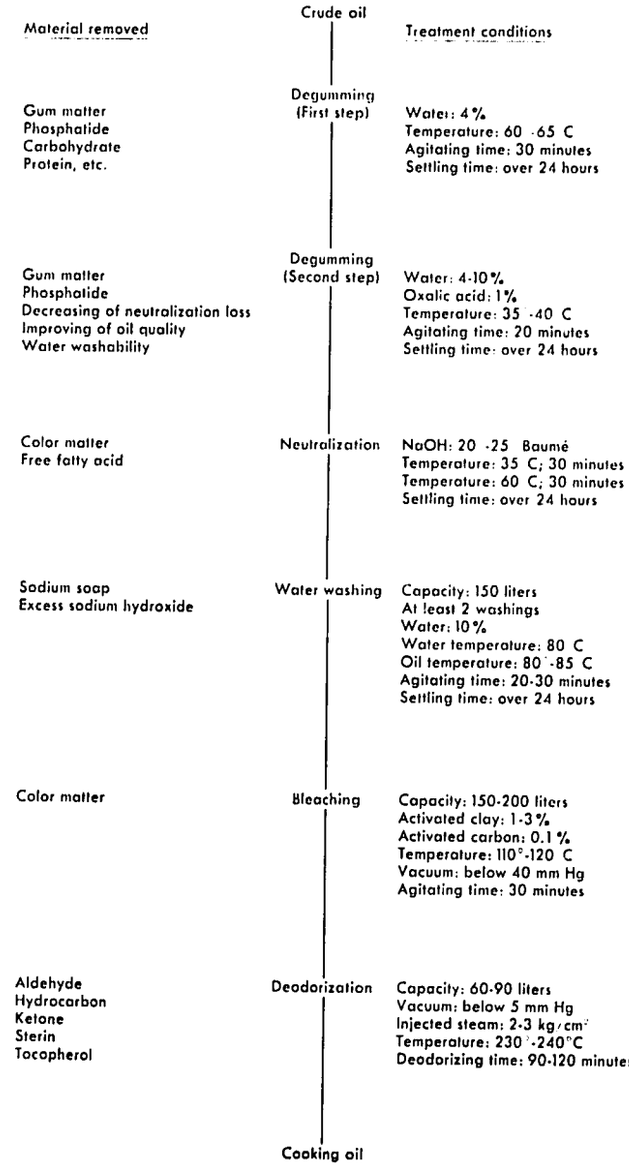
The water washing tank, which is similar to the degumming and neutralization tank, has a capacity of 150 liters. During the water washing treatment, the oil is mixed with 10 to 20 percent hot water and the temperature of the mixing solution is maintained at 80°C. The mixing solution is agitated thoroughly for 20 minutes to wash small amounts of soap from the oil. Separation of the water and oil is achieved by allowing the mixture to settle for 24 hours. The water is then drained from the bottom of the tank. Usually the oil is washed twice in a second operation identical to the first.

After the first washing, the oil has an acid value of 0.31, a soap content of 75 ppm, and the color value (Lovibond method) is yellow, 30.9, and red, 4.0. After the second washing, the acid value is 0.36; soap content, 12 ppm; and color value, 30.9 and 4.0 for yellow and red, respectively.

Bleaching Treatment

The bleaching tank, which is a cylindrical kettle with a conical bottom, has a mechanical agitator and steam heating coils. The operation begins by adding 3 percent activated bleaching clay and 0.1 percent activated carbon to the oil in the kettle before the bleaching temperature of about 110°C is reached. After heating is completed, agitation is continued for 30 minutes under a vacuum of less than 40 mm Hg. The oil is then pumped through the filter press for clay removal and the bleached oil

Fig. 3. Refining process.

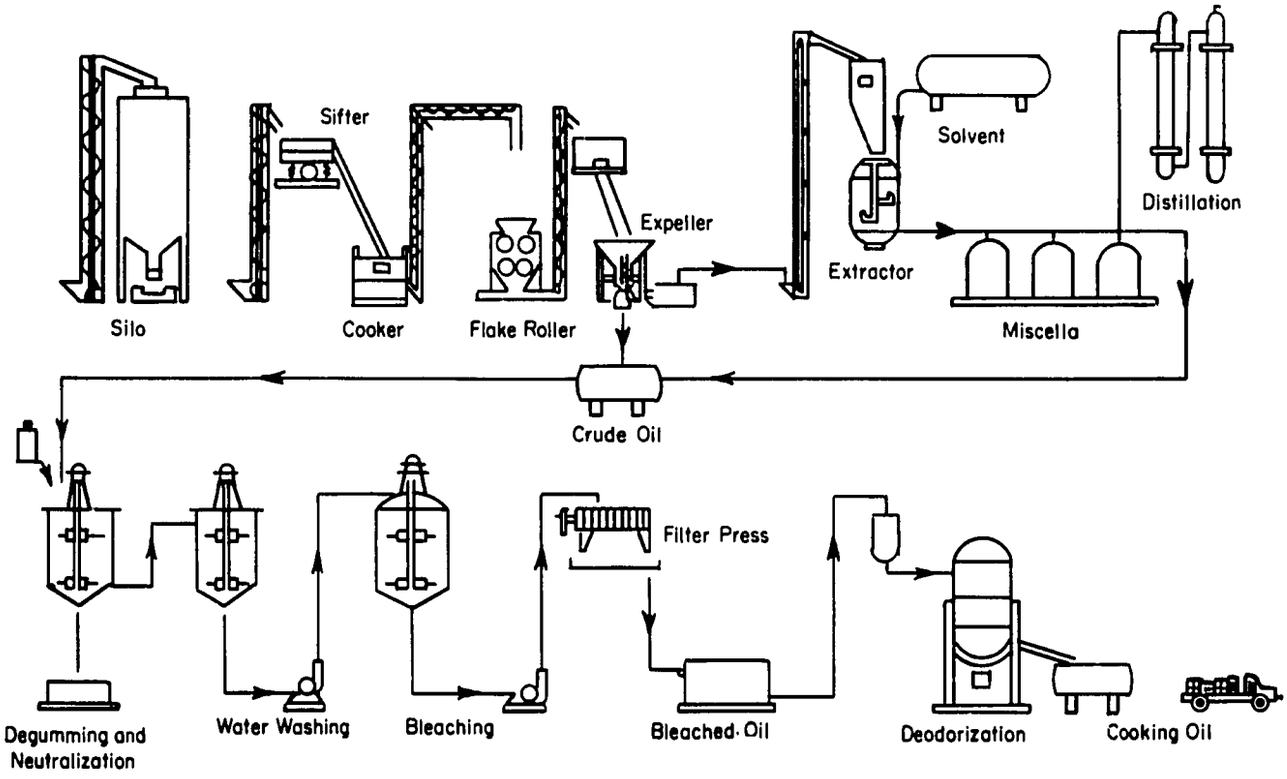


is obtained. At the end of this treatment the oil has an acid value of 0.40, a soap content of 10 ppm, and a color value of 20 and 2.0 for yellow and red, respectively.

Deodorizing Treatment

The capacity of the deodorizing tank is 60 to 90 liters. Stripping steam is injected into the bottom of the vessel at a rate of about 2 to 3 kg/cm^2 through a distributor, which consists of perforated radial pipes attached to a central steam delivery line. The oil in the vessel is heated by an external burner to 230° to 240°C. The distinct odor is thus eliminated with the steam as it is drawn off by vacuum (4 to 5 mm Hg). The deodorizing process requires 90 minutes.

Fig. 4. Scheme of oil seed pilot plant.



Fermented Soybean Foods

Hideo Ebine

In the Orient soybeans are traditionally used as food in two ways. First, they are used to make unfermented foods, such as tofu (soymilk curd) (Wantabe et al., 1974), products derived from soymilk, such as yuba (soymilk film), and kinako (roasted soy flour). Second, soybeans are made into various types of fermented products, such as miso, shoyu, natto, tempeh, and sufu.

In 1974 253,000 metric tons of whole soybeans and 178,000 metric tons of defatted soybeans were used in Japan to produce miso, shoyu, and natto (Tables 1, 2). Miso is a fermented paste made with soybeans, salt, and either rice or barley. Shoyu is made from either whole or defatted soybeans plus wheat and salt. Natto is produced from soybeans fermented with *Bacillus natto,* a process that results in the characteristic ropy or glutinous texture and typical flavor of this food. Each year in Japan the per capita consumption of miso, shoyu, and natto is 6.7 kg, 10.2 liters, and 760 g, respectively.

Although the various oriental soy food products appear to be highly nutritious from the standpoint of chemical composition (Table 3), many problems have yet to be solved before they can take their place with rice and wheat as food staples. After soybeans are cooked by ordinary methods, only 65 percent of the protein can be adequately digested. Moreover, soybeans contain certain carbohydrates that produce flatulence when they interact with microorganisms in the colon (Setta et al., 1967). The gas-producing carbohydrates consist of some of the oligosaccharides, such as raffinose and stachyose, and the polysaccharide, arabinogalactan; reducing sugars and sucrose do not contribute to the formation of intestinal gas. A second problem is that soybeans contain antinutritional factors, such as trypsin inhibitor, hemagglutinins, and saponin. Finally, the characteristic beany flavor is considered undesirable by westerners who are not accustomed to soybean foods. These problems are solved, however, by the fermentation process.

Digestibility is remarkably improved by proper cooking and grinding, followed by fermentation. During fermentation the enzyme in koji (the inoculant) and salt-resistant microorganisms partially digest the soybeans. Through fermentation, for example, 60 percent of the protein in rice miso is reduced to a water-soluble form containing polypeptides and amino acids. This alteration gives miso its palatable flavor. After 10 hours of fermentation the water-soluble nitrogen of natto is increased to as much as 55 percent (Ota et al., 1964). The undesirable carbohydrates are partly leached out during soaking and cooking, and the remainder are consumed during the fermentation process itself (Ebine et al., 1972a).

The antinutritional factors, such as trypsin inhibitor and hemagglutinins, are inactivated by cooking in steam or water, which is the initial step in the fermentation process (Liener, 1955). Elimination of the beany flavor is somewhat more complicated. As reported by Arai et al. (1970), this flavor is caused primarily by several carbonyl compounds, such as hexanal and pentanal. Our investigations revealed that these compounds are readily eliminated by the fermenting action of molds, such as *Aspergillus oryzae* and *Rhizopus oligosporus* (Fig. 1). In practice, the degree to which the beany flavor has been eliminated is a key to determining when to stop the fermentation or ripening process. The flavor of fermented soybean foods is further enhanced by the addition of cereals, such as rice, wheat, or barley. This also results in the improved nutritive value of the protein,

Table 1. Production of Fermented Soybean Foods in Japan

Name of food	Raw material	Amount (metric tons)
Miso		587,228
	soybeans	191,621
	defatted soybeans	2,200
	rice	102,104
	barley	22,280
	salt	80,265
Shoyu		1,213,350
	soybeans	14,278
	defatted soybeans	176,138
	wheat	176,319
	salt	209,674
Natto		90,000
	soybeans	47,000

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Table 2. Supply and Demand of Soybeans in Japan

Sources and uses of soybeans	Soybeans used (1,000 metric tons) in three years		
	1965	1970	1974
Total supply	1,852	3,477	3,705
Domestic production	121	57	60
Imported soybeans	1,731	3,420	3,645
Whole soybeans			
Oil extraction	1,341	2,505	2,727
Miso	150	174	192
Soy sauce	16	13	14
Other foods[a]	345	552	520
Total foods	511	739	726
Defatted meal			
Soysauce and miso	174	168	...[b]
Other foods	128	135	...
Feed	766	1,639	...
Other uses	0	8	...

[a] Includes tofu, koritofu, natto, kinako, and other miscellaneous products.
[b] ... signifies data not available.

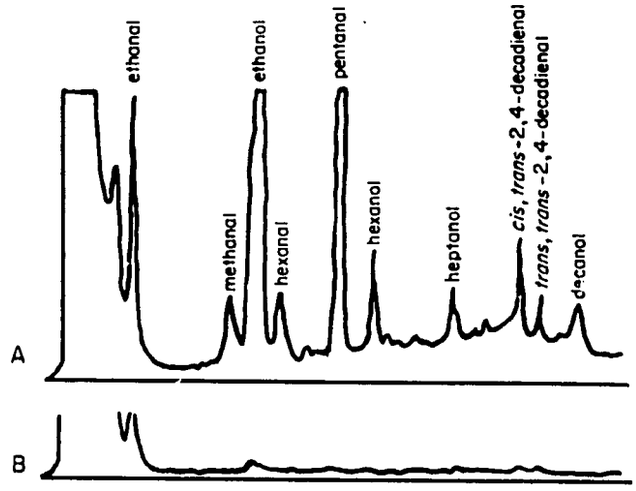

Fig. 1. Gas chromatographs of nonfermented (A) and fermented (B) soymilk.

because the amino acids deficient in one food are supplemented by the excess in another food.

Pathogenic or harmful microorganisms cannot survive in salt-containing soybean foods, such as miso and shoyu. Another interesting advantage of fermentation is that the mold, *R. oligosporus,* can produce an antioxidative compound (4′, 6, 7-trihydroxy-isoflavone) not found in soybeans. This compound has an activity comparable to that of NDGA (nordihydroguaiaretic acid) and is probably derived from isoflavones, such as genestin and daizin (Ikehata, 1967).

MISO

About 590,000 metric tons of commercial miso and 150,000 metric tons of home-made miso are produced in Japan annually. Depending on the raw materials from which it is made, miso is usually classified into three major types: rice miso made from soybeans, rice, and salt; barley miso made from soybeans, barley, and salt; and soybean miso made only from soybeans and salt. Each type of miso is further classified on the basis of color, taste, and the place where it is made. In this respect, it is similar to the various types of cheeses.

Miso is commonly used as an ingredient for making soup, as well as in the manufacture of a sweet paste and other foods. Although manufacturing methods differ somewhat from type to type, the basic method is essentially the same. The soybeans are first washed, soaked, and cooked. After koji and salt are mixed with the cooked soybeans, and a starter of yeast and lactic acid bacteria is added, the soybeans are allowed to ferment. When fermentation is complete, the miso is mixed well so as to supply aerobic microorganisms with air. Finally, different types of misos are blended, pasteurized if necessary, and packaged.

Because defatted soybeans are not suitable for making miso, whole soybeans are generally used as the raw material. Japanese domestic soybeans produce a miso of high quality. As a result of evaluation tests employing 101 U.S. soybean samples and 24 Japanese varieties (Ebine et al., 1972a and 1972b), we found that the most suitable soybeans have a soft, smooth consistency and a bright color after cooking. These soybeans also have a high water-absorbing capacity when soaked under specified conditions. Tests have shown that there is no correlation between the capacity to absorb water and the protein and oil content, but there is a high correlation between the carbohydrate content and the water-absorbing

Table 3. Chemical Composition of Soybean Foods

Soybean food	Moisture (%)	Protein (%)	Fat (%)	Soluble carbohydrate (%)	Fiber (%)	Ash (%)
Tofu	88.0	6.0	3.5	1.9	0	0.6
Aburaage	44.0	18.6	31.4	4.5	0.1	1.4
Kori-tofu	10.4	53.4	26.4	7.0	0.2	2.6
Yuba	8.7	52.3	24.1	11.9	0	3.0
Kinako	5.0	38.4	19.2	29.5	2.9	5.0
Natto	58.5	16.5	10.0	10.1	2.3	2.6
Miso						
Salty light	50.0	12.6	3.4	19.4	1.8	12.8
Salty red	50.0	14.0	5.0	14.3	1.9	14.8
Soybean	47.5	16.8	6.9	13.6	2.2	13.0
Soybeans	12.0	34.3	17.5	26.7	4.5	5.0

capacity. In the manufacturing of miso, soybeans of a large size are usually preferred because the ratio of hull to cotyledon is lower in the larger bean. Soybeans that have a pale yellow hull and hilum are especially acceptable for making white or light yellow misos.

Soybeans are washed and soaked to absorb enough water for cooking. They are then cooked in water or steam at a temperature of 115°C for about 20 minutes in a closed cooker of either the batch or continuous (conveyor) type. In preparing koji, rice is first cleaned and washed in water and then steamed in an open cooker for 40 minutes. After the cooked rice is cooled to 35°C, tane-koji (spoores of *A. oryzae*), which is prepared at a laboratory, is sprayed over the rice and mixed well. At present koji-fermenters of various types are used instead of the koji-rooms with many trays that were popular prior to World War II. After inoculation of the rice with tane-koji, the temperature of the rice, as well as the temperature and humidity of the air in the fermenter, is controlled so as to promote growth of the mold. About 40 hours are required for koji to develop.

When ready, koji is mixed well with salt to stop further development. Then koji is mixed with the cooked soybeans plus a starter that contains the microorganisms necessary to promote fermentation. Fermentation takes place in a vat at 25° to 30°C. The duration of fermentation varies widely, depending on the kind of miso desired. White miso, for example, takes about one week, salty miso one to three months, and soybean miso over one year.

Characteristics of Miso

The general constituents of some varieties of miso are shown in Table 4. As a protein food, miso has many desirable characteristics, such as its palatability, digestibility, and shelf life. In addition, it has a strong buffer activity caused by the protein, peptides, amino acids, phosphoric acid, and various organic acids produced during fermentation. This buffer activity plays an important role as a seasoning used in a variety of foods to which miso gives a palatable flavor.

Table 4. Constituents of Fermented Soybean Foods

Soybean food	Moisture (%)	Protein (%)	Reducing sugar (%)	Fat (%)	NaCl (%)
White miso	44	8	33	2	5
Salty light yellow miso	49	11	13	5	12
Salty red miso	50	12	14	6	13
Barley miso	46	11	15	5	11
Soybean miso	47	19	2	10	10

Advances in Miso Manufacturing

Application of starter. Although many kinds of microorganisms have been found in miso, only the halophilic strains are important in the fermentation of miso. Among these microorganisms, halophilic yeast and lactic acid bacteria have been determined as essential to fermentation. These same halophilic microorganisms are also used as starters in modern cheese factories. *Saccharomyces rouxii* and *Torulopsis* sp., *Pediococcus halophilus* and *Streptococcus* sp. are the most important microorganisms for miso production.

Use of new type cooker and koji-fermenter. A batch-type cooker was developed so that the temperature can be raised rapidly to over 120°C and lowered quickly immediately after cooking the soybeans. A continuous cooker was also developed and is now widely used for cooking rice and barley. The belt conveyor in this type of cooker allows for substantial savings in time and labor. Many types of koji-fermenters that regulate temperature and humidity have been developed.

Development of new types of miso. With the intention of reducing the concentration of salt to less than 12 percent and raising the level of protein, we investigated a new type of miso at our laboratory. The enzyme preparation, Takadiastase SS, was employed to digest the protein of soybeans (Ito et al., 1965). The new type of miso produced contains 53 percent moisture, 6.3 percent sodium chloride, and 17 percent protein. We also developed an instant, freeze-dried miso soup made with dried vegetables, baked wheat gluten, and seaweed. This new product is now available commercially.

Problem of Mycotoxins in Mold-Fermented Foods

There has been considerable concern regarding the possible presence of mycotoxins, especially aflatoxins formed by some strains of *Aspergillus flavus*. However, according to Manabe et al. (1968) of our institute, no aflatoxin-producing strains were found among the 238 strains of mold collected from the factories that prepare koji in Japan. Furthermore, no aflatoxins were detected in 28 rice kojis from miso factories, 108 commercial miso samples, 30 home-made miso samples, or 20 shoyu samples.

SHOYU

The origin of shoyu and miso appears to be the same. According to an old Japanese legend published in 1489, the juice from mash, which resembles a soft miso, was used as a liquid seasoning that gave a delicious flavor to Japanese foods. Based on this early description, similarities in the miso and shoyu of the present day can be seen with respect to raw materials, microorganisms, fermentation principles, and constituents. Only the main differences will be cited here.

For economic reasons defatted rather than whole soybeans are the major substrate used in making shoyu. Although many advances in shoyu manufacturing methods have been made, the most notable improvement has occurred in the level of nitrogen recovery. The level of nitrogen recovery refers to the percentage of protein found in the finished product compared with that found in the raw materials, including both soybean cake and wheat. After World War II shoyu technology focused on

increasing nitrogen recovery. For this purpose, a new cooker capable of cooking the soybean meal at a high temperature for a short period of time was developed. Koji-making technology was improved so as to increase enzymatic activity and reduce the amount of contaminants in the shoyu mash during fermentation. Finally, temperature controls for the fermenting mash were perfected. As a result of these improvements, nitrogen recovery was increased from 60 percent in 1945 to 90 percent in 1975, and the period for fermentation and ripening of the mash was shortened from 12 months or more to between 4 and 6 months. Moreover, the flavor of shoyu was improved remarkably so that it is now acceptable to consumers abroad as well as in Japan.

Shoyu is divided into three major types: koikuchi, a dark-colored shoyu; usukuchi, which is light; and tamari, which is of an intermediate color. About 90 percent of the shoyu used is of the koikuchi type. Chemical analysis of a good quality shoyu of this type has the following composition per 100 ml: 1.5 to 1.8 g of total nitrogen (9.3 to 11.2 percent amino acids); 3 to 5 g of reducing sugar; 1 to 2 g of organic acids, of which lactic acid and acetic acid are the major components; and 17 g of sodium chloride. In addition, koikuchi shoyu contains many other compounds that give it a characteristic flavor.

NATTO

Natto is classified into two major types: one called hamanatto, which resembles soybean miso in taste; and the other called itohikinatto. The natto commonly referred to is itohikinatto. This food is a unique soybean product fermented by *Bacillus natto*. The surface of fermented natto is covered with a characteristic viscous or slimy substance consisting of *B. natto* cells and polymers of glutamic acid.

In 1960 the National Food Research Institute initiated a project to develop a new type of soybean food in order to comply with a request from UNICEF to supply a nutritious protein food for children. The product thus developed is processed in the following way: soaked soybeans are first cooked in an autoclave at 121°C for 30 minutes. A starter of *B. natto* is then added to the hot, cooked soybeans and mixed well. The inoculated soybeans are fermented at 42°C for 8 to 10 hours. The fermented soybeans are then passed through a chopper and spread over trays for vacuum dehydration. The dried material is made into a powder for use as an ingredient, mixed with wheat flour, in biscuits. In animal feeding experiments this new food had an absorption rate of 83 percent and a biological value of 63 percent, a notable improvement compared with the absorption rate and biological value of raw soybeans.

CONCLUSION

An ancient legend indicates that the technology for making soybean foods with the aid of microorganism originated in China. These foods and the manufacturing process involved were introduced into Japan between 500 and 600 A.D. (Bush, 1959). As a result of modifications of the prototype, miso and shoyu as we know them today are now produced.

Although soybeans are highly nutritious from the standpoint of their chemical make-up, they must be adequately processed for use as human food. Fermentation, using comparatively simple facilities and equipment, has proved successful in eliminating many of the disadvantages associated with human soybean consumption. After World War II many advances were made in the manufacture of traditional, fermented soybean foods. The new technologies established in Japan are expected to contribute further to the improvement of processing methods and to the development of new foods that will be suitable for consumption of soybeans, as well as other legumes, in foreign countries.

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Discussion

F. B. Ballon: What causes the flatulence or gas-forming factor of soybean fermented food? Is there a varietal difference when it comes to this factor?

H. Ebine: Oligosaccharides, such as stachyose and raffinose, at a 3 to 5 percent level in soybeans cause flatulence because they are not absorbed until they move to the large intestine. The content of these oligosaccharides differs from sample to sample to some extent, but we are not sure whether the difference is due to variety differences. Some papers on this problem have been published by Dr. S. Kawamura, Agriculture Department, Kagawa University, Kagawa-Ken, Japan.

Simple Processing of Whole Soybeans for Food

L. K. Ferrier

The soybean is an excellent source of major nutrients. About 40 percent of the dry matter is protein, and the amino acid pattern approaches the optimum recommended by the Food and Agriculture Organization of the United Nations (FAO). The soybean also contains about 20 percent fat. The oil is desirable because it contains a large proportion of unsaturated fatty acids (Tables 1, 2). In addition, soybeans appear to be a good source of essential vitamins and minerals (Tables 3, 4). Thus, the soybean has great potential for people who rely mostly upon vegetable sources for protein.

Nearly all of the soybeans produced in the United States and Brasil are processed in oil extraction plants. The oil is generally used for cooking, mayonnaise, salad dressing, and margarine the world over. The extracted flakes, which contain about 50 percent protein, are used mainly as a protein source for animal feed. However, as discussed by Prof. Amara in this conference, food uses for the extracted flakes are increasing rapidly. Some of the products processed for human food from the extracted flakes include soy protein concentrates, isolated soy protein, textured vegetable protein, and soy protein meat analogues.

FOOD USES FOR WHOLE SOYBEANS

Another promising method for preparing foods for home consumption and commercial processing is to use the whole, full fat soybean. The Department of Food Science at the University of Illinois has developed procedures for processing whole soybeans into many products that appear to have culinary potential (Bird et al., 1973; Nelson et al., 1971; Nelson et al., 1975; Shemer et al., 1973; Wei et al., 1973; Anon., 1972). The processing procedure is straightforward and uncomplicated. The basic process is described in an earlier publication (Nelson, 1971). All of the processes start with field-dried soybeans, which are carefully cleaned to remove foreign material and damaged or moldy beans. After cleaning, the beans are hydrated by soaking in tap water for at least five hours, then precooked (blanched) in boiling water for 20 to 30 minutes. For products that require tender, blanched beans, 0.5 percent sodium bicarbonate is added to the blanching water. Products that do not require tender beans can be hydrated and blanched in a single operation that requires at least 20 minutes in boiling water. In some cases, the soybeans may be blanched with steam. After blanching, the beans are bland in taste and chewy to tender in texture, depending upon the methods followed in hydration and blanching. Water-blanched beans will contain 50 to 70 percent moisture, whereas steam-blanched beans will contain 20 to 30 percent moisture.

The bland taste of soybeans produced in this way is directly related to inactivation of enzymes, principally the lipoxygenase enzyme system, in the *raw* soybean before the tissue is disrupted. When the *raw* tissue is broken, the enzyme and substrate (oil) are liberated, and, provided some moisture is present, a bitter, beany taste develops very rapidly. However, the enzyme system is inactivated if the whole soybean is first hydrated and blanched in boiling water or steam. This enzyme inactivation completely *prevents* formation of any bitter, beany, or painty flavor. Blanching simultaneously destroys the trypsin inhibitors, hemagglutinins, and other known toxic factors present in the raw beans. If present, these inhibitors would substantially reduce the nutritional quality of the soybeans by inhibiting trypsin and other digestive enzymes. The length of time required to destroy these components decreases with increased moisture content of whole soybeans. For example, trypsin inhibitors can be destroyed in rehydrated beans (containing 50 to 60 percent moisture) by boiling for five minutes. However, if dry soybeans are used, they must be boiled for 20 minutes to destroy trypsin inhibitors. Lipoxygenase is inactivated in rehydrated soybeans by boiling for less than five minutes.

Boiling is also essential to produce an acceptable texture and, for practical purposes, the desired texture will dictate the boiling time required. Use of softened water (pH about 7.5) or of a 0.5 percent sodium bicarbonate

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Table 1. Amino Acid Composition of Soybean Protein

Amino acid	Amino acid content (g/g total nitrogen)							
	FAO pattern[b]	FAO data[a]		Other reported values (seed)[c]			Full fat flour[d]	Concentrate[e]
		Seed	Cake					
Isoleucine	4.2	4.5	4.8	5.8	6.4	5.5	4.8	4.9
Leucine	4.8	7.8	7.8	7.6	6.6	7.7	7.8	8.0
Lysine	4.2	6.4	6.1	6.6	6.4	6.2	6.5	6.6
Methionine	2.2	1.3	1.4	1.1	0.7	1.4	1.4	1.3
Cystine	4.2	1.3	1.7	1.2	..	..	1.6	1.6
Phenylalanine	2.8	4.9	5.0	4.8	4.8	4.9	5.1	5.3
Tryosine	2.8	3.1	3.8	3.2	3.1	..	3.9	3.7
Threonine	2.8	3.9	4.3	3.9	3.8	4.0	4.2	4.3
Tryptophan	1.4	1.3	1.5	1.2	1.2	1.7	..	1.4
Valine	4.2	4.8	5.2	5.2	5.0	5.4	5.0	5.0
Arginine	..	7.2	7.1	7.0	6.0	7.5	..	..
Histidine	..	2.5	2.5	2.5	2.3	2.5	..	..
Alanine	..	4.3	4.5	3.8	..	..	..	..
Aspartic acid	..	11.7	11.5	..	..	..	..	..
Glutamic acid	..	18.7	18.5	18.5	..	..	..	..
Glycine	..	4.2	4.5	8.3	..	..	..	..
Proline	..	5.5	5.6	5.4	..	..	..	..
Serine	..	5.1	5.6	5.6	..	..	..	..

[a] Amino Acid Content of Foods and Biological Data on Proteins, FAO, Rome, 1968.
[b] Lawrie, 1970.
[c] Cravens and Sipes, 1958.
[d] Iriarte and Barnes, 1966.
[e] Meyer, 1967.

solution (pH 7.5 to 7.9) results in much more rapid tenderization and reduces the cooking time required to about one-third of that required when tap water is used. The bicarbonate may be added to either the soaking water, the cooking water, or both. Use in both soaking and cooking water is the most effective. However, the use of sodium bicarbonate results in a slightly different taste compared with that obtained in tap water. We have not found the taste objectionable, but if it is to some people, or if sodium bicarbonate is in short supply, then soaking in bicarbonate solution and cooking in tap water may be a preferable method of processing. However, the cooked beans will be less tender. Also, the pH may be raised to 8.0 or 8.5 if faster tenderization is desirable. It is important to note, however, that a high pH will probably increase the loss of thiamine (vitamin B_1).

Soaking and boiling also remove about one-third of the oligosaccharides in soybeans, some of which are believed responsible for the production of intestinal gas, or flatus. Only a small amount of the protein (1 percent of the Kjeldahl N) is lost during soaking and blanching. Most of the nitrogen lost appears to be nonprotein nitrogen.

As mentioned earlier, when the tissue of the soybean cotyledon is disrupted or damaged and moisture is present, the characteristic beany or painty off-flavor develops. In University of Illinois tests, drum-dried flakes were prepared, using 0, 25, 50, 75, and 100 percent slightly

Table 2. Fatty Acid Composition of Soybean Oil

Saturated acids		Unsaturated acids	
Name	Range (%)	Name	Range (%)
Lauric	0.0-0.2[a]	Dodecanoic	.....
Myristic	0.1-0.4	Tetradecanoic	0.05-0.64
Palmitic	6.5-9.8	Hexadecanoic and palmitoleic	0.42-1.60
Stearic	2.4-5.5	Oleic	10.9-60.0
Arachidic	0.2-0.9	Linoleic	25.0-64.8
Behenic	.....	Linolenic	0.3-12.1
Lignoceric	0.0-0.1	Arachidonic	Traces
Total saturated acids	15.0	Total unsaturated acids	85.0

[a] Includes traces of lower molecular weight acids (Danbert, 1950).

Table 3. Vitamin Content of Soybeans

Vitamin	Mature bean		Meal	
	ug vitamin/g soybean	% of RDA[a] (100 g)	ug vitamin/g soybean	% of RDA[a] (100 g)
Thiamine	11.0-17.5	95	12.00-44.1	187
Riboflavin	3.4-3.6	19	2.7-3.3	17
Niacin	21.4-23.0	11	19.0-40.0	15
Pyridoxine	7.1-12.0	48	8.8	44
Biotin	.08	3	1.1-1.7	5
Pantothenic acid	13.0-21.5	..	13.3-16.0	..
Folic acid	1.9	47	3.7	92
Inositol	2,300	..	2,500-3,900	..
Choline	3,400	..	.....	..
Carotene (as provitamin A)	0.18-2.43	13	.....	..
Vitamin E	1.4	..	.....	..
Vitamin K	1.9	..	.....	..

[a] Based on mean value between the two extremes and an assumption that all of the vitamin is biologically available. Based on Recommended Daily Allowances from: Food and Nutrition Board, N.A.S.-N.R.C. (U.S.A.) for adult male (19-22 years old; 70 kg body weight), 1974.

Source: adapted from Smith and Circle, 1972.

Table 4. Mineral Content of Soybeans

Mineral	Mature bean		Meal	
	Amount	% of RDA[a] (100 g)	Amount	% of RDA[a] (100 g)
	percentage		*percentage*	
Calcium	0.16-0.47	39	0.24-0.31	34
Phosphorus	0.42-0.82	77	0.60	75
Magnesium	0.22-0.24	66	0.24-0.30	77
	mg/kg		*mg/kg*	
Zinc	37	24	55-77	44
Iron	90-150	120	140	140

[a] Based on mean value between the two extremes and an assumption that all of the mineral is available. Based on Recommended Daily Allowance from: Food and Nutrition Board, N.A.S.-N.R.C. (U.S.A.) for adult male (19-22 years old; 70 kg body weight), 1974.

Source: adapted from Smith and Circle, 1972.

damaged soybeans (Rodda et al., 1973). Taste panels could easily detect the beany off-flavor when 25 percent slightly damaged soybeans were processed, although the off-flavor was not pronounced. If hull damage is greater than 15 to 20 percent, blanching before soaking is recommended.

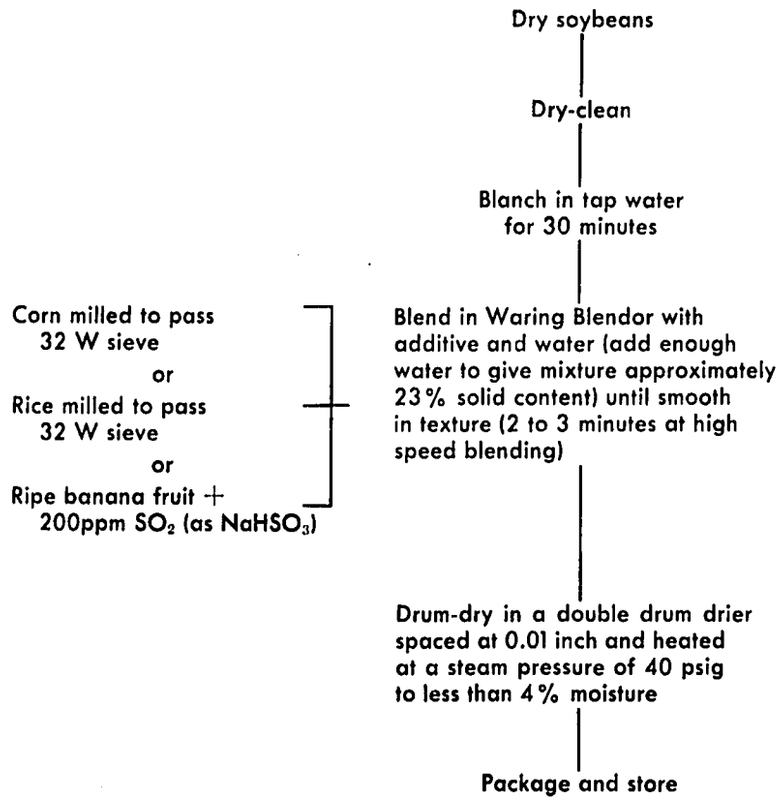
Properly hydrated and blanched soybeans offer great potential for processing into a wide variety of food products. Some of the foods that were made at the University of Illinois are listed in Appendix I. Each category will be discussed briefly.

CATEGORY I: DRUM-DRIED FLAKES

The drum-dried flakes were made by grinding cooked whole soybeans into a smooth slurry and drum drying the slurry on a double drum drier. If the final product contains other materials, such as fruit or cereals, these are mixed with the soybean slurry and the combination is drum dried (Fig. 1). The dried flakes may be ground to any fineness desired. These flakes may be used directly as a weaning food or they may be mixed into other food, such as baked goods, to increase the protein content. Mixtures of soybeans and cereals, such as corn or rice, improve the balance of essential amino acids. Cereals are typically low in lysine and adequate in methionine, whereas legumes, such as soybeans, are normally the reverse, that is, low in methionine and high in lysine. We have determined protein efficiency ratio (PER) for several drum-dried, soybean-cereal combinations and found that all PER's were between 2.0 and 2.5 (PER for casein = 2.5).

Drum-dried, soybean-fruit mixtures have potential because of the dominant fruit flavor and the increased protein and calorie content of the dried flakes. Soybean-

Fig. 1. Preparation of drum-dried soybean flakes using soybean-banana (50:50 or 60:40 on solid basis), whole soybean flake, soybean-rice (1:1), or soybean-corn (1:2).



banana flakes (1:1) were prepared in the manner described in Fig. 1, and by Bird et al. (1973). The best product resulted when very ripe bananas were used. This product was very stable and contained a good mixture of the major nutrients, viz., 23 percent protein, 9 percent oil, and 50 percent carbohydrate. It was found to be low in methionine (Spata et al., 1974) and its PER was below 2, but this deficiency can be corrected by adding maize to the formula (Bressani et al., 1974). This product should provide a tasty, nutritious weaning food simply by mixing with boiling water. This also provides a method for using very ripe bananas that would otherwise be discarded.

CATEGORY II: CANNED SOYBEANS

Hydration and blanching of whole soybeans offer possibilities for preparing a variety of foods for home use. Many recipes have been developed and are available from a number of countries. At present, however, the procedures in some of these recipes allow some lipoxygenase activity. We believe that the method of hydration and blanching described in this paper will eliminate this activity, thus improving the flavor of foods prepared from these recipes. We also believe that addition of sodium bicarbonate to the water will result in more tender, and therefore more acceptable, soybeans.

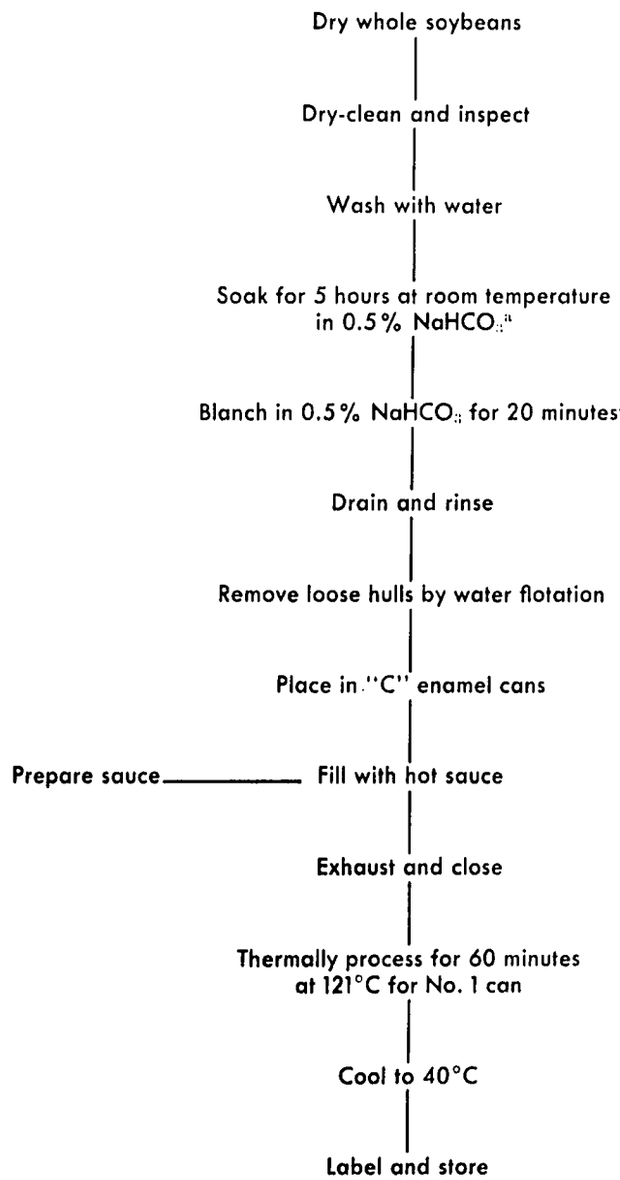
We have used a number of formulations to prepare canned soybeans having a variety of flavors (Appendices I and II). Except for the use of sodium bicarbonate in the soaking water, all of the procedures used are standard for canning beans. The major steps are listed in Fig. 2; three sauces are given in Appendix II. Organoleptic evaluations demonstrated that canned soybeans are highly acceptable. The response of visitors from many countries throughout the world indicates that cooked or canned soybeans should have very wide acceptance, provided they can be cooked to adequate tenderness in a reasonable length of time. Since sodium bicarbonate is not readily available in most developing countries, the tenderness and cooking time of soybeans is still an important obstacle to their acceptance.

CATEGORY III: DAIRY PRODUCT ANALOGUES

At the University of Illinois a simple process using blanched whole soybeans was developed to produce a stable soy beverage with no beany flavor (Nelson et al., 1975). This beverage contains up to 3.5 percent protein (depending on dilution), which is equivalent to the amount of protein in cows' milk and nearly twice that in soymilks currently marketed or soymilks manufactured by the traditional oriental process. About 99 percent of the protein and over 90 percent of the total solids are recovered from the bean cotyledons. The only losses occur during blanching, and these (primarily carbohydrate) are believed desirable with respect to reducing flatus (Wei et al., 1973). Basically the beverages are prepared by grinding cooked soybeans with water in a hammermill, homogenizing, adding sucrose and flavoring, homogenizing, and pasteurizing (Fig. 3). A University of Illinois patent covers the preparation of the soybean beverage base (Nelson et al., 1975).

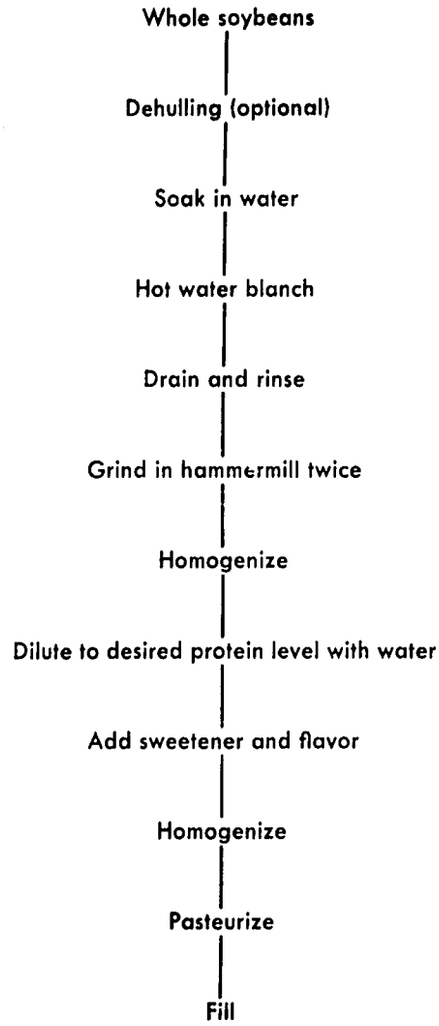
The major advantages of this process are an excellent, mild flavor, no off-flavor, destruction of antinutritional factors, and increased nutritional value relative to almost all other soybean beverages. The major disandvantage is the necessity of homogenization in order to produce a stable suspension. The beverage base has been used to replace milk in products such as soy ice cream, soy yogurt, custard, and diet margarine, all of which are prepared by conventional methods. It is presently manufactured on a pilot plant scale and marketed by G. B. Pant

Fig. 2. Canned soybean products.



[a] One, but not both, of these steps may be omitted if necessary. Soaking is important to develop more tender soybeans. Blanching is important for reducing gelation of the brine (FAO, 1968).

Fig. 3. Preparation of a soybean beverage base.



University, Pantnagar, India. The selling price, which allows some profit, is roughly three-fourths that of cows' milk.

CATEGORY IV: SPREADS

Spreads, or intermediate moisture foods, constitute another group. An excellent diet margarine was prepared by conventional methods but using soy beverage instead of milk solids. A very acceptable potato chip dip can be prepared simply by changing the flavorings used. Roasted soybean cotyledons plus added soybean or other oil can be processed, using a colloid mill, into a "soybean butter" that resembles peanut butter in texture and flavor.

CATEGORY V: SNACK FOODS

Tasty snacks may provide an avenue for introducing soybean foods to people who normally resist trying any unfamiliar food. Soybeans can be roasted to make a dry nut similar to peanuts. First, the dry soybeans should be dehulled with as little damage to the cotyledon as possible. At home, dehulling can be done by rubbing small handfuls of cooked soybeans between the hands. The mixture is rinsed with water to remove the hulls and fines. After blanching for 20 to 30 minutes and draining, the cotyledons are deep fried in oil at about 190°C for three minutes. In the home, they may be roasted in a frying pan with a little oil, but the roasting time will be longer. If the hulls are left on, the roasting time is still longer and the product will not be uniformly roasted. Salt or other flavorings should be added while the beans are still hot.

Puffed snack foods have also been prepared, using a Wenger X-5 extruder. The starting material contains about 20 percent full fat soy flour and 80 percent corn or rice flour. After adding oil and flavoring, as is usually done to this type of snack, the protein content is at least 3 g per 100 calories, or about 12 percent protein. (The recommended daily allowance in the United States is about 2.0 to 2.3 g per 100 calories.)

Many others have reported using whole soybeans for preparing high protein foods. For example, Bressani and coworkers (Fig. 4) reported the preparation and nutritional evaluation of numerous soybean:maize mixtures for possible use in tortillas (Bressani, 1974; Bressani et al., 1974). They found that the best ratio of soybean: maize was 28:72 (Table 5). This mixture gave a PER of 2.54, whereas 100 percent maize resulted in a PER of 0.69 (casein, 2.87). Tortillas made from a mixture of maize:whole soybeans (85:15) were prepared in a manner similar to that shown in Fig. 4, except that the dough, not the flour, was used directly to prepare the tortillas. The tortillas were reported to have physical and organoleptic characteristics very similar to those of tortillas made from maize. However, the protein content was increased from 10 to 14 percent and the PER increased from 0.95 to 1.72. More recent reports from the Instituto de Nutricion en Centroamerica y Panama

Fig. 4. Processing of mixtures of maize and soybeans (Bressani et al., 1974).

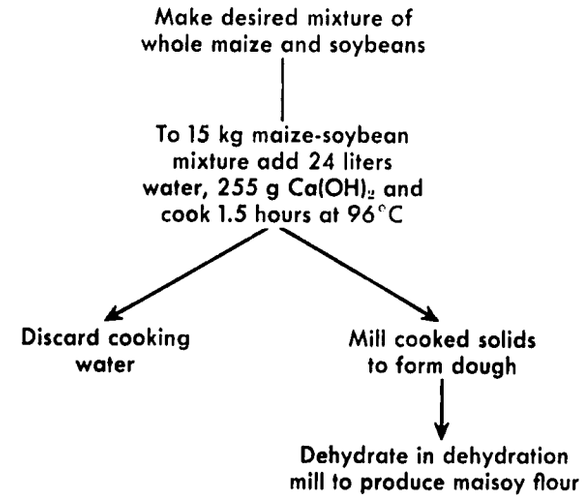


Table 5. Protein and Fat Content and Protein Value of Different Preparations[a]

Mixture		Content		Av wt gain (g)[b]	Protein efficiency ratio
Maize	Soybean	Protein	Fat		
(%)		(%)			
100	0	9.9	4.5	12	0.69
79	21	16.9	8.9	81	2.08
72	28	17.6	10.3	91	2.54
62	38	18.1	11.3	99	2.37
0	100	40.0	25.6	101	2.03
Casein		...	...	120	2.87

[a] All diets were calculated to contain 9 percent protein.
[b] Average initial weight: 47 g.

Source: Bressani et al., 1974.

indicate that an optimum PER was obtained if one-half the protein came from soybeans, and one-half from corn. Different optimum ratios were found for rice and wheat (Bressani, 1975).

Another interesting soybean:corn combination is Soy-Ogi, a product developed by the Federal Institute for Industrial Research, Oshodi (FIIRO) in Nigeria. (For information contact Director of Research, FIIRO, P.M.B. 1023, Ikeja, Lagos, Nigeria.) Test marketing for Soy-Ogi, which is produced by a pilot-scale production facility at FIIRO, began in July 1974. Preparation of Soy-Ogi begins by steeping whole corn in water for 24 hours. The corn is wet milled and placed in a fermentation vat. Whole soybeans are dehulled, steamed, ground, and added to the same fermentation vat. The ratio of dry soybeans and dry corn used is 3:7. As reported by Bressani, and as we have noted in our own work at the University of Illinois, a 3:7 or 2:8 ratio of soy:corn will yield an optimum balance of amino acids. The mixture is allowed to ferment, using the natural flora developed during the corn steep, and in a manner similar to that used in the preparation of Ogi, a staple Nigerian pap used for feeding children. After fermentation, the slurry is pasteurized and spray dried. The protein content of the powder is about 20 percent. An adult version of Soy-Ogi, which contains 12 percent protein, was also developed. Both products are prepared by mixing with water and bringing to a boil. Different amounts of water, or addition of other foods, may be used to prepare products with different thicknesses or flavors.

Spata et al. (1974) reported the development of a soybean dal. (Dals are cracked pulses and are a staple in many Indian diets.) Soybeans were dehulled, cracked, and the cotyledons and hulls separated. The cracked cotyledons were dropped directly into boiling water, blanched, and dried in the sun or with a hot air dryer. The estimated cost was within the range of locally used dals; organoleptic evaluation demonstrated good acceptability.

The Ethiopian Nutrition Institute has produced a cereal-legume mixture called Faffa, which is a combination of 57 percent wheat flour, 10 percent pea flour, 18 percent soy flour, 5 percent dry milk, 8 percent sugar, with 2 percent salt and vitamins added. The dry mixture contains over 20 percent protein and is intended as a baby or children's food. The mixture is prepared by dry milling and blending in a pilot plant, which costs about US$50,000 to build and which produces nearly 300 tons of Faffa per month.

These examples illustrate the wide variety of tasty and nutritious foods that can be manufactured from a single starting material, the cooked, whole soybean. We believe they demonstrate a great potential for this versatile food ingredient, and we believe that these and other soybean products can be adapted to fit the taste and texture preferences of people throughout the world.

APPENDIX I. PROTOTYPE FOODS MADE FROM WHOLE SOYBEANS

Category I: Drum-Dried Flakes

1. 100% whole soybean
2. Soy-rice (1:1, 1:3, and 1:4)
3. Soy-corn (1:1, 1:3, and 1:4)
4. Soy-brown sugar-peanut (50:35:15)
5. Soy-banana (1:1) weaning food

Category II: Canned Soybeans

1. Vegetarian soybeans
2. Three-bean salad
3. Soy with chicken
4. Soy with pork
5. Soy with lamb
6. Pork with soybeans

Category III: Dairy Product Analogues

1. Beverage, plain
2. Beverage, chocolate flavored
3. Blend of soy beverage and cottage cheese whey
4. Ice cream, mocha flavored
5. "Yogurt"

Category IV: Spreads

1. Diet spread, margarine flavor
2. Potato chip dip
3. Peanut butter analogue

Category V: Snack Foods

1. Roasted soybean cotyledon
2. Extruded, puffed rice and corn fortified with full fat soy flour

APPENDIX II. SAUCE FORMULATIONS FOR CANNED SOYBEAN PRODUCTS

1. Pork and Beans

Tomato pulp	80 liters
Onion powder	3.0 kg
Garlic powder	200 g
Sugar (brown)	20 kg
Molasses	10 kg
Salt	10 kg
Starch (corn)	800 g
Cayenne pepper	15.2 g
Hydrolyzed vegetable protein	20.0 g

Oil of clove	0.04 ml
Oil of allspice	0.04 ml

Yield sufficient for about 780 No. 1 cans.
Mix all ingredients and heat to boiling.
Fill at 96°-100°C.

2. Soybeans with Chicken

Use 145 g of blanched soybeans plus 28-30 g of precooked, diced chicken to fill a No. 1 can. Fill with sauce. Use proportionally larger amounts to fill larger cans.

Tomato pulp (5% soluble solids)	2.06 kg
MSG	22.5 g
Salt	450 g
Curry powder (McCormick)	22.5 g
Ground cayenne pepper (McCormick)	6.0 g
Corn starch	450 g
Water	2.85 liters
Chicken broth	9.90 liters

3. Vegetarian Soybeans

To fill a No. 1 can use 128 g of blanched soybeans, 28 g of diced carrots, and 14 g of cut green beans.

Tomato pulp (5% soluble solids)	4.11 kg
Salt	600 g
MSG	30 g
Curry powder (McCormick)	45 g
Ground cayenne pepper (McCormick)	45g
HVP (Magge 312)	300 g
Minced onion (Basic, dry)	150 g
Garlic powder (Stange #41019)	15 g
Water	25.5 liters

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Discussion

R. A. Buchanan: Many Asians prefer soymilk with a strong, beany flavor rather than the bland flavor preferred by most westerners. Do you know anything about the preferences of different groups in Asia?

L. K. Ferrier: No, I do not.

F. G. Winarno: This matter will be investigated in a survey we are carrying out among the many ethnic groups in Indonesia.

R. A. Buchanan: How does drum-dried soy flour compare with conventional, full fat soy flour?

L. K. Ferrier: Its functional properties appear to be similar to enzyme-inactivated, full fat flour. Because of the heat treatment given to it, drum-dried soy flour has a lower solubility, but a more bland flavor than enzyme-active (unheated) flour. Soy cereal mixtures prepared by drum drying do not tend to separate during handling, as many products do if they are prepared by dry mixing.

M. C. Saxena: The preparation of soy nuts involves deep frying of blanched beans. Have you made any estimates of PER on this product? I know of reports from Hyderabad in India that indicated deep frying of mung beans resulted in tremendous reduction in PER.

L. K. Ferrier: We have not made any estimates of PER on deep-fried soy nuts. However, the process is relatively mild. The wet cotyledons are dropped into oil (190°C). Steam escapes for about 2 to 2½ minutes; the protein should not be damaged nutritionally during that time. The cotyledons remain in oil for about 45 seconds more and *slight* browning occurs. Thus, we would not expect a serious reduction in PER.

Nutrition and Processing of Soybeans

F. G. Winarno and Darwin Karyadi

Many aspects of soybean nutrition and processing have been thoroughly examined and discussed in several papers and textbooks; hence no new findings in this area will be discussed here. Rather, this paper emphasizes the importance of soybeans in the nutrition of Asian people, traditional processing methods, and the development of new foods, which include high protein food mixtures using soybeans and cereals. Because the data available from other Asian countries is limited, this presentation is based on data only from Indonesia, which is used as an illustrative model with the hope that it is representative.

NUTRITIONAL STATUS

Although the data on the nutritional status of Asian countries, particularly those in Southeast Asia, are still incomplete, there is reason to believe that human nutrition is unsatisfactory (Winarno et al., 1975). Nutrition surveys and food pattern studies conducted in Indonesia in the last 20 years have shown that the main problems directly related to poor nutrition are protein and calorie malnutrition, vitamin A deficiency, anemia, and endemic goiter (Prawiranegara, 1974).

Generally, the mortality rate of the preschool child below the age of four years is high, and cases of protein-calorie malnutrition (PCM) are highly prevalent in villages and semiurban communities. A high mortality rate among infants and young children is often an indication of a country's poor nutritional status. Such is the case in Indonesia. In his address to the National Working Conference on Nutrition in 1974, Indonesia's President Suharto noted that out of 1,000 live births annually, about 150 babies die before the age of one year. In a country with good nutritional status the rate is 20 out of 1,000.

The high infant mortality rate is in large part due to the poor nutrition of pregnant and nursing mothers who do not get enough calories or good-quality protein, which results in a lowering of the infant's resistance. Samsudin (1971) reported that PCM was found in 30 to 50 percent of Indonesian children between the ages of 1 and 3 years. However, kwarshiorhor, a severe, chronic protein-calorie deficiency disease, was found in 1 to 2 percent of hospitalized children, with a peak incidence occurring in the 12 to 16 month age group.

In an evaluation study by the Applied Nutrition Program conducted in 1972-1973 (Sajogyo, 1975), nutrition problems in eight out of 26 provinces were studied from the standpoint of socio-economics and family food habits. The study recommended that nutrition improvement programs should give priority to pregnant and nursing mothers, and children below the age of two years.

In an attempt to produce more protein, ASEAN countries are collaborating on research of soybeans and other protein foods. Soybeans have been studied more intensively because they are the best plant source of good-quality protein. Moreover, most ASEAN people are familiar with and use soybeans or soybean products in their daily diets.

SOYBEANS AS SOURCE OF GOOD-QUALITY PROTEIN

Chemical Composition

In addition to the chemical components of soybeans shown in Table 1, Sherman and Salmon (1939) determined that ripe soybeans contain 18 to 243 micrograms of carotene per 100 grams. Depending on the chemical structure, carotene may be converted into vitamin A in the human body. Besides nicotinic acid, thiamine, and riboflavin, the beans also contain other vitamins of the B complex:

Pyridoxin (vitamin B_6)	1,180 mg/100 g
Pantothenic acid	2,150 mg/100 g
Biotin	80 mg/100 g

Other vitamins present in soybeans include vitamin E (d-tocopherol), 140 mg per 100 grams, and vitamin K, 100 mg per 100 grams (Shurpalekar et al., 1961).

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Table 1. Chemical Composition of Raw Soybeans

Nutrients	Average per 100 g soybeans
Moisture	7 g
Protein	35–45 g
Oil	18–22 g
Carbohydrates	12–14 g
Crude fibre	3.7–5.0 g
Ash	4.6–5.4 g
Calcium (Ca)	250 mg
Phosphorus (P)	700 mg
Iron (Fe)	7 mg
Potassium (K)	1,553 mg
Sodium (Na)	319 mg
Nicotinic acid	2.1 mg
Thiamine (vitamin B_1)	1,000 mcg
Riboflavin (vitamin B_2)	310 mcg

Source: Nichols et al., 1961.

Table 2. Protein Price of Different Commodities in Bogor, Indonesia, February 1976

Source	Price of food in US $ per kg	Protein (%)	Price of protein in US$ per kg
Beef	2.17	15	14.47
Pork	2.89	12	24.88
Poultry	2.89	20	14.45
Egg	1.57	12	13.05
Dry beans	0.36	23	1.57
Soybeans	0.48	38	1.27
Rice	0.36	7	5.14

Table 3. Composition of Essential Amino Acids of Soybean, Egg, Milk, and Rice Protein

Essential amino acid	Amino acid content (mg/g protein)			
	Egg	Milk	Soybean	Rice
Isoleucine	415	407	340	322
Leucine	553	603	480	535
Lysine	403	496	400	236
Phenylalanine	365	311	310	307
Tyrosine	262	323	200	269
Methionine	197	154	80	142
Cystine	149	57	110	80
Threonine	317	292	250	241
Tryptophan	100	90	90	65
Valine	454	440	330	415

Source: Lie et al., 1974.

Nutritive Value

Soybean has become an important food crop because of its high content of inexpensive, high-quality protein, oil, vitamins, and minerals. Comparisons of the price of various protein foods per kg indicate that soybeans are the cheapest source of protein. Table 2 compares costs of protein foods based on the average retail price in the markets of Bogor, Indonesia, at the beginning of February 1976.

High-quality animal and soybean protein has a favorable ratio in the contents of essential amino acids. Table 3 shows that the essential amino acid composition of soybeans is comparable to that of milk only, although the content of the sulphur-containing amino acid, methionine, is somewhat lower. This is the limiting amino acid in soybean protein.

Soybeans also have a relatively high oil content, which in turn is rich in polyunsaturated fatty acids, viz., linoleic acid (52.3 percent) and linolenic acid (7.2 percent). The digestibility of soybean oil in the human body is similar to that of other edible oils. These essential fatty acids, linoleic and linolenic acids, seem to reduce the cholesterol content of the blood, thus decreasing the possibility of heart and blood vessel diseases.

Other Components

Other compounds present in soybeans are trypsin inhibitors, hemagglutinins, and lipoxygenase. The trypsin inhibitor compound was isolated for the first time by Kunitz in 1947 in crystalline form. This inhibitor is a protein having a molecular weight of about 25,000 and an isoelectric point at pH 4.5. It inhibits the action of trypsin by forming an irreversible double protein compound. A solution of this inhibitor is stable over a wide pH range at temperatures below 10°C. Above 60°C the denaturation proceeds nearly to completion, and at 70°C it is completely denatured in less than 2 minutes (Kunitz, 1949). Irreversible denaturation takes place at 90°C.

Hemagglutinins, a protein compound that agglutinates red blood cells, were first isolated by Liener and Pallansch in 1952 (Smith and Circle, 1972). Raw soy flour contains about 3 percent hemagglutinins. Reports indicate that the hemagglutinating activity of raw soybeans is readily destroyed by moist heat treatment. Fortunately both the trypsin inhibitors and hemagglutinins in soybeans are thermolabile. Steaming at 100°C inactivates the antinutritional factors in raw soy flour, thus rendering a maximum protein efficiency ratio. Soymilk should always be boiled for 5 to 10 minutes before being consumed so that no active inhibitors and hemagglutinins will be present.

Lipoxygenase, an enzyme found in soybeans, catalyzes the oxidation of unsaturated fatty acids by molecular oxygen, which results in rancidity, off-flavors, and poor storage stability. Lipoxygenase is, however, very sensitive to heat and is destroyed at 82°C in 15 minutes (Baker and Mustakas, 1972).

STORAGE OF SOYBEANS

After harvest and during storage, soybeans are susceptible to damage that can result in impairment of their nutritive value and palatability. Proper post-harvest technology is important to prevent damage.

Soybeans stored in farm bins rarely become infested with insects, but occasionally bran beetles occur in high-moisture beans, which can be fumigated like small grains. Heating of soybeans stored in deep, poorly ventilated bins may take place if the beans are not dry when stored. Storing in shallow bins or on the floor until the

beans are dry is recommended. If soybeans are sacked, the sacks should be left open (Piper and Morse, 1943).

The nature of the surrounding atmosphere appears to have important effects on stored soybeans. Soybeans stored in open bins under high relative humidities deteriorate in a few months, but soybeans with 9 percent moisture content can be stored for about 21 months if high humidity conditions are avoided. Soybeans with a moisture content below 12 percent showed little deterioration after three years when stored in a tight bin. The relative humidity during storage should be less than 70 percent if the storage temperature is 25°C. The corresponding equilibrium moisture content will then be lower than 12.4 percent (Thio, 1975).

PROCESSING AND ITS EFFECTS ON NUTRITIVE VALUE

In contrast to the common legumes, soybeans are consumed in a variety of forms that require different processing methods. Traditionally two types of processes developed in Asian countries are used. One method, based on the use of water extracted from soaked and ground beans, is used to make bean curd and soymilk. The other method uses fungi to produce fermented products, such as soy sauce, natto, miso, and tempeh. In the latter case, the protein is digested to peptides and even to amino acids, and flavor is improved. These traditional foods have been produced for centuries in China, Japan, and Indonesia on a home or cottage scale. In Japan, however, soybean curd is being manufactured on a relatively large scale, some of it in the form of freeze-dried bean curd.

Soybean milk has been of considerable interest to nutritionists as a possible substitute for human or cow's milk, particularly in the feeding of infants who are allergic to animal milk, or where cow's milk may be either too expensive or unavailable.

Effects of Heating on Nutritive Value

Unless well cooked, ripe soybeans do not support animal or human growth. At present soybeans as such do not play an important role in human nutrition because they are relatively difficult to tenderize by ordinary cooking. Moreover, they have a bitter taste. Consequently, simple processing methods need to be developed and introduced into small-scale industries and kitchens in rural areas.

The nutritive value of soybeans may be improved by heat treatment or by processing into soybean products. The degree of nutritional improvement by heating depends upon, among other things, the temperature, duration of heating, pressure, and whether dry or moist heating is used. As mentioned earlier, two biologically active compounds (trypsin inhibitors and hemagglutinins) are thermolabile. The beneficial effects of heat treatment on the nutritive value is related to the inactivation of both components.

Excessive heating may destroy certain amino acids, such as lysine and particularly cystine, that are sensitive to heat. The loss by excessive heating may be more than 50 percent. Other amino acids, such as arginine, tryptophan, histidine, and serine, may also be partially destroyed (Smith and Circle, 1972). The effects of different heat treatments and processing methods on soybeans and soybean products are shown in Table 4.

Table 4. Effect of Treatments on Protein Efficiency Ratio, Biological Value, and Digestibility of Soybeans and Soybean Products

Product	Treatment	PER[a]	BV[b]	Digestibility
Raw, immature	none	1.1	49	88
	autoclaved	2.0	..	..
Raw, vine-ripened	none	0.5	69	85
	autoclaved	1.5	..	..
Raw, mature	none	0.7	58	82
	dry heated	0.7	..	..
	steamed	1.3	..	92
	autoclaved	1.3	64	90
Raw, germinate	none	1.4	..	..
	autoclaved	1.9	..	..
Meal, solvent extracted	none	0.5	52	74
	autoclaved	1.9	69	89
Soymilk	none	2.0	79	91
Tofu	none	1.8	68	96
Tempeh	none	2.2	..	..
	steamed 2 hours	2.1	..	..
	deep fat fried 7 minutes	0.6	..	..

[a] PER: Protein Efficiency Ratio -- Gain in body weight divided by weight of protein consumed (FAO/WHO 1965).
[b] BV: Biological Value — The proportion (%) of absorbed nitrogen retained in the body for maintenance and/or growth (FAO/WHO 1965).

Source: Thio, 1975.

Table 5. Effect of Steaming on Flavor of Soy Flour

Steaming (minutes)	Flavor score[a]	Flavor description
0	1.5	beany bitter, green
3	4.5	beany, bitter, nutty, toasted sweet
10	6.0	beany, nutty, bitter, toasted sweet
20	6.3	beany, nutty, bitter, toasted sweet
40	6.1	beany, nutty, bitter, toasted sweet

[a] 1 = Strong; 10 = Bland.

Source: Rackis et al., 1966.

Effects of Heating on Flavor

Raw, matured soybeans have a bitter, astringent taste, and when eaten in this form will generate gas (flatulence) and cause diarrhea. A high proportion of the carbohydrate in soybeans is indigestible. The effect of live steam on soybean flavor is shown in Table 5.

Raw meal is usually described as tasting beany, bitter, and green. The green taste disappears after steaming three minutes at atmospheric pressure. The beany, bitter flavor, as well as the nutty, sweet, and toasted flavors, varied in intensity with continued steaming. Data show that flavor scores were not improved by steaming longer

than 20 minutes, which is approximately the time required to achieve the maximum nutritive value.

Soybean Varieties and Processing Methods

There is also a need to develop special varieties of soybeans for specific methods of processing to get a product with improved flavor and nutritional value. Although efforts are being made in Asia and the Far East to develop varieties suitable for particular soils and climates and to give increased yield, hardly any effort has been made to develop varieties best suited to particular processing methods. At present, for example, most of the soybean varieties grown in the Far East are of the field type used for oil extraction rather than vegetable types (Anon., 1967).

HIGH PROTEIN FOOD MIXTURES

The deficiency of sulphur-containing amino acids, which characterizes the protein of most soybean products, can sometimes be minimized by combining such products with other protein foods not deficient in these amino acids. But more important perhaps is the fact that any amino acid that may be limited in other protein foods may be present in excess amounts in soybean protein. It is possible to combine soybeans with other protein sources in such a way as to provide a mixture that is nutritionally superior to each one alone. Marked improvement in PER (Protein Efficiency Ratio) value is obtained when soybean protein is used to supplement protein derived from various cereals. A number of food mixtures developed or produced in Indonesia will be described below.

Saridele. In 1952 the Institute of Nutrition started a study of soybean milk. As a result of the study, a factory was set up in Jogyakarta in 1957 with the assistance of FAO and UNICEF. The product, which was called Saridele, was made from soybeans, peanuts, and sesame seeds, and was fortified with minerals and vitamins. The nutrient composition of Saridele compared with that of cow's milk is shown in Table 6. The production of Saridele was discontinued after 1966 because of the irregular supply of soybeans and marketing problems.

Tempeh-fish-rice (TFR). This mixture, which was developed by the Nutrition Research Institute at Bogor, is composed of tempeh, fish, rice, sugar, and peanut oil. There are two formulas, the second of which was made to improve palatability and nutritional value. Given to children suffering from PCM, the mixture was found to improve body weight and the general condition of the child. The composition and nutrient content of TFR can be seen in Table 7.

Soya-rice baby food. El Rawi and Oey (1960) investigated the PER of mixtures of soybean and its products with rice. A mixture of one part Saridele (30 percent protein) and four parts ground brown rice contains 11.5 percent protein derived in equal amounts from rice and Saridele. The PER of the mixture is 2.98, very similar to that of milk and brown rice in comparable mixtures (PER = 3.24). The combination of rice and Saridele was not only of better biological quality (PER for Saridele was 2.23), but was also appreciably cheaper on a per calorie basis.

The authors also investigated the PER of mixtures comprised of different varieties of soybeans and both brown rice and white polished rice. The mixture is intended as a supplementary food for infants and children. So far, however, no commercial product of this type is available.

Soybean residue-fish-rice. In the preparation of tofu, a soymilk curd, a significant amount of protein is left in the residue. To save this protein, which would otherwise be wasted, the residue is dried. A blend consisting of 75 percent dried residue, 15 percent fish flour, and 10 percent rice flour contains 43 percent protein. The mixture has a standard NPU of 56 and an operative

Table 6. Nutrient Contents of Saridele and Cow's Milk

Nutrients		Saridele	Cow's milk
Protein	g %	30	26
Fat	g %	22	27
Carbohydrate	g %	40	37
Minerals	g %	5	6
Moisture	g %	3	4
Calcium	mg %	450	900
Iron	mg %	3.7	0.7
Vitamin A	IU	2,000	1,080
Thiamine	mg %	0.7	0.24
Riboflavin	mg %	1.0	1.3
Vitamin B_{12}	mcg %	1.0	..
Ascorbic acid	mg %	15	4

Source: Soedarmo, 1959.

Table 7. Composition and Nutritional Value of Tempeh-Fish-Rice

Ingredients	Composition in %	
	TFR-1	TFR-2
Tempeh	30	30
Fish	9	10
Rice	30	30
Sugar	27	25
Peanut oil	4	5
Nutrients	**Nutritional value**	
	TFR-1	TFR-2
Protein g %	23.7	23.7
Fat g %	9.4	7.8
Carbohydrate g %	59.6	61.2
Ash g %	2.3	2.4
Moisture g %	5.0	4.9
NPU std[a]	64	67
NPU op[b]	46	51

[a]NPU std:Net Protein Utilization value standard. This value is obtained by feeding test that is done under standardized conditions.

[b]NPU op: Net Protein Utilization value operative. This value is obtained by feeding experiments using young weanling albino rats, according to standard procedures.

Source: Hermana et al., 1972.

NPU of 30. If one part of the blend is mixed with four parts of rice to give a protein content of 14.7 percent, the NPU of the mixture is 53. The utilization efficiency of protein in the latter mixture, as calculated by net dietary protein calories percent, is 7.5, which is adequate for use as food for toddlers (Hermana, 1974; Lie, 1973).

The soybean residue-fish-rice blend can be made into cookies and crisps, added to vegetable soup, or roasted and eaten as is with rice. A mixture of soybean residue and other food, called "nasi tim," is currently being experimentally fed to infants at the Nutrition Research and Development Centre, Bogor.

Other food mixtures. Other food mixtures prepared by S. S. Hermana (unpublished results) are now being processed on an experimental scale at Bogor as a joint effort between CARE and Bogor Agricultural University (Table 8).

Table 8. Nutritive Value of Some Food Mixtures

Food mixture	Food stuffs	Weight (g)	Calories	Protein (g)	Protein score (%)	Net dietary protein calories (%)
I	Corn	40	340.6	16.16	64.1	7.8
	Dried cassava	20				
	Mung beans	20				
	Soya beans	20				
		100				
II	Corn	50	348.8	18.64	66.2	9.5
	Dried cassava	10				
	Mung beans	20				
	Soya beans	20				
		100				
III	Corn	50	348	17.74	67.0	9.9
	Sorghum	10				
	Mung beans	20				
	Soya beans	20				
		100				

Source: S. S. Hermana, unpublished results.

CONCLUSION

In Asia, particularly in Southeast Asian countries, protein-calorie malnutrition (PCM) is prevalent in villages and in semiurban communities. An evaluation study by the Applied Nutrition Program (1975) recommended that any nutrition improvement program should give priority to pregnant and nursing mothers, and children below two years of age.

The importance of soybeans in the human diet for providing high-quality protein, oil, vitamins, and minerals is well known. Soybeans are also the cheapest source of protein. Most Asian peoples are familiar with this legume and enjoy having soybeans or soybean products in their daily diet.

The effects of processing have been briefly discussed, particularly with regard to the nutritive value of the products. In Indonesia efforts have been made to develop high protein food mixtures using soybeans and cereals. The type of processing for these products is designed for use in the family, home industry, or small-scale industry. In an attempt to produce more protein, ASEAN countries are working collaboratively on research with soybeans and other protein foods.

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Discussion

Leslie Herath: What do you propose to do with the soymilk plant, and from where did you get it?

F. G. Winarno: It came from FAO-UNDP. They are now using it, rather than soybeans, for skim milk as raw material to make a new product called S.G.M. (Susa, Gula, Murjah). The product is a mixture of skim milk, sugar, and oil.

Small-Scale Processing of Soybeans for Food in Thailand

Amara Bhumiratana

Thailand is an agricultural country in which rice is the principal food staple. Although the quantity of rice is adequate to feed the Thai people, in recent years nutrition experts have become increasingly concerned about protein and calorie deficiencies that result from the customary rice diet. To improve the protein and calorie intake of the people, food scientists are concentrating their research efforts on finding improved ways of producing and using soybeans, which are rich in these nutrients.

The Institute of Food Research and Product Development, Kasetsart University, initiated several soybean utilization pilot projects five or six years ago. Using soybeans alone or combined with other ingredients, we have developed a range of products, such as baby foods, kaset protein, and snacks. Tests indicate that these foods are highly acceptable, being both palatable and nutritious. Some of these products are soon to be manufactured commercially by small-scale industries. This paper is a description of the soy food processing methods developed by the Institute.

FERMENTED SOYBEANS

Raw soybeans are soaked for 12 hours and then cooked in boiling water for 3 to 4 hours. After cooling, they are combined with crushed, roasted wheat and spread in bamboo trays. A starter, made from cooked rice inoculated with *Aspergillus oryzae* and incubated until covered with green mold, is thoroughly mixed with the soybeans and wheat. This mixture is allowed to incubate at room temperature for 20 days, after which it is placed in large, earthenware jars with brine, inoculated with yeast (*Zygosaccharomyces shoyu*), and left uncovered for 6 months. The mixture is then covered and left for 18 to 24 months until fully matured.

Chemical analysis:

	Percent
Moisture	56.17
Fat	2.20
Ash	17.70
Salt (NaCl)	11.83
Protein	11.10
Crude fiber	2.31

SOYMILK

Whole soybeans are cracked in a stone mill set on a coarse adjustment. The particles are then washed until clean, soaked in hot water at 80° to 90°C for 20 minutes, drained, and washed in a flotation washer until all the hulls are removed. Next, the dehulled beans are soaked in a solution of sodium bicarbonate at 70°C, drained after 10 minutes, and washed again. One part hot water (80°C) is combined with one part cracked beans and passed either through a stone mill set on a fine adjustment or through a Rietz disintegrator to form a thin paste. In a steam-jacketed kettle trisodium phosphate and additional water are mixed with the paste, which is then centrifuged in a Bird centrifuge. Clear limewater, cane sugar, and iodized salt are added to the decanted liquid and boiled for 5 minutes at 100°C. Coconut milk can be added at this stage if desired. The soymilk is homogenized by filtering twice through a fine cloth.

In the final stage the soymilk is pasteurized prior to bottling or storing in a tank cooler. Milk to be stored in bulk is passed through a coil to cool it to room temperature, and D,L-methionine is added. It is then collected in a tank cooler equipped with an agitator where it is kept chilled and ready for consumption at 1° to 2°C.

When soymilk is to be bottled, sodium metabisulphite (300 ppm) is added. Sterilized bottles are filled with the milk, closed with crown cocks, and processed in a retort at 116°C. After cooling in the retort, the bottled soymilk is ready for distribution.

Soymilk can also be prepared as evaporated canned milk. After sodium metabisulphite (300 to 400 ppm) has been added, along with fresh coconut milk if desired, the soymilk is heated for 2 to 3 hours. During this period it must be stirred constantly and the volume checked. When the volume has been reduced 25 to 50 percent, D,L-methionine is added, and the milk is homogenized

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and poured into hot, sterilized cans, which are then placed in a chamber where the air is exhausted and the cans machine-sealed. The temperature of the milk before exhaust is 80° to 90°C; after exhaust it is 90° to 95°C. The sealed cans are then processed in a retort at 116°C, cooled in running water, and labeled.

Chemical analysis:

	Percent
Moisture	74.50
Fat	4.12
Protein	6.76
Ash	0.80
Carbohydrate (by difference)	13.72
Crude fiber	0.00
Calories per 100 g	119.00
	mg/100 g
Iron	1.23
Calcium	40.05
Phosphorus	105.00
Sodium	142.70
Potassium	136.50
Vitamin A	not found
Vitamin C	not found
Vitamin B_1	0.037
Vitamin B_2	0.123
Niacin	0.125

YUBA

Yuba is made from soymilk heated to near boiling in flat, shallow, open pans until a surface skin is formed (Fig. 1). The skin is then lifted with sticks and air-dried on racks (Fig. 2). As new skin forms, it is removed and dried, a process that is repeated seven or eight times until no new skin forms. Yuba can be pressed or oil-fried to form meat substitutes, or it can be combined with other foods.

Chemical analysis:

	Percent
Fat	25.43
Ash	3.91
Protein	51.65
Crude fiber	0.72

YOGURT

After being washed, cracked soybeans are soaked overnight at room temperature. They are again washed, at which time the hulls are removed by flotation. The dehulled beans, to which one part hot water has been added, are ground and boiled, additional water (five times by volume) being added to form a paste. This paste is centrifuged and the filtrate drawn off into containers. After steaming for 30 minutes, the liquid is inoculated with *Lactobacillus bulgaricus* and *Lactobacillus acidophilus,* and incubated at 37°C for 16 to 20 hours. When matured, the yogurt is chilled for immediate consumption or canned.

Chemical analysis:

	Percent
Acidity	2.68
Fat	0.47
Protein	5.06
Total sugar	15.03
Total solid	25.37

SUFU

Sufu is made by inoculating tofu (soybean curd pressed into cakes) with *Actinomucor elegan.* This is put into jars and combined with ground red rice (Angkak) soaked in brine or red wine. The mixture is aged for 30 days at room temperature. It is usually eaten as a seasoning with soups.

Chemical analysis:

	Percent
Moisture	70.36
Fat	3.51
Ash	9.47
Salt (NaCl)	6.72
Protein	10.04
Crude fiber	0.35

SOYBEAN SNACK (PROTEIN CRISP)

A protein-rich snack has been prepared by inoculating soybean cake with *A. elegan* and incubating for 2 to 3

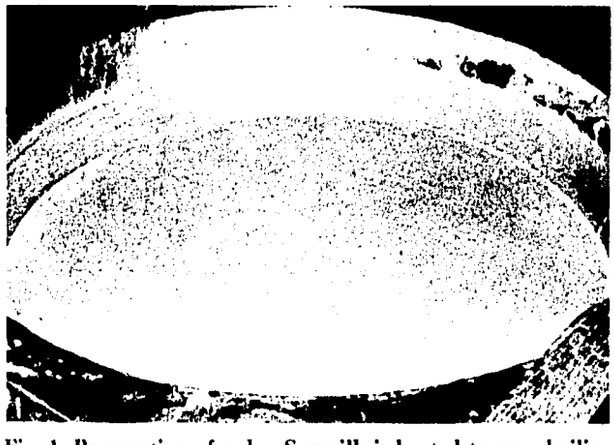

Fig. 1. Preparation of yuba. Soymilk is heated to near boiling in a shallow pan until a surface skin is produced.

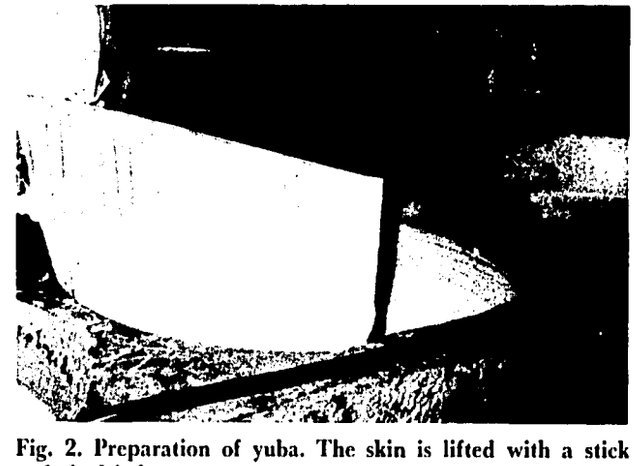

Fig. 2. Preparation of yuba. The skin is lifted with a stick and air dried.

Fig. 3. Preparation of tempeh. Soybeans inoculated with *Rhizopus oligosporus* are incubated 1 to 2 days at 31° C.

Fig. 4. Preparation of tempeh. The fermented beans were dipped in brine and fried in deep fat.

days at 30°C. After the soybean cakes have approximately doubled in bulk, they are sliced waffer-thin, and deep-fat fried.

Chemical analysis:

	Percent
Moisture	5-10
Protein	48-51
Fat	30-42
Ash	0.7-1.0
Crude fiber	1.6-1.7

TEMPEH

Following the usual cracking, soaking, washing, and dehulling process, the soybeans are cooked for 30 minutes. They are then spread on trays and inoculated with *Rhizopus oligosporus,* after which they are incubated at 31°C for 1 to 2 days (Fig. 3). The fermented beans are dipped in brine and fried in deep fat (Fig. 4).

Chemical analysis:

pH	6.3-6.5
	Percent
Moisture	45-55
Protein	20-25
Fat	18
Ash	1
Crude fiber	2

THAI DESSERT

Two desserts, Tou Guan and Med Khanoon, have been prepared from cracked soybeans. After soaking in warm water at 70° to 80°C for 1 to 2 hours and dehulled by flotation, the beans are cooked or steamed for 30 minutes, and finally ground. Tou Guan is made simply by adding sugar and coconut milk, and stirring to form a paste. To make Med Khanoon, sugar and either minced coconut meat or coconut milk are combined with the cooked, ground soybeans, then stirred and heated. After cooling, the mixture is molded into chunks, which are dipped first into beaten egg yolk and then into hot syrup.

Chemical analysis (Tou Guan):

	Percent
Moisture	36.57
Fat	1.36
Ash	0.84
Protein	6.87
Total sugar	41.10

Chemical analysis (Med Khanoon):

	Percent
Moisture	32.56
Fat	12.69
Ash	1.47
Protein	10.96
Crude fiber	1.13
Total sugar	31.80

KANOM PING KASET

These sweet, bite-sized snacks were developed from a blend of wheat flour (35 kg), full fat soy flour (15 kg), and baking powder (2.5 kg) sifted together through a 100-mesh sieve and thoroughly mixed. With a dough beater 96 whole eggs are beaten together with salt, margarine (20 kg), and sugar (23 kg) until foamy. The flour mixture is gradually beaten into the moist ingredients until smoothly blended. The dough is then spread out onto sheets, machine-pressed into the desired shape and size, and baked at 150° to 200°C for 15 minutes. After cooling, the snacks are packaged in plastic bags containing 1,000 grams each.

Chemical analysis:

	Percent
Moisture	4.90
Protein	10.00
Fat	24.21
Ash	2.12
Carbohydrate	57.40
Crude fiber	0.63

BABY FOOD

A nutritious baby food ready to serve when liquid is added has been developed from a combination of premixed vitamins and minerals (1.0 percent), sugar (15 percent), full fat soy flour (12.5 percent), and rice flour (71.5 percent). After being mixed together, these ingredients are blended for 15 minutes. A preconditioner is added, and sometimes steam is injected for precooking, although this is not essential. Following this, the mixture is conveyed by means of a screw feeder through an extruder cooker (X-25) equipped with five heads. Water is injected through the first and fifth heads and steam through the second, third, and fourth heads. The extruder processing time takes between 20 and 40 seconds, and the temperature at the fifth head is from 90° to 100°C. The puffed cereal is then put on a conveyer belt for drying and cooling. For this purpose the conveyer belt, which is 21 feet long, is divided into three sections, the first two of which dry the cereal at 110° to 120°C and 90° to 100°C, respectively. The temperature of the third section is somewhat cooler. Drying takes from 12 to 18 minutes. Finally, the cereal is ground into a powder and packaged in plastic bags of 500 g each.

Chemical analysis:

	Percent
Moisture	5.2
Protein	11.0
Fat	3.0
Ash	1.4
Crude fiber	1.0

KASET NOODLE

Noodles are made from a dough blended of wheat flour, defatted soy flour, D,L-methionine, lysine, sodium carbonate solution, yellow vegetable dye, and water. These ingredients are mixed in a dough mixer for 10 minutes and then rolled to a thickness of 1.5 mm between rollers. If necessary, the surface of the dough is dusted lightly with starch to prevent sticking. Next, the dough is passed through a roller cutter that can be adjusted to cut noodles of varying length and width. The noodles are then ready for immediate consumption.

If the noodles are to be packaged for later use, they are cut and put on bamboo sticks, each of which holds about 45 g of fresh noodles. Then they must be steam-blanched for 5 minutes and dried in a cabinet dryer at 70°C for 4 hours. They are then ready for packaging, four pieces of instant kaset noodle usually being included in each package. The noodles can be eaten alone or with an instant soup mix that consists of seasonings, pepper, and salt.

Amino acid composition:

	mg/g
Lysine	3.27
Histidine	1.97
Arginine	4.84
Aspartic acid	11.30
Threonine	5.14
Serine	7.88
Glutamic acid	43.40
Proline	15.80
Glycine	5.18
Alanine	5.40
Cystine	NC
Valine	4.08
Methionine	NC
Isoleucine	3.36
Leucine	8.03
Tyrosine	3.68
Phenylalanine	5.19
Tryptophan	0.97
PER	1.69
PER (Casein)	2.50

KASET PROTEIN

Kaset protein, a nutritious food supplement, is made from the following ingredients: (a) fresh soybean protein isolate, (b) fish protein concentrate (FPC), (c) fresh mung bean protein isolate, (d) fish sauce, (e) a seasoning agent, (f) iodized salt, (g) sodium carbonate, (h) D,L-methionine, (i) and hydrochloric acid (3 percent solution). In addition, vitamin B_1 (66.6 g), vitamin B_2 (7.68 g), vitamin B_6 (7.68 g), and niacin (87.30 g) are added. All of these required ingredients are mixed to a homogeneous paste in a dough mixer for 20 minutes, after which the mixture is spread on trays and cut into small pieces.

The trays are then put into a hot oven set at 150° to 200°C for 90 minutes to partially dry the mixture. The drying process is completed in a cabinet dryer set at 80° to 90°C for 8 hours. Following this, the dried protein is reduced to small particles in a comminutor and further ground to grits if desired. The dried, ground kaset protein enhances both the flavor and protein content of other foods with which it is combined.

Chemical analysis:

	Percent
Moisture	4.2
Protein	69.0
Ash	6.5
Fat	12.1
Crude fiber	2.2
PER	2.61
PER (Casein)	2.50

A Production Unit for Low-Cost Weaning Food in Ethiopia

Erwin Kopp

The Ethiopian Nutrition Institute was established in 1962 as a cooperative venture between the Ethiopian Government and the Swedish International Development Authority (SIDA). In addition to sponsoring activities related to health, nutrition, education, and communication, the Institute established a Food Production Department at the end of 1965. At that time the primary objectives of the Department were: (a) to improve Ethiopia's nutritional status in general and that of children and pregnant and lactating mothers in particular; (b) to assist low income groups by providing low-cost, nutritious foods; and (c) to develop new food products and thereby stimulate the growth of domestic industries capable of supplying basic materials such as soymilk powder. More specific goals included developing a low-cost, high quality weaning food derived principally from raw materials produced in Ethiopia, and enriching traditional staple foods with high quality nutrients.

After an initial period of product development and test marketing, a weaning food was introduced commercially in autumn 1968. This product is called FAFFA, an Amharic word meaning "Grow strong and healthy." FAFFA consists of various combinations of cereals, legumes, including soybeans and dried peas, nonfat milk, sugar, salt, iodine, iron, calcium, phosphorus, and 10 vitamins. The chemical composition per 100 grams of FAFFA flour is as follows:

Calories	340
	gram
Moisture	8.0
Crude protein	21.2
Fat	2.2
Carbohydrates including fiber	64.5
Fiber	1.0
Ash	4.1
	mg
Calcium	200
Iron	15

One hundred grams of FAFFA provide 20 grams of protein of high biological value. For infants, FAFFA can be prepared as a porridge by mixing the powder with cold water and boiling for five minutes, or it can be mixed with other ingredients to make bread for older children.

As demand increased after 1968, production facilities were enlarged and improved. FAFFA is currently made in a pilot plant, which is rapidly wearing out because of continuous use. The plant produced 842 metric tons of FAFFA in 1974, about 55 percent of which was purchased by UNICEF for famine relief. The remainder was sold locally as a baby food. However, contrary to our original intention of stimulating the growth of domestic industries, we found it necessary to import considerable quantities of soy flour and milk powder.

In this context it should be mentioned that a seminar, sponsored by FAO and UNICEF, was held in February 1971 in Kampala, Uganda, to discuss the production, utilisation, and marketing of soybeans. During this seminar it became increasingly evident to Ethiopian participants that concerted efforts should be made to grow and process soybeans in Ethiopia.

As an outgrowth of the seminar in Kampala the Ethiopian Nutrition Institute in cooperation with the Agricultural Research Institute and CADU (a Swedish agricultural aid project) initiated a small-scale program designed to test 200 soybean varieties at several locations throughout the country. Promising varieties were selected, and subsequently contracts for large-scale cultivation were negotiated with a number of farmers.

In 1974 INTSOY held its conference in Addis Ababa, an indication that our efforts are now receiving some recognition. Learning about the results of soybean research in other countries has increased our awareness of the importance of introducing a new food crop with extreme care. The intention of the Institute is to grow soybeans on a contract basis with carefully selected and supervised farmers and eventually to introduce the crop to small-scale and subsistence farmers.

We also plan to process full fat soy flour using domestic soybeans, thus eliminating the need for imports. With this purpose in mind, we designed an extrusion cooking system with the assistance of a Canadian engineer and a Danish company. Unfortunately, the equipment has not yet been installed.

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Viable Alternatives for Processing Soybeans in a Variety of Situations

Earl D. Kellogg and Sheldon W. Williams

The expansion of human consumption of soybean products has been recognized as one area deserving further development in the effort to increase protein consumption of people in less developed countries. In parts of Asia, of course, soybeans have long been processed on a small scale and consumed directly by people. Generally the nutritional value of soybeans may be obtained more cheaply through direct consumption than through animal products derived from soybean-fed livestock. Therefore, the challenge of processing soybeans for human consumption in low income countries is to develop acceptable low cost soy foods that fit into people's food preparation and consumption habits. This challenge may require various types of processing, as well as levels of sophistication within each type.

The objective of this paper is to discuss alternative methods of processing soybeans, situations in which each might be appropriate, and the effects of certain variables on the economic efficiency of alternative methods. Initially we will discuss and compare viable processing alternatives appropriate in various situations. Then, factors affecting the relative economic efficiency among methods will be analyzed. Most of the data presented in this paper are subject to wide margins of error. They are given to indicate general directions and levels. However, we are confident that most of the conclusions would remain the same after allowing for possible errors.

VIABLE ALTERNATIVES FOR PROCESSING SOYBEANS

An increasing number of viable alternatives are being developed for processing soybeans for human consumption. Some of these alternatives are being adapted from techniques used for years by Asian consumers and processors. Not only do new large-scale processing methods need to be developed, but also alternatives for small-scale processing need to be improved. In this section, only brief remarks are made describing the processes, the equipment necessary, and the product. When known, references are cited for details.

Home and Village Processing Alternatives

For low income people to directly consume soybeans, home or village processing is probably essential unless nutritive supplements are to be provided through mass feeding programs financed by governmental or charitable institutions. In most cases, the outreach of these programs is quite limited compared to the need. The manufacture of various fermented foods, such as miso, soy sauce, and tempeh, is one alternative for home and village processing (Martinelli et al., 1964). Many people in Asia, particularly Chinese, Japanese, and Indonesians, consume large per capita amounts of these products. The manufacture of soy sauce forms an important industry in Japan and China, while tempeh production probably provides partial employment for thousands of people in Indonesia. This process, in general, involves soaking, cooking, adding one or more fermenting agents, and extracting the desired product by various methods.

Soymilk can also be made by a simple process of soaking and grinding yellow soybeans, adding water, and straining. Tests in the Philippines have shown that 80 to 90 percent of the children and adults consuming soymilk mixed with sugar and vanilla indicated that it was acceptable (Bourne, 1971).

Soybean curds, usually referred to as tofu, are made by adding mineral salts or acid to soymilk, which then coagulates into a curd. This makes an excellent source of protein for people who do not eat meat. The Chinese proverb, "Tofu is meat without bone," is justified, since this soybean curd consists primarily of the protein matter of the soybean.

Soy flour made from soaking, cooking, drying, dehulling, and grinding soybeans can be used to make cereals, bread, milk and other products that have a higher protein content than the traditionally made products. The United States Department of Agriculture has developed a method of making soy flour where skilled labor, electric power, and steam are not available (Mustakas et al., 1967). Using this process, six men can make 136 kg of

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soy flour in eight hours, enough to supply half the daily protein need of more than 1,600 adults. The required equipment, estimated to cost $280 (US$) in 1967, would probably cost two to three times that amount in 1976.

In recent years small-scale extrusion cookers have been developed for on-the-farm processing of soybeans for swine, poultry, and other monogastric animals. The beans are fed through a pressure cooker and then discharged through a die to expand and cool. One available model can be operated from the power-take-off of a tractor or from an electric motor, and can process up to eight tons per day. A rough estimate of the cost for one model with insurance, freight, export preparation, ancillary equipment, and a 150-horsepower tractor delivered to the Philippines is $45,000 (Minguez, 1975). The basic equipment was estimated to cost $5,000, with the tractor estimated at $35,000. The annual fixed costs (depreciation, interest, taxes, and insurance) were estimated at $14,500, about three times the value of the cost, insurance, and freight of the equipment. With variable costs estimated at $8.65 per ton, the total cost per ton processed at 2,400 tons per year would be $14.70 per ton (Table 1).

This small extrusion cooker could be powered by a 100-horsepower electric motor. Without the tractor, this combination would involve a smaller investment (perhaps $15,000 to $20,000) but would require electric power of high voltage, and its mobility would be decreased. One question still unanswered is whether this equipment is suitable for producing human food products. Further testing of durability for continuous operation is also necessary. If this alternative does prove acceptable in terms of durability and processing, its use in less developed countries is promising because of lower operating costs, smaller capital investment, and mobility as compared to the larger size expeller or solvent processing equipment. Tests of this equipment are currently being conducted at the Agricultural Engineering Department, Colorado State University in Fort Collins, Colorado (Tribelhorn et al., 1975).

Table 1. Estimated Costs (U.S. dollars) and Output of Three Types of Soybean Processing Facilities, the Philippines, 1975

Item	Small extruder cooker	20-ton/day expeller (screw press)	100-ton/day solvent extraction
Capital investment	$45,000	$300,000	$3,000,000
Annual fixed costs	14,500	66,000	550,000
Variable cost per ton	8.65	22.70	10.00
Yearly output at capacity[a]	2,400 tons	6,000 tons	30,000 tons
Product per ton of raw soybeans			
oil	.....	300 lb	366 lb
meal	1,960 lb	1,660 lb	1,566 lb
loss	40 lb	40 lb	68 lb

[a] Shift operation of the cooker; 24-hour operation for others.

Source: Minguez, 1975.

Many of the oriental soy food products discussed above have a beany taste that may be objected to by consumers who are not accustomed to soy foods. However, the objectionable flavor can be minimized if soy flour, extruder products, and other types of soybean foods are properly prepared. Another possible problem of small-scale processing involves inactivation of the trypsin inhibitor, which affects the ability of humans to realize the full nutritional potential of soybeans. Many of the sources discussing small-scale processing techniques indicate that soybeans would have to be processed in certain ways to inactivate the trypsin inhibitor. However, Liener has made the following observations:

> Most of the work that has been done with trypsin inhibitors has related to the action of these inhibitors, such as those from soybeans, on bovine trypsin. But more recently, experiments have been undertaken to see what effect trypsin inhibitors have on human trypsin, a direct concern to us. Surprisingly human trypsin is not inhibited by the soybean inhibitor. In addition, ovomucoid, which is the inhibitor in egg white, does not inhibit human trypsin, and we know from tests with human subjects that ovomucoid has no deleterious effects. From these various lines of evidence, I am forced to conclude that trypsin inhibitors are really of little significance in human nutrition (Liener, 1972).

This issue needs to be settled because its resolution may affect the requirements placed on the kinds of processes that can be developed for home and village soybean processing.

Because of the paucity of economic data on many of these small-scale processing methods, it is difficult to compare their relative strengths and weaknesses and to judge their viability in various situations. More information is required on investment costs, labor requirements, physical transformation rates, and market values of the products produced. However, there does appear to be growing interest regarding improved small-scale processing methods. If nutrition programs aiming to increase consumption of soybean products are trying to reach rural people, development of village soybean processing methods must be an important consideration. For a large proportion of these people, access to products produced by large-scale processing plants is quite limited.

Larger Scale Processing Alternatives

The alternatives discussed in this section involve substantially higher volumes of input for one processing plant than the village or home processing methods. One decision basic to large-scale soybean processing is whether to produce whole bean products or to extract oil and meal separately. In countries that want to produce cooking oil or soybean meal for animal feed, processing almost inevitably involves oil and meal separation. In these situations, if the volume of soybeans is limited, processing costs will be high.

One of the most common processes for separating the oil and cake from raw soybeans is the expeller or screw

press method (Williams and Rathod, 1974). This involves cleaning and cracking the beans, then adjusting the temperature and moisture content to appropriate levels before pressing to separate the oil and cake. This cake usually contains 4 to 6 percent oil. The expeller process is quite versatile in that (with some modifications) it can be used for babassu kernels, castor beans, copra, corn germ, cottonseeds, linseeds, palm kernels, peanut kernels, rapeseeds, sesame seeds, soybeans, sunflower seeds, and tung nuts. Since the expeller process is less technically efficient for oil removal than is the solvent process (4 to 6 percent compared to less than 1 percent), some firms use the solvent process to remove residual oil in the cake. Expellers with recommended ancillary equipment purchased new from the United States involve substantial capital investments, roughly $300,000 for a 20-ton-per-day plant. Operating costs have been estimated for the Philippines at approximately $34 per ton of raw soybeans (Table 1).

Many Asian cities have expeller plants that process various oil-bearing materials. With some modification these plants could also produce soy oil and cake. Conversion costs would differ significantly, depending on the location and type of equipment to be modified.

To be economical, solvent extraction requires a larger volume of soybeans per plant than any of the other methods discussed. In this process the soybeans are cleaned, cracked, and flaked, then mixed with a solvent that extracts the oil and leaves the meal. With extra care soy flour can also be produced. The technical efficiency in terms of oil removal is high, with residual oil in the cake being less than one percent.

The initial investment for a 100-ton-per-day plant is about $3 million for U.S. equipment. Operating costs at 100 tons per day have been estimated at $28 per ton. However, these unit operating costs decrease as quantities processed increase to over 2,000 tons per day. In general, 100 tons per day is the smallest solvent plant that should be considered. It should be recognized that a plant of that size is clearly at a disadvantage if it is in open competition with large plants such as those in the United States. Because of high fixed costs and costs of start-up and shut-down periods, solvent plants should operate continuously to achieve lower operating costs. This means operating for at least 330 days per year for 24 hours a day. Power shut-offs or variations in power provision, which occur frequently in some areas, may significantly affect the efficiency of solvent plants.

Solvent extraction is a sophisticated operation requiring highly skilled personnel, and the solvent, hexane, is explosive. Therefore, in some situations it might be useful to attain a certain level of experience in less sophisticated processing methods before operating solvent plants.

Large-scale extrusion cookers offer another alternative. The process is similar to that of the small-scale extrusion cooker discussed in the village processing section. This process gives quick, high temperature cooking that results in a highly nutritive product with excellent flavor. A commercial size plant can process two tons per hour and can be much more versatile than the small-scale extruder. Soybeans can be processed alone or mixed with other cereals to make flours, finger foods, meat extenders, and other products. Oil and meal are not separated in this process.

Because of this versatility and quality of the products, there is much interest in extrusion cooking. Unfortunately for the developing countries beginning large-scale soybean processing, this method has some of the same drawbacks as solvent extraction. Commercial equipment with a capacity of two tons per hour, plus needed driers, coolers, and other ancillary equipment, requires a capital investment of approximately $1 million. Maintenance costs also are apparently high. As with solvent extraction, the extruder equipment operation necessitates highly skilled labor and a continuous supply of power.

Comparisons of these large- and small-scale methods show substantial differences in capital investments, processing costs per ton at various capacities, and raw material requirements at optimum levels. Table 1 gives the capital investments, annual total fixed costs, operating costs per ton, yearly output, and physical transformation data for the small-scale extrusion cooker, expeller, and solvent processes. Table 2 contains estimates of the total processing costs per ton at various levels of annual volume for these three methods, while Table 3 indicates the number of hectares of soybeans, under different yield assumptions, required to supply the processing alternatives with the raw material needed for one year's operation.

Solvent plants require large areas of soybeans to supply the needed raw materials. Depending on yield level, these plants require the total output from 20,000 to 37,500 hectares of soybeans to supply a plant producing the minimum of 100 tons per day. If a large solvent plant is considered, i.e., 2,000 tons per day, the required area of soybeans increases to 400,000 to 750,000 hectares.

Table 2. Cost Estimates of Processing Soybeans in Various Facilities, Philippines, 1975

Annual volume (ton)	Cost of three processing methods (US$/ton)[a]					
	Small extruder cooker		20-ton/day expeller		100-ton/day solvent extraction	
	Fixed	Total	Fixed	Total	Fixed	Total
30,000	..[b]	..	..	..	$ 18	$ 26
15,000	..	..	..	..	37	47
6,000	..	..	$11	$34	92	102
3,000	..	..	22	45	183	193
2,400	$ 6	$15	..	..	...	...
1,500	..	..	44	67	367	377
1,200	12	21	..	..	...	...

[a] Underused existing equipment of a type not requiring extensive modification could process additional volumes of soybeans at variable costs per ton of $9, $23, and $10 for small extruder cookers, 20-ton/day expellers, and 100-ton/day solvent extraction plants, respectively. Costs for transportation and handling are not included in these estimates.
[b] Data not available.

Table 3. Estimated Area of Soybeans Producing Various Yields Needed to Supply Processing Plants Operating 300 Days per Year at Capacity

Yield (ton/ha)	Soybean growing area (ha) required for three processing situations		
	Small extruder cooker	20-ton/day expeller	100-ton/day solvent extraction
0.8	3,000	7,500	37,500
1.0	2,400	6,000	30,000
1.2	2,000	5,000	25,000
1.5	1,600	4,000	20,000

Source: Minguez, 1975.

In comparison, the expeller method and small-scale extruder cooker require only 4,000 to 7,500 hectares and 1,600 to 3,000 hectares of soybeans, respectively. It should be emphasized that these calculations are based on the assumption that all the soybeans produced in the given areas are available to the processing plants. If farmers retain any of their production or market it to alternative uses, larger areas would be required.

In comparing alternative processing methods, the concept of economies of scale is important. In the long run, processors must recover their total cost of producing a ton of soybean products or go out of business. Therefore, they must not only recover their operating costs, such as power, containers, and labor, but must also consider their fixed costs, such as insurance, loans for equipment, and depreciation. Because of fixed costs, the cost of processing a ton of soybeans declines up to a certain point as the size of operation increases. The higher the initial investment costs, and hence the fixed costs, the larger the output level needs to be to produce a product at a cost competitive with other methods having lower fixed costs. Therefore, 100-ton-per-day solvent plants that produce less than 15,000 tons annually have much higher total costs per ton compared to expellers, small-scale extruders, or 30,000-ton-per-year solvent plants (Table 2). However, 100-ton-per-day solvent plants that can operate continuously for 300 or more days can produce a ton of soybean product at a smaller cost than can expellers. If this volume cannot be reached, expellers will be able to process as little as 10 tons per day for 300 days a year at lower costs. At volumes lower than this, the small-scale extruder cooker would be the lowest cost method, if it is proven suitable.

A country or area just starting soybean production may not yet be using expeller equipment at full operating capacity or may lack a soybean volume of 30,000 tons per year. If this is the case, for the reasons mentioned above it might be best to use expeller processing until there is good evidence that an adequate volume of production has developed and that the expertise needed is available to justify a substantial investment in new equipment. This recommendation is further strengthened since many solvent operations cannot handle material of high oil content, such as peanuts, palm kernels, sunflower seeds, and copra. If these materials must be processed, expellers will be required.

In some Asian countries solvent plants have been used mainly to extract residual oil from the cake produced from mechanical expelling of groundnuts, cottonseeds, and so forth. It may be feasible to modify such plants to process soybeans, but doing so is likely to require outlays of several hundred thousand dollars for equipment to prepare soybeans for processing and for heat treatment of the meal or flour. However, this may still be only a fraction of the cost of a new plant.

Lack of information makes it difficult to compare the various alternatives for home and village processing. These methods are important since they may be ways of providing soy food products to large numbers of poor, isolated people. But while the potential for increasing technical efficiency may be great, relatively little attention is being given to that possibility. The small-scale extrusion cooker appears promising, but needs further testing in field operations.

ECONOMIC EFFICIENCY AND CHOICE OF TECHNIQUE

The concept of economic efficiency involves, in this case, choosing the processing technique (a combination of capital and labor) that entails the least cost for producing a given amount of soy products. Therefore, economic efficiency is not the same as technical efficiency, which simply indicates the physical transformation of input to output. Thus, technical efficiency, investment costs, and processing costs per ton are not the only variables involved in economic efficiency. At first glance it might appear that solvent plants are the most efficient of all alternatives at volumes of 160 tons per day, using 48,000 tons per year, and producing soy products at $25 per ton. However, these 48,000 tons, for example, might be processed by 20 small extruder cookers operating at 8 tons per day with processing costs that may be less than $25 per ton. This example may not be entirely valid since two different products result from the two methods.

Since each technique, and even specific designs within each method, involves different amounts of labor and capital, choosing a technique entails defining a certain number of jobs at certain skill levels. This choice then relates directly to considerations regarding labor and capital substitution, distribution of economic benefits, and appropriate technology, all of which are currently major concerns in development.

The most economically efficient technique will depend on the specific situation. However, the effects of certain variables on efficiency and the choice of appropriate techniques are, in general, predictable and in some cases obvious, but occasionally they are overlooked. The following is a discussion of some of these variables.

1. The lower the price of labor (wages) relative to the cost of investment capital, the relatively more efficient labor intensive methods will be compared to more

capital intensive techniques. It follows then that as wages versus investment costs rise or fall, the most efficient technique would tend to be more or less capital intensive.

2. Technically more efficient techniques tend to be economically more efficient, everything else being constant.
3. If one assumes that the more capital intensive techniques are technically more efficient (as they often are) and that the price of input (raw soybeans) increases relative to the price of output (soy products), then these technically more efficient facilities will become relatively more economically efficient.
4. Higher interest rates tend to make more labor intensive techniques relatively more efficient. These variables change over time and space. For example, plants near large cities may face higher wages, lower interest rates, and higher input costs than plants in more rural areas. These factors tend to favor more capital intensive methods.

Practices that alter or distort these variables may cause businesses to invest in facilities that differ from those that could process soybeans at a minimal cost reflecting the true scarcity of resources. Undervalued interest rates, and overvalued exchange rates (which usually affect imported capital costs), reinforced with investment credits, depreciation allowances, tariff rebates, and high minimum wages, tend to favor more capital intensive techniques when the same amount of output could have been processed at lower real costs by more labor intensive methods (Eicher et al., 1970). An intelligent balance of these factors helps in the development effort by allowing the maximum possible output to be obtained from a given amount of resources. See Timmer (1973) for other examples.

Even economically efficient operations do not provide sufficient answers for difficult, dynamic distributional issues. Suppose it were decided to change from a more labor intensive technique that was previously most efficient to a more capital intensive method that is presently more efficient (they may not always be). Certain factors of production and possibly classes of people may experience a private loss of income from jobs or capital ownership. Others would gain, of course. This change may have caused as many as 50,000 people to lose their jobs. However, it may also have allowed food prices to be lowered for as many as 50 million. Therefore, merely finding the most economically efficient techniques will not solve problems of income and welfare distributions, but it is important to the development process.

CONCLUSION

The data in Table 2 strongly suggest that choice of the best type of equipment depends largely on the volume of material to be processed. Also, as the variable costs on the bottom line of this table indicate, considerable cost savings may be realized by using existing equipment if it has excess capacity and can be used without extensive modification.

The small-scale extrusion cooker with its low capital cost, high output, simplicity of operation, and product versatility may be particularly feasible in village areas with 3,000 hectares of soybeans. However, markets for extrusion cooked products need to be developed in most areas, and additional research is required to judge the capability of the extrusion cooker to produce human food and withstand continuous use. It does not separate oil and meal.

The expeller process does separate oil and meal, which have, in many cases, well developed markets. It is versatile in terms of processing many kinds of raw materials and is already in operation in many locations. However, if the expeller is purchased new, fixed as well as operating costs are relatively high, and its technical efficiency is lower for removing oil.

The solvent process is technically the most efficient for removing oil. Its operating costs are relatively low for output levels above 100 tons per day. However, to operate efficiently it requires large supplies of raw materials as well as high investment costs, experienced workers, and careful planning of plant location. At levels less than 100 tons per day, solvent plants involve high cost processing compared to expeller plants.

Selection of appropriate soybean processing methods requires input from a number of people who understand various relationships and variables. Soybean processing technology is changing continually, and more attention is needed to improve the productivity of traditional techniques. Governments need to be sensitive to the environments surrounding poorer, relatively isolated people if these people are to have access to soy food products for improving their nutrition. The public sector also must realize the effects of policies regarding capital and labor costs on certain groups of people and on the decisions of businessmen in choosing the most profitable techniques.

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Discussion

Dr. Yasni: Is there any study on processing soybeans in densely populated areas, such as Java, in comparison to vast lands in sparsely populated, outer areas? A study should be made immediately in this particular field, where a dual technology in soybean processing could be studied comprehensively. In the first case, production would be primarily for domestic consumption and in the second case, primarily for export.

E. D. Kellogg: I know of no study on soybean processing that compares appropriate techniques in Java versus the outer islands of Indonesia. It is entirely possible that the most efficient technique on Java would differ from the most economically efficient technique on other islands. The variables affecting economic efficiency vary over space as well as time. For example, processing plants located in densely settled rural areas may face lower wages, higher interest rates, and lower raw material costs than plants in areas with less dense settlement patterns. These values tend to favor more labor intensive methods. So, the most efficient plant configuration may be different among areas.

We should also be careful that we do not label capital intensive techniques as being somehow better than more labor intensive methods. Capital intensive techniques are often labeled "advanced," "up-to-date," "modern," implying superiority to more labor intensive techniques that are considered "not advanced," "out-of-date," "primitive," implying their inferiority. These terms tend to bias an investigation for appropriate, economically efficient techniques.

Developing Soybean Markets in India: Economic Aspects

K. L. Rathod

The technological development of an industry must, of necessity, operate within a certain economic framework. Thus, a crop introduced on a commercial scale must serve the intended market. From the standpoint of commercial production, soybeans can be considered a "new" crop in India. As such they must prove satisfactory for home and industrial use and also meet the cost requirements of the market. Before a viable market for soybeans can be developed, however, the following basic questions need to be answered: (a) what is the potential supply and demand for soybeans; (b) what are the obstacles to attaining the full market potential; (c) what are the opportunities for marketing soy protein products and what has already been done to realize these opportunities; and (d) what are some of the possible approaches that merit greater attention.

POTENTIAL SUPPLY AND DEMAND FOR SOYBEANS

Supply

Extensive trials during the past decade indicate that, particularly in north central India, soybean yields are high enough to warrant cultivation on a large scale. In many parts of the country agro-climatic conditions do not appear to restrict production. Given an active, sustained promotion, it has been estimated that the states of Madhya Pradesh and Uttar Pradesh alone are capable of growing approximately 2 million hectares annually (Williams et al., 1974). Experimental evidence also indicates that other Indian states have the capability to produce soybeans on a commercial scale. Soybeans can be raised as a cash crop to replace low-value crops such as local jowar, low yielding pulses and millets, indigenous maize, and perhaps low yielding upland rice. They can be intercropped with cotton and sorghum or planted as a substitute for low yielding *mandua* (ragi) in the hills. As a spring crop soybeans can be planted after the harvest of early potato, toria (lahi), sugar cane, and so forth, or as a mixed crop with sugar cane planted in the spring. Land now left fallow during the *Kharif* season can also be sown to soybeans.

All the available evidence indicates that soybeans, which are rich in oil and protein, can be produced in India on a large scale without appreciable reduction in the supply of traditional oil-seed crops, such as groundnut and cotton seed. Clearly, the supply potential appears to be large enough to support the needs of a developing market.

Demand and Market Outlets

Using available information, we can make some crude estimates of future market outlets. These estimates assume that soybeans are priced competitively with groundnuts and that soy products are all prime quality and, again, priced competitively with groundnut flour, protein isolate, dried skim milk, casein, and so forth.

There is no immediate prospect for using soybeans for direct consumption after cooking or traditional, home processing. Because of the scarcity of oil, however, there will be a strong incentive to process soybeans for oil and meal. The utilisation pattern of oil and meal will determine to a large extent the immediate market for soybeans in India.

During the late 1960's soybean oil imports averaged nearly one million metric tons per year, that is, the equivalent of 5 million tons of raw soybeans. Because soybean oil is more expensive to process and has a relatively shorter shelf life than groundnut oil, it will sell for about 10 percent less than groundnut oil on the open market.

Soybeans are commonly used as a source of nitrogen for streptomycin fermentation in India and were imported for that purpose in the past. The pharmaceutical industry has now switched to the purchase of full fat and defatted soy flour, which are currently available on the market. At present the industry requires about 4,000 tons of flour. Indian Drugs Pharmaceutical Ltd., Rishikesh, alone needs 1,500 metric tons of full fat and 500 tons of defatted soy flour. All the pharmaceutical factories have been licensed for expansion, and ultimately will provide a market for between 10,000 and 12,000 tons of soybeans.

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If properly processed and favourably priced, soy protein foods have a good potential market. Certain sophisticated, high-protein soy products, such as soy protein concentrate and soy protein isolate, have desirable organoleptic and functional qualities, although they will probably be too expensive for widespread use in India. Soybean flour, however, is a simply processed, comparatively cheap source of high-quality protein and is acceptable to consumers (Rathod and Williams, 1973). It has a wide variety of possible uses in breads and biscuits, weaning foods, balahar (a reinforced dietary supplement), fortified flour, confections, and snack foods. The demand for soy flour is likely to reach between 3,000 and 3,200 metric tons per year, or approximately 10 tons per day.

The demand for defatted soy meal for use in textured vegetable protein may be stretched from the present level of 200 tons to between 1,500 and 1,600 tons annually by the installation of an X-155 extrusion cooker. At present an X-25 extrusion cooker is in use, but the Soya Production Research Association, a joint venture of the Nave Technical Institute, Shahjahanpur, and G. B. Pant University of Agriculture and Technology, Pantnagar, plans to install the larger cooker in the very near future.

Soy beverages appear to have tremendous possibilities either as a high protein drink or for blending with cow or buffalo milk. The soymilk process patented by the University of Illinois and G. B. Pant University of Agriculture and Technology, Pantnagar, may take some time to be developed commercially. Within a few years, however, the quantity of soybeans used for beverages or milk extenders may well reach 2,500 to 5,000 tons annually. Thus, within a five-year period the demand for soybeans for human food may amount to 7,000 to 10,000 tons annually.

A small quantity of soybean meal could be used in mixed feeds in India. At present the estimated production of mixed feed is about 300,000 tons, one-third of which is used for poultry. Although production of mixed feed is expanding, at the current rate of production if soybean meal comprised 20 percent of all the mixed feed, this would provide an annual outlet for about 60,000 tons of soybean meal containing 50 percent protein. This is equivalent to the annual meal production of one solvent extraction plant processing 200 tons of soybeans per day.

With 10 to 15 percent of the soybean crop retained for use as seed during the subsequent growing season, coupled with export outlets, these market demands for processing material may sustain India's ambitious programme of 430,000 hectares of soybeans by 1978-79.

CONSTRAINTS ON ATTAINING POTENTIAL MARKET

Examined in terms of potential supply and demand, the slow expansion of soybean hectarage (Table 1) indicates that the programme is encountering problems. These problems can be grouped into three broad categories: (a) stimulating production at the farm level, (b) encouraging industries to invest in soybean processing at an economic level commensurate with the needs of growers and consumers, and (c) developing between growers and the processing plant a marketing organization and marketing practices conducive to the economic development of both parties. These problems are interrelated. We shall examine a few of the important economic aspects that have a vital bearing on the soybean programme in India.

Quality and High Price of Seed

The quality and the high price of seed are among the major causes of difficulties encountered in fulfilling productions goals. Soybean seed quality includes several important attributes, viz., genetic purity, physical purity, germinability, and seed vigour. The major, chronic seed quality problems in India are germinability and viability. The use of poor quality seed has, in part, contributed to low yields. The problem of quality is of paramount importance in commercial soybean seed production. The cumulative effect of seed quality problems and their consequences encountered in commercial production has resulted in a "feast and famine" situation. Although the potential demand for certified seed in India far exceeds the current supply, the actual demand is less and has, in fact, shrunk since 1971.

The risk and uncertainty combined with the greater care required in handling, processing, treating, and storage do not permit the seed industry to market seed at a price the farmers can afford at the present level of yield and financial return from soybeans. Thus, the high cost of seed, the relatively low yields and returns from soybeans, and commercial market constraints existing at the present do not provide an adequate incentive to farmers to use certified soybean seed on an extensive scale.

Except during the introductory phase of India's soybean programme, the use of certified seed has been insignificant. Planting with certified seed declined from 38 percent of seeds sown in 1971-72 to 4 percent in 1974-75. The extensive use of poor quality seed has contributed to the low yields obtained from farmers' fields. This has resulted in a vicious circle that adversely affects production and the commercial base of soybeans in India.

Table 1. Area Planted to Soybeans in India, by State

State	Area planted (ha)				
	1971-72	1972-73	1973-74	1974-75	1975-76
Madhya Pradesh	7,690	16,050	25,260	39,710	54,380
Uttar Pradesh	5,890	15,060	20,460	25,370	37,960
Maharashtra	18,160	1,310	1,060	480	320
Gujarat	580	1,270	580	820	(a)
Karnataka	(b)	(b)	(b)	170	170
National total	32,320	33,690	47,370	64,750	92,830

[a] Data not available.
[b] No production.

Competitiveness of Soybeans

The cultivator's choice of crops depends upon the advantages to be gained from raising a particular crop. The competitiveness of soybeans with other crops would be governed to a large degree by the production per hectare and market price of soybeans. The yields per hectare obtained from research and demonstration plots have been high. Yields from farmers' fields, however, have not been satisfactory. In Madhya Pradesh, for example, the break-even yield is about 10 quintals per hectare. The price that farmers receive for soybeans is primarily a function of the market value of soybean products. In India there are indications that, at least until the time when industry uses considerable quantities of soybean meal and cake in food manufacture, the price level of cake and meal will be closely related to the price levels of groundnut cake and meal, which are in turn influenced by the export market. The price of soybean oil will be determined largely by the price of groundnut and other leading vegetable oils for domestic use. Between 1972 and 1975 price estimates for soybeans, based on the market prices of oil and meal, were very similar to the actual market prices of soybeans. When the soybean yield is more or less stagnant, the competitiveness of soybeans is governed to a considerable extent by the immediate value of the oil for hydrogenation and of the cake and meal for animal feed. In the unstable oil-seed economy, fluctuating prices of oil, cake, and meal over the years account for significant variations in the ability of soybeans to compete with other crops.

The question of paramount importance is whether competition for markets similar to those used for groundnut products can initially provide a basis for producing soybeans on a large scale in India. The expansion of farm productivity and the development of an adequate marketing system are interrelated. At the farm level the realization of a production technology that reduces costs and enhances output, in addition to initial price supports at a favourable level, may be crucial in determining the basis of the soybean programme in India.

Investment and Risks in Processing

The high price of vegetable oil in India provides a strong incentive for processors to extract oil from soybeans. Consequently, it is reasonable that oil extraction should become the basic soybean processing industry.

With the technology now available, important economies of scale (Table 2) may be obtained by the establishment of new soybean processing plants. To operate at a reasonable profit, a plant should have a production capacity of at least 100 metric tons per day, although risk considerations tend to make industry favour a plant with a capacity of only 50 tons per day. Uncertainty with regard to the soybean supply and the large capital outlay discourage investment in new processing facilities. Even in India, where bulk handling and other highly mechanised operations may be out of the question, a plant processing 50 tons per day requires an estimated capital outlay of 5 to 6 million rupees (US$572,500 to $687,000). A versatile plant appears to have much better commercial prospects than a plant engaged solely in soybean processing. Expeller plants, selling oil to the regular market and cake to the livestock feed industry, can process soybeans. With suitable modifications, they can produce flour of an edible quality as well (Williams and Rathod, 1974).

Coordinating Production and Marketing

A fundamental problem of the industry lies in generation of the confidence basic to full growth of the industry. On the one hand, cultivators are reluctant to produce soybeans unless assured a dependable market at a price they consider remunerative. On the other hand, processors want evidence that adequate and regular crop production will develop before they establish expensive processing facilities. Although some measures have been taken to alleviate the problem, expansion of the industry has been limited by lack of the needed mutual confidence.

MARKET OUTLETS FOR SOY PROTEIN FOODS

Examined in the light of nutritional needs and programmes in India, soybeans should be regarded as a protein crop rather than an oil-seed crop. From this perspective soybeans offer an immense challenge to entrepreneurs to produce soy protein food products in the forms consumers will accept. The manufacture of soy foods is beginning to interest the food industry. We shall examine three products, viz., soy flour, soy beverage, and vegetable protein, that have had an initial, favourable response from the industry.

Soy Flour

Soy flour, both full fat and defatted, is being used in bakery products, such as bread and biscuits. Bread produced by the various units of Modern Bakeries is now enriched with defatted soy flour, as well as with vitamins and minerals. Modern Bakeries is also producing a special bread, containing as much as 12 percent defatted soy flour, for the nutrition programme of the Social Welfare Department. During the period from April to December 1975 190 tons of Balamul, a soy-reinforced weaning food, were produced. During 1973-74 approximately 60 tons of soy flour were used in Balamul and during 1974-75 150

Table 2. Investment, Processing Cost, and Returns on Investment of Soybean Processing Plants of Different Capacities

Capacity (ton/day)	Investment (100,000 rupees)	Processing cost per ton (rupees)	Percent return on investment
50	Rs32	Rs94.4	5.8
100	50	73.5	24.4
250	100	56.5	48.8
500	180	47.6	70.5
750	250	43.1	85.2
1,000	330	41.5	87.1

tons. In the Government's balahar programme 250 tons of soy flour were used in 1974-75 and 1,500 tons in 1975-76.

Soy Beverage

A pilot plant processing soymilk at Pantnagar has demonstrated the uses and the potential for such an enterprise in India. At Pantnagar and in the surrounding areas the sale of soymilk beverage indicates favourable consumer response. A commercial plant with a capacity of 10,000 liters per day would require a capital investment of Rs2,861,000 (about US$327,500). Based on cost and return estimates, the rate of return on the investment for a plant this size operating 300, 200, and 150 days a year would amount to 64 percent, 43 percent, and 26 percent, respectively (Table 3). The seasonal nature of the demand coupled with the time lag involved in the market build-up may initially restrict the operational period of such a plant to between 150 and 200 days a year. There is every reason to believe, however, that an enterprise based on the production of soymilk and soymilk products can be commercially exploited.

Textured Soy Products

The uses and advantages of textured vegetable protein in India are many. As meat extenders, either mixed with raw meats or added directly to curries and soups, textured soy products can play a valuable role in areas where meat is in short supply. They can also serve as a total meat substitute for people who cannot afford meat or who are vegetarian by custom. Compared with whole milk, mutton, and eggs, textured soy products provide low-cost protein (Table 4).

The Soya Products Research Association markets on a commercial scale three soy-based products, viz., TSP (textured soy protein), Protesnac, and Protein-plus. Among these products, TSP preparations constitute the major sales items and have been growing in popularity since they were first introduced. Consumers have responded favourably to TSP chunks and granules but not to TSP powder. The sale of Protesnac, a ready to eat snack made from defatted soy flour and rice, increased from 4 tons in 1972-73 to 19 tons in 1974-75. Protein-plus, a weaning food, has yet to be established on the market. In general, consumer response to textured soy products has been good, with a total of 172 tons of such products sold in 1974-75.

Table 3. Annual Profit and Return on Investment of a Soymilk Processing Plant with 10,000-Liter Capacity

Product	Planned production level (liters per day)	Annual profit (rupees) by days per year of operation		
		150	200	300
Soymilk (unsweetened)	3,000	Rs103,000	Rs138,000	Rs207,000
Soymilk (sweetened)	6,000	237,000	516,000	774,000
Soy ice cream	500	256,000	342,000	513,000
Soy curd	500	41,000	55,000	82,000
Total	10,000	637,000	1,051,000	1,576,000
Percent return on investment		26	43	64

Table 4. Comparison of Nutritive Values of Soya Products Research Association Soybean Food Products with Other Foods

Food	Cost (rupees/kg)	Grams protein or total nutrients per rupee	
		Protein	Total nutrients
Milk	Rs2.75	13.10	44.36
Mutton	12.00	11.22	24.17
Eggs (20 kg)	9.00	12.44	26.80
Textured soy protein	15.00	34.67	60.67
Shaktiahar	5.50	71.49	165.44

APPROACHES TO BE CONSIDERED

Given this response, the following courses of action merit consideration:

1. There is a need to link soybean market operations with those of related foods and livestock feed. An established, versatile plant has far better commercial prospects than does a new, completely separate enterprise based on soybeans.
2. In the long run, the future of the soybean development programme in India depends upon the price incentive provided by the product. To promote the development of the new industry, the Government can stimulate production, facilitate the orderly marketing of soybeans, and encourage processing and consumption. To market most soy protein foods successfully will take time, heavy financial expenditures, promotion, and ingenuity. With active governmental support, it should be possible to use substantial quantities of soy protein by subsidised distribution through public feeding, food fortification, and welfare programmes.
3. Expansion of nutrition research and of both basic and adaptive research in food technology is needed in order to investigate thoroughly the economic and marketing aspects of developing outlets for soybean protein foods.

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SYMPOSIA

Soybean Rust: Summary of Available Knowledge

K. R. Bromfield and Charles Y. Yang

This symposium brought together for the first time a sizable, international group of scientists concerned with soybean rust and its importance in soybean production. Panel members from India, Taiwan, Thailand, Indonesia, Australia, the Philippines, and the United States, and conference delegates from these and 14 other countries shared information and ideas about soybean rust and its control.

Dr. Yang opened the symposium with slides and commentary on the general distribution of soybean rust; diagnostic symptoms and signs; salient features of the host range, mycology, and biology of the pathogen, *Phakopsora pachyrhizi* Syd.; field, greenhouse, and laboratory techniques useful in studying both the fungus and the disease; breeding for resistance; fungicide tests; and specific problem areas warranting discussion by the participants.

GEOGRAPHICAL AND SEASONAL APPEARANCE

To further define problems and form a common base for discussion, each participant commented briefly on the geographical and seasonal appearance of soybean rust and its importance within his country.

In Australia the pathogen was first collected from soybeans in 1934, but serious proportions were not recorded until 1970-71. Subsequently, rust has been recorded at coastal and subcoastal sites in Queensland and New South Wales (17° to 33° S.). Infection has been reported occurring as far as 200 kilometers inland in southeastern Queensland. In the absence of chemical control measures, soybean rust may be limiting to soybean production on the Atherton Plateau in northern Queensland. No precise measurements of yield loss due to the disease have been made. Estimates of losses up to 60 percent have been recorded, and one case of total loss at Redland Bay near Brisbane occurred in crops not protected with chemical fungicides.

In India soybean rust has been noted during the rainy season in Uttar Pradesh and West Bengal. It was observed for the first time on soybeans at Pantnagar in 1970. Soybean rust was not apparent there during 1971, but some rust occurred late in the season in 1972 and 1973. It was severe in 1974, but absent in 1975.

In Indonesia approximately 80 percent of the soybean crop is grown on the island of Java. Soybean rust occurs throughout Java, but is thought to be more common and more severe in western Java, the region of the island that has the greatest number of rainy days and the highest total rainfall. Soybean rust is considered the most serious soybean disease in Indonesia. Observed yield reductions have ranged up to 81 percent.

In the Philippines rust became especially serious in 1970, although it was known before then. The months of peak incidence are December and January on Luzon, and August (dry season) on Mindanao. Losses ranging from 20 to 30 percent are common, and on Mindanao rust is at present a limiting factor in commercial soybean production. As soybeans become more widely cultivated in the Philippines, an increase in the importance of the disease is expected.

In Taiwan rust is considered the most serious soybean disease. It has been a significant economic factor since at least the early 1960's. The disease, which occurs on crops sown in the spring, summer, and fall, is most severe on the spring-sown and fall-sown crops. In both crops rust may occur within 30 days after sowing. Losses up to 50 percent may be observed, although fungicidal application will reduce such losses.

In Thailand, also, rust is considered the most serious soybean disease. First reported in 1966, it occurs in all major soybean production areas of Thailand during the main growing season, July to November. It is most prevalent and severe, however, in September and October, the months of most frequent rainfall. Soybeans grown during the dry season (January to April) may also become rusted, usually from March through April, but the rust is less severe than in the wet season. Representative, dry season losses are between 10 and 15 percent for the adapted Thai varieties SJ 1 and SJ 2.

In the United States investigations of the pathogen and the disease are being conducted under conditions of absolute quarantine within the containment facilities at the Plant Disease Research Laboratory of the United States Department of Agriculture (USDA). Rust has not been reported on soybeans in the United States, nor elsewhere in the Western Hemisphere.

BREEDING FOR RUST RESISTANCE

The consensus of the participants was that the search for genes conferring resistance to soybean rust must be intensified and broadened and that efforts to incorporate resistance genes into adapted and high yielding lines should be expanded and accelerated. Two types of resistance are now recognized: specific (vertical) and general (horizontal).

Specific resistance has been observed in the field and confirmed in the greenhouse in Australia and observed in the field in India. Progeny of crosses involving P.I. 200492 and varieties Tainung 3 and Tainung 4 (derived from P.I. 200492) react to the Australian rust population at Brisbane in one of three ways: (a) by producing normal sporulating rust lesions, (2) by producing lesions with no sporulation (hypersensitive reaction), or (c) by not forming lesions (immune reaction). Similar reactions have been noted on material at Pantnagar, India. In contrast, all genotypes including P.I. 200492, Tainung 3, and Tainung 4 recently observed at AVRDC in Taiwan have produced only the sporulating type lesion (susceptible reaction). This was attributed to racial differences in the pathogen population.

Recent results obtained at the USDA's Plant Disease Research Laboratory confirm this view. Sets of plants consisting of Tainung 3, Tainung 4, P.I. 200492, X74-853001 (progeny of P.I. 200492 x Ogden), Ogden, and Wayne were inoculated with uredospores of rust isolates obtained from Redland Bay, Australia; Pantnagar, India; and Taiwan. In those sets inoculated with the Australian isolate, Ogden and Wayne produced sporulating lesions of the susceptible type, but the other four genotypes were immune, that is, showed no macroscopic evidence of lesions. Identical results were obtained in those sets inoculated with the Indian isolate. However, in those sets inoculated with the Taiwan isolate, all six genotypes produced sporulating lesions of the susceptible type.

Observations made by workers in many areas indicate that accessions vary in the amount of rust that develops among them when they are subjected to the same inoculum load under the same environmental conditions. Thus, accessions vary in the degree of general resistance they possess. It is usually conceded that this type of resistance depends on the cumulative action of a large number of genes. This presents a difficult situation for the breeder attempting to incorporate general resistance into desirable agronomic types. Lack of a standardized rust assessment method has led to some confusion in identifying lines with usable degrees of field resistance.

Breeding for rust resistance is underway in all the Eastern Hemisphere countries represented by the participants. In Australia P.I. 200492, Tainung 3, and Tainung 4 are being used as rust-resistant parents in various crosses. The inheritance and the mechanisms of resistance are being studied. Five additional lines (P.I. 219653, P.I. 224268, P.I. 227687, P.I. 229358, and HY 2217) have shown resistant reactions at the University of Queensland and are being used in various crosses.

At Pantnagar immune lines and lines termed "moderately resistant" (nonsporulating lesions present) have been identified, as well as lines with general resistance. Among the lines reported to possess specific resistance are UPSL-18, UPSL-85, USPS-91, UPSM-168, PK 71-39, PK 73-84, PK 73-94, and the variety Ankur.

At Bogor in Java varieties with detectable levels of general resistance are Arosoy (P.I. 86736), LS_1 D_2, Sankuo, Jagus, Bilomi-1, Klungkung, and No. 842 (Ohito Okidaizu). In a test in which potted plants were inoculated with uredospores, accessions No. 986, Matsuura, and No. 1312 (P.I. HS/2) were rated resistant. Subsequent crosses between No. 986 and Orba, a high yielding variety, produced F_2 plants with high rust tolerance and high yield.

In the Philippines Tainung 3, Tainung 4, L-11, and TK 5 are reported to possess generalized field resistance to the rust population in the vicinity of Los Baños.

In Taiwan an extensive germ plasm collection has been assembled at AVRDC. This material is planted in nurseries and inoculated artificially to ensure a rigorous rust challenge. Lines with detectable degrees of general resistance have been identified. These are being crossed in various ways in order to combine the different resistance genes dispersed in the various genotypes into high yielding types with desirable agronomic characteristics. In a recent AVRDC screening of the USDA's germ plasm collection maintained by Dr. E. E. Hartwig, P.I. 230970, P.I. 230971, and P.I. 371609 were observed to have a high degree of general resistance in addition to other desirable characteristics.

Breeders in Thailand have crossed Tainung 4 with the local varieties SJ 1 and SJ 2 and have obtained lines with enhanced rust resistance. Selected lines from this program are expected to be available soon for general release in Thailand.

Symposium participants expressed concern about the present, widespread dependence on P.I. 200492 as the source of genes for both specific and general resistance. Additional sources of resistance genes are urgently needed. The induction of rust-resistant mutants by radiation is an avenue warranting enhanced research effort. It was pointed out that success in finding resistant mutants will depend mainly on the effectiveness of the screening techniques employed for their detection.

ADDITIONAL RUST CONTROL MEASURES

Chemical fungicides are being investigated wherever soybean rust is economically damaging. Of the large number of materials and formulations under test, zinc ion-maneb complex, benomyl, and oxycarboxin were frequently mentioned as having potential for effective control. It was recognized, of course, that the feasibility of using any fungicide must be determined within a particular cropping system at a particular location because locations differ in physical, biological, meteorological, managerial, economic, and other factors.

A fungal species in the genus *Darluca* has been ob-

served parasitizing soybean rust pustules in Indonesia. Perhaps this hyperparasite and others that may exist have potential as biological control agents for soybean rust.

BIOLOGY AND LIFE CYCLE

Discussion of the biology and life cycle of the rust pathogen revealed many gaps in our knowledge of the organism. Although *P. pachyrhizi* produces teliospores, no one has reported their germination. Therefore, it is not known whether the rust is autoecious and completes its life cycle on soybeans, the uredial host, or whether it is heteroecious and requires an alternate host to complete its life cycle. The distinction is of more than academic interest. Strategies to reduce the formation of new races would differ markedly if the rust were heteroecious rather than autoecious. Similarly, the source of the primary inoculum that initiates an infestation in a new planting or in a new cropping season would be expected to differ if the rust were autoecious or heteroecious. At present we do not know for certain the source or sources of primary inoculum. Although races of *P. pachyrhizi* have been demonstrated, no standardized scheme for their identification has been developed. A knowledge of the range of pathogenicity within the rust population and the geographic distribution of genes for virulence is crucial to the development of schemes for the rational deployment of resistance genes within the soybean population.

A remarkable feature of the soybean rust fungus is its ability to parasitize species in a rather large number of legume genera. At least 17 genera contain one or more species on which sporulation of the pathogen has been reported. Further exploration of the host range should be made, and the role, if any, that alternative hosts play in the perpetuation of the fungus and initiation and development of epidemics should be determined.

Field observations indicate that temperatures above 30°C tend to decrease sporulation. Whether this is because of temperature alone or because of an interaction between increasing temperature and decreasing atmospheric relative humidity in the phyllosphere remains to be determined. Reports indicate that heavy rainfall and overhead irrigation reduce sporulation, but again the mechanism remains unknown. Numerous examples of this sort point to the need for quantitative studies on the effect of environmental factors on rust development and sporulation.

A curious parallel in rust development at Brisbane, Australia, and at Pantnagar, India, was revealed during discussions. In both locations rust was severe in 1970, light or not apparent in 1971, light in 1972 and 1973, severe in 1974, but light or absent in 1975. Whether this was sheer coincidence or can be related to some large-scale environmental cause is currently open to speculation, but again our lack of understanding of factors leading to epidemic outbreaks or, conversely, to suppression of rust development is revealed.

INTERNATIONAL WORKING GROUP

Precise information on losses caused by the disease is meagre at the present time. Valid information on yield losses is needed by the grower to enable him to make sound decisions. Such information is also needed by those seeking funds for research projects relevant to the disease and its causal organism and by those establishing research priorities within regions or countries.

Information presented during the soybean rust symposium made the fact clear that rust is a serious threat to soybean production in Asia, Oceania, and potentially to other regions of the world. It is a disease about which we must learn a great deal more as quickly as possible. To this end, two additional informal meetings were held to discuss cooperative research on soybean rust. In addition to fostering a valuable exchange of information on research results, techniques, and approaches, these meetings produced three tangible accomplishments: (a) agreement on a method for evaluating and recording rust severity in the field, (b) formulation of plans to send seed of elite breeding materials to researchers at sites throughout the Asian area for rust screening, and (c) organization of the International Working Group on Soybean Rust.

The purpose of the soybean rust workers' group is to stimulate development of scientific information on soybean rust and to provide a means for the rapid, worldwide dissemination of research results and materials among those scientists whose assignments and interests encompass any aspect of the rust problem. Initially, dissemination of relevant information will be made through publication of a newsletter. The first newsletter will discuss the newly developed, standardized rust assessment scheme, provide guidance for its use, and present suggestions concerning the testing of soybean materials to be provided to members of the workers' group for rust reaction observations.

Elected officers of the International Working Group on Soybean Rust are Charles Y. Yang, chairman; K. R. Bromfield, vice-chairman; and S. Shanmugasundaram, secretary.

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Biology and Control of Major Insect Pests of Asian Soybeans

Introduction

Michael E. Irwin

Asian-grown soybeans are plagued by large numbers of diverse insect pests, partly because of the tropical to semitropical setting of much of Asia, but mainly because Asia is the home of the soybean. Many insects have evolved with soybeans and have moved freely from area to area as soybean cultivation has expanded.

If one were to categorize in order of importance the insect pests of Asian-grown soybeans, one would surely list first the complex of lepidopterous pod borers, because they destroy the seeds directly. Another important group of pests are the stink bugs (Hemiptera:Pentatomidae), which also attack the seed. Stem flies (Diptera:Agromyzidae), which can destroy a crop in the seedling stage, are also important in many tropical areas. Although there are many other important groups of insect pests in Asian-grown soybeans, these three complexes are probably the most important, and they will be covered in this symposium.

In the general sessions of this conference certain insect topics were developed: insect pest diversity and succession in Asian soybeans (R. E. Rejesus), control of soybean insect pests in Thailand (Pisit Sepswasdi), entomophagous insects in a soybean pest control strategy (M. E. Irwin and P. W. Price), and soybean disease and insect pest management (M. Kogan). These topics, broad in scope, were meant to provide background information about Asian soybean pests and their control. They also endeavored to introduce the concepts of diversity, natural control, and integrated pest management. Two important cornerstones of pest management were not covered: (a) the concepts of low dosage pesticides and (b) soybean resistance to insect pests. These two topics, along with the three important insect pest complexes associated with Asian-grown soybeans, are treated in this symposium.

I sincerely hope you take with you from this symposium a better understanding of the importance of entomology in your respective soybean programs and some rudimentary principles for approaching and solving insect pest problems.

Resistance in Soybean to Insect Pests

Marcos Kogan

Soybean pest management research programs give high priority to the development and use of pest-resistant cultivars. From an ecological point of view, among the most desirable features of plant resistance are: (a) specificity to the target pest, (b) cumulative effect towards reduction of the pest population over successive generations, (c) persistence over long periods of time, (d) harmony with the environment, (e) compatibility with other control tactics, and (f) a potentially synergistic effect with parasites and predators or with chemical insecticides. Among the limitations of resistance are: (a) time of development, (b) genetic limitations in the plant, and (c) development of biotypes in local pest populations capable of damaging lines resistant to other biotypes of the same species (Kogan, 1975).

Interest in soybean resistance to insect pests is not new, but it has been rekindled by the enthusiasm of pest management specialists for this control technique (Turnipseed, 1972; Turnipseed and Kogan, 1976). Various aspects of soybean resistance to insects have been reviewed recently. Schillinger (1976) described breeding schemes applicable to programs in soybean insect resistance. Turnipseed and Sullivan (1976) presented a historical review of resistance research in soybeans and described current efforts to produce cultivars resistant to defoliating pests in the United States.

Breeding for insect resistance is a team effort. A complete program requires the integration of input from entomologists, plant geneticists, and breeders. Breeders and agronomists contribute the techniques for crossing and hybridization, the genetic analysis of progenies, and the evaluation of agronomic characteristics of selections. It is up to the entomologist to identify sources of resistance, characterize the mechanisms involved, and develop field and laboratory procedures to assay the fate of resistance throughout the breeding program. In this paper I will concentrate on the entomological aspects of resistance research.

EXISTING RESISTANCE IN SOYBEAN CULTIVARS

Most North American cultivars present a normal type of pubescence. This pubescence lends the plants considerable protection against small, leaf-sucking insects such as leafhoppers. Length and erectness of trichomes were considered more important than density in the effect on potato leafhopper populations (Broersma et al., 1972). In experimental plots glabrous (P_1) genotypes (Bernard and Singh, 1969) and curly pubescent (pcpc) genotypes of near isogenic lines of Clark were heavily attacked by leafhoppers. Populations on these plants were three- to sixfold higher than on adjacent, normal and dense (P_d genotypes) pubescent isolines (Kogan and Helm, unpublished).

In the Orient, however, curly and glabrous varieties may be more desirable because the soybean pod borer, *Grapholitha glycinivorella* (Mats.), lays fewer eggs on these than on pubescent varieties (Nishijima, 1960). So far Shore is the only released variety claiming some resistance to a defoliating species, viz., the Mexican bean beetle (*Epilachna varivestis* Mulsant). This is a group V variety developed by breeding programs in Maryland and Virginia in the United States.

EXISTING SOURCES OF RESISTANCE

Screening programs in several research institutions have identified sources of resistance. Table 1 summarizes some of the documented information on these sources. The levels of resistance of the various lines is expressed in relative terms on the basis of available reports. Local breeding programs wishing to use any of these sources should confirm their resistance characteristics under local growing conditions.

Breeding programs in the United States are concentrating mostly on resistance to defoliating species, primarily using PIs 171,451 and 229,358 as sources of resistance. Recurrent parents are selected from the best cultivars in the maturity group adapted to the region.

ENTOMOLOGICAL INPUT IN RESISTANCE RESEARCH

Certain areas of resistance research are the direct responsibility of entomologists. These areas generally involve manipulation of pest populations in the field or development of bioassays in the greenhouse or laboratory.

Identification of Sources of Resistance

Screening programs of large germ plasm collections use single or replicated rows 1 to 2 meters long. It is

Table 1. Soybean Lines Selected for Resistance Against Various Insect Species

Target species	Lines	Maturity group	Screening method	Level of resistance	Source
Mexican bean beetle (*Epilachna varivestis*)	54,615	III	Greenhouse and lab	Moderate	Illinois[a]
S. green stink bug (*Nezara viridula*)	.....[b]	V-VI	Field	Low-mod.	Louisiana[c]
Mexican bean beetle	90,481	V	Field and lab	Moderate	Maryland[d]
Mexican bean beetle	96,089	V	Field and lab	Moderate	
Mexican bean beetle	157,413	V	Field and lab	Moderate	
Mexican bean beetle, bean leaf beetle (*Cerotoma trifurcata*), corn earworm (*Heliothis zea*), Japanese beetle (*Popillia japonica*)	229,321	VII	Field and lab	Moderate	N. Carolina[e]
	163,453	VII	Field and lab	High	
	203,246	VII	Field and lab	High	
Mexican bean beetle, corn earworm, bean leaf beetle, green cloverworm (*Plathypena scabra*)	171,451	VII	Field and lab	High	S. Carolina[f]
	227,687	VII	Field and lab	High	
	229,358	VII	Field and lab	High	
Bean fly (*Melanogromyza phaseoli*)	83,868[g]	IV	Field	High	Taiwan[h]
	92,748	II	Field	High	
	180,520	?	Field	High	

[a] M. Kogan and C. Helm, unpublished.
[b] Several lines in maturity group VI identified with some levels of resistance.
[c] Herzog et al., 1975.
[d] Elden et al., 1974.
[e] Campbell et al., 1974 and 1975.
[f] Van Duyn et al., 1971.
[g] Eight lines and named varieties were reported with resistance to stem flies. Only three plant introductions were listed here.
[h] AVRDC, 1975.

common practice to interplant known susceptible varieties with the rows of test plants. The susceptible variety serves to trap the pest population and also serves as a basis of comparison for rating the lines. When promising resistant lines are identified, the seed is increased and retested in larger replicated plots. Plots 3 to 5 meters long are usually adequate for retesting selected sources of resistance.

Evaluating Resistance in Progenies of Crosses

After the actual breeding program starts, it is necessary to develop reliable and rapid methods of progeny evaluation. Since thousands of plants may be involved, the method cannot use detailed or time consuming techniques. For most practical purposes a 1 to 5 scale (susceptible, moderately susceptible, intermediate, moderately resistant, and resistant) is sufficient. Interplanting of both resistant and recurrent parents at convenient locations provides a basis for comparative progeny evaluation. Certain workers prefer a direct scale based on percent defoliation, using intervals of 10 percentage points. A variable scale was proposed, using the percent defoliation of the progeny lines as compared with the susceptible, recurrent parent. Rows of lines and parents are alternated for the purpose of this comparison.

Obviously these tests apply only to defoliators. Specific tests must be developed to permit evaluation of other types of injury. In many cases the need for nondestructive methods of observation and evaluation poses serious difficulties for the researcher. Stem fly damage, for example, is difficult to evaluate without destroying the plant. Stem borer injury may be indirectly detected by observing exit holes. Stink bug injury is usually evaluated by carefully examining the seed. Nondeforming stink bug punctures can be detected by means of the tetrazolium tests for viability (Delouche et al., 1962) if no other type of injury occurs; however, direct observation under the microscope is the best method for positively identifying the punctures. Very conspicuous damage caused by certain leaf and pod-webbing species, e.g., *Epinotia aporema* in South America, can be evaluated by direct observation of plants.

Estimation of damage for resistance evaluation is a problem in sampling and it poses inherent difficulties in any sampling program. No universal prescription can be given, and researchers have to develop techniques best suited to the needs of their specific breeding program. Nevertheless, attempts should be made to standardize evaluation methods so that data from different workers can be readily compared and uniformly interpreted.

Field tests in the presence of consistent population levels. Assuming that differential damage levels are caused solely by resistance, screening and evaluation should be based on direct readings if high populations of the target pest are present in the test site. No manipulation of plants or pest populations is needed.

Field tests in the absence of consistent population levels. If the occurrence of a target pest is erratic in the test site, certain steps can be taken to assure that the test plants are exposed to enough insects to reveal eventual resistance or susceptibility. Some of the techniques of pest manipulation in soybean resistance research include: (a) trapping pest populations on preferred hosts; (b) mass releases in the open field of laboratory-reared or field-collected insects; (c) releases of insects inside field cages; and (d) attraction of ovipositing females by means of lights.

The plant trap method is widely used in the United States. Most soybean pests in North America prefer feeding on other legumes, such as common beans (*Phaseolus vulgaris*) or lima beans (*Phaseolus lunatus*). Common beans are planted interspersed within soybean rows or as border rows surrounding the plots. At the University of Illinois we first sow common beans at 20- to 30-cm intervals and then sow soybeans at a normal rate of 20 to 25 seeds per meter of row in rows 1 meter wide. The *Phaseolus* plants grow fast and mature in about 60 days. As the plants become senescent, the trapped insect population migrates to the adjacent soybeans, thus generating the population pressures necessary to evince potentially resistant lines.

In a southern region of the United States where late maturity varieties (groups VI-VII) are generally planted, an early variety, such as Clark 63 (group IV), is often sown as a border around the field about two weeks before the rest of the field is planted. At low latitudes Clark sets pods very early and attracts stink bugs that prefer to feed on pods. When the test plants reach the pod-set stage, the Clark rows are already senescent or are removed, forcing the stink bug population to disperse to the rest of the plots.

The mass release of insects on experimental plots frequently causes an upsurge of predators; thus, results in open fields may be rather erratic. J. Hatchett, United States Department of Agriculture, Stoneville, Mississippi (personal communication) uses a large screen cage to cover about one tenth of a hectare. Test plants are sown in short rows, and at convenient times insects are released within the cage and allowed to feed.

Lights can be used to attract populations of ovipositing adult moths. For maximum efficiency the distribution of light sources, the nature and intensity of the light, and the length of time the lights stay on have to be adjusted according to the behavioral characteristics of each species. This technique has not been tested in resistance research.

Greenhouse and laboratory tests. If greenhouse or laboratory tests are used, caution should be exercised in the extrapolation of the data to field conditions. Many plant characteristics, including the expression of resistance, are drastically affected by greenhouse growing conditions. Tests can be based on two types of plant material, viz., seedlings and excised plant parts.

Seedlings were used at the University of Illinois in a mass screening program of about 600 early maturity,

germ plasm collection plants. Six rows of six plants from each entry were planted in 54 x 38 cm flats on a sand, vermiculite, and top soil (1:1:1) mixture. When one trifoliolate leaflet was completely open, the growing tips were excised. Groups of four flats (24 entries) were placed inside screen cages in a greenhouse. One hundred adult Mexican bean beetles were released inside the cages and allowed to feed for five to seven days. Within each cage there was one row of Clark 63 soybeans, a susceptible variety. Evaluations were made on the basis of the number of leaflets destroyed. Each plant contained a total of five leaflets (two unifoliolates and one trifoliolate). Ratings were based on a 1 to 5 scale, in intervals of 20 percent defoliation.

Excised leaflets or leaf discs are frequently used in both nutritional and preference tests (Kogan, 1972a and 1972b; Kogan, 1975). In one series of tests to monitor resistance in progenies of crosses, the central leaflet of the third leaf from the growing tip was inserted into plastic-capped medicine vials filled with water. The lateral leaflets were removed. Leaflets were held upright by means of a fine, wooden stirring rod. The test plants were randomized and positioned inside screen cages with Mexican bean beetle adults. Ratings were based on comparisons with both parents, which were always represented in each replication.

Identification of the Mechanisms of Resistance

Resistance usually operates via three main mechanisms: (a) the plant affects the insect's responses, oviposition, or feeding (nonpreferences); (b) the plant affects the insect's physiological processes, resulting in syndromes ranging from delayed growth to premature death (antibiosis); and (c) the plant has no direct effect on the insect, but nevertheless can withstand attacks by insect populations that would be damaging to other plants (tolerance).

Preference tests are used to measure preference or nonpreference as a resistance mechanism. Dual choice preference tests were extensively used in soybean resistance to insects. These tests are convenient because preference is defined by comparison with a standard plant (Kogan, 1972a). Antibiosis has been measured by force feeding larvae on an exclusive diet of the test plants. Growth rates, weight gain, and food utilization are good indicators of the various aspects of antibiosis (Kogan, 1972b). Tolerance can only be determined in the field by recording the recovery and yield of plants submitted to various levels of insect attack.

Physiological Basis of Resistance

Studies are under way to identify the chemical characteristics that render certain soybean lines resistant to insect defoliators. Phytochemical analyses of resistant and susceptible plant types are performed to compare the chemical makeup of the plants. Differences in chemical composition are evaluated and tested using bioassays designed to detect effects at various levels of the host selection process. In addition, plant extracts are systematically fractionated, and the biological effect of each fraction is monitored by means of adequate bioassays. An example of the method and some of the bioassays used is presented in Kogan and Goeden (1971). No obvious indications regarding the physiological nature of resistance in soybeans are yet available, since work in this area is just starting.

Genetic Control of Resistance

There is reason to believe that resistance in soybeans to insect defoliators is under multiple gene control. Preliminary preference tests with an F_1 line of a Bragg x PI 229,358 cross suggested a semidominant type of inheritance (Kogan, 1972a) or an additive type of gene action. In fact, Sisson et al. (1974) suggested that several genetic factors are involved in the expression of soybean resistance to the Mexican bean beetle.

CONCLUSION

In many parts of the world soybeans are being introduced for the first time. Pest populations in most cases can be conveniently controlled by means of well-timed, low dosage applications of nonpersistent pesticides. During this rather comfortable phase in the dynamics of insect/soybean interactions, the time factor is in favor of resistance research. This is a long process, but identification of sources of resistance against the main potential pests should receive high priority in breeding programs. Field and laboratory techniques are available to promote adequate progress in evaluation of progenies. For most practical breeding purposes a scoring scale ranging from 1 to 5 seems sufficient. For more refined studies on the genetics and mechanisms of resistance a detailed evaluation based on plant and animal growth and development analyses may be necessary. Investigations into the physiological bases of resistance should greatly accelerate progress in breeding by providing more direct means of evaluating progenies and screening germ plasm collections. Finally, in view of the inherent tolerance of soybeans to defoliation and depodding, breeding programs do not have to aim at 100 percent resistance. Moderate levels of resistance may interact with the effect of natural enemies to keep pest populations below the economic injury level. It is also possible that partial resistance renders insects more susceptible to lower dosages of insecticides, thus permitting the use of lower dosages of nonpersistent pesticides should the need arise.

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Bean Flies and Their Control

R. I. Rose, C. S. Lin, S. P. Kung, H. W. Kao, C. Y. Su, and C. Y. Chang

Soybeans are among the hosts preferred by two species of agromyzid bean flies at the Asian Vegetable Research and Development Center (AVRDC). *Melanagromyza sojae* Zehntner is relatively specific to soybeans, while *Melanagromyza phaseoli* Coquillett has a host range including at least eight different genera of legumes. It occurs in Africa, India, Indonesia, Thailand, Malaysia, the Philippines, Taiwan, and elsewhere. *M. phaseoli* is probably the predominate species in Southeast Asia, and infestations frequently necessitate replanting following the death of the seedling caused by larval tunneling.

SEASONAL FLUCTUATIONS IN POPULATION DENSITY

Soybeans were planted at two-week intervals throughout most of 1975 to determine seasonal fluctuations in the percent of plants damaged by *Melanagromyza* spp. Two 100-plant samples, collected from each planting after three and four weeks of growth, were dissected. The percent of damaged plants rose from March through April to over 90 percent and declined from May to August to about 50 percent. Damage levels again rose during August, reaching nearly 100 percent in September and remaining at or near 100 percent through early November. The percent of damaged plants declined sharply in the latter part of November and December. The actual number of bean fly larvae and pupae in 100-plant samples was correlated with the percent of damaged plants. Populations were high from April to June; declines occurred in June, July, and early August and rose thereafter to a maximum of 2.6 larvae and pupae per plant in November. The population declined sharply during November and December.

Adult bean flies were most abundant in the spring and fall, and less abundant in the summer. This correlated closely with damage and infestation levels obtained by dissection. Adult bean fly numbers were monitored by means of an air suction trap constructed at AVRDC for US$230. Details of this trap are available from the authors.

BIOLOGICAL CONTROL

Parasitism rates for bean flies infesting soybeans were determined during the spring and summer growing seasons of 1975 at AVRDC. The most prevalent of the four species of hymenopterous bean fly parasitoids observed was *Plutarchia* sp. (Fig. 1). In soybean fields the pupal parasitism of *Plutarchia* increased to nearly 50 percent during April and July in both species of bean fly (Fig.

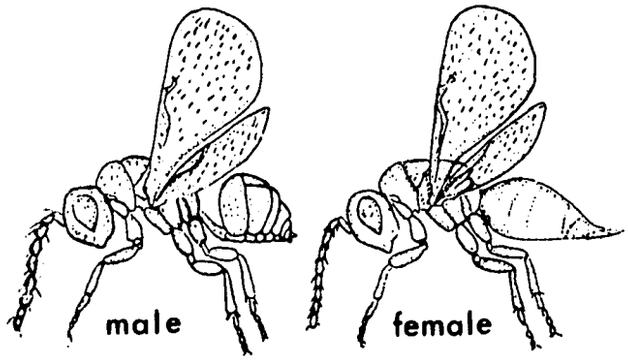

Fig. 1. *Plutarchia* sp. (Hymenoptera:Eurytomidae), a parasitoid of *Melanagromyza phaseoli* Coq.

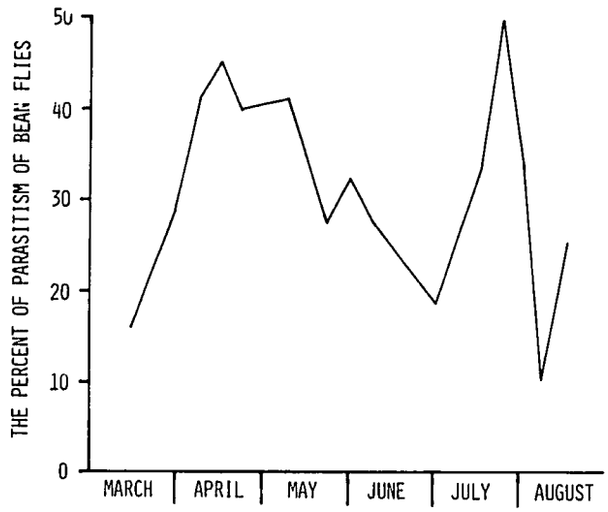

Fig. 2. Percentage of bean flies (*Melanagromyza phaseoli* and *M. sojae*) parasitized by *Plutarchia* sp. on soybean at AVRDC, Taiwan.

2). Rate of parasitism was found to be dependent on the density of bean fly populations.

INSECTICIDES

Both preventative and curative insecticides are at present the most practical method to control the bean fly. Field plot insecticide evaluations were conducted in 1974 at AVRDC, and the following insecticides were found to provide the best control: Furadan, Dimethoate, Azodrin, Hostathion, and Folimat. The most effective insecticides found in 1975 were Dimethoate, Folimat, Furadan, Cytrolane, Surecide, Vydate, and Formothion.

The use of preventive, soil systemic insecticides on a regular basis is costly and impractical for Asian farmers. The quantities of active ingredient necessary are considerably greater than those required in spray formulations. In addition, bean fly populations frequently are not high enough to affect yield. Soybeans will tolerate light to moderate infestations by compensating for stand thinning, and plants frequently survive the presence of one or two larvae. Bean flies can probably be controlled most economically through the use of curative sprays after bean flies are detected in large numbers in the field and some seedling mortality has occurred. This requires surveillance of the crop early in the growing season, followed by corrective action during this critical period.

VARIETAL RESISTANCE

Because the use of insecticides to control the bean fly is costly and laborious, screening for varietal resistance was begun at AVRDC in early 1974. Since different bean fly species are reported and biotypes may be expected with insects in different geographical areas, additional trials were carried out in Thailand and the Philippines in October and November 1974. After field testing 1,246 soybean cultivars, the following were considered moderately resistant: Indonesia 637, Indonesia 1288, S.P. Soybean, Huang-Pau-Tsu, Wilken, PI 180520, PI 83868, and PI 92748. In the autumn of 1975 an additional 187 soybean cultivars were screened for resistance to bean flies. The mean infestation level of each of the 187 lines was determined, and the cultivars were ranked. Twenty lines of the 187 evaluated had infestations well below the overall mean (Table 1).

Table 1. Bean Fly Infestation Rates for Twenty Most Resistant Lines in Field Screening Trials of 187 Soybean Lines at AVRDC, 1975

Cultivar	No. bean flies per plant[a]
1390 D.H.S.	0.50
Clay	0.60
Harosoy	0.70
Wilken	0.70
PI 227687	0.70
887 Genjah slav	0.70
826 Klungkung	0.73
Ada	0.83
88508 650	0.87
D 514-20	0.87
153234	0.90
82235 321	0.90
1005 Hernon	0.90
16 Otan	0.90
189952	0.93
83945-1	0.93
189956	0.97
96201	0.97
317 Ringgit	0.97
Gesjamyum	1.00
Mean of 187 lines tested	1.44
Standard deviation	0.43
$LSD_{.05}$	0.64

[a] Data shown include both larvae and pupae and are based on dissection of 10 plants in each line. Planting was on 6 November and sampling on 20 December 1975.

Discussion

M. E. Irwin: Can oviposition wounds and economic injury levels be correlated?

R. I. Rose: Oviposition wounds are closely correlated

with infestation levels, but they have not yet been used as a measure of infestation level in insecticide tests where economic injury level information has resulted. Counts based on the dissection of plants have been used instead, because they provide a direct measure of the actual infestation and require only a little more time.

Marcos Kogan: Have you considered infrared photography to determine infestations by bean flies?

Rose: Individual plant examination using infrared photographs could be quite costly, but it may have merit for aerial photographs of whole fields to determine concentrations of damage. We have considered a fluoroscope using a mild X-ray source to scan plants, but have not developed the technique because of lack of time and resources.

Unknown: Is there any apparent yield difference in varieties that have been screened and classified as resistant?

Rose: Those varieties identified as relatively resistant or less preferred have not had notable or outstanding yield characteristics.

Pod Borers and the Seed Pest Complex in Asian Soybeans

Takashi Kobayashi

The major pod borers found in Japan include the soybean pod borer, *Leguminivora glycinivorella* Matsumura; the lima bean pod borer, *Etiella zinckenella* (Treitschke); the Azuki pod worm, *Matsumuraeses phaseoli* Matsumura; and *M. falcana* (Walsingham).

BIOLOGIES OF SOYBEAN POD BORERS

Soybean pod borer (*L. glycinivorella* Matsumura) (Lepidoptera:Trotricidae). This species occurs throughout Japan, Korea, China, and Siberia, where the larvae damage seeds of the domestic soybean as well as seeds of two wild legumes, *Glycine soja* and *Pueraria hirsuta* (Kobayashi, 1972). Damage is generally most severe in the cooler, more northerly areas of Japan where this pest has a single generation per year; in warmer, more southerly areas the borer destroys less and completes two generations per year. The adult female lives for 8 to 30 days and is active in the morning and evening. She deposits eggs selectively just after completion of pod elongation and lays between 200 and 300 eggs during her life span. The incubation period is 7 to 9 days, and the newly hatched larvae bore into pods and feed exclusively on developing seeds.

Soybean seeds, incompletely consumed by the developing, white larva, can be found within pods, along with minute, ellipsoidal fecal pellets after the fully developed larva, 9 mm long and light reddish-yellow (Fig. 1), has bored an elliptical hole in the pod and escaped to hibernate in the ground.

Varietal differences greatly influence survival of this species. For instance, female moths lay fewer eggs on varieties with glaborous pods than on those with hairy pods; larval mortality is higher on long-leafed, small-seeded varieties (Nishijima and Kurosawa, 1953) available to farmers in Japan as a means of cultural control. Podding periods of very early and late varieties also escape peak abundance of adult moths (Kobayashi et al., 1972).

The soybean pod borer is known to be parasitized by seven species of Hymenoptera in Japan: one egg parasitoid, *Trichogramma jezoensis* Ishii (Trichogrammatidae); three larval parasitoids, *Bracon abscissor* Nees (Braconidae), *Mastrus tenuibasalis* Uchida (Ichneumonidae), and *Scambus glycinivorella* Uchida (Ichneumonidae); and three larval-pupal parasitoids, all belonging to the family Ichneumonidae, viz., *Dichrogaster tenuibasalis* Uchida, *Isperopus hakoneusis* Ashmead, and *Pristomerus chinensis* Ashmead (Yasumatsu and Watanabe, 1965). Figure 2 shows a female *Scambus* sp. searching for a soybean pod borer larva.

Lima bean pod borer (*E. zinckenella*) (Treitschke) (Lepidoptera:Pyralidae). Nearly cosmopolitan in distribution, this species undergoes two generations per year in central Japan and three in southern Japan. Larvae feed on various pulses, e.g., soybean, pea, cowpea, string bean, kidney bean, lima bean, mung bean, *Glycine soja, Vicia* spp., and *Lathyrus* spp. (Kobayashi, 1972). Damage to soybeans is more severe in warmer climates and where earlier podding varieties are planted. In soybean varieties sown in the fall, a larva consumes only a few seeds before hibernating in plant debris in the ground. Adults are active at night. A single female lays between 1 and 3 eggs on each young pod, calyx, or leaf stalk and deposits a total of 60 to 200 eggs during her lifetime. During the summer, egg incubation is 5 to 7 days, and the newly hatched larvae bore into pods and feed on developing seeds. Larvae reach maturity in about 20 days and thereafter emerge from pods to pupate in the ground. The last instar larva is about 15 mm long and pale bluish-green with light red spots on the body (Fig. 3). The pupal period lasts about 10 days.

Pod injury by this species is recognizable by specific characters even when the larva is absent, i.e., feeding marks are rough and the injured pod contains large, round fecal pellets and has a large, round hole through which the larva has emerged.

Only one parasitic species, *Philomacroploea pleuralis* Ashmead (Hymenoptera:Braconidae), has been reared from larvae of *E. zinckenella* from Japan and Taiwan.

Azuki pod worm (*M. phaseoli* Matsumura) and *M. falcana* (Walsingham) (Lepidoptera:Tortricidae). There are two closely related pod worms in Japan, *M. phaseoli* from Japan, Korea, and Amur, and *M. falcana* from Japan, China, Taiwan, and Nepal (Razowski and Yasuda, 1975).

Larvae of *M. phaseoli* attack numerous wild legumes and leguminous crops, e.g., red bean, cowpea, soybean, kidney bean, and broad bean (Kobayashi, 1972). Up to 30 percent of the soybean harvest can be destroyed in the warmer parts of Japan. In early maturing varieties, larvae bind leaves together and reduce photosynthetic activity. As the plant becomes larger, the larvae bore into stems and break branches. In late maturing varieties, larvae bind pods, leaves, and branches together and feed on soybean seeds and pods (Fig. 4). The last instar larva is about 15 mm long, light grayish-brown, and has scattered, minute gray granules on the body. This species has three to four generations per year in southern Japan. Larvae sometimes bind the leaves of broad beans together and hibernate inside. The biologies of this species and *M. falcana* are incompletely known.

Natural enemies of these pests have not been determined. However, some spiders, such as *Pardosa laura* Karsch, appear to be predators of these and other pod borers.

FACTORS THAT INFLUENCE DAMAGE BY SEED PESTS

Regional variation in damage by seed pests. The total amount of damage to soybean seeds by all seed pests, including pod borers, stink bugs, and the pod gall midge, was surveyed at harvest time in the Tohoku, Kanto-Tosan, and Shikoku areas of Japan. Although damage varied with place and year, there was a tendency for greater damage in warmer districts, sea-coast areas, and warmer years than in cooler districts, inland areas, and cooler years.

Tohoku was divided into three regions on the basis of pest occurrence (Kobayashi et al., 1972; Kobayashi and Oku, 1976). In Region I, north of the January isotherm of −1.5°C, the only economically important seed pest is the soybean pod borer. In Region II, between the January isotherms of −1.5°C and +2°C, the soybean pod borer predominates in cooler years, while stink bugs and the pod gall midge predominate in warmer years. In Region III, south of the January isotherm of +2°C, stink bugs and the pod gall midge always predominate. Damage to harvested seed averaged 17, 23,

Fig. 1. Fully developed larva of *Leguminivora glycinivorella* and soybean seed damage.

Fig. 3. Last instar larvae of *Etiella zinckenella* and soybean seed damage.

Fig. 2. *Scambus* sp., female, searching for soybean pod borer larva.

Fig. 4. Last instar larva of *Matsumuraeses phaseoli* and soybean pod damage.

and 28 percent in Regions I, II, and III, respectively. Correlations were high between regional variation of seed damage and regional fluctuation of mean monthly temperatures based on data gathered over seven years (Kobayashi et al., 1972). Percent damaged seed and mean January and August temperatures were positively correlated with all seed pests, all southern seed pests, stink bugs, and the pod gall midge, and were negatively correlated with the soybean pod borer.

Generally speaking, the seed pest complex was simpler and the percent damaged seed lower in Region I than in the other regions; thus, Region I may be regarded as the area where a higher proportion of nondamaged seed can be grown most easily.

Prediction of damage caused by insects. Significant correlations were detected between annual variation of seed damage and annual fluctuation of monthly mean temperatures for January, July, and August for Tohoku (northern Japan) and for each of its three aforementioned regions. In northern Japan insecticide applications are most effective from mid-August to early September. Thus, by using linear regression equations calculated to predict severity of damage to soybean seed by each seed pest, damage estimates are possible prior to initiation of insecticide applications (Kobayashi et al., 1972).

Control of seed pests by insecticides. The pod gall midge, stink bugs, and four species of pod borers infest soybean plants during early pod set, from middle pod elongation to middle seed thickening in the southern half of Tohoku. During this period two or three applications at intervals of one to two weeks are adequate to control these pod-infesting pests. Effective insecticides, including Lebaycid, Cyanox, Sumithion, PAP (Elsan, Papthion), Ortran, Dursban, and EPN, are applied on the basis of the forecast system mentioned above.

Cultural control of insect pests of seed. In Japan late podding varieties are generally less damaged by seed pests, including stink bugs, than are early podding varieties. In fact, the damage clearly decreases even within the same variety when the sowing date is delayed (Ishikura et al., 1955). Therefore, careful consideration should be given not only to choice of variety, but to time of sowing to avoid temporal coincidence of peak abundances of insect pests and the soybean podding period. It is also desirable to adopt intercropping systems that contain tall crops like maize and to adopt reasonable crop rotation on a large scale to assist in pest control.

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Stink Bug Complex in Soybeans

E. A. Heinrichs

The complex of phytophagous stink bugs (Hemiptera: Pentatomidae) is one of the most important groups of insects attacking soybeans throughout the tropics and subtropics. Nymphs and adults of stink bugs damage primarily the bean portion of the soybean plant by inserting their piercing-sucking mouthparts through the pod and into the bean. Both soybean yield and quality are reduced by stink bug feeding.

SPECIES COMPOSITION

Species composition of the stink bug complex varies from region to region throughout the world. Generally, only a few species are of economic importance, while most are of minor importance. In the southern United States the most common species are the southern green stink bug, *Nezara viridula;* green stink bug, *Acrosternum hilare;* and the brown stink bug, *Euschistus servus* (Miner, 1966). In Rio Grande do Sul, southern Brasil, the complex is made up of more than a dozen species, *Piezodorus guildinii, N. viridula, Dichelops furcatus, Edessa meditabunda, E. rufomarginata, Acrosternum armigera, Mayrinia curvidens, Tibraca limbativentris, Acledra* sp., *Barnasa* sp., *Arvelius* sp., *Oebalus* sp., *Proxys* sp., and *Brachystethus* sp. *P. guildinii* and *N. viridula* are abundant, *D. furcatus* and *E. meditabunda* moderately so, the rest rare. The relative abundance of *P. guildinii* and *N. viridula* varies from one portion of Rio Grande do Sul to another.

Of the economically important stink bug species, *N. viridula* is the most cosmopolitan, being found through-

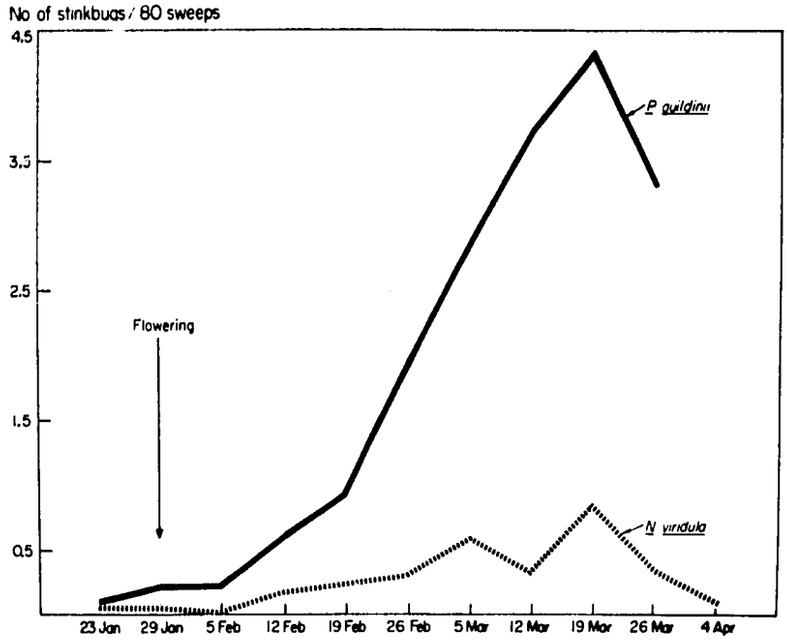

Fig. 1. Seasonal occurrence of *P. guildinii* and *N. viridula* in Davis soybeans planted 26 October 1974. Guaiba, Rio Grande do Sul, Brasil. Source: M. H. Galileo and H. O. Gastal.

out the tropical and semitropical regions of the world (Singh, 1973). The southern green stink bug and other species are polyphagous, feeding on numerous hosts (Miner, 1966; Singh, 1973). When soybeans are introduced into a new area, stink bugs readily move from native host plants to soybean fields.

SEASONAL OCCURRENCE

Stink bugs may appear in a soybean field shortly after germination and continue through harvest, but they generally become abundant only after the pods begin to develop. In our research plots in Brasil *P. guildinii* and *N. viridula* occurred simultaneously (Fig. 1). *P. guildinii* was present in low numbers from germination to one week after flowering. When pods began to form, it began to increase in numbers and reached a peak when the beans were nearing maturity. *N. viridula* peaked during the same week as *P. guildinii,* but *P. guildinii* was much more abundant.

DAMAGE

It is generally assumed that phytophagous stink bugs prefer to feed on pods. This is not true, however, for all stink bug species. In 1974 we conducted a study to determine the economic threshold of *E. meditabunda.* At the termination of the experiment, pods were harvested and beans removed. None of the beans was damaged, even at levels as high as 80 bugs per meter of row. This experiment was repeated in 1975. Detailed observations indicate that this species feeds only on stems and branches, not on pods. Stems and branches become black after pest feeding because of the sooty mold growing on the sap that exudes from the pierced plant. The feeding damage did not affect yield.

Pod feeding is more common. Miner (1966) studied the histological aspects of stink bug damage to soybeans. The stink bug apparently injects histolytic agents that liquify cell contents; ingestion causes rupture and removal of cell walls. The chalky spots in the damaged parts of the bean are probably due to air spaces left when cell contents are removed, rather than to pathogen damage as has been reported.

Feeding early in the pod development stage prevents bean development, and pod drop occurs. As beans increase in size, the degree of pod drop due to stink bug feeding lessens. Research conducted by I. Corso, P. S. Lehman, and the author (unpublished results) indicated that pod drop was normal. However, pod drop in plots with seven stink bugs per meter (mostly *P. guildinii*) was twice that in plots free of stink bugs. Having the ability to compensate for insect damage, soybeans set additional pods on damaged plants. At harvest there was no significant difference in numbers of pods in the insect-infested and the insect-free plots. Infested plots, however, contained fewer, smaller, and poorly developed beans.

At harvest the number of pods was greater on caged plants infested with 12 or 20 *P. guildinii* per meter of row than on uninfested plants (M. H. Galileo, unpublished observations). The number of beans per pod decreased slightly but significantly as a result of stink bug feeding. Bean weight was severely affected, and the degree of damage was related to the stage of pod development at the time of attack.

FOLIAR RETENTION

Foliar retention under severe stink bug attack, as reported by Gomes (1966) in Brasil and Rizzo (1972) in Argentina, occurs when beans fail to develop normally.

When pods are removed by caterpillar feeding or are damaged by severe stink bug feeding, plants retain their leaves, and their stems remain green long after normal maturity. The presence of these green plants makes harvesting difficult. The degree of foliar retention increased with an increase in the number of stink bugs per meter of row, and attack early in bean development was more severe than later attack (Fig. 2).

GRAIN QUALITY

Feeding by stink bugs profoundly affects soybean quality. Daugherty et al. (1964), Todd and Turnipseed (1974), and Miner and Wilson (1966) reported that percent oil and protein are related to degree of stink bug feeding. Daugherty et al. reported that oil content decreased and that percent protein and fat acidity values increased with an increase in the number of stink bug punctures per bean. As a result, seeds damaged by stink bugs deteriorate rapidly in storage. Fat acidity increases because of bean fat decomposition induced by microorganisms that enter through punctures made by stink bugs. Decomposition is especially severe at high moisture levels (Miner and Wilson, 1966). Todd et al. (1973) found that stink bug damage to developing soybeans caused changes in the fatty acid composition of soybean oil. As the severity of stink bug damage increased, palmitic, stearic, and oleic acids increased, while linoleic and linolenic acids decreased.

GERMINATION

Germination decreases as stink bug damage increases. Daugherty et al. (1964) reported that germination dropped from 98 percent in undamaged beans to 37 percent in beans with eight or more punctures. According to Jensen and Newsom (1972), the location of the puncture is more important than the number of punctures. One puncture in the radicle-hypocotyl axis prevents germination, while several punctures in other portions of the cotyledon may not affect germination. Vigor, however, may still be affected.

We studied the relationship between degree of damage and germination after a six-month storage period. According to Jensen and Newsom (1972), beans were classified into four damage categories: none, slight, moderate, and severe. Of the nondamaged (normal) seeds, 93 percent germinated, while only 5 percent of the severely damaged seeds germinated (Fig. 3). Light damage (indicated by a discolored but wrinkle-free area) late in the bean development stage did not significantly affect germination. We also found that seeds damaged by stink bugs and left in the field past maturity degenerated much more rapidly from weathering than did nondamaged seeds. Culturing of damaged seeds indicated that numerous secondary microorganisms were present, while undamaged seeds were, for the most part, free of such organisms.

TRANSMISSION OF PATHOGENS

Besides predisposing soybean seeds to the entrance of secondary organisms, stink bugs have been proven to transmit the fungus *Nematospora coryli* Peglion. Daugherty (1967) showed that six species were vectors of the *N. coryli* causal agent of yeast spot disease. Corso et al. (1975) isolated *N. coryli* from heads of *N. viridula* and *P. guildinii* collected in soybeans in Brasil. Clarke and Wilde (1970a and 1970b) found that adult *Acrosternum hilare* infested with *N. coryli* remain infested for life and that 23 percent of field-collected adults were infested.

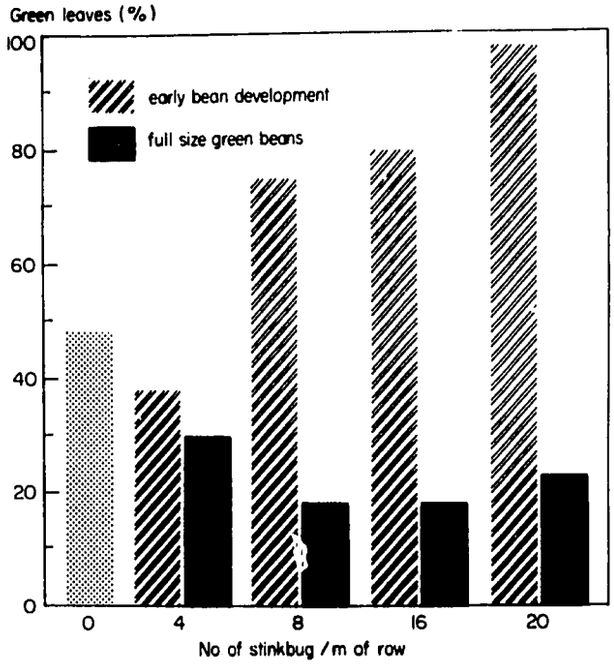

Fig. 2. Foliar retention of Davis soybeans at near harvest after caging with stink bugs at two stages of plant development. Guaiba, Rio Grande do Sul, Brasil, 1974. Source: M. H. Galileo.

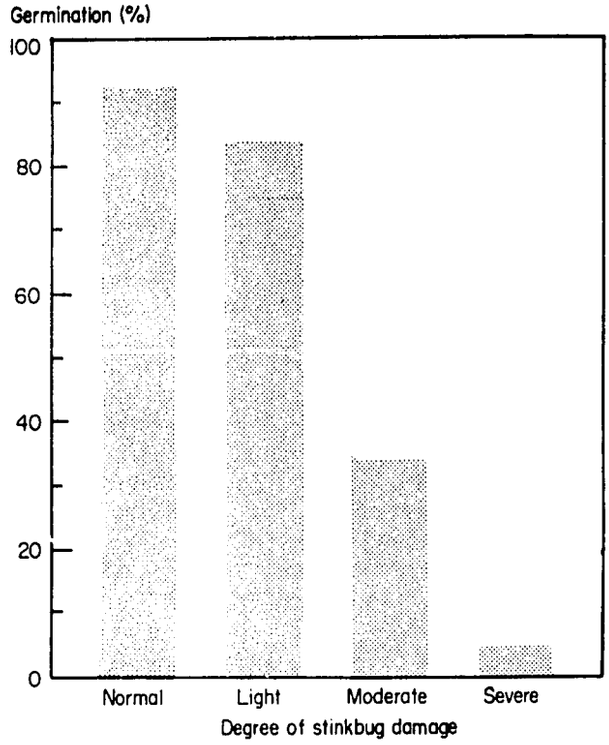

Fig. 3. Germination of soybeans with different degrees of stink bug damage after five months in storage. Guaiba, Rio Grande do Sul, Brasil, 1974. Source: M. H. Galileo.

Clarke and Wilde (1971) studied the effects of yeast spot on soybean quality. They examined beans stored for 18 months and found no distinct differences in the oil and protein of beans fed upon either by bugs infested with *N. coryli* or by bugs free of the pathogen. Weight loss in storage, however, was significantly higher in beans fed upon by infested bugs.

VARIETAL DIFFERENCES

Very little has been done in the development of varieties with resistance to stink bugs. M. Sullivan (personal communication) is screening germ plasm in a search for stink bug resistance in the southeastern United States.

No resistant varieties have yet been released, but varieties do differ in their response to stink bug attack, not because of resistance, however, but because of escape. Short-duration varieties tend to avoid attack to some extent. Daugherty (1964) and Miner (1966) reported that later maturing varieties tend to be damaged more than early maturing varieties. Early plantings also have more damage than late plantings. In early maturing varieties where the blooming-to-maturation period is shortened, the period at which plants are available for feedings is shortened. Early maturation can allow plants to mature before the stink bug population reaches a peak.

ECONOMIC INJURY THRESHOLDS

Todd and Turnipseed (1974), who determined the economic thresholds of *N. viridula,* found that a population of more than 3 bugs per meter of row caused economic damage. In Florida the extension service recommends applying insecticides when the population reaches 3 bugs per meter of row (Strayer and Greene, 1974). In our project on insect management for soybeans in Brasil, we recommended treatment when the number of bugs (0.5 cm or longer) approached 2 per meter of row in 60-cm rows.

The threshold level is determined by various factors, including variety, stink bug species, row width, number of pods per meter of row, and period of pod development at which damage occurs. Regional studies must be conducted to serve as a basis for local recommendations.

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Discussion

R. E. Ford: Rosetting and foliar retention symptoms similar to those you described can be caused by tobacco ringspot virus or tobacco streak virus, and the foliar retention symptom is commonly caused by soybean mosaic virus. Do you know of any reports or evidence implicating stink bugs as vectors of plant viruses?

E. A. Heinrichs: I know of no literature indicating that stink bugs are capable of transmitting a plant virus to soybeans. Foliar retention can be caused by numerous factors, including severe stink bug attack.

Minimum Effective Rates of Insecticides in the Control of Soybean Insects

E. A. Heinrichs

Insecticides are the primary method of controlling insects that attack soybeans, and they will remain so for some time to come. Even when practical, alternative control methods become available, insecticides will be an integral component of a soybean insect management program.

Application of minimum effective rates, i.e., the lowest rates at which an insecticide can effectively control a target pest, should be incorporated into such a program. Especially important in view of the rapidly rising costs of insecticides, application of minimum effective rates is one method of decreasing production costs. Certain insecticides are ecologically more compatible when application rates are lowered, because the lower rates allow greater survival of natural enemies. The presence of natural enemies prevents the resurgence of pest species that would require additional pesticide applications to maintain control.

Farmers have used high insecticide rates for years. Surprisingly, research on the concept of minimum effective rates was only recently initiated, primarily because (a) farmers wanted nearly 100 percent kill of target pests; (b) recommendations for given chemicals for soybean pest control are often based on the species in a pest complex most difficult to control, even though its population density may be below the economic threshold; (c) until recently, the importance of natural enemies as mechanisms of pest population regulation was not well known and their conservation was considered inconsequential; and (d) research has failed to provide the extension agent with sufficient information upon which to base recommendations for minimum effective rates. Thus, as researchers we must provide the farmer with information he can use to maintain pest control and at the same time decrease production costs by decreasing the quantity of insecticide applied to the soybean ecosystem.

Results of recent research in parts of the United States on minimum effective rates have been used as a basis to lower recommended rates of insecticides to control soybean pests elsewhere. For example, rates of 1 to 1.5 kg active carbaryl per hectare were formerly recommended in Florida for the control of velvetbean caterpillar, *Anticarsia gemmatalis* Hubner (Lepidoptera:Noctuidae) (Hinson, 1967). Based on more recent research, the recommended rate was lowered to 0.25 to 0.75 kg per hectare (Strayer and Greene, 1974). Recommended rates of carbaryl were also reduced for the control of

corn earworm, *Heliothis zea* (Boddie) (Lepidoptera: Noctuidae), and the southern green stink bug, *Nezara viridula* (L.) (Heteroptera: Pentatomidae).

Thus, progress has been made in certain regions, but farmers in major portions of the soybean-producing areas of the world have not been provided with soybean insect control recommendations based on research to determine minimum effective rates.

MINIMUM EFFECTIVE RATES OF BROAD SPECTRUM INSECTICIDES

Control of target pests. Recommendations for broad spectrum insecticides are often higher than necessary to provide adequate control. Turnipseed et al. (1974b) determined minimum effective rates, i.e., 80 percent mortality at 48 hours after treatment, for some soybean pests in the southeastern United States: Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae); green cloverworm, *Plathypena scabra* Fabricius (Lepidoptera: Noctuidae); corn earworm; and velvetbean caterpillar. Control effectiveness depended upon type of insecticides, insect stages attacked, and species of pest. Methomyl was most toxic. Rates of carbaryl and methyl parathion at five and ten times that of methomyl were required to effectively control the corn earworm. Mexican bean beetle larvae were controlled with 0.2 kg active methyl parathion per hectare, while 0.9 kg was required to control adults. The corn earworm was the most difficult species to control, requiring five times more carbaryl than the Mexican bean beetle. Da Silva (1975) tested several broad spectrum insecticides at low rates of 0.25 and 0.13 kg active ingredient per hectare for velvetbean caterpillar control in Brasil. Insecticides distinctly differed in effectiveness between application rates. Methomyl and monocrotophos provided excellent initial control at both rates; however, at three days after treatment with carbaryl, control was adequate only at the higher rate. Residual activity was short for all broad spectrum insecticides.

Effect on natural enemies. Conservation of predators in a soybean ecosystem is an important aspect of integrated control. Certain broad spectrum insecticides that are highly toxic to natural enemies at currently recommended rates may allow significant survival at lower rates. Turnipseed (1972) and Turnipseed et al. (1975) studied the effect of low rates of broad spectrum insecticides on *Geocoris* spp. and *Nabis* spp., both hemipterous predators of soybean pests. Excellent survival of both predacious genera was obtained with carbaryl, even at extremely high rates of 4.5 kg active ingredient per hectare. Methomyl was highly toxic to *Nabis* spp. but not to *Geocoris* spp. Methyl parathion was highly toxic to both predacious groups, even at low rates.

Wilkinson et al. (1975) studied the contact toxicity of several broad spectrum insecticides against five parasitoids and two predators of soybean pests. When various insecticides were applied at the minimum recommended field rate and lower, their toxicity to natural enemies in order of decreasing activity was methyl parathion > toxaphene > carbaryl > malathion. Thus, a distinct difference in the effect on natural enemies is evident even among the broad spectrum insecticides, a characteristic that must be taken into consideration in the development of pest management programs.

LOW RATES OF SELECTIVE INSECTICIDES

The role of selective insecticides in an integrated control program has been discussed by Ripper (1956) and

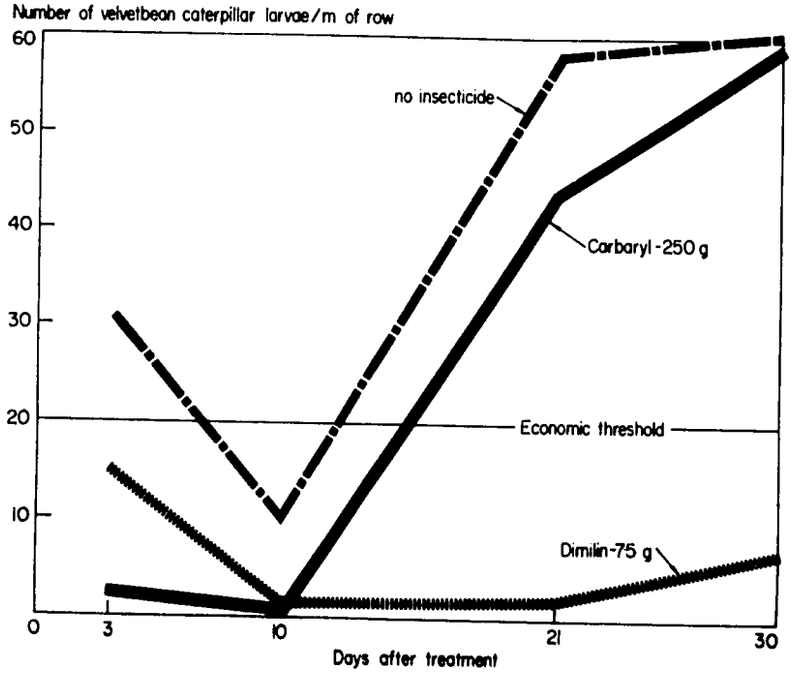

Fig. 1. Residual activity of carbaryl and Dimilin in the control of velvetbean caterpillar. Guaiba, Rio Grande do Sul, Brasil, 1975.

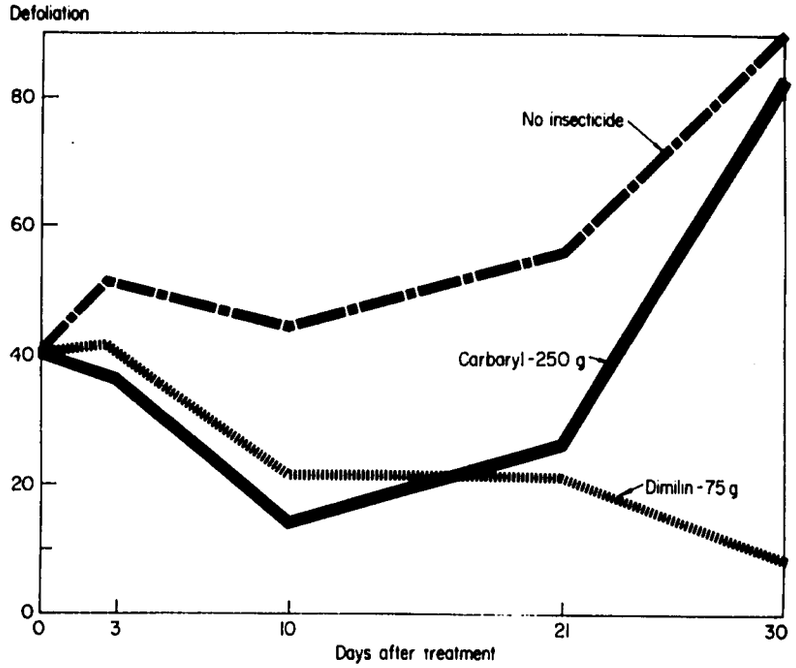

Fig. 2. Defoliation of Davis soybeans by velvetbean caterpillar in a field treated with Dimilin and carbaryl, insecticides that differ in their residual activity. Guaiba, Rio Grande do Sul, Brasil, 1975.

Smith and van den Bosch (1968). Because of their narrow ranges of insecticidal activity, selective insecticides are commercially unattractive to the pesticide industry, and thus only a few are available. Those that are, however, provide an important and attractive means of control in an integrated approach. Wilkinson et al. (1975) tested the contact toxicity of the botanical insecticide pyrethrin, the microbial agent *Bacillus thuringiensis* Berliner, and the *Heliothis* nuclear polyhedrosis virus against five parasites and two predators occurring in the soybean ecosystem. All three were extremely safe for natural enemies, whereas the broad spectrum insecticides tested were highly destructive.

We have field tested the selective insecticide Dimilin against velvetbean caterpillar (Turnipseed et al., 1974a) and found it very effective at low rates. Dimilin is a urea-based chitin inhibitor that prevents normal molting when ingested by the pest. Consequently, it has a very low mammalian toxicity (Mulder and Gijswijt, 1973). Because of its mode of action, it was not expected to have a direct, adverse effect on predators.

Initial tests with Dimilin against the velvetbean caterpillar in Brasil indicated that rates of only 75 g active ingredient per hectare were extremely effective (Fig. 1, 2). Further tests indicated that rates as low as 5 g active ingredient per hectare provided satisfactory control. Our research also indicated that Dimilin had no adverse effect on the common predators occurring in Brasilian soybean fields, viz., nabids, geocorids, and spiders (Table 1). Monocrotophos and methyl parathion, on the other hand, decreased numbers of all three predatory groups.

Resurgence of the velvetbean caterpillar in the monocrotophos-treated plots at 20 days after treatment was probably due to the absence of natural enemies. Dimilin not only had a much longer residual effect than other insecticides, but also prevented a resurgence of the pest, presumably because of its nonadverse effect on population-regulating organisms.

Dimilin did not satisfactorily control *Plusia* sp., a species that is generally more difficult to kill than the velvetbean caterpillar. The population of *Plusia* sp. is usually low in Brasil, however, and only infrequently is control of this pest economically justifiable. This illustrates the importance of determining the economic impact of various pest species before deciding on control recommendations. A new group of compounds, the synthetic pyrethrins or pyrethroids, seems very effective at extremely low rates for controlling *Plusia* sp. R. Colas

Table 1. Resurgence of Target Pest (Velvetbean Caterpillar, *Anticarsia gemmatalis*) and Decline of Predators in Soybean Field After Application of Insecticides, Guaiba, Rio Grande do Sul, Brasil, 1975

Insecticide[b]	Velvetbean caterpillar (no./m of row)	Predators/m of row (no.)[a]		
		Geocorids	Nabids	Spiders
Dimilin	3.6a	1.1a	0.3ab	3.5b
Chlordimeform	22.0b	0.9a	0.5ab	3.9b
Carbaryl	58.3c	1.1a	0.3ab	2.3c
Methyl parathion	52.1c	0.2b	0.0b	2.1c
Monocrotophos	91.3c	0.1b	0.0b	2.1c
Check	22.0b	1.1a	0.7a	5.6a

[a] Based on beat cloth counts. Predator counts made at 7 days after insecticide treatment and velvetbean caterpillar counts at 20 days. Means followed by a common letter are not significantly different at the 5 percent level (DMRT).
[b] All insecticides applied at rate of 250 grams active ingredient per hectare with a motorized mistblower delivering 520 liters of water per hectare.

(personal communication) reported from research conducted in Brasil in 1975 that the pyrethroid Decis effectively controlled *Plusia* sp. at 36 g active ingredient per hectare.

Bacillus thuringiensis is another selective insecticide that is toxic to lepidopterous species and nontoxic to natural enemies and humans. Because of its mode of action, it takes longer to become effective, but it still provides adequate control of the velvetbean caterpillar.

LOW RATES OF INSECTICIDAL COMBINATIONS

Our 1974 research in Brasil indicated that combinations of *B. thuringiensis* and chlordimeform provided initial control of the velvetbean caterpillar equal to that of *B. thuringiensis* alone at twice the rate of the combination; residual activity also increased. The reason for the greater effectiveness of the combination is not known, but may be partially due to the egg-killing activity of chlordimeform (Creighton and McFadden, 1974; Dittrich, 1967) and a repellent action on ovipositing moths (P. Wright, personal communication). Both of these factors could have been responsible for the low number of larvae hatching and reinfesting the chlordimeform-treated plots.

B. thuringiensis is safe to natural enemies, but its short residual activity is a disadvantage. Ignoffo (1974) observed that 65 percent of its activity was lost within 24 hours. Increasing the residual activity of *B. thuringiensis* by combining it with chlordimeform, an insecticide that also appears innocuous to predators (Table 1), seems to provide an ecologically compatible method of controlling the velvetbean caterpillar.

FUTURE RESEARCH

Ecological studies are urgently needed in Asia to determine which pest species are of economic importance within the complex. Studies must then determine the role and importance of various natural enemies in regulating populations of these economically important pest species. Chemicals and rates that provide adequate control of these economically important pests while allowing at least a portion of the natural enemies to survive should then be sought.

The minimum effective rates of broad spectrum insecticides on various soybean pests in Asia must be determined. These studies should be conducted with the objective of cutting production costs for the Asian soybean producer and, it is to be hoped, simultaneously decreasing the adverse ecological effects of these insecticides. Future research is needed on combinations of chlordimeform plus other chemicals, such as carbaryl, that are generally not very toxic to natural enemies at low rates.

Pesticide producers must constantly search for new selective chemicals. The pyrethroids hold promise in the control of certain soybean pests at low rates. In preliminary work pyrethroids show some promise in the control of the bean stem fly, *Melanogromyza phaseoli* Tryon (Diptera: Agromyzidae), a pest of Asian soybeans (M. E. Edgar, personal communication). Accelerated testing of these and other new compounds should be encouraged to determine their effectiveness in controlling additional soybean pests and to determine their effect on natural enemies.

CONCLUSION

In recent years research on minimum effective rates has rapidly advanced, with a consequent decrease in the rates of insecticides recommended to control soybean insect pests. Most of the research, however, has been conducted in only a few geographical areas of the world and on a limited number of pests. This type of research should be expanded in Asia, where insect pests are significant constraints on production.

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Breeding Tropical Soybeans

Introduction

Carl N. Hittle

The tropical soybean breeder must take many factors into consideration. Frequently he will be confronted with more problems, and the need for more objectives, than the temperate zone breeder. Therefore, it is natural that a symposium on breeding tropical soybeans deal with many diverse but related topics.

Each of the topics discussed in this symposium is significant in tropical breeding programs. However, insufficient knowledge of tropical soybeans and inadequate time will not allow all topics of importance to the tropical breeder to be covered. Although breeding for rust resistance is not discussed in this symposium, it is discussed briefly in the rust symposium. Breeding for seed quality, which is of the utmost importance in most, if not all, tropical soybean breeding programs, is briefly discussed here, but is also dealt with in other discussions in this conference.

One of the greatest concerns of a tropical soybean breeding program is the germ plasm, and information on that germ plasm, available to the breeder. T. Hymowitz has compiled a working list of soybean germ plasm collections known to be in existence (see following page). In order to keep this list up to date as more knowledge becomes available, breeders are requested to send information on other collections, as well as additional information on these collections, to Dr. T. Hymowitz, Department of Agronomy, University of Illinois, Urbana, Illinois 61801, U.S.A.

United States National Soybean Germ Plasm Collections

R. L. Bernard and C. N. Hittle

The United States Department of Agriculture (USDA) has attempted to acquire and maintain all available soybean germ plasm since 1949. In that year two collections were established, one of early varieties at Urbana, Illinois, and one of later varieties at Stoneville, Mississippi. USDA was able to gather from various experiment stations many of the old varieties, a total of about 1,500 strains, introduced from eastern Asia during the previous 50 or 60 years. In addition to the foreign varieties, all of the U.S. and Canadian varieties that still could be found were preserved. The collection has grown steadily since that time, until today there are nearly 6,000 strains being maintained. Seeds of these strains are made available to researchers throughout the world.

The USDA collection now consists of several divisions (Table 1). The collection of named varieties consists of past and present commercial varieties of the United States and Canada. The older varieties in this division are simply introductions brought from eastern Asia in the 1910's, 1920's, and 1930's and grown commercially in the United States. The more recent varieties are mostly pure-line selections following controlled hybridization. Currently in the United States there are many privately developed varieties, blends, and so forth being sold to farmers, but because of the confusion involved, the United States Department of Agriculture no longer enters any varieties of secret origin in the germ plasm collection.

The largest division in the collection is that of the foreign cultivars, several thousand in number, identified by FC and P.I. numbers. The genetic collection was established to aid in the preservation of materials useful in qualitative genetic studies. In the genetic type collection, USDA tries to preserve each gene, preferably in the original strain used by the author who described the trait. There are about 100 strains, including a number of mutants not yet studied genetically. In addition to the type collection, there is an isoline collection developed by backcrossing and involving about 60 genes and five recurrent parents. A third subsection of the genetic col-

SOYBEAN GERM PLASM COLLECTIONS

Country and Curator	Address	Number of Accessions	Nature and Origin of Accessions
France			
R. M. Ecochard	Ecole Nationale Superieure Agronomique 145 Avenue de Muret Toulouse	500	Bulgaria, Hungary, China, United States
India			
H. R. Bhatia	Plant Introduction Station Amravati, Haharashtra	1,800	Nepal, Sikkim, India, and many other countries
B. B. Singh	Department of Plant Breeding G. B. Pant University Pantnagar, Uttar Pradesh	4,000	Duplicates of U.S., U.S.S.R., India, Japan collections
Indonesia			
Sumarno	Central Research Institute for Agriculture Jalan Merdeka, No. 99 Bogor	400	Local and introduced
Japan			
T. Egawa	National Institute of Agricultural Sciences Hiratsuka, Kanagawa Prefecture	2,928	Japan
J. Fukui	Plant Breeding Laboratory Iwate University, Ueda Morioka, Iwate Prefecture	200	*Glycine* species
Nigeria			
W. Steele	International Institute of Tropical Agriculture Private Mail Bag 5320 Ibadan	2,000	East Africa, Tanzania
People's Republic of China			
C. L. Wang	Northeast Agricultural College Harbin, Heilungkiang Province	Not available	Land races
T. C. Chang	Institute of Crop Breeding Kirin Academy of Agriculture Sciences Kung-chu-ling City, Kirin Province	Not available	Land races
Republic of South Africa			
J. W. Snyman	Institute for Crops and Pastures Private Mail Bag 116 Pretoria	600	Duplicates of U.S. collections
South Korea			
K. Y. Park	Crop Experiment Station Office of Rural Development Suweon	300	*Glycine* species
S. H. Kwon	Atomic Energy Research Institute P.O. Box 7 Cheong Kyang, Seoul	1,300	Native land races
Sweden			
S. A. Holmberg	Algot Holmberg and Soner AB Plant Breeding Station at Fiskeby 605 90 Norrkoping	1,200	East and North Asia
Taiwan			
S. Shanmugasundaram	AVRDC P.O. Box 42 Shanhua, Tainan 741	9,000	Worldwide collection, many duplicates of U.S. collections
Chan Ko Lein	Taiwan Agricultural Research Institute Taichung	2,800	Many duplicates of U.S. collections
United States			
R. L. Bernard	U.S. Regional Soybean Laboratory Urbana, Illinois 61801	4,100	Genetic types, varieties, *Glycine* species, worldwide northern collection
E. E. Hartwig	Delta Branch Experiment Station Stoneville, Mississippi 38776	1,700	Genetic types, varieties, *Glycine* species, worldwide southern collection
T. Hymowitz	Department of Agronomy University of Illinois Urbana, Illinois 61801		Computer-stored and data retrieval system for *Glycine* germ plasm available in Urbana and Stoneville collections
U.S.S.R.			
N. I. Korsakov	Vavilov All Union Institute of Plant Industry Gerzem 44 Leningrad	2,500	East and North Asia

Additional Collections: **Australia:** CSIRO, Division of Plant Industry, P.O. Box 1600, Canberra City, A.C.T. 2601
Bulgaria: National Institute of Agriculture, Sofia
Hungary: Agricultural Experiment Station, Iregszemcse
Philippines: College of Agriculture, University of the Philippines, College, Laguna
Rhodesia: R. Tattersfield, Ministry of Agriculture, Causeway, Salisbury
Romania: Agricultural Experiment Station, Fundulea

lection is the recently established cytogenetic collection, which will be developed and maintained by Reid Palmer, cytogeneticist at Iowa State University, Ames, Iowa. In the species collection, USDA has represented all or almost all of the known species of *Glycine,* including *Glycine soja* and seven perennial species.

In Table 2 the collection is broken down into the maturity groupings used in the United States and Canada. The genetic and the species collections are not included in this grouping. Of the total 4,941 strains, 3,287 are from the northern and 1,654 from the southern regions. Varieties and strains of maturity groups VII, VIII, IX, and X are of special interest to tropical soybean programs. However, earlier maturing varieties, such as Williams, Davis, and Hill, have done well at some tropical locations.

The history of soybean introductions into the United States is summarized in Table 3. The active collection periods of the 1920's and early 1930's and of the past two years contrast with the slow accession rate for most of the intervening 40 years. The northern collection is predominately from eastern Asia, with about 30 percent from China, 30 percent from Korea, 20 percent from Japan, and 20 percent from Europe. The southern collection is predominately from eastern and southern Asia, with major collections from Korea, Japan, India, Indonesia, and the Philippines, as well as from several other Southeast Asian countries. Some recent additions have come from South America and Africa. These accessions range from primitive, native varieties to recently developed, experiment station varieties. Many have come in from commercial or other nonagricultural sources, and there is no information about the nature of their origin.

The breakdown of the annual wild soybean (*G. soja*) collection is shown in Table 4. Seventy-one percent of these accessions fall within maturity groups V and VI. Recent collections in Korea and Japan have appreciably increased the number of accessions from these two countries. Intense interest is being shown in collections of the annual wild soybean, which appears to have the most potential value to the breeder because it will cross with the cultivated soybean, while the perennial species will not.

The distribution of the 161 accessions of each of the seven perennial species, with a predominance of accessions from *G. tabacina, G. tomentella,* and *G. wightii,* is indicated in Table 5.

Details of the procedure for requesting seeds from the USDA soybean germ plasm collection are indicated in Appendix I. Collection lists and evaluation reports are also available upon request.

Table 1. Divisions of USDA Soybean Germ Plasm Collection, 1976

Category	Location		Total
	Urbana	Stoneville	
U.S. and Canadian named varieties	237	101	338
FC strains	51	39	90
P.I. strains	2,999	1,514	4,513
Genetic			
Types	99	...	99
Backcross isolines	215	20	235
Species			
Annual	361	...	361
Perennial	161	...	161
Total	4,123	1,674	5,797

Table 2. Maturity Grouping of USDA Soybean Germ Plasm Collection, 1976

Maturity group	Named varieties	FC strains	P.I. strains	Total
Northern region				
00	15	5	210	230
0	18	6	287	311
I	42	3	308	353
II	45	6	545	596
III	52	13	667	732
IV	65	18	927	1,010
Unknown	..	..	55	55
Total	237	51	2,999	3,287
Southern region				
V	24	10	733	767
VI	25	10	189	224
VII	25	17	218	260
VIII	26	2	189	217
IX	..	..	49	49
X	1	..	136	137
Total	101	39	1,514	1,654
Grand Total	338	90	4,513	4,941

Table 3. History of Soybean Introductions into the United States

Period	No. of years	Rate/yr	Introduced strains (no.)	Germ plasm collection			
				Groups 00-IV		Groups V-X	
				P.I. strains	Named varieties	P.I. strains	Named varieties
1898-1907	10	10	105	1	12	0	4
1908-1923	16	60	961	49	20	3	7
1924-1928	5	380	1,902	275	5	13	9
1929-1932	4	1,190	4,775	911	30	100	5
1933-1972	40	70	2,800	1,264	..	846	..
1973-1975	3	350	1,051	499	..	552	..
Total	78		11,594	2,999	67	1,514	25

Table 4. Maturity Grouping and Origin of Accessions Through 1976 in USDA Wild Soybean (*G. soja* Sieb. and Zucci.) Germ Plasm Collection

Maturity group	Country of origin				Total
	U.S.S.R.	China	Korea	Japan	
00	4	..	..	..	4
0	1	..	..	..	1
I	5	..	..	..	5
II	5	17	..	..	22
III	..	..	..	..	0
IV	..	..	20	5	25
V	..	8	90	45	143
VI	..	4	24	85	113
VII	..	1	..	45	46
VIII	..	..	..	..	0
IX	..	..	..	..	0
X	..	2 (Taiwan)	..	..	2
Total	15	32	134	180	361

Table 5. Species Distribution of USDA Perennial *Glycine* Collection, 1976

Species	Country of origin	Number
G. canescens	Australia	1
G. clandestina	Australia	11
G. falcata	Australia	3
G. latrobeana	Australia	1
G. tabacina	Australia	17
	Taiwan	5
	Japan	3
G. tomentella	Australia	17
	Taiwan	8
	Philippines	1
	Ethiopia	1
G. wightii	Africa	93
	India	
	Total	161

APPENDIX I: PROCEDURE FOR REQUESTING SEEDS FROM THE USDA SOYBEAN GERM PLASM COLLECTION

USDA maintains a collection of soybean germ plasm, comprised of about 6,000 strains of current and obsolete American varieties, foreign introductions, genetic types, and related species. Seed packets are available for research purposes upon request. The following points are a guide for requesting seeds:

- Address requests for early varieties and P.I. and FC strains (maturity groups 00 to IV), genetic types (T-strains), and wild species of *Glycine* to: Dr. Richard L. Bernard, U.S. Regional Soybean Laboratory, 160 Davenport Hall, Urbana, Illinois 61801; telephone (217) 333-4639. Address requests for late varieties and P.I. and FC strains (group V to X) to: Dr. Edgar E. Hartwig, Delta Branch Experiment Station, Stoneville, Mississippi 38776; telephone (601) 686-9311, extension 230. Requests will be filled as soon as possible after being received, but large requests may take a month or more, and unspecific requests even longer. There is no charge for seed for research purposes.
- Specify how many seeds you want. A standard request is about 50 seeds per packet, but we can easily furnish a smaller number, and if seed supply permits, will also furnish larger amounts. If no amount is specified, we will send 50 seeds. Seed counts are only approximate: we usually cup the seeds and can only partially compensate for size and germination variation. In the case of named varieties, we can sometimes furnish larger amounts, up to approximately one kilogram, and even more in the case of varieties we are currently yield testing. The tropical perennial species (all species other than *G. max* and *G. soja*) are difficult to grow and reproduce, and normally only five to ten seeds will be sent.
- Before sending your request, please verify the accuracy of your strain designations and whether the strains are maintained at Urbana or Stoneville by checking them against a current checklist or evaluation report. We get many requests for nonexistent varieties and P.I.'s. You are in a better position than we are to correctly identify what you want.
- Lists and reports are available to assist you in selecting and requesting germ plasm. With the exception of those marked otherwise, all can be obtained from Dr. Bernard at Urbana, Illinois.

Checklists of name and maturity group:

Groups 00 to IV varieties, 1976
Groups 00 to IV FC and P.I. strains, 1975
Groups V and VIII varieties and FC and P.I. strains, 1975 (Dr. Hartwig, Stoneville, Mississippi)

Evaluation reports giving origin of strains and descriptive, agronomic, and seed composition data:

Varieties, groups 00 to IV, 1970
Varieties and FC and P.I. strains, groups 00 and 0, 1965
Varieties and FC and P.I. strains, groups I and II, 1966
Varieties and FC and P.I. strains, group III and IV, 1969
Varieties and FC and P.I. strains, groups V to X, 1975 (Dr. Hartwig, Stoneville, Mississippi)
Recent additions, varieties, and P.I. strains, groups 00 to IV, 1970

List of Genetic Type Collection
List of backcross isolines of Clark and Harosoy
List of wild soybeans, *Glycine soja*
List of perennial *Glycine* accessions

We appreciate knowing the intended use of the seeds in all cases, and we must know it in the case of requests for very large amounts. We also appreciate receiving copies of publications or other information derived from the use of these seeds.

An Integrated Strategy for Daylength and Temperature-Sensitive Screening of Potentially Tropic-Adapted Soyabeans

R. J. Summerfield and F. R. Minchin

It has long been recognized that appropriate adaptation to daylength is important in soyabeans. Indeed, scores of scientists, among them, Weiss (1949), Hamner (1969), and Shibles et al. (1974), have written about the effects of photoperiod on floral induction, as well as almost all other aspects of soyabean growth and development. As Howell noted in 1960, "There appears to be no case in which a soybean variety is indifferent in its response to day length." Howell again made a similar observation in 1963, and Weber in 1968. More recently, day neutrality with respect to the onset of flowering, especially for varieties from early maturity groups, has been reported by Criswell and Hume (1972) and Polson (1972), among others.

Unfortunately, research related to the effects of temperature on flowering has been markedly neglected despite early observations by Steinberg and Garner (1936) and Parker and Borthwick (1943) that cool temperatures, particularly at night, can reduce the response of soyabeans to inductive photoperiods. Too often neither day nor night temperatures have been precisely controlled (Polson, 1972) if at all (Byth, 1968). In 1968 Byth observed that "the country or latitude of origin of accessions is of limited value in predicting adaptation to specific environments," and that "a relatively complex system is involved in the action of genes controlling photoperiodism in soybeans." Recently, however, the iterative regression analysis technique was developed to relate the rate of soyabean reproductive development to differences in both daylength and temperature (Major et al., 1975). Although average daily temperatures were used, it was found that the coolest regimes had the greatest effects on reproductive ontogeny.

PREDICTIVE SCHEMES AND SCREENING TECHNIQUES

The climates of both the humid and the seasonally arid tropics vary significantly with respect to daylength and temperature. Relatively small differences in altitude can bring about large differences in night temperature (Huxley and Beadle, 1964). It is necessary, therefore, to determine the effects and interactions of all these factors on as many soyabean accessions as possible in order to select varieties prudently for breeding and local trials. Numerous "time-of-planting" studies have been carried out, especially at higher latitudes in the United States, in attempts to quantify photoperiodic effects on phasic development (Hartwig, 1954; Osler and Cartter, 1954). In isolation, such studies are not well suited to photoperiodic research, because they offer no control over other environmental factors (Best, 1959). It is not possible during the growing season to field test the effects of daylength on time to first flower in potentially tropic-adapted soyabeans, for example by sowing at different dates, unless the effects of temperature can be studied simultaneously, for example by sowing at different altitudes. Nor is it possible to accelerate photoperiodic screening of large germ plasm collections by exposing successive batches of plants to inductive daylengths for a small number of diurnal cycles and then growing them under natural daylengths of 13 to 16 hours (Huxley et al., 1974).

A range of photoperiods can be created at any given latitude by extending the natural daylength with incandescent lights suspended above the crop. Light intensities as low as 2 foot-candles are ample to elicit photoperiodic response in soyabeans (Yoshida, 1952). For comparative purposes, the natural daylengths in hours of light above 1, 2, 5 or 10 foot-candles at different latitudes are readily available (Francis, 1972). Flowering of some daylength-sensitive varieties, however, is increasingly delayed as light intensity is increased from 1 to 12 foot-candles (HTA, 1973); the possibility, indeed probability, of temperature interactions with these treatments cannot be ignored (Polson, 1972). Furthermore, the use of low-intensity, incandescent lighting cannot equate to different daylengths in energetic terms and may even have adverse effects on nodulation and hence plant growth (Lie, 1971).

Soyabean seed yields are dependent upon the product of both vegetative and reproductive components, which themselves are markedly affected by photoperiod and day and night temperatures. For determinate varieties, which cease vegetative growth at or soon after flowering, the plant size, and hence the number of nodes produced, depends on the rate of vegetative growth and the duration of the preflowering period. Under tropical environmental conditions, time to first flower is determined by genotypically controlled responses to both photoperiod and night temperature, whereas the rate of vegetative growth appears far more dependent upon night temperature than either daylength or day temperature (Huxley and Summerfield, 1974). Moreover, this vegetative component, described in Fig. 1 as the "phenological potential" for seed production, may not realize its full potential, i.e., reproductive efficacy, because of adverse effects of warm, day temperatures on flower and pod abortion. The rate of leaf senescene and nodule longevity (yield culmination) may also be adversely affected. Clearly, a strategy

Fig. 1. Components of seed yield in soyabeans.

1. Number of nodes plant^{-1} (N_n) ⟶ { Vegetative growth rate × Duration of preflowering period }

2. % of N_n which become reproductive

(1 × 2) = Phenological potential

3. Number of flowers per reproductive node (F)

4. % of F which set pods

} Number of pods per reproductive node (P)

5. % of P which are retained

6. Number of seeds per pod (S)

(3 × 4 × 5 × 6) = Reproductive efficacy

7. % of S which attain maturity ⟷ { Carbon supply / Nitrogen supply

8. Mean seed weight ⟶ { Mean seed growth rate × Duration of pod fill

(7 × 8) = Yield culmination

∴ Yield/Plant = (1 × 2) × (3 × 4 × 5 × 6) × (7 × 8)

is required to screen large numbers of accessions for their responses to photoperiod and day and night temperature, not only with respect to the onset of flowering, but also with respect to the overall efficacy of seed production thereafter (Summerfield, 1975a).

Even though conditions in controlled environments are uniform in space and time, research should be able to predict the climatological situations in which particular varieties are unlikely to succeed. If the direction and magnitude of the effects of climatic factors on selected varieties are known, the types needed for particular circumstances can be more critically defined, and potential sources of genetically adapted or invariant material can be identified (Summerfield, 1975b). However, it is all too easy in poorly controlled and/or in poorly simulated environments to produce plants that bear little resemblance in growth and development to plants growing in the field, especially nodulated legumes (Summerfield et al., 1976b). Furthermore, although world collections of potentially tropic-adapted material may incorporate several thousand genotypes, the numbers that can be accommodated in controlled environments such as glasshouses in any one year may represent only a small fraction of the total germ plasm collection, especially when plants need to be grown to reproductive maturity. It is therefore desirable to develop an integrated approach whereby preliminary screening for daylength sensitivity is carried out in the field and appropriate varieties then examined further for temperature responses in the glasshouse. Such a strategy has been adopted and tested for cowpea (*Vigna unguiculata*), and has proved accurate and reliable (Summerfield et al., 1976a). Experiments are in progress to assess the reliability of this technique for screening work with soyabeans.

EXPERIMENTAL BACKGROUND

In a series of factorial experiments carried out in glasshouses, wherein daylength and day and night temperatures are automatically and precisely controlled, we have investigated the effects on flowering of different daylengths and night temperatures characteristic of humid tropical values (Huxley and Summerfield, 1974). Table 1 summarizes the results of these experiments. As expected, many varieties flowered earlier during the shorter of the two daylengths (11 hours 40 minutes compared with 13 hours 20 minutes), but during warmer nights (24°C) sensitive cultivars such as Improved Pelican flowered by as much as 20 days sooner than during cooler nights (19°C). In several cultivars, including TK 5, Bossier, and Belgian Congo, the effects of the longer daylength in delaying flowering and of the warmer nights in hastening it almost exactly offset one another. As a result, the differences in time to first flower under the extreme environmental combinations (short days/cool nights and longer days/warmer nights) were no more than two days (Table 1). It could therefore be very difficult to interpret data on time to flowering collected in

Table 1. Effects of Daylength and Night Temperature on Time to First Flower (Days from Sowing) in Selected Soyabean Varieties, Three Replicates

Variety	Environmental treatment combination				Sensitivity to	
	11 hr 40 min		13 hr 20 min		Daylength	Night temperature
	24°C	19°C	24°C	19°C		
Grant	25	27	25	27	–	Slight
Clark 63	26	28	26	31	Slight	Slight
SRF 300	26	27	26	30	Slight	Slight
Tokachinagaha	26	29	26	30	Slight	Slight
CES 407	26	44	>60[a]	>60	+	+
Hshi-Hshi	28	33	28	34	–	+
TK 5[b]	29	35	35	44	+	+
Bossier	31	34	35	42	+	+
Belgian Congo	31	37	37	44	+	+
Improved Pelican	32	37	39	59	+	+
Bukalasa	34	41	52	>60	+	+
Yellow Keeble	35	46	>60	>60	+	+
3H55F	37	45	>60	>60	+	+
Hernon	37	45	>60	>60	+	+
HLS 223	39	45	>60	>60	+	+

[a] > indicates no flowering by the number of days shown when, because of overcrowding, these daylength-sensitive plants were discarded.

[b] Note the consequence of equal and opposing temperature and daylength effects on flowering of TK 5, Bossier, Belgian Congo, and Improved Pelican when grown under short-day, cool conditions or longer day, warm conditions.

field trials at stations in different localities. Clearly, a breeder cannot hope to study the inheritance of time to first flower unless he knows the physiology of these interactions that produce similar phenotypic results from opposing, genetically controlled responses.

In experiments using controlled environmental growth cabinets we have examined the effects of factorial combinations of daylength, and day and night temperature on growth, reproductive development, and seed yield of variety TK 5. Plants are grown to maturity in eight environments comprising all combinations of two short daylengths (11 hours 40 minutes and 13 hours 20 minutes), two day temperatures (27° and 33°C), and two night temperatures (19° and 24°C) (Huxley et al., 1976). Taller, later flowering plants with more branches were produced in the longer daylength, but seed yield was hardly affected because the yield components did not all respond in a similar way. In the warmer, day temperature treatments, seed yield per plant was reduced by half because all yield components were adversely affected, pods per plant by 34 percent, mean seed dry weight by 24 percent, and seeds per pod only slightly. There was a marked effect of the warmer night temperature, which promoted early vegetative growth and induced early flowering. Although the overall number of pods per plant was reduced by 48 percent, seed yield per plant was little affected because mean seed dry weight increased by 37 percent. The number of seeds per pod also increased slightly. Similar responses have been recorded for cowpeas in which warm, day temperatures after flowering can markedly reduce phenological yield potential. Cumulatively increased abortion of flowers and young pods, combined with rapid leaf and nodule senescence, results in yield reductions of at least 50 percent compared with plants that first flower at more or less the same time, but mature under cooler temperatures (Summerfield, 1975a).

An integrated screening technique, rather than one that screens for photoperiodic effects alone, is highly desirable in matching soyabean varieties to particular parts of the tropical agricultural calendar.

INTEGRATED SCREENING STRATEGY

In Nigeria results for 29 cowpea cultivars grown in the field with incandescent lamps have shown close agreement with data obtained in daylength- and temperature-controlled glasshouses at Reading (Table 2). Sixteen cultivars were allocated an identical ranking for daylength sensitivity with respect to flowering; the remaining cultivars differed only by one rank. Field trials failed to identify those cultivars with only slight daylength sensitivity (Summerfield et al., 1976a). However, because night temperatures were relatively warm (22°C) throughout the field trials, those cultivars identified as "daylength-insensitive" must still be checked in the glasshouse for night temperature sensitivity (Table 1). A reliable method having been established for daylength-sensitivity screening in the field, glasshouses can now be used as an adjunct to field trials in screening cultivars identified as "daylength-insensitive" for effects of night and day temperature on flowering and seed yield (Fig. 2). An identical approach is currently in progress to test this hypothesis on soyabeans.

DISCUSSION

The effects of daylength and night temperature on days to flowering in both soyabeans and cowpeas can be differentiated with respect to ways in which the two environmental factors affect sensitive, compared with insensitive, varieties. Warmer night temperatures cause only a small decrease (1 to 4 days) in number of days to first flower in temperature-insensitive varieties (Huxley and Summerfield, 1974; Summerfield et al., 1976a). The greater day-night temperature difference (30° and 19°C, compared with 30° and 24°C) gave a more protracted vegetative period in daylength-sensitive cultivars under the longer daylength. Our data agree with those from a recent study by Wallace and colleagues (in preparation). Using quantitative detail, they investigated the effects of four daylengths, four night temperatures, and two diurnal ranges (3° and 6°C) in factorial combination on flowering of daylength-sensitive and daylength-insensitive cultivars of *Phaseolus vulgaris*. They concluded that both daylength and temperature affect the rate of plant development and differentiation. They also found that for daylength-sensitive cultivars the effects of night temperature, daylength, and interactions between these two factors were all much larger when the diurnal temperature range was 6°C rather than 3°C. Clearly, appropriate adaptation to factors other than

Table 2. Times from Sowing to First Flower for Selected Cowpea (*Vigna unguiculata*) Cultivars Grown Under Similar Daylength and Night Temperature Regimes in Glasshouse and Field in the Tropics

Cultivar	Glasshouse trials		Field trials	
	Days to first flower[b]	Sensitivity ranking[a]	Days to first flower[c]	Sensitivity ranking[a]
TVu 32	>100	2	>65	2
TVu 76	41	0	41	0
TVu 155	60	1	48	0
TVu 264-2	46	1	47	0
TVu 301-1	56	0	49	0
TVu 354	49	0	47	0
TVu 1000	60	0	60	1
TVu 1016	46	0	44	0
TVu 1035	52	1	51	1
TVu 1174	38	1	38	0
TVu 1190	79	2	>65	2
TVu 1503	40	0	37	0
TVu 4352	44	1	45	0
TVu 6198	41	0	41	0

[a] Sensitivity ranking:
0 = insensitive; range between treatments 0-3 days
1 = slightly sensitive; range between treatments 4-10 days
2 = very sensitive; range between treatments > 10 days
[b] Ranking at 13 hours 20 minutes for 24°C night temperature.
[c] Ranking at 13 hours 30 minutes for 22°C night temperature.

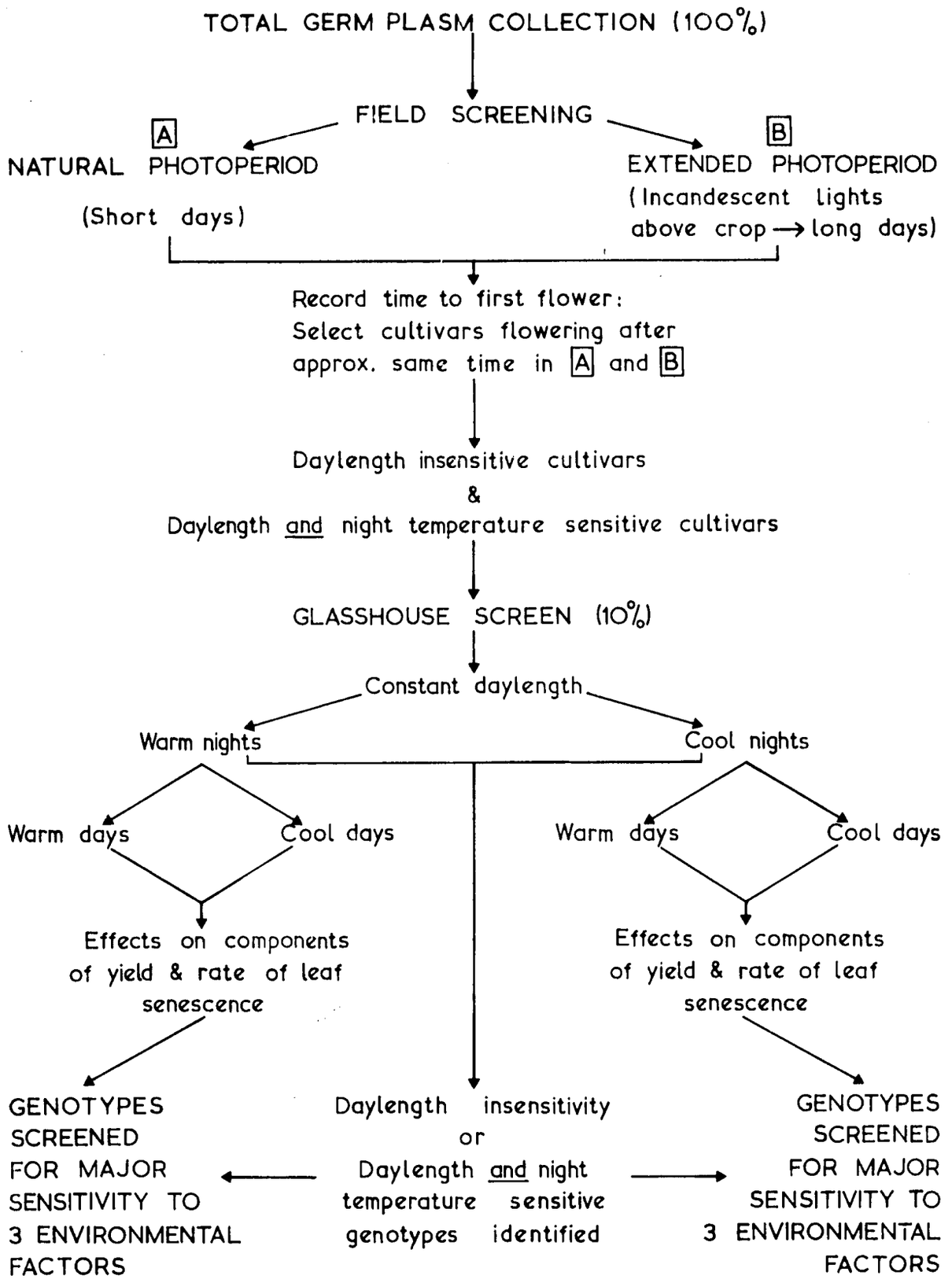

Fig. 2. Schematic representation of an integrated strategy for daylength and temperature-sensitivity screening of potentially tropic-adapted soyabeans.

daylength alone are of major importance, and interactions between factors should not be neglected when selecting cultivars for particular locations.

Extending natural daylengths in tropical localities with low-intensity, incandescent lighting should prove effective for daylength-sensitivity screening in soyabeans. However, in addition to extending natural daylengths to maximum values characteristic of any given geographical range, the efficacy of night-break lighting, e.g., two hours of low-intensity, incandescent light in the middle of each dark period, as a screen for daylength neutrality may well merit investigation.

Furthermore, it may be prudent to use minimum light intensities of about 10 foot-candles at canopy level in order to maximize photoperiodic responses. Whichever approach is adopted, it seems clear that for many legumes, including soyabeans, the field screening site should be located in tropical environments that experience warm days and cool nights. In this way the effects on flowering of daylength, night temperature, and diurnal changes in temperature can be maximized. This should not prove too difficult, since small changes in altitude can bring about large differences in night temperature at any latitude within the tropics (Huxley and Beadle, 1964).

Many reports in the literature, including Bula (1973), have indicated that controlled environment facilities are advantageous for studying the effects on plant growth of closely correlated, diurnal, and seasonal factors encountered in the field situation. There are problems involved in extrapolating from experiments in controlled environments to the natural situation, as Evans (1963), among others, has observed. Perhaps the most severe limitations occur when using controlled environments to study the relative magnitude of the effects of individual environmental factors in isolation. Limitations are also encountered in assuming that a single environmental combination is optimal for all stages of plant growth.

By the judicious use of controlled environment facilities as a complement to field research (Raper, 1973), scientists have devised strategies to substantially reduce the cost-benefit ratio for agricultural research. The integrated approach described above would seem to be an appropriate example of the way in which collaborative research can be productive and efficient. Indeed, there seems little point in screening soyabean varieties only for daylength sensitivity up to first flower (Byth, 1968) and ignoring the effects of temperature and interactions with daylength over this same period and thereafter. Genotypic differences in sensitivity to warm, day temperatures during the later stages of reproductive ontogeny (Fig. 1) may well dictate the outcome of phenological potential for seed production whether or not this has been maximized by appropriate selection for daylength and/or temperature effects during vegetative growth.

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Important Considerations for the Development of a Soybean Classification System for the Tropics

S. Shanmugasundaram

The soybean is recognized as a short-day plant with sensitivity to changes in photoperiod (Borthwick and Parker, 1939; Garner and Allard, 1920). Because of their photoperiod sensitivity, varieties from the temperate zone flower too soon and mature too early when grown in the tropics and subtropics. Thus, a variety's range of adaptation is limited (Cartter and Hartwig, 1963). However, experimental results show that varietal differences in response to photoperiod do exist in soybeans (AVRDC, 1974 and 1975; Criswell and Hume, 1972; Huxley and Summerfield, 1974; Johnson et al., 1960; Polson, 1972; Rachie and Plarre, 1975).

Rice farmers in tropical areas have for many years been aware of two distinct types of rice cultivars, namely, the "date-fixed" or "season-fixed" type, which exhibits a marked sowing date effect, and the "period-fixed" type, whose sowing to heading interval is relatively unaffected by sowing date (Chandraratna, 1964; Chang and Vergara, 1972). Similarly in soybeans, there are cultivars whose duration to flowering is relatively unaffected by planting date (AVRDC, 1974 and 1975; Criswell and Hume, 1972; Polson, 1972). These cultivars can be termed period-fixed; the term "duration-fixed" is also suggested. The relative duration from flowering to maturity is a constant within a cultivar (Johnson et al., 1960). The date-fixed or season-fixed varieties will be season, as well as location, specific. Conversely, the duration-fixed types have wide adaptability. If duration-fixed varieties are available, specific types can be selected for any particular duration requirement, regardless of location or time of planting. Such varieties should fit in well with various multiple cropping schemes commonly practiced in the tropics and subtropics. Therefore, th AVRDC soybean germ plasm collection is being screene to identify photoperiod insensitive genotypes, which ar necessary if duration-fixed varieties with wide adapt ability are to be developed.

SOYBEAN CLASSIFICATION SYSTEMS

During the early 1900's several classification system based on seed coat color and other morphological trait were developed for soybeans. The first classification base on maturity was developed by Piper and Morse (1943) who classified the germ plasm into seven groups: very early, 81 to 90 days; early, 91 to 100 days; medium early, 101 to 110 days; medium, 111 to 120 days; medium late, 121 to 130 days; late, 131 to 150 days; and very late, more than 150 days.

Nagata (1972) initially classified soybeans into summer, intermediate, and autumn types. The summer types were subdivided into three classes: SI, SI_p, and SII; the intermediates into two classes: MIII and MIV; and the autumn types into three classes: AV, AVI, and AVII. This classification was based on (a) the days from sowing to first flowering, (b) flowering duration, and (c) days to maturity and their interrelationships. Another classification, based on determinate and indeterminate growth habits, was developed later. According to the number of nodes after first flower, subclasses 0, I, and II in the determinate group, and III, IV, V, VI, and VII in the indeterminate group were distinguished. Fukui (1961)

modified the classification specifically for Japanese soybean varieties.

The United States Department of Agriculture soybean germ plasm collection has been classified into 12 maturity groups numbered 00 to X. The placing of a genotype into a maturity grouping is based on long-term maturity classification in relation to a reference variety for each maturity group (Weiss, 1949). The varieties in each group have a narrow range of adaptability because of photoperiod sensitivity.

INAPPLICABILITY OF EXISTING CLASSIFICATION SYSTEMS IN THE TROPICS

Of the existing soybean classification systems, the U.S. maturity groups have been developed exclusively for the United States and southern Canada, i.e., for the temperate zone, where there is usually only one growing season. Planted during long photoperiods, soybeans flower and mature as the daylength becomes shorter. When the U.S. and Canadian classification is used in the tropics, the different planting periods throughout the year cause complications. The behavior of cultivars within groups varies during different seasons, and even within a season the identity of the groups is lost.

The following examples are cited to indicate the inapplicability of existing soybean classification systems for the tropics:

1. Woodhouse and Taylor (1913) recognized from their soybean plantings that the relative maturities of varieties were considerably different in India than they were in the United States.

2. In recent years a large percentage of the USDA germ plasm collection has been screened by researchers in India. It was found that the maturity classification commonly used in the United States and Canada is unsatisfactory.

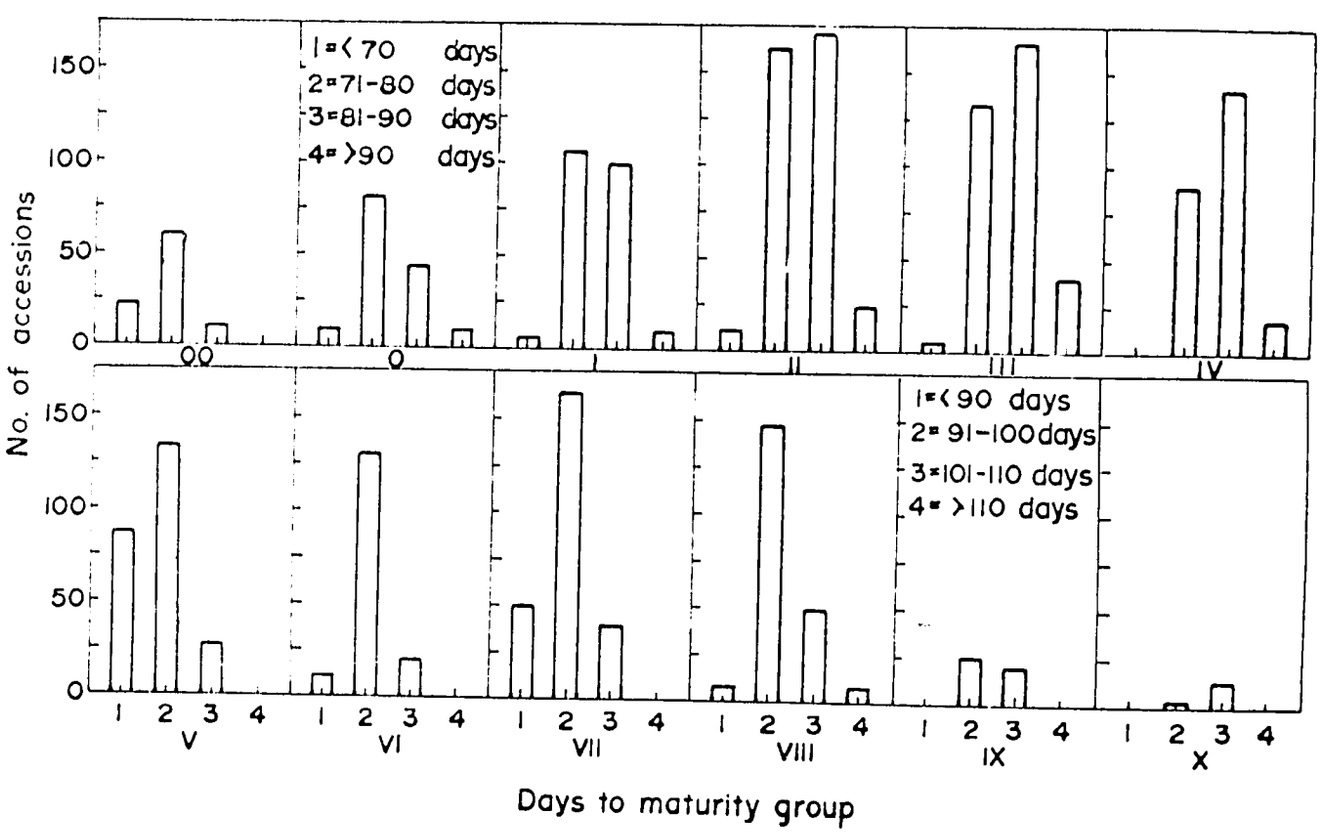
3. Results from INTSOY-ISVEX trials, conducted at the present time in many parts of the world with representative cultivars from different maturity groups, also indicate the inapplicability of the U.S.-Canadian classification, especially at low latitudes (Whigham, 1975).

4. When grown in the tropics, all varieties in early maturity groups invariably flower too soon and perform poorly (Hartwig, 1970).

5. The classification system developed in Japan was also specifically designed for temperate conditions. Days to flowering, flowering duration, and days to maturity, which are the basis for the classification, varied considerably in the tropics, making the system inapplicable for tropical regions.

At AVRDC, recent evaluation of germ plasm for flowering and maturity also indicates the weaknesses of existing maturity classifications. In an observational

Fig. 1. Frequency distribution of 2,476 soybean accessions belonging to the 12 U.S. maturity groups when classified for days to maturity at AVRDC.



screening trial in which all 12 maturity groups (00 through X) were represented, 2,476 accessions from the AVRDC germ plasm collection were grown under natural daylength in 1974 and 1975. Many of the accessions were planted on 13 September 1974 and the remainder on 24 September 1975. Some accessions were grown in both plantings. Data were collected on days to flowering and days to maturity.

Many genotypes from different U.S. maturity groups matured in the same number of days when grown at AVRDC (Fig. 1). However, the 2,476 accessions can be classified into either five groups based on days to flowering or six groups based on days to maturity (Fig. 2). When the accessions are grown in latitudes closer to the equator than the AVRDC location (23°N.), as well as at varying altitudes and during different seasons, their photoperiod response will be different. Thus, this classification also may not be satisfactory.

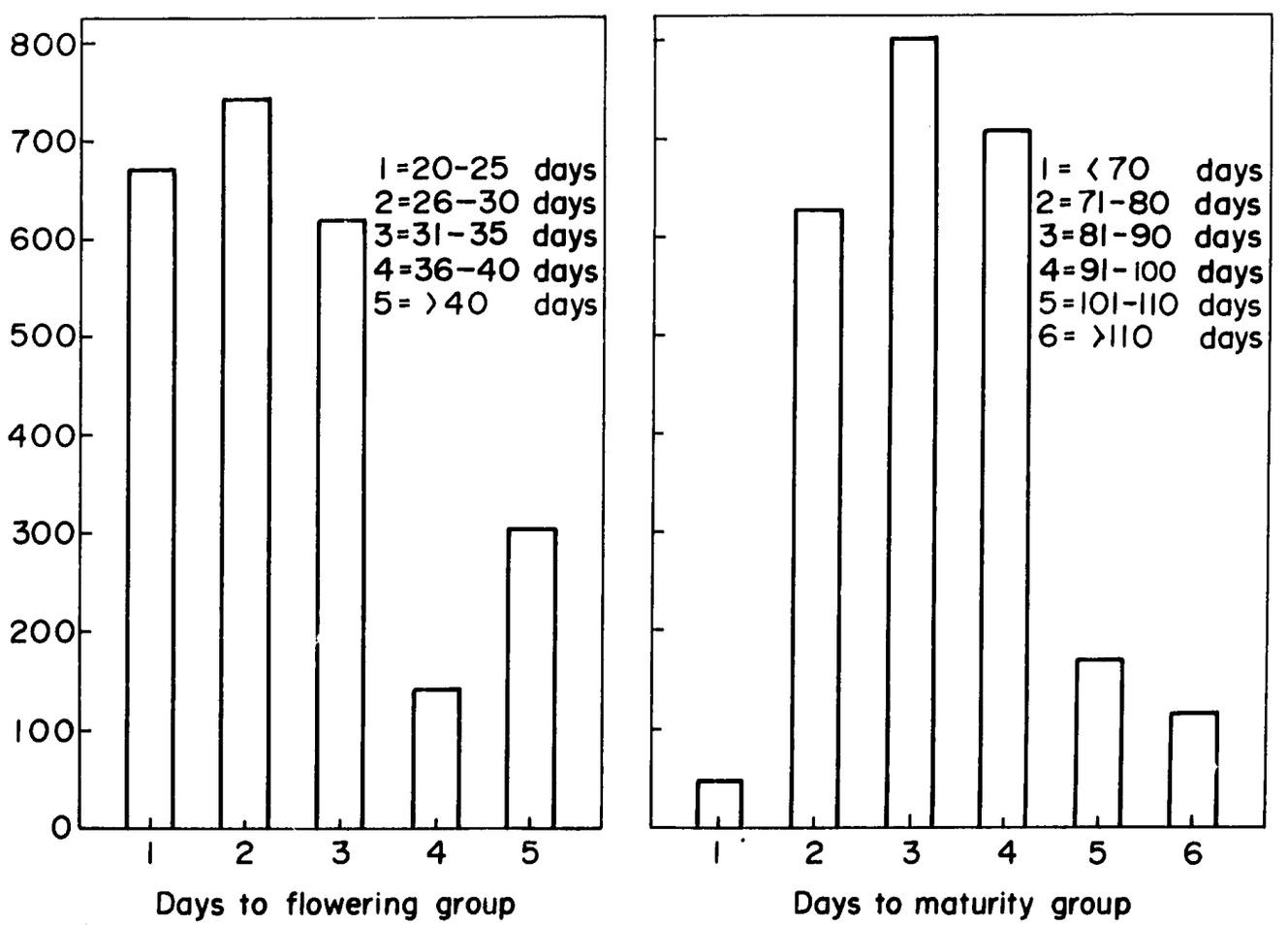
FACTORS TO BE INCLUDED IN A TROPICAL CLASSIFICATION SYSTEM

In designing a tropical classification system for soybeans, several factors must be considered. The photoperiod sensitivity or insensitivity of the varieties will determine their major usefulness. Therefore, identification of accessions insensitive to photoperiod was attempted in the soybean germ plasm at AVRDC. Initial screening of photoperiod insensitive lines (AVRDC, 1974) enabled us to define photoperiod insensitivity (Pi). A Pi line is defined as one that will flower within a range of 5 days regardless of daylength. At AVRDC daylength ranges from 12 to 16 hours (AVRDC, 1975).

During the spring of 1974, 1,978 cultivars from the AVRDC germ plasm were screened in the field, using only the natural day treatment, i.e, about 12 hours of daylight. A separate but otherwise identical planting was supplemented with incandescent lights (500 lux or 50 foot-candles) for the 16-hour treatment (AVRDC, 1975). Observations for days to flowering were made daily for each cultivar until 80 days after planting. The screening was repeated during the fall of 1974 with 2,042 cultivars.

The natural daylength during the spring screening varied from 12 hours 10 minutes to 13 hours 30 minutes, while the fall daylength ranged from 11 hours 50 minutes to 10 hours 50 minutes. Between planting and flowering,

Fig. 2. Frequency distribution of 2,476 soybean accessions when classified into groups according to days to flowering or days to maturity at AVRDC.

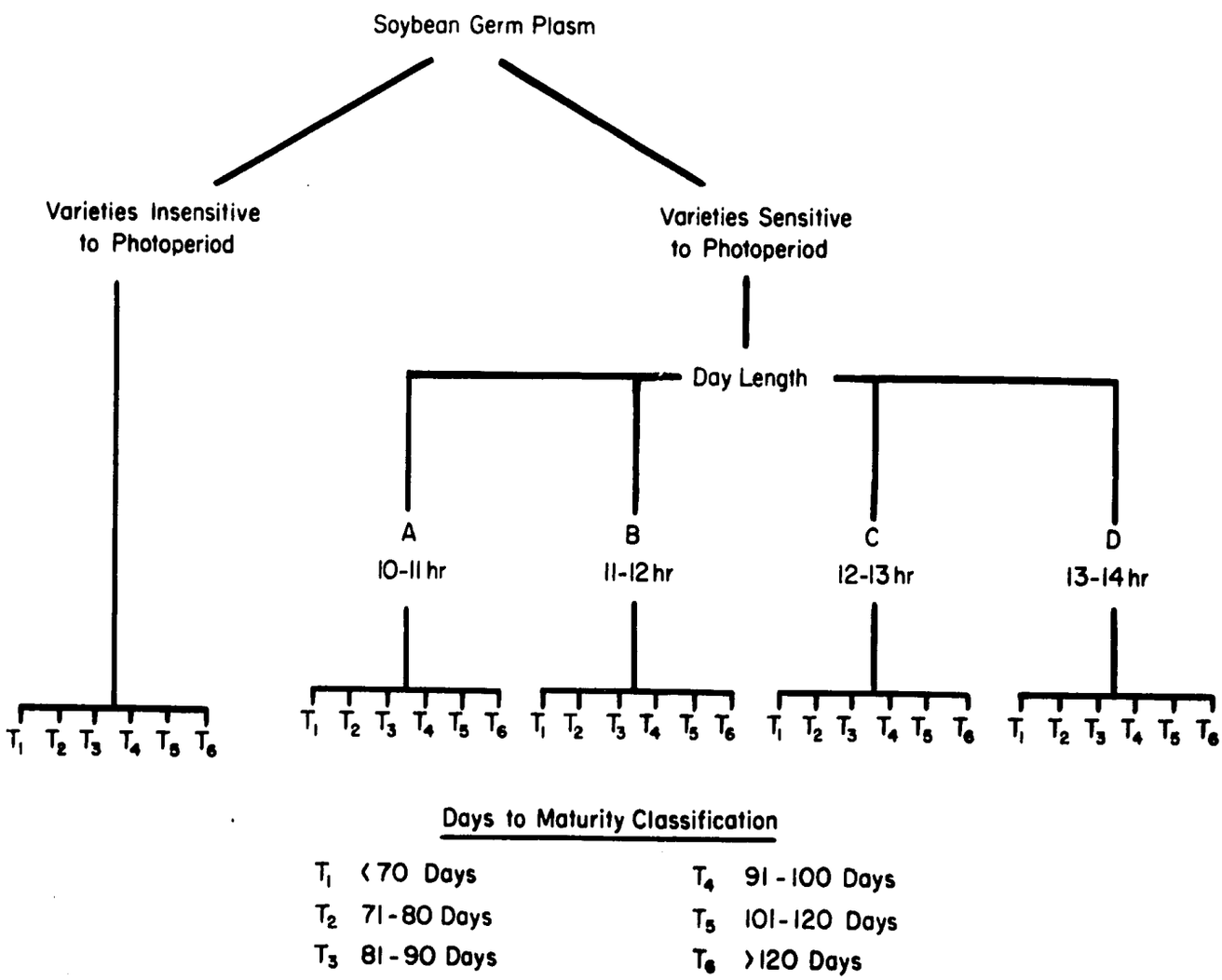


the mean temperatures during the spring screening varied from 19° to 30°C and during the fall from 28° to 18°C (AVRDC, 1975). Some cultivars that were insensitive in the spring trial were sensitive in the fall, while others that were sensitive in the spring were insensitive in the fall. This indicated that factors other than photoperiod may also influence the flowering of soybeans. Huxley and Summerfield (1974), for example, reported that low, night temperatures are particularly influential in delaying flowering. The initial temperatures during the spring at AVRDC were much lower than the early fall temperatures. Thus the interaction of photoperiod and temperature must be considered. Based on our screening in spring and fall, genotypes that were insensitive during both seasons were considered as photoperiod insensitive. Therefore, photoperiod screening will divide the germ plasm into two primary groups. Subdivision of the Pi group can be based on number of days to maturity, which will be relatively constant regardless of time of planting or location.

Because maturity is the primary factor determining a variety's adaptability to a location and its suitability in a cropping system, classification should be made on the basis of number of days to maturity. Whether soybeans are planted as a monocrop or intercropped with other crops, maturity duration is of vital consideration. Early maturity is essential when two or three crops are taken from the same land in a year. Ten days or more difference in maturity will frequently allow the farmer to select a variety he can harvest before rainy weather. An arbitrary 10-day interval between groups will be useful.

Throughout the year the photoperiod in the tropics varies from 10 to about 14 hours. Depending upon the time of planting in any tropical location, the days to maturity of varieties sensitive to photoperiod will vary. Hence, maturity should be specified in relation to the photoperiod prevailing at the time of planting. This will satisfy any particular time and any specific location, because photoperiod is the major factor changing with location and time. In the tropics about 30 days intervene from planting to flowering, and during this period the change in photoperiod is less than one hour. Therefore, one-

Fig. 3. A proposed soybean classification system for use in the tropics.



hour photoperiod increments will be logical in any classification system.

At low latitudes, if the highland areas are disregarded, year-round temperature differences are not drastic. For the purpose of this classification, we have to assume that temperature is not a dominating factor. Including temperature would create complications, and simple classification would not be likely.

In the development of this classification, the AVRDC germ plasm collection will be screened under natural daylength and long-day conditions at AVRDC (23° N.) during the spring and fall seasons to identify the F_1 lines. Representative samples of the germ plasm will also be evaluated at Los Baños (15° N.) and Mindanao (7° N.), the Philippines; Bogor, Indonesia (3° N.); and Brasil (5° S.). The trial planting in these locations will be made at specific periods so that the minimum age plants should reach before responding to stimulus that leads to flowering (Salisbury, 1963) will coincide with the designated photoperiod classification.

PROPOSED TROPICAL SOYBEAN CLASSIFICATION SYSTEM

A proposed maturity classification system for soybeans grown in the tropics is indicated in Fig. 3. There are 30 groups in this classification. A cultivar belonging to group AT_1 may also come under group BT_2 and other groups. This is because the classification is based on both photoperiod and days to maturity.

The above proposal is tentative and open for discussion. Success in the execution of this proposal depends largely upon the cooperative evaluation of the germ plasm at different locations over a number of years, as has been done by those researchers responsible for the evaluation, maintenance, and disbursement of the USDA germ plasm collection.

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Daylength Sensitivity in Maturity Group III Soybean Germ Plasm

C. R. Nissly, E. H. Paschal II, C. N. Hittle, and R. L. Bernard

It is well established that the soybean is a short-day plant, that is, it will flower sooner under short-day conditions than under longer photoperiods (Borthwick and Parker, 1939; Allard and Garner, 1940). Varieties adapted to higher latitudes flower and mature more rapidly in the lower latitudes, while flowering and maturity of varieties adapted to lower latitudes are delayed if they are grown in higher latitudes (Cartter, 1958).

Soybean varieties vary in their response to photoperiod (Garner and Allard, 1920). Day neutrality has been re-

ported in crops such as corn, rice, millet, and wheat (Francis et al., 1969; Bhardwaj and Webster, 1971; Yu and Yao, 1969). Day-neutral, i.e., insensitive to photoperiod, soybean varieties have been reported in maturity groups 00 and 0, some of the earliest maturing lines (Criswell and Hume, 1972; Polson, 1972). This study attempts to identify soybean strains insensitive to photoperiod and to describe the variation found in the accessions of maturity group III germ plasm.

METHODS

Accessions from maturity group III of the United States Department of Agriculture soybean germ plasm collection were screened in the field at Urbana, Illinois (40° N. latitude) and at Isabela, Puerto Rico (18° N. latitude). Single replicate hill plots with three or four plants per hill were grown under both natural daylengths and daylengths artificially extended by 150-watt incandescent lighting. In the Urbana experiment the dark period was interrupted with 5 hours of light, while at Isabela the lighted plots received continuous light. Intensity ranged from 50 to 100 lux under the lights. Estimates of sensitivity to photoperiod are made by comparing the delay of flowering and maturity of a strain in the extended light treatment with development of that strain under natural photoperiods. Two reference varieties, Williams and Adams, were placed randomly throughout both treatments to give a measure of variation for the characters measured.

RESULTS AND DISCUSSION

Urbana, Illinois

Group III germ plasm was first screened at the University of Illinois, Department of Agronomy, South Farm during the 1973 growing season. Planting was on 19 May, and the experiment ended with the first heavy frost on 6 November, 172 days after planting. Table 1 summarizes the results in days to flowering and maturity. Under natural daylengths the 515 strains flowered from 45 to 75 days after planting, with a mean of 60 days. Under extended daylengths date of flowering ranged from 51 to 123 days, with a mean of 91. The mean delay was 31 days.

All entries matured under natural photoperiods in 110 to 137 days. In the lighted plots, however, only 24 of the strains matured in less than 171 days. The mean maturity date of the 24 lines that matured was 164 days after planting. The mean delay was 40 days.

Isabela, Puerto Rico

Group III germ plasm was again screened at the University of Puerto Rico, Isabela Substation. Planting was on 3 July 1974. At this location, temperature is relatively constant throughout the year. The germ plasm was evaluated for 235 days after planting.

As shown in Table 2, under natural daylengths all strains flowered within 33 days of planting, with a mean of 27 days. The maturity range was from 69 to 91 days for all genotypes. Under continuous light all strains had flowered within 112 days after planting, and 65 percent or 286 of the lines had matured at the termination of the study, 235 days after planting. The mean delay in flowering was 50 days, with 99 percent of the accessions delayed more than 20 days. The average delay in maturity was 117 days for the lines that matured before termination of the experiment.

Table 1. Response of Group III Soybean Germ Plasm to Natural and Artificially Extended Daylengths at Urbana, Illinois

	No. of strains		No. days to flowering and maturity		
			Extended daylength	Natural daylength	Difference
Days to flowering	515	Range	51 to 123	45 to 75	−2 to +60
		Mean	91	60	31
Days to maturity	24	Range	124 to 171	115 to 134	−3 to +52
		Mean	164	124	40
	491	Range	>172[a]	110 to 137	....
		Mean		126	

[a] Plants in this group failed to mature.

Table 2. Response of Group III Soybean Germ Plasm to Natural and Artificially Extended Daylengths at Isabela, Puerto Rico

	No. of strains		No. days to flowering and maturity		
			Extended daylength	Natural daylength	Difference
Days to flowering	439	Range	30 to 112	23 to 33	3 to 85
		Mean	77	27	50
Days to maturity	286	Range	95 to 233	73 to 90	11 to 120
		Mean	196	81	117
	153	Range	>235[a]	69 to 91	....
		Mean		82	

[a] Plants in this group failed to mature.

Interpretation of Differences

A large range in sensitivity to photoperiod, as measured by the delay in flowering and maturity under the extended light regime, was expressed in the Urbana experiment (Fig. 1). Three strains had delayed flowering of less than 5 days, while five of the lines were delayed more than 55 days. Of the 24 accessions that matured in less than 172 days at Urbana, only one was delayed less than 24 days. The 491 lines that did not mature before termination of the experiment were in various stages of development from early bloom to senescence at the end of 172 days.

Fig. 2 shows the distribution of delay in flowering and maturity for strains at Isabela under the continuous light regime. Flowering was delayed from 3 to 85 days. Only one strain was delayed less than 10 days in flowering, while three were delayed more than 80 days. All strains eventually flowered under the continuous photoperiod.

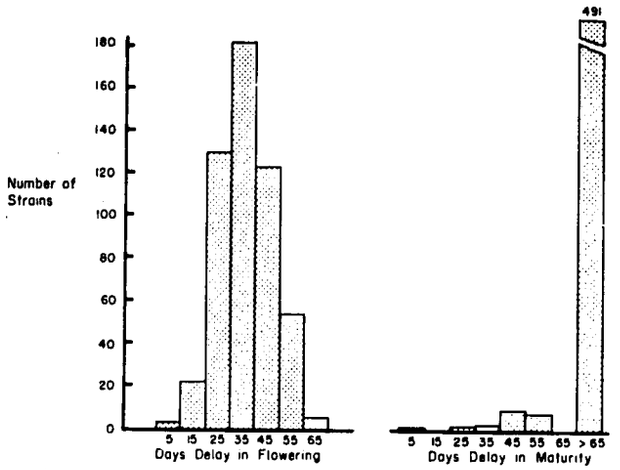

Fig. 1. Frequency distributions of delay in flowering and in maturity caused by the extended photoperiod at Urbana, Illinois, 1973.

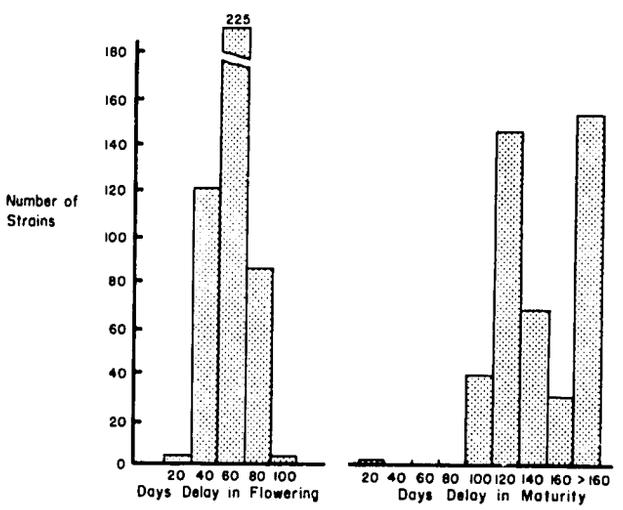

Fig. 2. Frequency distributions of delay in flowering and in maturity caused by the extended photoperiod at Isabela, Puerto Rico, 1974-75.

Maturity was delayed much more than flowering in all but one of the lines, P.I. 317334B (Kitami Shiro). Only 153 of the strains failed to mature by the end of the experiment, 235 days after planting. Most of these were progressing toward maturity.

Comparison of Urbana and Isabela Results

Under natural photoperiods, flowering and maturity proceeded more rapidly at Isabela than at Urbana. All strains flowered an average of 33 days earlier and matured an average of 43 days earlier at Isabela. The difference between the natural and the extended daylength treatments was greater in the Isabela experiment in which flowering was delayed an average of 19 days and maturity an average of 77 days longer than at Urbana. The greater delay experienced at the tropical site may be attributable to various factors: (a) the shorter natural photoperiods at Isabela induced a more rapid rate of development than did the longer natural daylengths at Urbana; (b) the 24-hour light period of the Isabela experiment delayed development more than the Urbana treatment in which the dark period was interrupted by a 5-hour photoperiod; and (c) higher temperatures early in the growing season at Isabela resulted in accelerated development. The effects of these factors are probably responsible for the greater differences between treatments observed at Isabela.

There was a high correlation between the two locations for delay in flowering, that is, those strains that were least delayed at Urbana were among those least delayed at Isabela. This correlation was not as great, however, for delay in maturity.

Insensitive Genotype

This study identified one line, P.I. 317334B, possessing unique photoperiod insensitive properties. The variety Kitami Shiro (P.I. 317334) was introduced into the United States in 1966 from the Hokkaido Experimental Station, Sapporo, Japan. When it was grown at Urbana, Illinois, an off-type plant of later maturity (group III) was observed, and its progeny were designated P.I.

Table 3. Response of Selected Group III Soybean Accessions to Natural and Extended Photoperiods at Urbana, Illinois, and Isabela, Puerto Rico

	No. days to flowering			No. days to maturity		
	Extended daylength	Natural daylength	Difference	Extended daylength	Natural daylength	Difference
P.I. 317334B (Kitami Shiro)						
Urbana	51	53	−2	124	127	−3
Isabela	30	27	3	95	84	11
P.I. 82232						
Urbana	61	61	0	167	130	37
Isabela	47	25	22	>160[a]	84	>76[a]
Williams (means)						
N = 18, Urbana	89	54	35	>172[b]	133	>39[b]
N = 26, Isabela	80	26	54	>235[b]	90	>145[b]

[a] Plants died at 160 days.
[b] Plants not mature by termination of experiment.

317334B. The remainder of the plants were classified as group II, and the progeny of one of them is maintained as P.I. 317334A. P.I. 317334B exhibited strong photoperiod insensitive tendencies in both locations of this study. Both sublines of Kitami Shiro are short in stature with highly determinate growth habit, extensive branching, and large leaves. P.I. 317334B flowered 2 days and matured 3 days earlier under extended, compared with natural, daylengths at Urbana (Table 3), whereas under continuous light at Isabela, flowering was delayed 3 days and maturity 11 days. The next least sensitive strain, P.I. 82232, although not delayed in its flowering, was delayed 37 days in maturity at Urbana. At Isabela this same strain was delayed 22 days in flowering and failed to mature before the experiment was terminated. Williams, on the other hand, exhibited delays in flowering of 35 days at Urbana and 54 days at Isabela and failed to mature at both locations. These results suggest that P.I. 317334B possesses unique, day-neutral characteristics that may be useful in breeding soybean lines with wide latitudinal adaptation.

It remains to be seen how valuable this apparent photoperiod insensitivity of Kitami Shiro will prove to be. In Puerto Rico we have made a series of crosses, using the insensitive plant introduction and a diverse group of cultivars as parents to study the inheritance of insensitivity and its genetic relationship with other characters, especially maturity. This insensitivity will be of limited value in the tropics if it cannot be transferred to varieties that mature later and produce higher yields than Katami Shiro.

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Interrelationship Between Soybean Varieties and Indigenous Rhizobium Strains in Northeast Thailand

Arnooth NaLampang

On the basis of climatic and soil characteristics, soybean growing areas in Thailand can be geographically divided into three major regions, namely, the North, the Central Plain, and the Northeast. At present, the first two regions are suitable for soybean production, and relatively high yields (about 2,000 to 2,500 kg per hectare) can be obtained with proper management using the standard varieties, SJ 1 and SJ 2. Furthermore, in the North and in the Central Plain nodulation, with or without inoculation, has been observed in every location. In contrast, soybean yields from the Northeast region are low and lack of nodulation is common.

Since the Northeast encompasses about one-third of the nation's arable land, the solution of problems currently limiting soybean production is essential before production can be increased. To this end, investigations in the Northeast are being intensified. From a climatic standpoint the Northeast is considered suitable for soybeans, but poor soils generally limit yields. As in other tropical countries, high rainfall and sandstone parental materials may be primarily responsible for heavy leaching and weathering. Laboratory analyses have shown that most of the soils are acidic (pH values from 4.5 to 5.5) and low in important plant nutrients, thus making them unsuitable for production of both Rhizobium and soybeans. At the present time, liming and application of fertilizers are considered uneconomical because of the high cost of materials and transportation.

A major factor limiting growth of soybeans in the Northeast has been the lack of nodulation, which prevents plants from attaining their normal growth and invariably results in poor yields (about 300 to 500 kg per hectare). Attempts to induce nodulation by application of inoculum rarely succeed. Moreover, large-scale inoculation is considered impractical at this time because inoculum is unavailable; consequently, farmers have yet to learn how to apply it.

In soybean seed multiplication fields of SJ 1 and SJ 2 in the Northeast, poor plant growth is common. However, a few normal plants occasionally appear in these

fields. Close examination has shown that these healthy and vigorous plants possess nodules and have good seed-setting ability. This in turn suggests the possibility of specific interrelations between host genotypes and Rhizobium races.

To confirm this hypothesis, a set of differential soybean varieties, including the native strains SB 60 and Pakchong, the recommended varieties SJ 1 and SJ 2, and the introduced variety Lincoln, were planted without inoculation in several Northeast experiment stations where records indicated soybeans had never been previously grown. The results (Table 1) indicate that only the native varieties SB 60 and Pakchong formed nodules. This led us to conclude that indigenous strains of Rhizobium existed naturally in the soil and that nodules were produced only in the presence of compatible host genotypes.

Table 1. Evaluation of Five Uninoculated Soybean Varieties at the Roi-ed Experiment Station, Northeast Region, 1972

Variety	Plant height (cm)	Dry weight (g/plant)	Number of pods	Seed weight (g/plant)[a]	Nodule score[b]
SJ 1	25.1	...	16	...	0
SJ 2	23.2	4.5	25	2.5	0
SB 60	42.8	13.6	91	12.8	3
Pakchong	36.5	17.6	112	12.1	4
Lincoln	...	...	...	...	0

[a] On the basis of these plant yields and at a recommended population of 200,000 plants/ha, SJ 2 is expected to yield 500 kg/ha, while SB 60 and Pakchong are expected to produce up to 2,500 kg/ha.
[b] Scored on 0 to 5 basis, 5 indicating heavy nodulation.

Another study was conducted concurrently by placing one seed of SB 60 along with one seed of SJ 2 in the same hill in soils that had never grown soybeans. Only SB 60 plants formed nodules; no nodules were observed on SJ 2 plants. These results suggest the existence of genotype x race interactions of soybeans with Rhizobium and raise the question of whether the lines that do not form nodules are incompatible with all Rhizobium strains or are incompatible only with those strains present in the study.

Because native varieties are generally inferior in yield and seed quality and unfit for existing cropping patterns, a breeding program has been initiated. One objective of this program is to transfer the nodulating ability of native varieties to standard varieties. Crosses between SB 60 and SJ 2 were made and progenies subsequently grown in virgin soils devoid of *Rhizobium japonicum*. Unfortunately, a clear-cut pattern of segregation could not be distinguished because of the difficulty in identifying plant genotypes under field conditions. Only those plants that showed normal growth were saved and checked for nodulation at harvest time. There was a reasonably good correlation between normal growth and nodulation. Selection had been advanced to the F_6 generation, when an early outbreak of rust seriously damaged the entire set of materials. Neither parent is resistant to rust. However, from the information obtained we are reasonably confident that superior lines able to utilize naturally occurring Rhizobium strains can be developed by proper selection following hybridization. We hope that soybean varieties adapted to the acidic and low fertility soils of the Northeast will be available in the future.

Soybean Breeding for Different Cropping Seasons in Thailand

Takashi Sanbuichi and Kouichi Sasaki

The two main soybean cropping seasons in Thailand are the rainy season and the dry season. The rainy season crop, which is grown in the upland areas of the Central Plain, is usually planted in May and June and harvested in August and September. The dry season crop, which is grown in northern Thailand, is planted after paddy rice in January, usually with supplemental irrigation, and harvested in April. A small area of soybeans is grown in the late rainy season in Saraburi Province. Differences between day and night temperatures during the rainy season are much less than during the dry season. Early and mid dry season temperatures are much lower than those of the rainy season.

The experiments discussed in this report were conducted by the Thailand Department of Agriculture with assistance and technical cooperation from Japanese soybean breeders working under the Colombo Plan. Information on maturity and plant height of four Thai varieties indicates considerable variation in height, but only 10 days difference in maturity (Table 1). In the rainy season the yields of SJ 1 and SJ 2 were no different, and both varieties lodged appreciably (Table 2). Yields of both varieties were drastically reduced by soybean rust

Table 1. Days to Maturity and Plant Height of Four Thai Varieties, Averaged Across Several Planting Dates, Mae-Jo Agricultural Experiment Station

Variety	Days to maturity		Plant height	
	Number	CV	cm	CV
SJ 1	99	11.9	77	19.5
SJ 2	104	10.0	65	28.0
Pakchong	99	12.5	43	25.2
SB 60	109	12.3	81	19.4

Table 2. Seed Yield and Lodging and Shattering Scores of Thai Recommended Varieties in Different Seasons

Season and location	No. experiments	SJ 1			SJ 2		
		Yield (ton/ha)	Lodging (0 = none)	Shattering (5 = serious)	Yield (ton/ha)	Lodging (0 = none)	Shattering (5 = serious)
Rainy, Sukothai	2	1.96	3.4	...	1.96	3.7	...
Rainy, Chiang Mai[a]	2	0.90	3.0	...	0.70	4.0	...
Late rainy, Chiang Mai and Saraburi	3	1.84	...	3.3	2.07	...	0.6
Dry, Chiang Mai	4	1.77	...	1.7	1.97	...	0.9

[a] Soybean rust occurred.

(*Phakopsora pachyrhizi* Syd.). In the late rainy season at Saraburi and Chiang Mai and in the dry season at Chiang Mai, SJ 2 outyielded SJ 1 by 0.2 ton per hectare. Yields of SJ 2 had less shattering than those of SJ 1.

It is probably unrealistic in Thailand to attempt to breed a variety adapted to both the rainy and the dry seasons. Now as in the past, efforts are directed toward breeding specific varieties for a specific season. Dry season types grow too tall and thick in the rainy season, and rainy season types are very short and produce poor yields in the dry season.

The following characteristics are desirable in a rainy season variety: short plant height, resistance to lodging, a growing period of 100 to 105 days as in SJ 1, and resistance to soybean rust. Desirable characteristics in a dry season variety include large plant type; a growing period of 105 to 110 days, a little longer than that for SJ 2; and resistance to shattering.

Soybean breeding by hybridization was begun in 1970 by the Department of Agriculture. A primary objective for development of rainy season types is to breed for resistance to soybean rust. Fortunately, a rust-resistant strain (64-104) was found in the Mae-Jo Agricultural Experiment Station germ plasm collection during the rainy season of 1970. This strain was crossed with SJ 2 and Acadian, and from the segregating progenies five promising strains were selected in the F_{11} segregating

Table 3. Breeding for Soybean Rust Resistance in Rainy Season

Cross number	Combination	F_2 (no.)[a]	F_3 (no.)	F_{11} (no.)
7019	Acadian X 64-104	1,000	208	2
7024	64-104 X SJ 2	1,700	314	3

[a] Number of plants or lines selected.

Table 4. Seed Yield and 100-Seed Weight of Rust-Resistant Strains and Rust-Susceptible Varieties

Strain	Presence of rust (Chiang Mai)		Absence of rust (Sukothai)	
	Yield (ton/ha)	100-seed weight (g)	Yield (ton/ha)	100-seed weight (g)
Rainy Season 1971				
SJ 1	1.02	8.7	1.67	14.7
SJ 2	0.70	8.6	1.62	13.2
64-104	1.93	19.3	1.27	17.4
Rainy Season 1975				
SJ 1	0.77	7.8	2.24	14.3
SJ 2	0.70	7.6	2.29	13.2
7019-1	1.51	12.6	2.62	16.9
7019-2	1.73	12.8	2.07	16.8
7019-3	1.41	12.9	2.08	15.5
7024-1	1.72	11.1	2.41	16.7
7024-2	1.23	12.2	2.49	16.6

Table 5. Seed Yield and Shattering Scores of Promising Dry Season Strains, Chiang Mai

Strain	1974		1975	
	Yield (ton/ha)	Shattering[a]	Yield (ton/ha)	Shattering[a]
SJ 1	1.89	2.0	1.23	4.0
SJ 2	2.06	1.0	1.49	1.7
7020-1	2.29	1.0	1.67	2.0
7020-2	2.36	1.0	1.73	1.7
7021-1	2.02	2.0	1.93	2.0
7021-2	...	...	1.64	1.7

[a] 0 = no shattering, 5 = very serious shattering.

Table 6. Oil and Protein Content of Thai Varieties Harvested in Different Cropping Systems

Variety	Season[a]			
	A	B	C	D
Oil Content (%)				
SJ 1	21.3	...	20.6	...
SJ 2	22.6	22.8	21.4	21.6
Pakchong	18.8	19.4	17.8	18.5
SB 60	19.6	19.0	15.0	18.3
Protein Content (%)[b]				
SJ 1	39.7	...	44.3	...
SJ 2	41.8	42.9	44.0	42.1
Pakchong	42.9	44.3	46.2	41.2
SB 60	40.2	42.8	48.1	43.3

[a] A: dry season of 1971 at Mae-Jo Agricultural Experiment Station (AES).
B: dry season of 1971 at Kalasin AES.
C: rainy season of 1971 at Sisamrong AES.
D: late rainy season of 1971 at Mae-Jo AES.
[b] Protein content (%) = total N (%) x 6.25.

generation (Table 3). The performance of these strains, in comparison with that of 64-104, SJ 1, and SJ 2 and in the presence and absence of rust, is indicated in Table 4. Under normal conditions yield levels are about the same for the Thai recommended varieties and rust-resistant strains. When rust is prevalent, however, the yields of the resistant strains are nearly twice those of SJ 1 and SJ 2. The resistance of these strains to rust is not complete, but apparently it is sufficient to be classified as field resistant. All resistant strains are shorter and more resistant to lodging than SJ 1.

Many crosses have been made in an attempt to develop high yielding, dry season varieties. Four selected strains from the cross SJ 2 x KS 252 appear promising. The parent, K 252, introduced from Taiwan, has high yielding ability but has green seed. Seed yields and shattering scores of these selected strains are shown in Table 5. The average yields of the selected strains are more than 10 percent higher than those of SJ 2, resistance to shattering is equal to that in SJ 2.

SJ 1 and SJ 2 have a higher percent oil content than the Thai, native varieties (Table 6); however, Pakchong and SB 60 have a slightly higher average protein content than SJ 1 and SJ 2. Soybean seeds produced in the dry season usually have a higher oil content and a lower protein content than seeds produced in the rainy season.

Variability for Resistance to Seed-Borne Pathogens in the Tropical Soybean Germ Plasm Collection

E. H. Paschal II

The importance of high quality seed in soybean production, especially in the tropics, cannot be over emphasized. Emergence and stand establishment are the most important stages in the life cycle of the plant. Without emergence or an adequate stand we cannot hope to produce satisfactory yields. The Puerto Rico-based INTSOY plant breeding project has undertaken a program to improve soybean seed viability and vigor through the combined efforts of specialists in plant pathology and plant breeding.

The incidence of seed-borne diseases has been attributed to natural pathogen populations and environmental conditions that favor pathogen invasion of the host tissue. Recent research results indicate that some genotypes may possess a form of genetic resistance to attack by seed-borne organisms. Wilcox (1975) reported on the heritability of virtual immunity to purple seed stain (causal organism *Cercospora kikuchii*) found in P.I. 80837, a maturity group IV, germ plasm accession. Although, in his opinion, purple seed stain is not serious enough to warrant the incorporation of the newly found resistance into improved cultivars, it is encouraging that such a host-pathogen relationship has been discovered. If resistance to a seed-borne fungus, even one that is not very injurious, exists, then it is not unreasonable to assume that resistance to more important seed-borne pathogens also exists.

The main objectives of the seed quality program are: (a) to identify soybean genotypes with resistance to seed-borne organisms, (b) to study the relationships between seed-borne pathogens and the tropical germ plasm, (c) to develop techniques for assaying seed health of tropical germ plasm and breeding lines, and (d) to incorporate seed health attributes into tropically adapted cultivars.

This work has been initiated by screening all of the nearly 400 accessions in maturity groups VIII, IX, and X of the United States Department of Agriculture soybean germ plasm collection. Seeds used in the screening were produced at the Isabela Substation (18° N.) of the University of Puerto Rico, Mayaguez Campus. Groups VIII and IX were planted in early June and group X in late August 1975. In view of these different planting dates, direct comparisons between group X and the two earlier groups should be made with caution. The group X planting received excessive rainfall during the latter part of the growing season, when plants were maturing. This resulted in generally lower seed quality in the group X lines than in group VIII or IX accessions, which matured under more favorable conditions. The term "more favorable" is relative. Although a great deal of rainfall did not occur during the critical maturation period of groups VIII and IX, temperatures and relative humidities were higher than average mean temperatures in the temperate zone.

BIOASSAY PROCEDURES

Samples of 100 seeds from each line are being used in a bioassay to determine the germination percentage and the percentage of seeds associated with internally seed-borne microorganisms. The bioassay consists of planting four surface-sterilized seeds on petri dishes containing potato dextrose agar and incubating them at 25°C for 5 to 7 days.

At the end of the incubation period each seed is classified into two main categories, germinated or nongerminated. Within these classifications are subdivisions for seeds germinated without microorganisms, with a fungus, or with a bacterium, and for seeds that did not germinate as a result of association with a fungal or bacterial microorganism. There is also a classification for seeds that fail to germinate without any apparent reason. All the

microorganisms are identified and pure cultures of each are maintained.

PRELIMINARY RESULTS

Visual seed quality scores of the three maturity groups are summarized in Table 1. This rating system of scoring seed quality from 1 to 5, with 1 representing the highest quality, is widely used in soybean breeding programs. To determine seed quality score, factors such as cracked seed coat, wrinkled seed coat, and moldy and rotten seed are considered. Mechanical damage, caused by threshing or other operations, or seed coat pigmentation, including purple seed stain, are not considered. The strong influence of environment on seed quality is evidenced by the distribution of seed quality scores from the two plantings. More than 50 percent of the lines from group X scored 4 or 5, while 44 percent of the lines in VIII and IX scored 1 or 2. Even though each line of the group X experiment was harvested promptly at physiological maturity, the prevailing high rainfall and temperature caused significant deterioration of the seed.

Table 2 illustrates the diversity of reaction encountered so far. The four accessions listed in Table 2 are of maturity group VIII, grown in the same environment but quite diverse in their seed quality attributes.

The following are the genera of the more common fungi identified in the study: *Alternaria, Aspergillus, Botrydiplodia, Cercospora, Chaetophoma, Cladosporium, Corynespora, Curvularia, Diaporthe, Fusarium, Penicillium*, and *Phoma*. Genera of the more common bacteria are *Bacillus* and *Xanthomonas*.

CONCLUSION

The search for soybean genotypes resistant to seed-borne microorganisms and to the loss of seed quality associated with the presence of these organisms is of high priority in our Puerto Rico-based breeding project. Approximately 200 lines of the three latest maturity groups have been bioassayed. On the basis of these results a replicated field trial has been planted in Puerto Rico, using the best lines from the germ plasm collection and several check varieties. Yield and other agronomic characteristics, as well as seed quality properties of these lines, will be evaluated. Delayed harvest techniques will be used to determine how well these selected genotypes resist seed deterioration during the period between physiological maturity and harvest.

Table 1. Visual Seed Quality Scores of Maturity Groups VIII, IX, and X at Isabela, Puerto Rico, 1975

Maturity group	Planting date	Seed quality score[a] 1	2	3	4	5	Total number of lines
		Number of lines					
VIII	Early June	24	71	89	27	3	214
IX	Early June	6	15	19	8	0	48
X	Late August	5	20	40	27	43	135
Total		35	106	148	62	46	397

[a] 1 = highest quality; 5 = lowest quality.

Table 2. Comparison of Seed Quality Score and Internally Seed-Borne Microorganisms of Four Group VIII Lines, Isabela, Puerto Rico, 1975

Genotype	Seed quality score	Days to maturity	Germination (%)	Fungi (%)	Bacteria (%)
P.I. 279088	1	136	100	0	0
P.I. 204339	2	118	81	19	0
P.I. 204336	3	110	47	52	1
P.I. 319533	4	124	0	100	0

The Use of Radiation in Soybean Breeding

Sumin Smutkupt

This report briefly summarizes results obtained by the author from soybean radiation experiments conducted in Thailand. Mutation experiments were started at the Faculty of Agriculture, Chiang Mai University, in June 1970 as a coordinated research project supported jointly by the Food and Agricultural Organization and the International Atomic Energy Agency. The first objective was to find a suitable dose of gamma radiation for inducing mutations in soybeans. Seeds of SJ 2 and Sansai varieties were irradiated with gamma rays of a cobalt source at the Institut für Strahlenbotanik, Hannover, Germany. Five different doses, viz., 5, 10, 15, 20, and 30 krad, were used.

The majority of soybean mutants were yellow seedlings. A yellow seedling mutation frequency ranging from 3 to 5.3 x 10^{-3} was observed in an M_2 population of approximately 20,000 plants. The 15 krad dose, which was well below the LD_{50} dose, was effective in giving a high mutation frequency. Other soybean researchers have also indicated that 15 krad is an appropriate dose for the production of soybean mutants. Brown seed coat mutants were produced in both varieties. A lethal Sansai mutant with an extreme reduction in plant growth also was produced.

Some of the mutants and mutation-derived lines were successfully established. Yield, percent protein and oil,

and fatty acid composition were determined for some of the lines. Seed yield of mutants or mutation-derived lines was always lower than that of the control. Mutants of SJ 2 and Sansai had an increase in protein content of approximately 2 and 3 percent, respectively. There was a 1 to 4 percent reduction of oleic acid in SJ 2 mutants, but a 1 to 6 percent increase in mutants and mutation-derived lines of Sansai. SJ 2 mutants had an increase of approximately 2 to 4 percent in linoleic acid and approximately 1 percent in linolenic acid. Conversely, Sansai mutants had approximately a 2 to 4 percent reduction in linoleic acid and less than a 1 percent reduction in linolenic acid.

Another mutation experiment was conducted in 1972. Seeds of SJ 2 (line 27-9) were irradiated with gamma rays of a cobalt source at Seibersdorf Laboratory, Niederösterreich, Austria. Six different doses (10, 15, 20, 25, 30, and 35 krad) were used. One hundred plants with phenotypic high seed yield were selected from the bulked M_2 populations of each treatment. An increase in protein percent was realized. Samples high in protein content (45 to 49 percent) were advanced to the M_4 and M_5 generations. The average protein content in the M_4 generation was lower than that in the M_3. Thus, the lines high in protein had disappeared. Selected lines with approximately 42 percent protein are now being tested in a yield trial at Pakchong.

A third mutation experiment was carried out in Bangkok in 1975. Seeds of SJ 1 (line 56-12), SJ 2 (line 27-9), Sansai (line 24-306), Cutler 71, and Wakashima were irradiated in the Gammator at the Radiation and Isotopes Division, Kasetsart University. The Gammator contains a caesium 137 source of 1,600 Ci that can deliver up to 68 krad per hour. The objective of this experiment was to study morphological changes in relation to seed and protein yield. Some macromutations, such as white flower color in the purple flowered Wakashima variety and black hilum in the brown hilum SJ 2 variety, were observed. All mutations are currently being tested in the field at Pakchong.

In general, soybean breeders favor the utilization of existing variability before attempting to create new variability through mutation breeding. Thus far there have been only four soybean varieties developed from mutation breeding. However, when desired characteristics cannot be isolated from existing variability, then an attempt to create variability by radiation has considerable merit. For example, if natural resistance to soybean rust (*Phakopsora pachyrhizi* Syd.) is not available in existing germ plasm, mutation breeding should be attempted. Success in obtaining disease resistance will depend largely on the effectiveness of screening techniques. The possibility of radiation breeding as a useful tool for soybean improvement should not be overlooked.

Comments on Mutation Breeding

B. B. Singh

The importance of inducing mutations through irradiation has been well established for many crops; however, only limited use of this technique has been made for soybeans. A soybean mutation breeding program was initiated in 1970 at G. B. Pant University of Agriculture and Technology, Pantnagar, India, to create useful mutations, particularly for male sterility, because prior to 1970 there had been no reports of male-sterile-female-fertile lines. Results of the induced male-sterile mutant studies are reported in Soybean Genetics Newsletter, Vol. 1, April 1974, pp. 19-20. Another objective of the program was to look for narrow-leaved mutants. Although the variety Semmes, for example, yields well in northern India, its leaf size is too large. Through irradiation several narrow-leaved mutants have been isolated and are being evaluated.

In any mutation breeding program the objectives must be clearly defined and kept as simple as possible. Moreover, mutation breeding should be used only when there is no existing variability for a particular characteristic. As an example, mutation breeding might be useful in the search for soybeans low in linolenic acid. As is well known, linolenic acid causes rancidity during soybean seed storage, thus reducing the shelf life of soybeans. At Pantnagar the entire soybean germ plasm has been screened for linolenic acid. The lowest value of all accessions was 4.5 percent. Screening indicated that there is no existing variability for linolenic acid. Thus, mutation breeding will be used in an effort to produce mutants low in linolenic acid.

Soybean varieties respond differentially when subjected to irradiation. In the Pantnagar experiments Clark 63 had a rather high mutation rate, and Semmes a somewhat lower frequency of mutants. Irradiation of Lee produced fewer mutants than Semmes; no mutants were obtained from Bragg.

The use of radiation is simply another tool available to the plant breeder. It should be most useful where many desirable characters (yield, lodging resistance, etc.) are present in a genotype that lacks one or two necessary characters, such as resistance to soybean rust or virus.

Summary

D. E. Byth

The presentations and discussions in this symposium amply illustrate the many problems that confront the tropical soybean breeder. In his program, the breeder has to take into consideration a great many factors. The presentations emphasized two main aspects of breeding. First, in order to be effective, selection and manipulation of populations must take into account the problems as they exist in the real world of plant breeding. The breeder must accept these problems and breed with them in mind. Second, the breeder should try to build environmental models on plant responsiveness to given environmental factors. He must develop "screens" through which selection can be made for specific types of responses.

The yield levels frequently referred to in this and other conferences are incredibly low. When yields are only 1.0 to 1.5 metric tons per hectare, or lower, we probably should not talk about a breeding program. We should talk about environmental or management limitations. If we are interested in yield improvement and improvement in other quantitative, or continuously distributed, characteristics, it is totally useless to attempt to select these characteristics under test conditions that result in yields of only 1.0 to 1.5 metric tons per hectare. The yields are so restricted by environmental factors, such as nutrition, disease, nodulation, and so forth, that we are not able to allow the innate genetic variability of our soybean population to be expressed. Therefore, we cannot select for quantitative characteristics.

We have to separate the program into two parts:

1. Selection for yield and agronomic improvement. The breeder must protect the soybean population from, among other factors, the massive influence of soybean rust, gross nutritional deficiencies, and poor nodulation if he is to have any chance whatsoever of moving toward an idealized plant type and a significant improvement in yield, chemical composition, and other characteristics.
2. Recognition of specific environmental limitations. The panel presentation on the interrelationship between soybean varieties and Rhizobium strains illustrated this point. Thai scientists now have a program to study nitrogen fixation through nodulation. They must solve this problem before they can expect any quantitative yield improvement. The same concept applies to moisture stress and to nutritional response in cases of aluminum toxicity, manganese toxicity, or, in higher alkaline soils, zinc deficiency. The breeder cannot manipulate genes for quantitative characteristics and populations when yield levels are low.

As emphasized, potential improvement can be gained through mutation breeding if (a) we have no other sources of genetic variability available, and (b) we can identify very specific objectives of the program. Unless these two criteria are met, mutation breeding should not be considered. In the tropics especially, the development of soybean programs is limited because of insufficient personnel and inadequate scientific knowledge of soybeans. In my opinion, a breeder cannot afford to dilute his efforts unless hes has very strong reasons for employing mutation breeding.

Discussion

Question: When screening for photoperiod sensitivity and looking for temperature effects, over what period do you calculate the average temperature?

R. J. Summerfield: The period from planting to the appearance of the first flower.

Question: How insensitive is Fiskeby 5 to tropical day and night temperatures?

R. J. Summerfield: Fiskeby 5 is very insensitive. According to the U.S.-Canadian classification, it could be classified as 0000.

Question: What cultivars are photo- and thermo-insensitive?

R. J. Summerfield: Of those screened so far, Clark 63 and Grant.

Question: You mentioned in your talk that a pure line from P.I. 86736 yielded 7 tons per hectare in field trials. What population levels were used, and what was the response of this line to population variables?

S. Shanmugasundaram: In a population density experiment conducted during 1974, four population levels were used, viz., 10, 20, 30, and 40 plants per square meter. The plot size was 4.5 m x 8.5 m. Yield levelled off at 30 plants per square meter. Reference is made to the 1974 AVRDC Annual Report for additional details.

Question: Soybeans are frequently grown in multiple croppir g systems where high yields are also desired. Varieties developed for a monoculture system may not be the best varieties for multiple cropping. Is a specially de-

signed variety trial desirable for testing those soybean varieties to be used in multiple cropping?

S. Shanmugasundaram: For intercropping, mixed cropping, and multiple cropping situations the segregating populations and advanced breeding lines must be tested under the conditions in which the crop will be grown, and selection must be done in the specific cropping system. In general, varieties developed for monocropping may not be suitable for other cropping systems, although there may be exceptions.

Question: Have you studied the correlation between flowering and maturity in your soybean germ plasm?

S. Shanmugasundaram: We have not determined these correlations; however, the time to flowering is usually influenced by photoperiod, but the period from flowering to maturity is relatively constant in a variety.

Question: Kitami Shiro is one of the leading varieties in Hokkaido, Japan. Did you use the parents of Kitami Shiro and other Hokkaido varieties in your experiments? Also, there are several closely related varieties used in Hokkaido. Among all Hokkaido varieties tested, did you find only Kitami Shiro to be nonsensitive to daylength?

E. H. Paschal: The parents of Kitami Shiro were evaluated for photoperiod sensitivity after it was discovered that P.I. 317334B was photoperiod insensitive. One of the parents exhibits a strong tendency toward day neutrality. The results of these studies will be published in the near future.

Of the 515 genotypes (all in maturity group III) screened for photoperiod response, P.I. 317334B was the only one identified as possessing unique photoperiod insensitive properties. There was no attempt to evaluate Hokkaido varieties that are closely related to Kitami Shiro, most or all of which are probably earlier maturing than group III varieties. As indicated in the presentation, all but one (P.I. 317334B) of the plants from Kitami Shiro were classified as group II. It has been reported that the early maturing varieties of Hokkaido have less photoperiodic response than later maturing varieties.

Question: In the photoperiod screening at Isabela, Puerto Rico, P.I. 82232 flowered in 25 days and matured in 84 days under a natural photoperiod. Have you tested this P.I. at other locations? If so, what is its performance at these locations, and do you think it can be used as a parent for developing early maturing varieties in Thailand or other low latitude areas?

E. H. Paschal: We have not tested P.I. 82232 at other locations. It could probably be used to develop early maturing varieties, but a better choice would be the more insensitive line, P.I. 317334B. We are in the process of testing insensitive and partially insensitive strains at several tropical locations.

Question: Have you identified the Rhizobium strains you are working with in Thailand? Are the nodules observed in some breeding lines effective nitrogen fixers? Also, what soil type and what indigenous nutrient status are present in the soil in your experimental plots?

Arwooth NaLampang: We have not yet isolated single strains, nor have we identified the effectiveness of these strains. We have observed, however, that the nodulated plans grow vigorously, with yields of about 1.5 metric tons per hectare.

In general, the soils in the Northeast are light, sandy in texture, and low in pH and fertility. If properly nodulated, native varieties of soybeans yield about 1.5 to 1.8 tons per hectare.

Question: In order to overcome depressed nodulation experienced under certain soil conditions, would it be considered more feasible to identify and adopt different varieties that will nodulate more efficiently, or to identify and adopt different Rhizobium strains that will promote nodulation more efficiently?

Arwooth NaLampang: We have tried both approaches. At present, inoculum is not produced in Thailand in appreciable quantities. However, Rhizobium strains are present, at least in some areas. Therefore, selection of soybean genotypes adapted to existing strains might have merit.

Question: B. B. Singh suggested a seed size of about 12 to 15 grams per 100 seeds for tropical soybeans. Would this seed size be acceptable for the Japanese market?

T. Sanbuichi: I am not very familiar with details of marketing in Japan. However, about 70 percent of the soybeans are used for oil, and any seed size can be used for this purpose.

Question: What is known about the genetic control of the narrow leaf and male-sterile mutants?

B. B. Singh: Genetic studies of the narrow leaf mutants are in progress. The male-sterile mutant studies were reported in Soybean Genetics Newsletter 1:19-20 (April 1974). Inheritance studies indicate that sterility in all the three lines (Semmes M.S.1, Semmes M.S.2, and N69-2774) is recessive and is governed by single gene pairs. Pollen studies and differential pod set on the male-sterile plants indicate that the genes for sterility are different in different lines.

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Small-Scale Soybean Processing: What Is Needed?

Introduction

L. K. Ferrier

In recent years food scientists have become increasingly concerned about the nutritional status of people in the developing nations of the world. Many see a close relationship between improving the nutrition and health of people in these countries and improving social and economic conditions. The purpose of this symposium is to exchange ideas about methods of utilizing soybeans for human consumption and to discuss the kinds of equipment necessary to achieve this end.

Nutrition education is an important aspect of any nutrition improvement program. People must become aware of their nutritional needs, but at the same time they must be offered nutritious products that are both palatable and low in cost. Consequently, it is essential to develop a food technology that will serve the dietary and economic needs of consumers, as well as meet the test of commercial feasibility.

Participants in this symposium believe that the development of small-scale processing equipment for use in the home, village, or small industry is crucial. Successful, small-scale technology should be imported from other countries, and technological and research information should be freely exchanged. Existing methods for processing soybeans on a small or intermediate scale should be further developed. One useful method for doing this appears to be to adapt "old fashioned" technology and equipment, thus minimizing costs and allowing production on a smaller scale than would otherwise be possible.

Practical Problems in Developing A Small-Scale Soybean Food Industry in Thailand

Ubolsri Cheosakul

Soybeans have occupied a significant place in the oriental diet for centuries. They are also found in the diets of people from practically every nation in the modern world. Hence it is desirable that concerted efforts should be given to research on high-protein but low-cost food products made from soybeans. With this objective in mind, the Food Technology Unit (FTU) of the Applied Scientific Research Corporation of Thailand (ASRCT) has prepared many prototypic, high-protein foods, such as soy beverage, cream, cookies, porridge, tonic beverage powder, and sweetened condensed soymilk.

During the course of developing these products FTU has experienced many practical problems related to a small-scale soybean food industry in Thailand. The following is a discussion of some of these problems.

RAW MATERIAL: POOR QUALITY AND ADULTERATION

The cleaning and grading of raw soybeans is the first processing step necessary to ensure high quality in the finished product. When the quality of the raw material is substandard, the processing costs of the finished product will be higher because of greater losses during processing and higher labour costs.

Soybeans available on the local market were found to contain an appreciable amount of unusable material, such as sand and dirt (about 1 percent), as well as immature, damaged, hard-seeded, and old beans (about 10 to 25 percent). This low quality results from improper cleaning and grading, as well as from the dishonesty of merchants who adulterate their soybeans. To avoid a reduction in profit many merchants, instead of discarding the waste from the cleaning process, mix it with the new, high-quality beans in various proportions for local sale.

Even though improved varieties of soybeans are now available in Thailand, processors cannot always get beans of uniformly good quality on the local market. The government, therefore, must take strong action against poor

quality and adulteration to protect processors from financial loss and to ensure high quality in the finished products. In order to improve the quality of the raw material, several points should be taken into consideration.

Grading Standards and Sampling Procedures

Standards for grading should be set by law. In order to conform to predetermined standards, numbered quality tests for size, appearance, moisture content, approximate composition, and so forth must be carried out and, in the case of export, be certified by a government laboratory. Sampling procedures should be drawn up in order to obtain representative samples to determine uniformity of quality. The law must be enforced by punishing those who practice adulteration.

To meet grading and certification requirements a committee composed of various government agencies, such as the Ministries of Agriculture, Commerce, Industry, Communication, and Health, should be established. The working group of this committee must be very active so that quality standards for the raw material can be improved.

Handling and Storage

Facilities for the proper handling and storage of soybeans should be developed. Undue breaking and cracking of the seeds during handling and transportation must be avoided. Each storage facility must be equipped with an appropriate device to limit the humidity, because initial bean germination generates heat that together with high humidity will promote further germination. Proper storage will also reduce other factors causing biological changes, such as the formation of fungus, the invasion of insects, and the inhabitation of mites.

Unless farm bins are constructed to exclude moisture, no advantage is gained by taking great pains to dry the soybeans. Waterproof roofs and good ventilation are the most important features in farm bins, rather than the size, shape or colour.

PROBLEMS IN RESEARCH AND DEVELOPMENT OF NEW LOW-COST VEGETABLE PROTEIN FOODS

Early in 1967 ASRCT initiated an active, food technology research programme with particular emphasis on the development of new protein foods adaptable to the Thai situation. The research programme also emphasized the examination of conventional food protein sources, the investigation of additional sources of protein foods for direct human consumption, and the conduct of nutritional, sociological, economic, and marketing studies on new, low-cost protein foods. During this programme, researchers identified the need for the following:

Facilities to determine nutritive value. Because the ASRCT facility for certain types of studies is limited, samples of basic food stuffs and food products adapted to Thai eating habits have been sent abroad for determination of protein efficiency ratio (PER) and some amino acids such as lysine, methionine, and tryptophan. Therefore, a source of technical assistance in this area must be found.

Adequate pilot-scale equipment. In November 1968 UNICEF and ASRCT made an agreement to cooperate in a series of studies on regional, semicommercial-scale food preparation at ASRCT. Nutritious, high-protein food products, such as soymilk and peanut cookies, have already been developed at ASRCT on a laboratory or kitchen scale, using soybeans, mung beans, or peanuts as the main ingredient. However, these products have not been market tested because no funds were available. It is believed that these developments at ASRCT will be of interest and significance to several other countries in Asia.

In 1975 part of the request for pilot-scale processing equipment was approved by the Australian Government through ASEAN under the Protein Food Project. Some items of the equipment on request were not approved, however, because of budget limitations. ASRCT badly needs a packaging machine for liquid and powder, a pilot-scale drum drier, and a cold storage facility.

Facility to design, fabricate, and repair special equipment. Repair services and construction facilities for equipment need to be improved and expanded. Small spare parts must often be ordered from abroad because such items cannot be purchased or constructed locally. Occasionally the quality of a product can be improved by a change in the processing equipment, but at an increased cost. For example, soymilk powder prepared by a spray drier is of a better quality than that processed by a drum drier, but the production cost is higher. A drier designed to yield the desired product without affecting the cost of production is required. In order to solve these problems, a workshop for repairing, designing, and constructing scientific equipment and instruments should be established and supported by the government.

Techno-economic feasibility studies. Last but not least, information on economic feasibility is equally as important as the availability of technological expertise. A project may appear very attractive on the technical side, but be undesirable from the economic point of view. For example, a highly acceptable textured protein can be produced from soybeans, but its price is beyond the reach of the average person in Southeast Asia. If small-scale production of this textured protein were launched, it might easily result in a serious financial setback possibly ending in bankruptcy.

CONTRIBUTIONS BY OTHER PANEL MEMBERS

Hideo Ebine: In the field of fermented soybean food production many key points must be borne in mind to make acceptable, high-quality foods. Koji making, however, is probably the process of greatest importance to the fermentation industry. The following is a discussion of those points that are central to the manufacture of high-grade koji.

Koji, which is widely used by the Japanese fermentation industry for producing sake, shoyu, and miso, is a

source of those enzymes that convert starch into sugars and proteins into peptides and amino acids. Its function resembles that of malt in making beer or whiskey in western countries. The fermentation of sake, shoyu, and miso can be said to start with the enzymatic activity of koji.

The microorganisms found in koji are fungi of the genus *Aspergillus*. In Japan the seed or inoculum used to make koji is called tane-koji, which at the present time is prepared in a tane-koji maker. The numerous varieties of tane-koji derive their individual characteristics from the activity of particular enzymes, such as the amylolytic or proteolytic enzymes, and from their ability to grow on the rice used in koji making.

In the process currently in use extreme care is taken to prevent any possible contamination by harmful microorganisms so as to ensure the production of a vigorous tane-koji. Modern processing begins with growing a select strain of *Aspergillus oryzae* on an agar slant in pure culture. Spores from this pure culture are used to inoculate partly milled, sterile, steam-cooked rice to which 2 percent wood ash is added to provide trace elements necessary for the vigorous growth of the mold. Cultivation is carried out under conditions as clean as possible, and the temperature is maintained at 27° to 30°C. After five days, when the rice is covered with mycelia and greenish-yellow spores, the mixture is dried at 40° to 50°C and stored at low temperature and humidity to preserve the activity of the enzymes.

Before beginning the koji-making process it is important to select a suitable tane-koji from the available, commercial varieties in order to ensure the proper balance of enzymatic activity. The amylolytic type, for example, is suitable for making sake and a few kinds of miso, while the proteolytic type is best for shoyu and most kinds of miso.

For koji making on a small scale the following equipment is necessary: (a) a vat for washing and soaking rice overnight at 15°C, (b) a steam cooker, (c) a vat in which to inoculate the cooked rice with tane-koji, (d) trays on which to spread the inoculated rice, and (e) an appropriate room in which the temperature is maintained at 27° to 30°C throughout fermentation of the koji. The tray method, however, is rarely used today in the Japanese fermentation industry, but has been replaced by the bulk culture method. This method can be divided into two types, one that uses a rotary fermenter and the other a koji-fermenting chamber. The rotary method is suitable for small-scale plants that use between 300 and 500 kg of raw material, while the fermenting chamber is used primarily in large-scale production. The type of method selected should be determined on the basis of the quantity of raw material to be processed by a factory.

The fermenter should be designed to meet the following requirements: (a) ease of cleaning to prevent contamination by harmful microorganisms; (b) adequate aeration for development of the mold; (c) some provision for breaking up lumps that form in the cereal during fermentation, either by the rotation of the fermenter itself or by a motor-driven stirrer; (d) an air conditioner to maintain the proper temperature and humidity during the development of the mold; and (e) a device to remove the koji mechanically when cultivation is completed.

Erwin Kopp: Dry-roasted soybeans have met with considerable success in Ethiopia. Processing is relatively easy because every household has the necessary equipment, viz., a simple, charcoal oven and a flat pan. Many Ethiopians customarily eat roasted cereals and pulses for breakfast, and hence were willing to try roasted soybeans as a substitute. It was a mistake, however, to believe that soybeans, which have not been traditionally used in Ethiopia, could be integrated into the daily diet within a short period of time. A booklet, "Soyabean Made into Traditional Ethiopian Dishes," was published, but because 90 percent of the population is illiterate, the booklet did little to ease the enormous communication problem.

Soybeans have also been processed into full fat flour in Ethiopia. The flour was used to prepare Faffa, a nutritious, acceptable infant food. Because small-scale processing equipment could not be imported, we developed our own equipment, using a new method for dehulling and an extrusion cooker with a specially designed head. Unfortunately, this equipment is not currently in operation.

F. G. Winarno: In 1976 Indonesia launched an ambitious program called the National Campaign for Nutrition Improvement of the Nation, whose purpose is to combat protein and calorie malnutrition. Four organizations are involved: (a) the Nutrition Intervention Program, (b) the Food Technology Development Center, (c) the Nutrition Research and Development Center, and (d) the Nutrition Education and Training Program.

The Nutrition Intervention Program (NIP) will provide headquarters for the new, cooperative program, while the other three organizations will act as support components. The target of NIP is to improve the nutrition of the people, particularly the most vulnerable groups, such as pregnant women, nursing mothers, and children under two years of age. Nutrition programs are also intended to counteract vitamin A and iron deficiencies, anemia, and endemic goiter. Target populations consist of vulnerable groups in villages and semiurban communities.

NIP is actually an intersectoral program coordinated by the National Department of Health. The NIP approach includes nutrition education, for example through group study sessions for nursing mothers, and food supplementation during four months per year. Food supplementation is based on the needs of a particular village. For example, a village of 600 households with a total of 3,000 people would contain approximately 100 pregnant and nursing women and 64 babies under two years of age. Annual supplies for such a village would include 1.0 metric ton of soybeans and 2.5 tons of rice or corn delivered over a four-month period. Supplies

are to be distributed on a temporary basis with the expectation that within a short time the village will be able to provide its own food from local lands. Villages are grouped into subregions and subregions into regions. About 30,000 tons of food supplements are required for each region. NIP plans to form a special organization to handle storage and distribution.

The Food Technology Development Center (FTDC), which will be built in the future, will concentrate primarily on the nutrition problems of vulnerable groups. It will develop needed machinery and equipment, which must be low in cost, easy to repair, and easy to operate. In addition, FTDC will develop fortified and supplemental foods acceptable to the local people.

FTDC will also be responsible for encouraging small-scale industry. At the present time the major problem is the scarcity of people trained to transfer technology from the laboratory to small industries, which have chronic problems related to soybean storage and shelf life of the product. Efficient methods of processing need to be developed to ensure consistently high quality.

SUMMARY OF GROUP DISCUSSIONS

After the presentations by the panelists, symposium participants were divided into small groups, each of which was asked to develop and present two ideas the members thought would be beneficial for encouraging improved soybean or protein intake in developing nations. The following is a digest of some of the key concepts discussed.

* * * * * *

International cooperation is necessary in order to meet the need for improved foods to upgrade the nutrition of vulnerable groups, such as infants and pregnant and nursing women. Products already established in some countries could be tested and the technology for their production transferred to other areas of that country or to neighboring countries. Assistance from governmental or other agencies is at the present time a requisite for promotion and distribution.

It was suggested that new food products be adapted from products that have met with success in other countries, rather than be developed as a totally new concept or product. Moreover, prototype foods developed by governmental or other research organizations should be made available if possible for manufacture and marketing by commercial enterprises. Simple recipes for preparing nutritious meals or foods for vulnerable groups need to be perfected.

International cooperation is urgently needed on both small- and large-scale processing technology. There is a need to adopt and transfer machinery, product technology, and training programs consistent with the socio-economic needs of the region. Areas of emphasis should include low cost, acceptability of product and process, simplicity of process, and cultural and socio-economic suitability to the region.

It is important that national governments set favorable policies on tax incentives, project financing, nutrition campaigns, and price supports conducive to the establishment of small-scale soybean processing industries. There is a need to adjust and reorient processing, utilization, and marketing programs based on systematic surveys and evaluations of the nutritional, processing, and marketing aspects of high-protein foods. Each country must evaluate the cost benefit to the nation as a whole in terms of production, processing, and utilization of soybeans.

Improvement of technology for manufacturing and using full fat soybean flours is highly desirable. Simpler and cheaper extrusion cookers should also be developed and made more readily available.

Finally, INTSOY meetings should continue on a multi-disciplinary level, with increased emphasis placed on national five-year plans, particularly with respect to human improvement, income distribution, and increased production and employment.

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Extension of Research to the Village Farmer

Extension Workers in Agricultural Development

Yookti Sarikaphuti

My presentation addresses the following questions:

- What can be done to make the importance of extension work more visible to the public and to students?
- What can be done to improve the relationship between extension workers and research personnel?

Let us look at some facts about our target group, the village farmers. Small farmers occupy a key position in Asia's future agricultural development. In all Asian countries small farmers, who outnumber the medium and large farmers, have a considerable share of the farm land. The term "small farmer" is used broadly to include different categories of low income agricultural producers, such as small landowners, tenants, and sharecroppers with holdings and income below the average for a particular rural area. Landless agricultural laborers are also included.

Although the farming level varies considerably within this group, the small farmers' production potential is relatively underdeveloped in most Asian countries. Often their productivity is low; only a part of the small farmers' production is market-oriented; participation in the technological progress lags behind that of larger farmers; and, for various reasons, small farmers are reluctant to respond to governmental promotional efforts.

A problem being recognized more and more is the impact of the depressed income situation of small farmers on future political and economic development. The success of development agencies in promoting the welfare of small farmers will determine whether adequate food supplies will be provided, rural employment increased, and incomes better distributed in the future. Small farmers could contribute more capital than they often do now.

How, then, can extension services help raise the productivity of small-scale farming and encourage small farmers to make more innovative and rational decisions? It is obvious that most extension services are not in the position to get deeply involved in additional campaigns. Each agent usually has to deal with large numbers of clients. Small farmers are relatively difficult to communicate with, and it is questionable whether the average extension worker is sufficiently prepared to meet this challenge.

Should extension workers endeavor to deal equally with all farmers or should they concentrate only on certain groups? There are arguments for both approaches. Often the decision is made in favor of the second alternative, because it is basically impossible to work with the same intensity with all farmers in a region. If resources are scarce, it may be advisable to give preference to activities with the most favorable cost-benefit ratio. The difficulty is that this results in the selection of large and medium farmers for attention instead of the small farmers. If one strictly follows the response principle, that is, if concentration is focused on progressive farmers who quickly react to extension efforts, the already existing gaps among the farmers' groups will widen and obvious imbalances in incomes and in the social situation will become greater.

What can be done to make the importance of extension work more visible to the public and to students? In a recent FAO publication extension is defined as "a service or system which assists farm people, through educational procedures, in improving farming methods and techniques of increasing production efficiency and income, bettering the levels of living, and lifting the social and educational standards of rural life." In many countries extension is still viewed only as a means of boosting production without improving the standard of living of the rural family. In some countries efforts aimed at improving the rural milieu by the formation of cooperatives or youth and women's programs are still regarded as a waste of time and money.

Most extension services have catered exclusively to the adult male population. International Labour Organisation figures show, however, that women constitute 51 percent of the agricultural labor force in Thailand, 39 percent in Tanzania, and 36 percent in India. Yet even though women perform a large part of the agricultural work and make many of the important decisions, women's programs tend to concentrate on home economics to the exclusion of agriculture.

Although many extension services have a rural youth component, this element is generally weak. Much stronger efforts are needed. In a recent survey, 50 percent of the fathers admitted they had adopted some of the new agricultural methods that were part of their sons' projects. This lends strong support to using young people in the modernization of the rural sector. Extension must especially avoid aiming solely at the male farmer and seek to involve women and youth as well as men in its programs. To serve the farm community as a whole should be the major objective. Only by first looking closely at the client groups and by obtaining the view of the local people before plunging in with a program can extension workers identify areas of need. With limited resources an initial program aimed at a selected clientele may be successful if evaluated regularly and its direction readjusted periodically as the program develops.

A pilot area in the country should be selected to begin the program, with plans for expanding it to other parts of the country. This has proved to be a wise strategy because it deals with a small, manageable area and a small number of farmers before a national program is started. It also provides an opportunity to test ideas and materials on a small scale before launching the program on a nationwide basis. This helps reduce waste and avoid possible frustration in launching such a program.

A massive endeavor is necessary to create farmers' organizations, associations, and groups. Such organizations or associations must give farm families the chance to participate in planning and decision making. They must also assist farm families to develop an awareness of their potentialities and the extent to which families can help each other. Moreover, the private sector should be involved in this work and encouraged to expand its present programs.

What can be done to improve the relationship between extension workers and research personnel? The lack of an adequate relationship between research and extension is well known. A partial cause is the lack of appreciation for the value of the two-way communications link that helps research workers identify problems. A competent and effective research program is essential to any extension service if development goals are to be realized. Without this essential support little progress can be made. Although research and extension are two separate areas of responsibility, research without extension or vice versa will result in minimal impact. Research without extension is meaningless; extension without research is empty. When placed together, they tend to make each other effective. They should always be considered complementary functions because both elements are essential for agricultural development. Therefore, at the planning level close links between research and extension will be mutually beneficial in establishing common goals and planning necessary action that is in closer conformity with actual needs and possibilities.

It is now widely accepted that extension work should not only be oriented to improve agricultural production, but must also be directed to improve people's lives and rural societies. For this purpose, technical knowledge needs to be supplemented with a complete understanding of the relevant human and social aspects of the rural communities where progress and development are attempted. Social aspects are as important as technology. Efforts should be made to expand research activities to cover this field. Sociological research should be undertaken in combination with studies of economic factors. This could take the form of "situation studies," which in turn could lead to more appropriate planning. Such studies should establish bench marks against which progress may be measured, and also methods for periodic evaluations to determine program effectiveness. Research institutions should be in a position to collaborate with extension services in performing tasks essential to the orientation, planning, and improvement of the extension service.

Research institutions often require fields to conduct field trials under actual farm conditions. To this end, extension services can be most useful to research and can profit in turn by obtaining firsthand information on new findings and materials ready for wider distribution. In this way extension workers can assist in promoting research-proven materials.

Extension frequently needs specialists to solve particular problems, to train field workers in specialized skills, to backstop extension field workers, and to conduct regional trials or other educational events. When extension services have their own specialists, these should be in constant contact with researchers, preferably participating in their work. They should play a major role in the two-way communication flow from rural families to researcher and back again. Abundant evidence indicates that research results are not properly used at the farm level and that farm-level problems do not always reach the research workers. Much research languishes in research journals because it has not been adapted for use in extension. These findings need to be put into language easily understood by farmers. This could be done by extension specialists in different fields of research. When specialists are not available in the extension service, however, they should be obtained from the research stations. A close liaison is required between researchers and extensionists. Cooperation should be encouraged by the directors and carried out at all levels.

Field days at experiment stations for extension workers and farmers provide a means of information exchange that should be encouraged. Extension and research workers should not overlook the opportunity for collaboration in field days. Training of field workers and farmers in the latest developments can best be done by demonstration. In general, gatherings involving the three parties — farmers, extension agents, and research staff — can contribute positively to the prestige of the institutions and gain for them the greater confidence of the farming communities.

Written materials produced by research institutions

for public distribution are more apt to accomplish their purpose if research and extension workers collaborate in their preparation. Extension workers should be considered the main centers for their distribution.

CONTRIBUTIONS BY PANEL MEMBERS

F. Jameson Bell: An examination of the record of soybean production in Thailand shows that the cultivated land devoted to soybeans can be directly related to the price. But while the record shows a steady increase in the total production of soybeans, this reflects only the increase in the area planted. The yield per unit area has not changed. For 15 years it has been less than 175 kg per rai or 1.1 ton per hectare. There are a number of reasons for this stagnation. The seed quality is poor and campaigns to increase production have been generally uncoordinated.

Boonyawart Lumpaopong: In its multiple cropping project Chiang Mai University has given attention to bridging the gap between research and farmer. Conference participants will have a chance to visit the research plots and the fields of cooperating farmers. A number of cropping sequences are being evaluated experimentally. At the same time, we are examining traditional farming techniques to be sure that the cropping systems developed will fit into the farmers' cropping patterns.

To improve communications between extension agents and university researchers, Director-General Yookti and I have met frequently. At one meeting scientists from Chiang Mai University presented a seminar on the multiple cropping program to extension staff. After the formal presentations we broke into small workshop groups, and the extension staff had a chance to critique the program. I think we all benefited from this exchange. I hope we will have more such sessions in the future.

William G. Golden: I would like to briefly describe a program that has been a success. We began the rice production training program at the International Rice Research Institute (IRRI) in 1964. Next month the program will enter its eleventh year, and during that time over four hundred individuals have been trained. Trainees spend about half their time attending classroom lectures by internationally recognized experts in rice production, culture, and utilization. The remaining time is spent in the paddy, sloshing through the mud with a water buffalo, growing their own rice crop. Most extensionists can talk about growing a crop, but they cannot demonstrate it in the field. And that is where they fail. This training program is unique in that it trains the trainers by changing their attitudes. The premise of the program is that science plus skills equal self confidence and credibility. And the training does not end with the completion of the course. The follow-up with the individual after he has returned to his country is critical.

The program cannot be successful without the backing of the trainee's government and the involvement of an international center. The six months away from their normal environment at a quality institution is essential. Before they come, their home government must commit itself to stating exactly what position the individual will be in when he returns. And then after he graduates and returns, we keep the heat on to encourage him to change the attitudes of others. We do not let the coals die once the participants are fired up.

In Sri Lanka a similar multiple cropping training program was initiated. By the time I left the program, the Ceylonese were training not only their own citizens but foreigners. Indonesians were taught by Ceylonese. This is the multiplier effect that is needed if we are to make a real impact on agriculture in developing countries.

James J. Riley: Recently the press has given considerable attention to agricultural development in mainland China. I have asked Peter Kung to give us a brief review of the system employed in the People's Republic of China to transfer technology in agriculture.

Peter Kung: Since the rediscovery of mainland China in recent years, many people are interested in the Chinese model of agricultural development. At present it is still difficult to say whether this approach is transferable to countries with different sociopolitical systems. The Chinese believe that ideological pressure and organizational transformation can increase the ability of farmers to adopt modern technology. They also believe that social reform should precede technical reform.

Along with food grains and cotton, the oil crops such as soybeans and peanuts have dominated production, marketing, and distribution. In a campaign against underdevelopment, production is promoted by mobilizing resources, including the growers, who are organized into communes. Every commune is visualized as a battlefield against poverty. Frequent use of slogans makes every farmer aware of policy priorities.

Brigades and production teams are set up in each commune. Each brigade is assigned a fixed production target. In a brigade there may be several production teams, each of which consists of 10 to 30 families that live in one or more villages. Each team is governed by a committee that includes representatives of the local households. The committee, chaired by a party member, decides how assigned targets will be met, what crops will be planted, and what management systems will be used.

Brigades may become highly specialized, providing certain services such as seed production and storage for the entire commune. In a commune at least one brigade will have responsibility for field experimentation. Scientists from agricultural colleges or research institutes are assigned to such brigades and are entitled to work there for one year every three years. This brigade evaluates new varieties, cultural practices, and cropping patterns in trial plots. Any techniques judged superior by the experimental brigade are immediately adopted on an extensive scale by the whole commune.

This reliance on local insight has psychologically encouraged coordination of research and extension. The association of the scientists with production brigades provides a mechanism for the extension of new technology. Students and teachers of the agricultural schools work side by side in field routines, spending three or four months per year with the farmers at the commune. They are considered members of the production teams. Many industrial plants producing farm inputs or processing agricultural products have been built up as part of communes. This also helps funnel modern technology into agriculture.

Performance records of teams, brigades, and communes are compared and used to encourage emulation. Outstanding performances are given recognition via an awards system. The best communes are used as demonstration farms for the county, the province, or the nation as a whole.

In the democratic world, private enterprise is respected. Farmers who own their lands make their own decisions. Competition rather than cooperation is part of the free enterprise system. Agricultural extension in a free society therefore involves mass education of farmers through persuasion. I do not believe the Chinese model can be transferred to these countries. A high percentage of the 800 million people in the People's Republic of China are engaged in food production. The hub of the organization is the commune, of which there are 70,000 in China. Agricultural development proceeds on a region by region basis and heavier technical input is used especially in areas with higher productivity. The agricultural lands of the country are generally divided into modernizing regions and traditional regions. First priority is given to the modernizing regions, which are subdivided into high, stable yield areas and improved yield areas. Emphasis is given to the former.

Riley: What is being done with soybeans in the People's Republic?

Kung: Actually very little. More emphasis is being given to grain crops. Annual soybean production is about 11 million metric tons, which is consumed entirely within the country. However, in the pre-war period China annually exported some 2.5 million metric tons of soybeans to the international market.

Mohamad Jamil: As I see it, the principal question in extension is how to get the farmer to grow soybeans. Research technologies are developed at a distance from the farmers. For example, the early IRRI varieties were introduced into areas of Malaysia where environmental conditions were different from those for which they were developed, and as a consequence their performance was poor.

S. Shanmugasundaram is right when he says that we should transfer earlier generation breeding lines to the farmer's field. If this is done, it is possible to evaluate them in the areas where the released varieties will eventually be planted. The IRRI multiple cropping system is developed along these lines. After the applied research has proven successful, the results can then be introduced over a wide region.

The question has been posed, "What can be done to raise the status of the extension officer?" I think an analysis must be made by the worker himself. Extension officers must learn management and decision-making practices. The country should be divided into manageable production zones each of which is relatively homogeneous. These must be the basic units of any agricultural program. Using political or other artificial divisions within a country will not work. Extension and research must be developed together. Whatever the program used, it must bring research closer to the farm community. In short, *we must recognize the client.*

In Malaysia most new ideas have been introduced through the commercial sector.

Yookti Sarikaphuti: In Thailand the policy maker is being stimulated. The key is the involvement of the civil service organization and the governor of the province. A meeting of all provincial workers is held twice a year. Local problems are noted and brought to my attention. In addition, direct dialogues are scheduled between farmers and staff members of the Ministry of Agriculture.

Golden: The active and objective involvement of the politician is instrumental to the success of an agricultural development project. I can cite two outstanding examples in the Philippines.

Governor San Luis of Laguna Province participated in a one-week rice production training program at IRRI, staying in the student quarters on campus and not returning to his office during the entire week. Following the training, he distributed IR 8 seeds through his office, lectured to farmers on how to improve their yields, and visited farmers' fields to learn of their production problems. He later confided that he was falling behind in his office work because he enjoyed walking the rice levees with farmers and discussing rice matters. Clearly he was comfortable in the rice paddies with farmers and was viewed as something of an expert after his training.

In the northern Luzon province of Ilocos Sur, former Governor (Mrs.) Crisologo personally attended extension meetings and encouraged farmers to use modern rice technology to increase their yields. As a frequent visitor to IRRI she searched for new information and seeds of the new varieties, which she transported back to Ilocos Sur in her own truck. When experimental plantings were ready for harvest in her province, she officiated at the "ribbon cutting" ceremony.

Yookti: Field demonstrations are the best method of transferring technology. The farmers in the Chiang Mai area may plant as many as 20 seeds in one hole because the seed quality has been poor. When a better seed is introduced, the farmers will have to be convinced by results before they will accept a recommendation to plant only three to four seeds per hole.

Jamil: In Malaysia the responsibility for extension has been transferred to the new Farmers Organization

Authority. The hope is that this will strengthen the farmers and raise their prestige.

The problem of the extension of technology is not caused solely by poor communications. Rather, a major part of the problem is that too often the research being done is not, as I like to say, bankable. That is, it has not attracted credit suppliers who provide funds for further research and development. Therefore, if we push to make our research programs produce results that are bankable, funds for projects can be attracted, and the transfer of technology will be accelerated.

The Malaysian Agricultural Research and Development Institute (MARDI) selected a rice variety especially for an irrigation scheme. Field tests that proved the yield potential of the variety were instrumental in convincing the bank that the project was bankable. Now dollars for development are flowing into the project area.

Golden: I agree completely. We must scrutinize projects carefully and learn what has been tried in other countries. The production of *Rhizobium japonicum* soybean inoculant in Thailand is under discussion. Thailand should look carefully at India's experience. In my judgment, they should buy commercial inoculum as an interim step until it can be shown that the local production of inoculum is economical.

We should remember that what we are talking about here today is not just the extension of soybeans, but production development. The organization of research along commodity lines has proved successful. But for the introduction of new technology at the farm level we need to share experiences. Sundar Shanmugasundaram has shown that it is genetically possible to produce 7 metric tons of soybeans per hectare. Jameson Bell has shown that the average soybean yield on farmers' fields in Thailand is 1 ton per hectare. This is the gap we must try to close.

Boonyawart: At Chiang Mai University we are now working to identify problems at the village level. The research and extension programs are directed towards producing solutions to these problems.

Jamil: The blame for the present status of development has often been placed on colonialism, but I discount this argument. The present state of inefficiency in extension will continue, unless the income level of the extension workers is raised so they can have an adequate standard of living. Some of our extension agents had a study period in Taiwan. Just seeing the possibility of success greatly inspired them. For example, they saw that the extension workers on motorcycles could get more done.

Golden: Rewards follow successes. We must give the extension agent the ability to be successful; this in itself will lead to attitudinal changes. I like to refer to the three D's of agriculture development: Direction, Dedication, and Discipline.

Bell: I think it is appropriate for us to ask what lies ahead. There may be changes in the making. Northeast Thailand has a tremendous potential for soybeans that has never been realized. When Dr. Bhakdhi Lusanandana was the Director-General for Agriculture in Thailand, he secured a loan from the World Bank to support soybean research. Many good opportunities are lost because of lack of initiative or not knowing how to get support. Fortunately, this is not the case in northeast Thailand.

Yookti: A new project for increasing seed production has just been initiated. Both Thailand and USAID have committed US$4 million. Initially 400 metric tons of certified seed, including soybean, will be produced annually. In six years production should reach 2,500 metric tons of seed per year.

I recommend that workshops be organized at the farm level and experts assembled for a 10-day intensive dose of local problem solving focused on the problems of the farmer. To make progress we must strengthen the farmers' associations and increase our work with the progressive farmers.

DISCUSSION BY PANELISTS AND AUDIENCE

Question: Do farmers in communes of the People's Republic have the freedom to select what crops or methods of farming they are going to use, or do they have to do what the production team tells them?

Kung: They have little freedom and generally must follow the dictates of the commune leaders or the Communist Party member of the revolutionary committee.

Question: Please tell about the marketing of farm products in the People's Republic. Where do the farmers sell their products?

Kung: Roughly 50 percent of the products goes to the members as wages. But by deducting the free food, free clothes, free medical care, and so forth, which are paid for with farm products, there is hardly any left to be sent to the market.

Question: Do they have any price incentives in China to encourage farmers to produce more?

Kung: No. There is no price incentive at all. The major incentive in all areas is political consciousness. The agricultural program in the People's Republic is devoted to the mobilization of the people and to directing all available means toward the production of food until self-sufficiency is reached. The average rice yield per unit area in China is one of the highest in Asia. It appears that the economies of scale outweigh any decrease in food-producing capability of the individual.

Question: The key to extension outreach is the extension worker. His attitude toward the farmer and the farm family, however, frequently makes him ineffective. This is especially true when he feels superior to the farmer, as do many of the educated in developing countries. How can the attitude of the extension worker and that of the educated group from which he comes be changed?

Golden: One must train the trainers so that when you do change an attitude, the effect can be multiplied. The

best mechanism I know of to change attitudes is the intensive field and classroom training offered by the international agricultural institutes.

Question: Why does Mr. Golden feel that help from an external international agency is obligatory in keeping a program such as soybean production going?

Golden: International agricultural institutes can do things others cannot, and the quality of staff and facilities cannot and should not be replicated locally. It is simply a matter of making the best use of the resources available. Since the institutes are there, the national programs should take advantage of them.

Question: Do the farmers' associations in Malaysia assist in extension work?

Jamil: The farmers' associations are one of the most successful means of transferring new information. They are assigned geographic areas of responsibility that correspond to the agricultural zone divisions. As I have already stated, much of the information is brought to the local association and the farmers by commercial representatives. These middlemen are satisfactory up to a certain point, but the extension service must also play a role. The extension service must be concerned not with the selling of a product but with human development.

Summary

James J. Riley

To summarize this discussion is difficult. I therefore intend to emphasize the key points made by the panel members and the uniqueness of the speech given by Director-General Yookti. His words lend themselves to quotation:

- "Give the farmer a voice."
- "Only by first looking closely at the client groups and obtaining the view of the local people before plunging in with a program can extension workers identify areas of need."
- "A massive endeavor is necessary to create farmers' organizations . . . or associations [which] must give farm families the chance to participate in planning and decision making."
- "Farmers — Extension — Research."

William Golden also gave us some maxims to remember:

- "Change the change agent [the extension worker]."
- "Science plus skills equal self confidence and credibility."
- "We must change attitudes."
- "The basic problem is at the top; if leaders can be convinced, there is a chance of success."

No amount of discussion would produce the solution to the problem of extending research results to the village farmer. There is no single general solution, only numerous particular solutions. By examining these, we can gain insight into how to solve future problems.

Tan Sri Mohamad Jamil left us with two key ideas: "We must recognize the client" and "We must strive to make our research bankable." Frankly, I am encouraged by the degree of competence that Asian leaders, such as those represented on this panel, bring to the task of transferring agricultural technology.

William Golden said we must convince the leaders. I say the leaders here today are convinced.

I want to thank members of the audience for their frank questions and the members of the panel for their direct answers. In closing, I recommend we keep Director-General Yookti's words in mind: "Research without extension is meaningless; extension without research is empty."

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COUNTRY REPORTS

Current Status of Soybeans in Australia

J. S. Russell and R. J. Lawn

Although soybeans were grown in Australia over 50 years ago (Anon., 1922), it is only in the last five years that the crop has become significant. In the past, only small areas were sown to soybeans because suitable varieties were not available and because there was no awareness of the importance of photoperiodic response with respect to adaptation and agronomic and cultural practices. Climate has also restricted expansion of soybean production, and undoubtedly will continue to be a problem, because only small areas of Australia have adequate summer rainfall. The production of maize, which has similar climatic and soil requirements, has never exceeded 200,000 hectares and is currently less than 100,000 hectares.

Recent research, the acquisition of suitable varieties, and favourable market conditions have led to an increase in soybean production since 1968 (Table 1). Major expansion began in 1970-71, and over a seven-year period there has been almost a twenty-fivefold increase in area and an even greater increase in production. Yields per hectare leveled off between 1972 and 1975 at about 1,360 kg per hectare, probably because of the extension of soybeans into drier, rain-fed areas, an increase in the number of inexperienced farmers growing the crop, problems of weed control, and the difficulties of obtaining effective stands. There was also more rainfall than usual during this period. In 1975-76 the decrease in the area sown to soybeans is possibly related to price factors.

Table 1. Area Sown, Production, and Mean Yield of Soybeans in Australia, 1968 to 1975

Year	Area sown (ha)	Production (metric tons)	Mean yield (kg/ha)
1968-69	2,090	1,739	832
1969-70	4,970	5,027	1,012
1970-71	7,330	8,933	1,219
1971-72	18,020	28,136	1,561
1972-73	27,960	37,923	1,356
1973-74	40,849	55,580	1,361
1974-75	50,500	68,750	1,361
1975-76	27,000 (estimate)	....	...

Most of the current production is in Queensland, with the remainder principally in New South Wales. A considerable proportion of the areas sown, especially in New South Wales, is irrigated. Production occurs largely between 26° and 33° S. latitude, and much of the future expansion should occur in this region (Laing and Byth, 1972). Areas sown in subcoastal regions should also be increased. Development of suitable varieties could extend soybean growing into lower latitudes and possibly into areas with less rainfall.

VARIETIES

The availability of improved cultivars from the southern United States has been an important factor in soybean expansion in Australia during the last five years (Lawn and Byth, 1976). Well over 1,000 accessions have been made since the 1930's (Byth, 1971). Some of these have since been lost, but a combined national collection of 500 to 600 accessions, mostly of tropical and subtropical origin, is maintained at several institutions.

The majority of current cultivars are direct accessions from named U.S. cultivars. There are five exceptions to this. Ross, Gilbert, and Daintree were released by Byth from the University of Queensland program for use primarily in low latitude areas. Wills and Semstar are farmer releases, Wills being an unreleased U.S. line, and Semstar probably a selection from a natural cross.

Extensive regional trials have been carried out, particularly in eastern Australia, to evaluate cultivar adaptation (Williamson and Rose, 1973; Filet and Williamson, 1974; Laing et al., 1974; Sheridan and Cutting, 1974). Cultivars currently recommended in Queensland (Walsh, 1975) include Gilbert, Ross, and Improved Pelican at 17° to 20° S.; Daintree, Wills, and Davis at 24° S.; and Davis, Bragg, Hampton, Hill, and Semstar at 25° to 29° S. Almost without exception, cultivar recommendations for New South Wales consist of named U.S. cultivars.

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AGRONOMY

Low temperature is less of a constraint on the potential growing period in Australian soybean areas than it is in areas at higher latitudes (e.g., 40°). Although the lack of temperature constraints increases the flexibility of planting date, it makes it imperative that the interaction between particular cultivars and planting dates be understood. Several studies (Byth, 1968; Lawn and Byth, 1973 and 1974) have elucidated these relations for a number of cultivars at latitude 27° S. Studies of planting date are currently in progress at Kimberley Research Station, latitude 16° S. (Russell et al., 1976). At this frost-free station the research aim is to find cultivars that can grow in the winter, that is, under daylength conditions of 11 to 12 hours.

Plant population, involving both row width and plant management, is also an important factor affecting optimum plant yield. In general, comparatively wide row widths (70 to 90 cm) are recommended for long-season crops (120 to 130 days from planting to maturity), while narrower rows (35 to 70 cm) are required to achieve maximum yields from short-season crops (100 to 110 days). Within the row, plant densities of 20 to 40 plants per metre are usually recommended. Plant populations range from 300,000 to 400,000 plants per hectare for irrigated crops, and 150,000 to 200,000 plants per hectare for rain-fed crops. However, short-season cultivars or long-season cultivars planted late are spaced closer than usual to promote higher yields, taller plants, and increased height of the first pods above the ground. This last characteristic reduces losses due to mechanical harvesting.

Ideally, equidistant planting would produce optimum plant yields, since this appears to result in more effective utilization of soil moisture (Lawn, 1971). In practice, weed control and irrigation usually necessitate planting in rows. However, various bedding practices have evolved in irrigated areas. At the Kimberley Research Station, for example, four rows at 25-cm widths are generally planted on 1.5 metre beds, thus approaching the ideal of equidistant plants while allowing irrigation and weed control.

DISEASES

Soybeans are susceptible to a wide range of diseases, although few of these occur in Australia (Anon., 1974). There are three bacterial diseases: bacterial pustule (*Xanthamonas phaseolii* var. *sojensis*), bacterial blight (*Pseudomonas glycinea*), and wildfire (*Pseudomonas tabaci*). Plant resistance to pustule and wildfire is available, but there is no known resistance to blight. Control measures include using resistant plants where possible, removing volunteer plants, and rotating crops to facilitate the rapid breakdown of plant trash.

There are three main fungal diseases: soybean rust (*Phakopsora pachyrhizi*), Sclerotinia stem rot (*Sclerotinia sclerotiorum*), and charcoal rot (*Macrophomina phaseolina*). No varieties are resistant to rust at present. Suggested controls (Anon., 1974) include growing away from known hosts and, in the early stages, using a fungicide. Because the rust pathogen has a wide host range, many native legumes present in soybean growing areas can act as hosts. Charcoal rot can frequently be reduced by preventing water stress in irrigated plants. Sclerotinia rot can be controlled by not planting in areas known to have this disease.

Two virus diseases, soybean mosaic and peanut mottle, occur, but neither is currently of major importance.

INSECTS AND WEEDS

At present the green vegetable bug (*Nezara viridula*) is the most troublesome in the main soybean growing areas. Chemical control of this insect is readily obtained. The lucerne stem borer (*Zygrita diva*) is currently of concern in the north, and research is in progress to determine population dynamics and control. Under some conditions the spur-throated locust (*Austrachis guttolosa*) can cause substantial crop damage.

Weeds can be a significant factor affecting soybean yields. In most established areas weeds are controlled by cultivation and the use of selective herbicides (Felton, 1973). In tropical areas weed control is of particular importance, especially during the period from pod filling to maturity. During this period, when soybean leaf cover is decreasing, rapid growth of some weeds can result in harvesting problems. Major weeds in these areas include horehound (*Hyptus suaveolens*), hops (*Nigranda phaseoloides*), goathead burr (*Bassia bicornis*), and Mossman burr (*Cenchrus echinatus*).

RESEARCH

Five organizations have undertaken various aspects of soybean research. The University of Queensland and the University of Sydney both have active research programs. The Queensland Department of Primary Industries and the New South Wales Department of Agriculture are involved in the applied aspects of soybean culture, and the former is also involved in soybean breeding. The Division of Tropical Agronomy of the Commonwealth Scientific and Industrial Research Organization (CSIRO) is involved in selection and agronomic studies in northern Australia, and in the higher latitudes it is engaged in physiological field studies, particularly in relation to nitrogen fixation. The Division of Plant Industry has some interest in plant introduction and studies of soybean land races.

Much progress has been made in recent years. Developing better varieties for the lower latitudes and drier areas is still a major challenge. Further studies of plant nutrition, especially in relation to zinc, are also necessary. In the lower latitudes the development of management systems, including weed control and water management, is necessary. A clearer understanding of the physiological processes in nitrogen fixation should enable farmers to include soybeans in land systems that maximize the nitrogen fixation ability of soybeans.

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Soybean Research in Bangladesh

Lutfar Rahman, M. Z. Hoque, and Peter R. Hobbs

Bangladesh is crowded into a relatively small area of 55,000 square miles. With a population of about 75 million, it is one of the most densely populated and poorest countries in the world. Total cultivable land is about 22.5 million acres and this has a cropping intensity of about 149 percent. Monthly mean temperatures never fall below 60°F; hence the climate is very favourable for year-round crop production. The average minimum and maximum rainfall is about 52 inches and 108 inches (five-year average), respectively. The heaviest rains occur in June, July, and August. About 95 percent of the annual rainfall occurs from April to October, and about 58 percent of this is in June, July, and August. The average rainfall in Bangladesh from November to April is very low, about 2.5 to 4.5 inches. This low rainfall is insufficient for sustaining good crops.

More than 87 percent of the total area is an alluvial plain stretching from the northernmost part of the country south to the Bay of Bengal. This vast, flat area lies between sea level and 150 feet above sea level. Annual floods cause siltations, which replenish the soil fertility each year. The predominant kinds of soils of Bangladesh are loam, sandy loam, silty loam, clay, and clay loam.

The two cropping seasons of the country are *Kharif* (April to September) and *Rabi* (October to March). In the *Kharif* season more than 80 percent of the total cultivable land is planted, principally with rice and jute. In the *Rabi* season, when land utilization is less intense, the important crops are Boro rice, wheat, millet, potatoes, sweet potatoes, peanuts, mustard, pulses, and winter vegetables. Except for the sugar cane areas, the cropping patterns of the country are essentially rice-based.

All the pulse crops and almost all oil-seed crops are cultivated during the winter and post-winter seasons. The most important types of pulses and oil-seeds are lentil, gram, mung bean, mustard, sesame, and groundnut. Yields are generally very poor compared with those of other countries. In spite of the fact that these crops cover a large acreage, production falls far below the total requirement for protein and edible oils. The per capita consumption of oil and pulses, a large quantity of which are imported, is only about 1.1 and 3.0 kg per year, respectively. This rate of consumption is extremely low compared with that of many countries in Southeast Asia, Oceania, and other countries in the world (Anon., 1973). Thus, a comprehensive production programme for growing crops that can supply both protein and oil is a pressing need in Bangladesh.

POTENTIAL OF SOYBEANS IN BANGLADESH

Soybeans are by far the most suitable crop for supplying good quality oil and protein. Soybeans are not yet a farmers' crop in Bangladesh, but their economic importance is at last being recognized by planners in various fields. Experiments revealed that the agricultural conditions of the country are highly favourable to soybean production throughout most of the year. Moreover, soybeans are regarded as important to the national economy because they yield more oil and protein per acre than other crops raised for similar purposes (MCC, 1975). Thus it would seem that a comprehensive effort to introduce soybeans into Bangladesh will be very effective. Short-season varieties of soybeans will be especially suitable for intercropping with sugar cane (Razzaque, 1975).

Soybeans in Potential Cropping Patterns

Throughout most of Bangladesh soybeans will not be competitive with rice and hence must be designed into rice-based cropping systems if they are to be successfully cultivated by farmers. In the rainy (*Kharif*) season enough moisture is available, but soybeans can only be grown in the highlands and some of the flood-free plains. In the dry season irrigation is necessary in the highlands. On some of the plains and in the lowlands the crop can

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be grown by using residual soil moisture. Stubble planting of soybeans immediately after the harvest of transplanted Aman rice in November and December has potential and would efficiently use available soil moisture.

During the dry season in Bangladesh soybeans can be incorporated into the major cropping patterns following the rainy season crops of jute or deep-water rice, or they can be planted during July and August following Aus rice and succeeded by winter crops. In yet another pattern soybeans can be planted in the dry season after Aus rice (rainy season) and transplanted Aman rice (July and August). Sugar cane, a rainy season crop, can be intercropped in its early vegetative stages with soybeans. Soybeans can also be planted with corn or watermelon to increase the efficiency of land use.

Present Status

A coordinated soybean research project has been initiated by the Bangladesh Agricultural Research Council. This three-year project involves the following institutions: Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University (BAU), Bangladesh Rice Research Institute (BRRI), Bangladesh Council for Scientific and Industrial Research (BCSIR), Sugar Cane Research Institute (SRI), Institute of Nuclear Agriculture (INA), Bangladesh Food and Allied Industries Corporation (BFAIC), and Bangladesh Agricultural Development Corporation (BADC).

Varietal selection, yield trials, and other agronomic aspects of crop production are being studied by the appropriate divisions of these institutions. A considerable amount of work in extension, including some research trials, is being done by a few voluntary organizations operating in the country, particularly the Mennonite Central Committee (MCC). UNICEF is also attempting an extension programme. The food technology division of BCSIR is working on the storage and food processing aspects of soybeans. The important products being considered included soymilk, soy flour, and biscuits. Plans have also been made by BCSIR to produce soybean inoculum locally.

EXPERIMENTS AND RESULTS

Varietal Performance

The committee has arranged to have about 182 varieties, strains, and populations collected from the United States, Taiwan, Australia, and the Philippines. Most of the recently collected varieties are photoinsensitive and mature early. An earlier collection includes varieties of photosensitive types. Even during the June planting most of the varieties in this earlier collection require about 129 to 135 days to mature (Khaleque, 1975). Varieties that mature early require a maximum of 120 days during the rainy season. However, there are varieties that take only about 90 to 105 days to mature. These varieties may fit into the present cropping system and give substantial yields.

The first comprehensive yield trial for nine soybean varieties in Bangladesh was initiated by the Mennonite Central Committee. Averaged over six locations, the data relating to different characters indicates a fairly good performance for varieties such as Adelphia, Hark, Rampage, Bragg, and Improved Pelican regardless of location. This was dry-land farming during the post-winter season with supplemental irrigation. The results indicate better adaptability of the crop to different regions.

Using 21 varieties, the second experiment, also initiated by MCC and conducted by various organizations from January to May 1974 suggests that some varieties can produce as high as 3,135.6 pounds per acre (MCC, 1975). The lowest yield obtained was about 885 pounds per acre. Most of the varieties, however, produced more than 1,660 pounds per acre. The experiment conducted at the Bangladesh Agricultural University showed that varieties such as Mack, Davis, Lee-68, Lee-74, Bragg, and Pickett-71 produced more than 1,500 pounds per acre.

The same 21 experimental varieties were also given to the Pulses and Oilseed Division of Bangladesh Agricultural Research Institute. The performance of these varieties under the red soil condition was reported by Khaleque (1975), who noted that the following 10 varieties can be arranged in order of performance: Mack, Bragg, Bossier, Forrest, Davis, Semmes, Improved Pelican, Lee-74, SRF-100, and Adelphia. The yield range in these varieties was 890.32 to 1,315.0 pounds per acre. Majid (1975) also worked with the same 21 varieties during the same season. According to her, the best performing varieties at Dacca Centre, which has soils of acidic reaction, were the following: Mack, Forrest, SRF-425, EC-39752, Lee-68, Bragg, Clark 63, Dare, EC-11780, and Tainung. Mack and Bragg performed well at all three experimental stations.

During the rainy season (June to October) in 1975, experiments using 71 varieties tested at three different institutes indicated that performance varied for each variety and location. When the 15 top-performing varieties from each institute were graded, the total number of varieties stood at 40 (Table 1).

The following five varieties were common to each participating institute: Davis, Bragg, Bossier, Hardee, and Lee-68, an indication of their overall good performance. The next six varieties (Tracy, Improved Pelican, Dare, Clark 63, Pickett, and Forrest) were common to two of the institutes.

Row-Spacing Trials

Results of three row-spacing trials using varieties as reported by Moore (1975), Shahidullah (1975), and Rahman (1975) indicate that a closer plant spacing produced higher yields. Spacings of 30 cm between rows and 4 to 5 cm between plants in the same row influenced the per-acre yield significantly.

Effects of Inoculum

In an experiment using inocula and nitrogen it was observed that nodulation was greatest at the lowest rate

Table 1. Varieties from Four Different Institutes Graded According to Yield Potential

Yield grades[a]	Varieties			
	DAU[b]	BCSIR[c]	BRRI[d]	BARI[e]
1	EC-111780	Lee-68	Cocker Hampton	Lee-74
2	UPSM-19	Hardee	Bossier	K-16
3	Davis	Davis	Ankur (UPSS-38)	Area tuba
4	Imp. Pelican	Bossier	Hark	Pelican Ctg.
5	Bragg	Tracy	Hutton	FC-30594
6	Tracy	EC-39752	Hardee	FC-30621
7	Semmes	D-70-3185	Davis	Pelican
8	Dare	Forrest	Bragg	P-3 Malaya
9	Clark 63	PaiMaiTan	AVRDC-19	Imp. Pelican
10	Lee	PK-71-39	SJ-2	P-3
11	Bossier	Pickett	Jupiter	M-1
12	Q-40	Ankur	Imp. Pelican	T-18
13	Pickett	Dare	Lee-68	PaiMaiTan
14	Hardee	Bragg	Forrest	M. Malaya
15	Lee-68	UPSM-229	Clark 63	EC-39752

[a] Yield grades represent superiority range from 1 to 15 in serial order of performance.
[b] BAU — Bangladesh Agricultural University (Rahman, 1975).
[c] BCSIR — Bangladesh Council for Scientific and Industrial Research (Shahidullah, 1975).
[d] BRRI — Bangladesh Rice Research Institute (Haque, 1975).
[e] BARI — Bangladesh Agricultural Research Institute (Khaleque, 1975).

of nitrogen and when seeds had been inoculated. No nodulation occurred in the noninoculated treatments (Haque, 1975). High rates of nitrogen application also made the plants susceptible to insect infestation, primarily to hairy caterpillar. However, according to Moore (1975), nitrogen applications of 0.02 pounds per acre when inoculated seeds were used, followed by urea applications of 40 pounds per acre, produced considerably higher yields per acre (2,477 pounds). But interestingly, this yield was not significantly different from that obtained when inoculum only was used.

Stubble Planting

Preliminary results on stubble planting of soybeans following the Aman rice harvest are encouraging. Care must be taken to provide suitable drainage to promote vigorous growth. Varietal difference in the adaptability of soybeans to this method of cultivation must be taken into consideration. The taller, medium-maturing varieties were better than the short, early-maturing varieties.

Separate experiments on the methods of sowing seeds during the rainy season are being evaluated. Ploughless farming seems to be quite advantageous in sowing the seeds during this period (Haque, 1975; Rahman, 1975).

Pest and Disease Problems

The prevalence of soybean diseases is quite high in the rainy season. The pathogens belonging to different species were isolated from seven varieties of soybeans. According to a survey of soybean diseases conducted in August 1975 (Ahmed, 1975), the prevalence of bacterial pustule (*Pseudomonas* spp.) and yellow mosaic is very high during the rainy season. Leaf curl, chlorosis, and leaf spot were also prevalent. Ahmed found that all varieties were infested with bacterial pustule and yellow mosaic diseases. The hairy caterpillar (*Diachrisia obliqua* W. and *Epidosome rydia* Butl.) was the most serious insect pest of the crop in this country.

FUTURE SOYBEAN RESEARCH IN BANGLADESH

In order to establish this crop in the country, the following comprehensive steps, which need both national and international support, should be taken:

1. Adaptation, acclimatization, and subsequent development of a few short-season, photoinsensitive varieties of soybean.
2. Development of varieties resistant to drought, insects (mostly caterpillar), and diseases (mostly yellow mosaic virus and bacterial pustule).
3. Research on seed viability, including the study of adequate storage facilities and development of varieties that can inherit long viability. The possibility of such breeding programmes will have to be explored internationally. Mutation may be a field for such study.
4. Local development of inocula and an economic assessment of the comparative performance of soybean varieties under inoculated and noninoculated conditions.
5. Development of packaging methods.
6. Further investigation to evaluate the cost-benefit ratio for sugar cane-soybean intercropping.
7. Development of marketing facilities to enable farmers to sell their soybean crop.
8. Expansion of extension activities so that farmers can have access to new technology and information on the various methods of production and uses of soybeans at the farm level.

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Soybeans in India

M. C. Saxena

In a predominantly vegetarian society such as India, fats and proteins of vegetable origin are of special significance. The importance of soybean production in Indian agriculture, therefore, is obvious. Soybeans have been grown for centuries in the low hills of the Kumaun and Garhwal regions of the Himalayas, foothills of this tract, and some scattered pockets in central India. However, the varieties grown have generally been of long maturity duration, viny growth habit, with small and freely shattering pods, black seeds, and very low yields. Seeds from these varieties were used primarily as pulses by the local population, and the green and dried vegetative parts were used as forage for cattle. Prior to 1965 several attempts to introduce high yielding, commercial varieties from the United States and other countries failed. Some advances in this connection were made during 1965 and 1966 through the cooperative programme of the University of Illinois at Urbana, USAID, the University of Agriculture and Technology at Pantnagar, and the University of Agriculture at Jabalpur. Initial efforts in this programme failed to improve yields because of improper varietal selection and crop management. In 1966, however, more systematic efforts were made to establish the feasibility of direct introduction of soybean varieties developed in the United States and to realise their full yield potential under Indian conditions (Leng, 1969; Saxena and Pandley, 1971; Saxena et al., 1971).

Encouraged by the success of soybean production at Pantnagar and Jabalpur, the Indian Council of Agricultural Research, New Delhi, started an interinstitutional Coordinated Soybean Research Project in 1967 with the Indian Agricultural Research Institute, New Delhi, as the main centre. Pantnagar and Jabalpur were established as special centres, and another six subcentres were designated at locations throughout the country. Since 1975 the All India Coordinated Soybean Research Project has expanded considerably. As a result of research and development efforts, soybean cultivation has increased consistently, thus permitting optimistic production targets to be set. It is projected that by 1978-79 430,000 hectares will be planted to soybeans, an increase of 363,400 hectares over the 1974-75 soybean hectarage. Most of the developed area is in Madhya Pradesh and Uttar Pradesh. Other states encouraging soybean cultivation are Karnataka, Maharashtra, Gujarat, Bihar, and Haryana.

CROPPING PATTERNS

India can be broadly divided into four agricultural zones, viz., the northern hill, northern plain, central, and south zones. As a rainy season crop (July to October), soybeans can be grown in all these zones (Saxena, 1975). As a spring crop (February to June), they can be raised in the northern and the central zones with the use of irrigation. As a winter crop (October to March), they can be grown in parts of the central and the south zones, with either irrigation or residual moisture. In the northern hill zone soybeans do well as a monsoon crop up to an altitude of 1,000 to 1,500 meters and are replacing the poor yielding, low income crop of fingermillet (*Elusine coracana*). Soybeans are intercropped with maize and fingermillet on the bunds of paddy fields and in young orchards at low altitudes. In the northern plain zone soybeans are grown on land that would otherwise lie fallow, or they replace poor crops of maize and sorghum. They are also intercropped with pigeon pea, cotton, sugar cane, sunflower, and maize. In order to conserve moisture for the subsequent winter season, soybeans are grown in central India on lands formerly left fallow during the monsoon season. In the southern zone they are intercropped with sorghum, cotton, sugar cane, and pigeon pea, and they also show promise when planted in rice fallows.

VARIETAL IMPROVEMENT

Starting with the introduction of promising varieties from the United States, the varietal improvement programme has passed through several phases. Emphasis

M. C. Saxena: All India Coordinated Soybean Research Project, G. B. Pant University of Agriculture and Technology, Pantnagar, India.

has been on the development of varieties suitable for different regions of the Indian subcontinent, which extends from 8° to 36° N. latitude. Germ plasm from different parts of the world was systematically evaluated at several centres, and promising selections were further tested in various parts of the country. Singh and Saxena (1975) have identified the following varieties as suitable for commercial production during the monsoon season: (a) northern hill zone: Bragg, Lee, Clark 63, Picket, UPSM-19, and Punjab-1; (b) northern plain zone: Bragg, Lee, Ankur, PK-7121, and UPSM-19 in the west and central regions, and Bragg, Ankur and Improved Pelican in the east; (c) central zone: Bragg, Ankur, Monetta, Davis, JS-2, EC 1077, UPSM-229, and J-231; and (d) southern zone: Davis, Hardee, Improved Pelican, and EC 39821 (8/3).

Many exotic varieties have shown high susceptibility to a series of diseases and pests. Hence, breeding programmes for developing high yielding varieties with high resistance to diseases and pests have been started at Pantnagar, Jabalpur, and Delhi as well as at some of the other centres. Major objectives have included breeding for (a) high yield, with varietal adaptation to local conditions; (b) disease resistance, particularly to mung bean yellow mosaic virus, rust (*Phakopsora pachyrhizi*), Rhizoctonia aerial blight (*Rhizoctonia solani*), and charcoal rot (*Macrophomina phaseolina*); (c) better seed quality, with improved germination under adverse conditions and greater viability under normal storage; (d) maturity duration to suit different cropping patterns and different seasons; (e) plant type, including semidwarf, nonlodging, and nonshattering types for monocropping, and compact, early maturing, moderately shade-tolerant types for intercropping among long duration crops; and (f) suitability for commercial and home uses. With these objectives in view, breeding programmes using different methods have developed newer lines that show a higher yield potential than Bragg, formerly the most adaptable variety (Tables 1 and 2).

Germ plasm is being maintained at Pantnagar, Jabalpur, Poona, Amravati, Bangalore, Delhi, and Ludhiana. A total of 4,198 germ plasm lines and five wild soybean species are being maintained at Pantnagar, and about 2,000 lines at Amravati. Germ plasm showing resistance to rust includes UPSM-38, PK-71-39, UPSM-91, and UPSM-168. Immunity to yellow mosaic has been found in P.I. 171443 (UPSM-534) and in the wild type, *Glycine formosana* (Singh et al., 1974a and 1974b). Charcoal rot resistance has been found in Hill, EC-1077, and EC-25166. Lines resistant to these diseases have been used in developing varieties with high resistance and good agronomic characters. F_6 and F_7 progenies of some of the crosses have been evaluated, and lines combining suitable agronomic characters, resistance to both yellow mosaic and rust, and good germinability have been selected. In addition, mutation breeding has been used for developing male sterility (Patil and Singh, 1975).

Within the same latitudinal range, varietal suitability differs. For example, in the northern hill zone Bragg can be grown successfully at altitudes below 1,500 meters, but not between 2,000 and 2,500 meters. At the latter altitude Hark and Harosoy showed promise (Singh and Saxena, 1975).

Table 1. Performance of Some Advanced Breeding Lines Included in Initial Evaluation at Pantnagar, Monsoon Season 1974

Breeding line	Days to maturity	100-seed weight (g)	Yield (kg/ha)	Rust
PK-73-84	132	14.4	4,335	R[a]
PK-73-86	132	16.7	3,909	R
PK-73-75	130	15.9	3,857	R
PK-73-88	133	15.0	3,770	R
PK-73-87	134	14.7	3,709	R
PK-73-83	133	14.8	3,687	R
PK-73-90	130	14.2	3,546	R
PK-73-89	133	13.0	3,320	R
PK-73-67	123	21.5	3,277	R
PK-73-69	124	13.2	3,274	R
PK-73-72	129	14.5	3,268	R
PK-73-82	130	13.7	3,196	R
PK-73-70	132	14.9	3,159	R
PK-73-81	130	13.5	3,122	R
PK-73-76	133	16.7	3,092	R
PK-73-73	132	15.7	3,083	R
PK-73-79	124	18.2	2,909	R
PK-73-71	133	15.3	2,833	R
PK-73-68	123	19.7	2,820	R
PK-73-80	131	12.9	2,755	S[b]
PK-73-85	130	18.6	2,579	S
Bragg	123	15.2	2,542	S
PK-73-66	124	14.7	2,500	R
PK-73-74	133	14.1	2,390	R
PK-73-78	129	15.9	2,370	S
PK-73-77	128	15.0	2,153	R
CD			873.74	
CV			16.90%	

[a] R = resistant.
[b] S = susceptible.

Table 2. Performance of Some Advanced Breeding Lines Evaluated at Pantnagar, Spring 1974

Line/variety	Days to flower	Days to maturity	Yield (kg/ha)
Goldsoy	36	102	3,563
PS-73-4	39	102	3,229
PS-73-7	37	100	3,066
PS-73-10	37	100	3,065
PS-78-6	39	102	2,993
Adelphia	39	102	2,877
Harrowmanchu	40	96	2,809
PS-73-11	39	100	2,799
Harosoy-63	37	100	2,755
Hark	35	97	2,557
PS-73-5	37	100	2,493
Grant	36	95	2,354
PS-73-13	37	99	2,068
Henry	39	101	1,831
CD			780

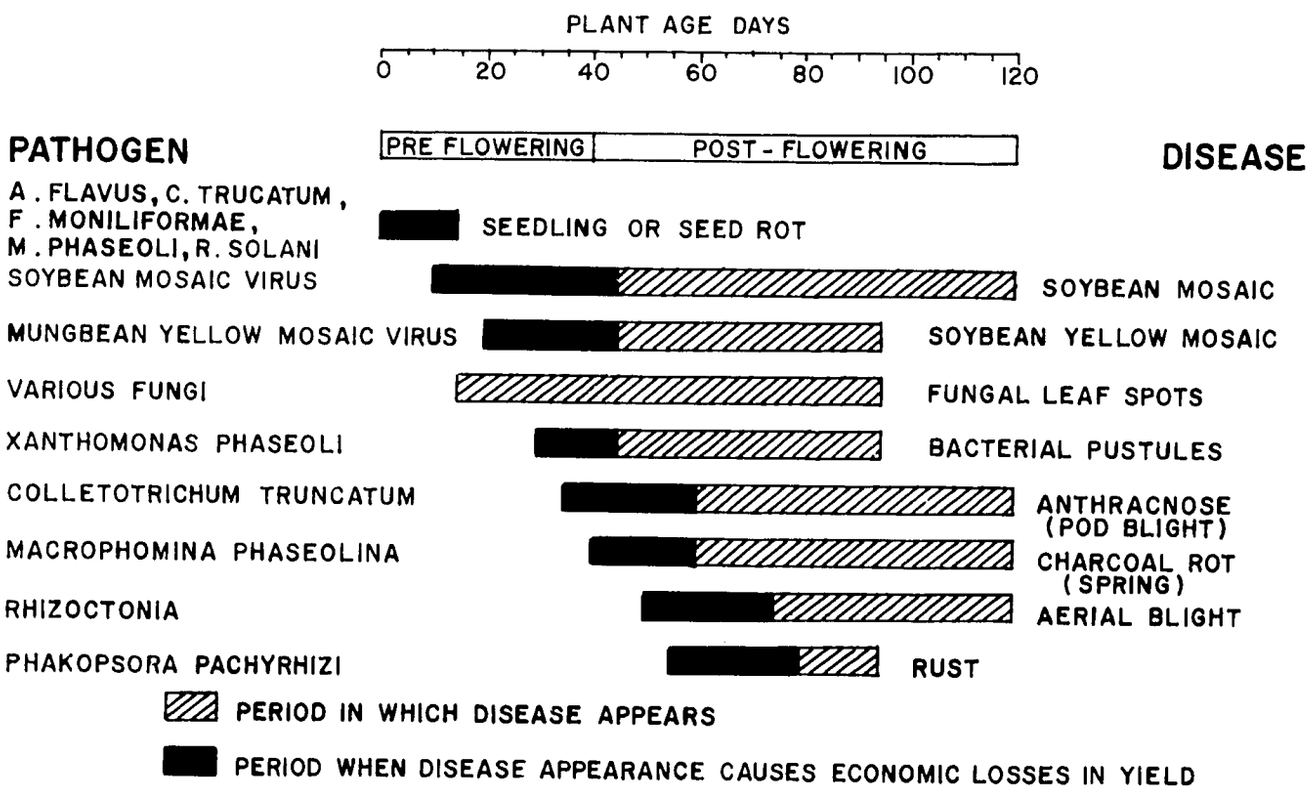
PRODUCTION AGRONOMY

Experiments have been conducted in different parts of the country to develop production methods for different agricultural conditions. Studies on depth of planting have revealed an optimum depth of 3 to 5 cm, but under high soil moisture conditions a depth of more than 3 cm reduced emergence appreciably (Singh et al., 1971b). A bulk density of more than 1.4 g/cc adversely affected root growth and nodulation (Singh et al., 1971a). Studies on planting dates, plant population, and row spacing revealed that crops planted before the monsoon thrived, whereas in crops planted after the monsoon the establishment of desired population was difficult. Crust formation, which conspicuously reduced emergence, could be avoided by mulching with straw immediately after planting. A population of 300,000 plants per hectare at row spacings of 45 to 50 cm proved satisfactory for premonsoon planting, whereas a population of 500,000 to 600,000 per hectare at row spacings of 30 cm was optimum for spring planting. Studies on planting methods revealed that drilling with a grain drill resulted in better stands than those obtained by conventional seeding in furrows. Treating the seeds with fungicides such as Thiram at 3 grams per kilogram of seed protected seedlings from fungal rots and improved stands (Nene et al., 1972).

Results of water management studies revealed that monsoon crops required one preplanting irrigation and one or two more irrigations during the pod fill stage in cases when the monsoon withdrew early. Surface drainage was important for good growth. Ridge-planting ensured a better rhizosphere environment in fields with poor subsurface drainage. Spring and winter crops responded well to irrigation, which was essential at 40 percent depletion of available moisture.

Rhizobium inoculation was essential at all locations. Peat-based cultures proved better than other types (Bhargava et al., 1974; Tilak and Saxena, 1974). An indigenously developed, peat-based culture, commercially manufactured at Pantnagar, has been as effective as inoculum imported from manufacturers in the United States. Establishment of *Rhizobium japonicum* on sandy loam soils poor in organic carbon and exposed to high temperature during germination has been a problem. Irrigation, mulching with straw, and using high inoculation rates have been effective in reducing this problem (Balasundaram, 1975). Lime, gypsum, and talc pelleting of inoculated seed has also proved effective at some locations. Yields from a well inoculated crop of soybeans with no nitrogen fertilization were as high as those obtained with 240 to 300 kg N/ha applied to a noninoculated crop or a nonnodulating isoline raised on the silty loam soils of Pantnagar, which are rich in organic carbon (Singh and Saxena, 1972; Pal and Saxena, 1975a). Studies on the contribution of symbiosis to total N needs of soybeans revealed that when nodulating and nonnodulating isolines were used, the maximum contribution was about 83 percent, which decreased as the rate of N fertilization increased (Pal and Saxena,

Fig. 1. Soybean disease complex in northern India.



1975b). Responses to a starter nitrogen dressing applied at the rate of 15 to 20 kg N/ha were positive only on poor fertility soils. Positive response to phosphorus application up to 80 kg P_2O_5/ha was obtained on low P status soils (Singh and Saxena, 1973). Responses to potassium application were negligible. Zinc deficiency was observed in the field, but could be corrected by a foliar spray of 5 kg zinc sulphate combined with 2.5 kg lime in 1,000 liters of water per hectare. Varieties differed in their susceptibility to zinc deficiency (Saxena and Reddy, 1973).

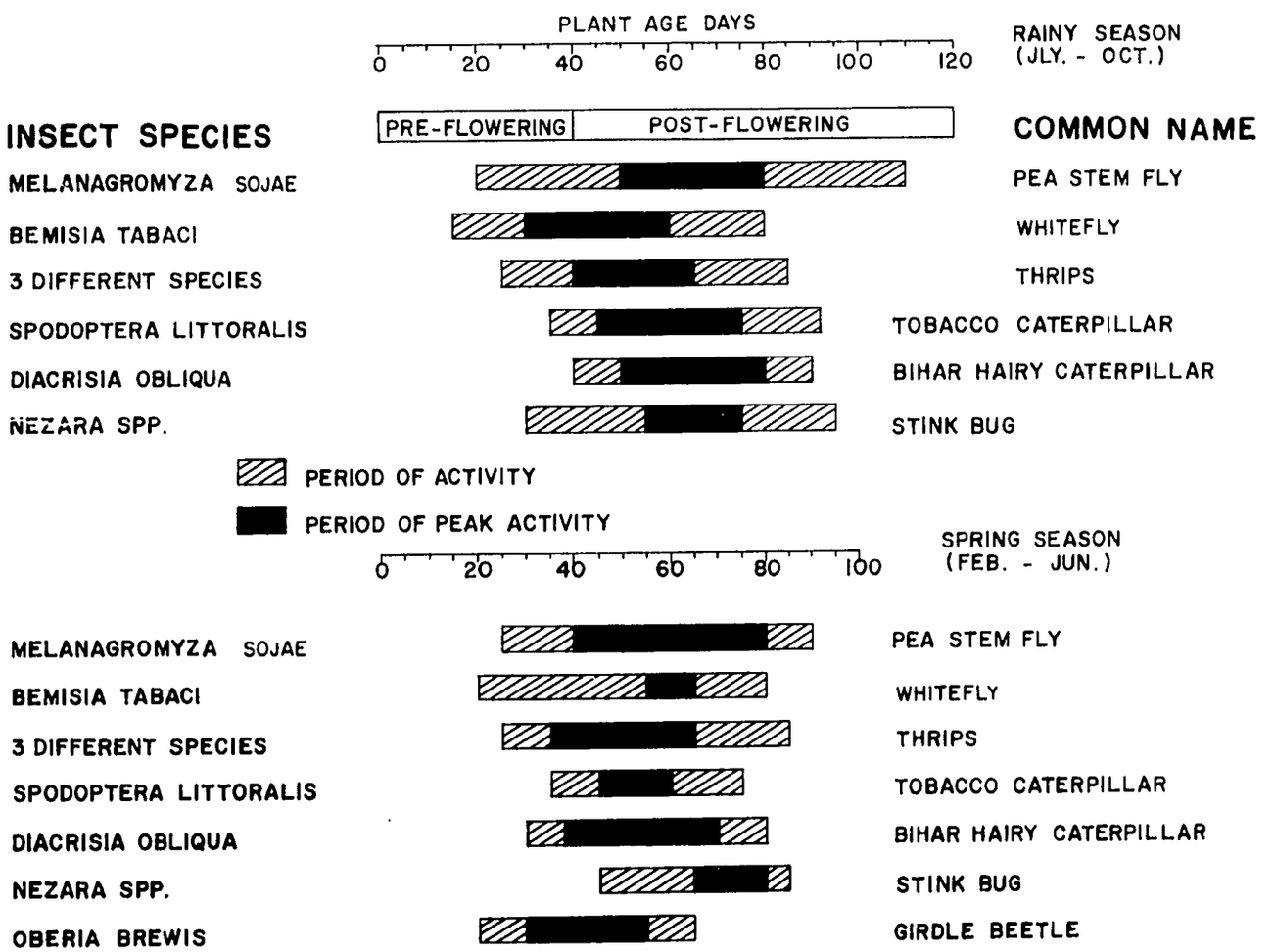
PLANT PROTECTION

Effective weed control during the first 30 days of crop growth was essential (Bhan, 1974). One mechanical weeding 15 to 30 days after planting gave excellent weed control. Chemical weed control using a preemergence application of alachlor, nitrofen, or sencor has been very effective. Alachlor and nitrofen are being used commercially by farmers. Weed control obtained by gramoxone sprayed between the rows with hooded sprayers has also been practised by some farmers.

Fungal, bacterial, and viral diseases have been observed in different soybean growing regions of India (Fig. 1). Crops in the hilly area are generally free from most of the diseases. Mung bean yellow mosaic virus, which is a serious disease, affects crops primarily in the Tarai area and on the plains of the northern zone. The virus is spread by the whitefly (*Bemisia tabaci*), which can be effectively controlled by following a spray schedule using a combination of 0.1 percent malathion and 0.1 percent metasystox started 20 to 25 days after planting and repeated at 10-day intervals until pod formation starts (Nene, 1972). Yellow mosaic resistance is being bred into several varieties. A new yellow mosaic resistant variety, PK-71-21, is now undergoing seed multiplication and will soon be released. A schedule for the control of soybean rust, caused by *P. pachyrhizi* (Sarbhoy et al., 1972; Sathe, 1972), has been developed using 2.5 kg Zineb per hectare applied 50, 60, and 70 days after planting (Thapliyal and Singh, 1973).

As shown in Fig. 2, a wide range of insect pests attacks soybeans throughout the life cycle of the crop (Gangrade, 1974). Studies on the chemical and biological

Fig. 2. Soybean insect pest complex in northern India.



control of these pests have been carried out at Pantnagar, Jabalpur, and Delhi. Insecticidal sprays used to control the whitefly are also effective in controlling defoliators and sucking insects. In cases where pea stem fly (*Melanagromyza phaseoli*) infestations are high, the use of systemic granular insecticides, such as thimet or disyston, at planting has proved very effective. *Bacillus thuringiensis* has provided effective biological control of common lepidopterous insects, although it is not yet recommended for practical use on farmers' fields because studies of some aspects of its use are still incomplete. With the exception of *Ephestia cautella*, found in low hills, no major insect pests have been observed on soybeans in storage.

SEED PRODUCTION AND STORAGE

Conditions conducive to high quality seed production include mild temperatures and low humidity during the maturity phase. The foothills and the low hills of the northern zone are ideal for seed production. The greatest damage to seed quality occurs as a result of post-harvesting weathering and handling. Threshing at a moisture content of 12 to 13 percent with a low cylinder speed was satisfactory. A soybean thresher with a production capacity of 6 to 8 quintals per hour has been developed for commercial threshing.

Conditions for safe storage of seed have also been identified. Loss of seeds stored at 5°C and 40 percent relative humidity is much less than loss under normal room conditions (Singh and Setia, 1974; Agrawal, 1975); however, successful storage under normal room conditions is possible in areas where the humidity is low (Agrawal and Kaun, 1975). Certified seed is now being produced on a commercial scale for the varieties Bragg, Lee, Ankur, and Clark 63 by the Tarai Development Corporation, Ltd., Pantnagar, and by the National Seeds Corporation, Delhi.

UTILISATION

Home processing methods for the use of soybeans in the daily diet have been developed at Pantnagar, Delhi, Jabalpur, and Bangalore (Singh, 1970; Kanthamani, 1970; Krishnamurthy and Shivshankar, 1975). Green beans of Hardee are used for making popular, south Indian dishes, such as Uppitu, Husli, Thovi, and Sambar. JS-2 and Coker types are good for blending with potatoes to make vegetable cutlets. Vegetable soybeans, such as Kim, Prize, Magna, Bansai, and Kanrich, are used for making curries. Dried seeds of Hardee have been used for making Idli and Chatni. Recipes and methods of preparation have been demonstrated to the farming community through mass communication channels, including the Satellite Instructional Television Experiment.

Commercial processes for making soybean beverages, soy curd, soy ice cream, soy candy, extrusion-cooked products, weaning foods, and soy nuts have been developed. Experiments with fermented foods show that a highly acceptable "cheese" and "cheese spread" can be prepared. The Soy-Production and Research Association, Bareilly, Uttar Pradesh, is making extrusion-cooked products on a commercial scale, using a Wenger X-25 extrusion cooker and full fat and defatted soy flour. Expansion of production by using a Wenger X-155 extrusion cooker has been proposed.

Currently, a considerable portion of soybeans produced in India is being solvent extracted. The cake is exported for animal feed, and the oil is used for hydrogenated fat production. The full fat and defatted soy flours are used by bakeries and the antibiotics industry.

MARKETING

The marketing of soybeans is still not well organised. From time to time the Government has announced a support price, but it is generally not very attractive to farmers. The price of other oil-seeds, particularly groundnut, and their availability on the market has determined the price offered by processors to soybean farmers. Rapid development of marketing channels and the regulation of prices are essential for encouraging the cultivation of soybeans in India. Cooperatives have an important role to play in this venture.

EXTENSION

Intensive education of farmers in the cultivation of soybeans has been necessary. In Uttar Pradesh, Madhya Pradesh, and Karnataka demonstrations have been used successfully to familiarise farmers with the selection and cultivation of suitable varieties, the use of manure fertilizers, materials and techniques of inoculation, and herbicidal weed control measures (Table 3). Field meetings, farmers' fairs, training sessions, radio broadcasts, films, distribution of literature, and correspondence courses for literate farmers have also been used. The Central Government is sponsoring a soybean development programme during the fifth Five-Year Plan with the intention of popularising soybean use and production and spreading

Table 3. Average Soybean Yields from Farmers' Fields in Northwestern Uttar Pradesh[a]

Year	No. of demonstrations[a]	Yield (kg/ha)	Cost of production (Rs/ha)	Net profit (Rs/ha)	Sale price (Rs/q)
1969	23	2,507	1,023	1,484	100
1970	39	2,213	1,054	1,159	100
1971	61	2,259	1,030	1,229	100
1972	124	1,974	1,078	1,389	125
1973	69	1,911	1,155	1,712	150
1974	49	2,263	1,542	4,115	250
1975	51	2,171	1,730	2,611	200

[a] Data from demonstrations conducted by the Extension Programme, G. B. Pant University of Agriculture and Technology, Pantnagar.

information on effective techniques for soybean cultivation. It is hoped that this programme will help in the expansion of soybean cultivation and will permit India to achieve its production target by 1979.

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Current Status of Soybean Research and Utilization in Indonesia

Sadikin Somaatmadja and Edi Guhardja

Soybeans, which serve as a source of protein in the diet of the people, are an important crop among the food legumes grown in Indonesia. At present soybeans occupy fifth place among the other food crops, after rice, cassava, maize, and sweet potatoes. Research on soybeans is conducted at the Central Research Institute for Agriculture (CRIA) at Bogor and its substations, including Sukamandi and Ujung Pandang; at several universities, such as the Institut Pertanian Bogor, Universitas Gadjah Mada, Jogyakarta, and Brawijaya Malang; and at other research institutes, including Badan Tenaga Atom Nasional, Jakarta, and Lembaga Biologi Nasional, Bogor.

PRODUCTION

Hectarage and Yield

From 1970 to 1973 the annual harvested hectarage of soybeans averaged 703,878 hectares with a production of 517,199 metric tons and an average yield of 7.34 quintals per hectare (Table 1). Approximately 80 to 85 percent of the total soybean hectarage in Indonesia is in Java-Madura. Other important areas producing 10,000 metric tons or more of soybeans annually are found in Central and East Java. On the basis of a five-year average (1965-1969), 24 counties (Kabupaten) can be considered major soybean production areas in Java. Outside Java-Madura expansion of soybean production has taken place in Bali and parts of Nusa Tenggara, Sumatra, and Sulawesi.

PRODUCTION TECHNIQUES

Systems of Cultivation

Soybeans are cultivated in *sawah* fields during the dry season as well as in dry fields (*tegalan*) during the wet season. In both types of fields, soybeans may be planted in monoculture, intercropped, or planted in rotation with other upland crops. In the *sawah* fields three different systems are generally used, viz., simple, semi-intensified, and intensified methods of cultivation. In *tegalan* fields either a semi-intensified or an intensified method of cultivation is used.

A simple method is preferred by farmers in regions with a pronounced dry season. In this method land preparation or soil tillage is not practiced in order to hasten the planting time so that the crops can make good use of the soil moisture still available at the end of the wet season. Seeds are sown either before or after rice is harvested. Most farmers, however, broadcast or dibble the seeds after the rice harvest. The planted fields are usually covered with straw to prevent or reduce evaporation.

In the semi-intensified method of cultivation, which is usually practiced in regions without a pronounced dry season, the soil is tilled first. Seeds are then either broadcast or dibbled, 2 to 5 cm deep with two or three seeds per hill at plant distances of 25 x 25, 30 x 20, 40 x 15, or 20 x 20 cm, depending on the growth type of the plant.

The intensified method is carried out with soil tillage, dibbling seeds at regular plant distances, weeding, irrigation, and pest control. Fertilizers are usually not used in soybean cultivation. It is commonly believed that soybeans are not very responsive to fertilizers and that soybeans grown in rice fields usually make use of residual fertilizers from the previous crops. This is generally true when soybeans are grown in sequence planting following sugar cane.

Most Indonesian farmers practice the simple method of cultivation in their rice fields, because they consider it the most efficient and practical way to grow soybeans.

Table 1. Five-Year Averages for Harvested Hectarage and Production of Soybeans in Indonesia

Years	Area harvested (ha)	Production (tons)	Yield (qt/ha)
1950-1954	431,742	294,834	6.82
1955-1959	549,830	378,115	6.87
1960-1964	596,210	410,577	6.73
1965-1969	601,644	410,197	6.84
1970-1973	703,878	517,199	7.34

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Table 2 shows cropping patterns of soybeans in rice fields and upland areas.

Inoculation

In most cases inoculation is done when the crop is introduced to a new region or when it is first planted on land where legume crops have not yet been grown. For this purpose farmers usually mix the seeds with soil taken from the place where the soybeans were previously grown.

Harvesting and Processing for Storage

Harvesting is done either by uprooting the whole plant when it is ripe or by cutting down the plants with sickles. Prior to threshing, the harvest is put into several heaps and covered with bamboo mats to protect it from rain. Threshing is done by treading the whole plant under foot or by beating it with bamboo sticks. This is then followed by winnowing and screening. The drying phase may take several days because of the high relative humidity of the air, which slows down the dehydration of plant tissues.

Storage

The dried beans are usually stored in bulk, in silos, or bagged in the godown. The seeds are not easy to store because of attack by pests, molds, and bacteria. Generally the storage facilities are also poor and cause a marked reduction of germinability within a very short time.

FACTORS AFFECTING SOYBEAN PRODUCTION IN INDONESIA

The average soybean yield in Indonesia is about 7.30 quintals per hectare, which is low compared with average yields in other countries, such as the United States, Canada, Brasil, and Japan. The following is a discussion of the most important factors responsible for low yields.

Seed Viability and Seed Supply

Farmers are rarely able to obtain good soybean seeds. This naturally results in a poor crop stand, which in turn lowers the yields. Many gaps in soybean stands occur because of the low germinability and viability of the seeds. The number of plants usually harvested ranges from 50 to 60 percent of the total number of seeds planted per unit area.

The seed needed by most soybean growers is supplied by seed merchants. In some regions the flow of seed is coordinated by the Koperta (Farmers' Cooperative), while in the Bimas program seed is supplied by the Directorate of Production. The trouble with soybean seed production is that it is virtually impossible to maintain high germination over rather long periods of time. Germination usually drops very fast after three months' storage. This points out the need for good storage facilities. In order to overcome this handicap, farmers in the uplands usually use seeds from the wet season harvest for planting in rice fields during the following dry season.

Pests

Numerous insect pests have been found associated with soybeans in Indonesia (M. A. Iman and colleagues, personal communication). Infestation by the following insects has been found on vegetative parts: *Phaedonia inclusa, Prodenia litura, Plusia chalcites, Longitarus sturellinus, Lamprosema indicata, Agromyza phaseoli, Agromyza dolichostigma, Agromyza sojae*, and *Stomopteryx subsecivella*. The following insects cause damage to the generative parts of soybeans: *Etiella zinckenella, P. inclusa, Nezara viridula*, and *Riptortis linearis*. At present *P. inclusa, R. linearis, N. viridula, E. zinckenella*, and *A. phaseoli* are considered to be of the greatest economic importance in the country.

Diseases

Prior to 1961 soybean diseases were not considered as important as soybean pests. The occurrence of rust disease in Kuningan, West Java, during the 1961-62 wet season, however, taught us the significance of certain diseases. Rust disease, caused by *Phakopsora pachyrhizi*, may occur in regions with high relative humidity and can destroy the entire crop. Other diseases, such as bacterial wilt (*Xanthomonas solanacearum*), bacterial diseases on leaves (*Xanthomonas phaseoli* and *Pseudomonas glycinae*), blight (*Sclerotium rolfsii*), anthracnose (*Colletotrichum*), and witches'-broom have also been observed.

Table 2. Cropping Patterns of Soybeans in Rice Fields and Upland Areas in Indonesia

Land use	Irrigation during dry season	Sequence of crops before soybeans	Times of sowing soybeans	Times of soybean harvest
Paddy rice	Yes	Paddy rice	Apr.-May	Aug.-Sept.
			Jul.-Aug.	Nov.-Dec.
		Paddy rice, other crop	Aug.-Sept.	Dec.-Jan.
		Paddy rice, dry rice	Aug.-Oct.	Dec.
		Sugar cane	Sept.-Aug.	Jan.
Paddy rice	No	Paddy rice	Sept.-Oct.	Jan.
Rainfed paddy rice	No	Paddy rice	Apr.	Aug.
		Paddy rice, soybeans	Oct.-Nov.	Feb.-Mar.
Upland	No	Multiple cropping	Jan.	Mar.-Apr.
		dry rice or maize	Feb.-Mar.	May-Jun.

Cultural Practices

Most farmers practice the simple method of cultivation in their rice fields. In Indonesia it has been demonstrated, however, that soybeans respond favorably to the use of improved cultural practices. Proper soil preparation, pest and disease control, weed control, and fertilizer application ensure excellent results, with yields twice as large as those obtained by the use of traditional methods. It is apparent that the lack of application of more advanced practices should not be attributed solely to the vocational level of the farmers, which is generally good, but rather to economic factors that prevent farmers from utilizing advanced practices.

Varieties

The potential yield of the existing varieties is not as low as is usually presumed. With good cultural practices variety No. 29 (Table 3) may give a reasonable yield. The same is true for No. 27, Ringgit, and Sumbing (Tables 3, 4). The objection to these varieties is that the grain quality, especially of No. 29, is poor. These varieties also lodge heavily with high plant density. For these reasons efforts should be made to develop varieties that tolerate high plant density and respond to high soil fertility.

Table 3. Improved Soybean Varieties in Indonesia

Variety	Color of seed	1,000-seed weight (g)	Maturity (days)
No. 16	black	70	90–100
No. 27	black	70	100–110
No. 29	yellow	70	100–110
No. 317 (Ringgit)	yellow	80	85–90
No. 452 (Sumbing)	yellow	75	80–85
No. 520 (Merapi)	black	70	80–85
No. 945 (Shakti)	yellow	120–160	80–85
No. 1248	yellow	120–160	85–90
TK-5	yellow	120–160	85–90
Orba	yellow	120–160	80–85

Table 4. Local Soybean Varieties

Variety	Color of seed	Maturity (days)
Genjah slawi	yellow	75
Sindoro	yellow	75
Lawu	yellow	85
Welirang	yellow	80
Pandan	yellow	90
Petek	yellow	74
Davros	yellow	85
Presi	yellow	85–90
Sinyonya	yellow	90–95
Krawe	yellow	90–100
Ijo	yellow	90
Jepun	yellow	85–90
Mentik	black	80
Klungkung	yellow (mottled)	90

CONSUMPTION AND UTILIZATION

Soybeans and other pulses, such as peanuts, mung beans, and cowpeas, play an important role in supplementing protein in the human diet.

Per capita consumption of protein in Indonesia is considered to be below the necessary level. For this reason efforts are being made to boost the production of food legumes, and soybeans in particular, to increase the protein intake. Per capita consumption of soybeans in Indonesia reflects the distribution of the crop. In Java the per capita consumption each year is about 5.04 kg; in Sumatra, Kalimantan, Sulawesi, and Maluku/Irian Jaya between 0.10 and 1.04 kg; and in Bali about 3.43 kg.

Soybeans are not consumed directly, but are processed into a large number of products. Tempeh (fermented soybeans), tahu (soybean curd), tauge (soybean sprouts), kecap (soy sauce), tauco (fermented mixture), and oncom (residues of soymilk and tahu) are consumed as side dishes with rice. Roasted beans, tahu chips, and boiled seeds are eaten as snacks, and boiled young pods are prepared as a green vegetable. Soymilk is consumed as a beverage.

Soybeans are also used for livestock feed, especially for chickens, but only a small part of the soybeans produced in Indonesia is used for this purpose.

MARKETING

Most of the soybean crop is marketed in Indonesia. Monthly price fluctuations occur not only at the farm level, but also from market to market and from province to province. Marked fluctuations at the farm level usually occur during the harvest period. However, fluctuations also occur during other months from one area to another.

Indonesia's annual soybean exports between 1968 and 1973 are presented in Table 5. Indonesian exports account for .02 to .25 percent of the total world soybean export and between 0.2 and 6.7 percent of the national production.

EXTENSION

Training

The Central Research Institute for Agriculture (CRIA) conducted a one-month legume training session in 1974. The purpose was to introduce new practices to extension officials, who in turn will teach farmers some methods of extending production and ways of intensifying soybean cultivation in order to increase soybean production.

Method Used to Increase Soybean Production

Expansion of hectarage. Expansion implies more than developing special production areas; it can also be achieved by intensified use of land. Multiple cropping

techniques are very effective for this purpose. In other words, we should be able to incorporate soybeans into existing cropping patterns or create new cropping patterns for certain areas where soybean production should be encouraged.

Intensification. Intensification involves the following steps in order to increase yields per unit area: (a) the use of superior seed from recommended varieties; (b) the application of improved cultural techniques; (c) fertilizer application; (d) control of pests, diseases, and weeds; (e) improved irrigation; and (f) improved harvesting and processing.

Varieties. The numerous varieties of soybeans are often grouped according to seed color (white or yellow, and black), maturity, and kernel weight. White or yellow varieties are cultivated much more frequently than black ones because of their popular use in rice dishes, as well as their use as refreshments or snacks. In many districts farmers prefer early varieties (75 to 85 days) to enable them to incorporate soybeans into the cropping pattern. The kernel weight of Indonesian soybean varieties is between 7 and 16 grams per 100 kernels. Tables 3 and 4 show the known local varieties and those recommended by research institutes.

Table 5. Soybean Exports from Indonesia in Relation to World Exports and Total Production in Indonesia

Year	Soybean exports (metric tons)		Total Indonesian production (metric tons)	Indonesian production exported (%)
	World total	From Indonesia		
1968	8,322,403	8,316	419,932	2.0
1969	9,380,501	749	388,907	0.2
1970	12,234,241	3,953	497,883	0.8
1971	12,598,259	732	515,644	0.1
1972	13,726,969	3,055	518,229	0.6
1973	14,600,886	36,000	541,040	6.7

Source: FAO Statistical Yearbook, 1973.

Soybean Production and Research in Iran

M. C. Amirshahi

Soybean production in Iran has increased from 500 hectares in 1967 to 54,000 hectares in 1975, when production reached 64,800 metric tons. This represents an average yield of 1,304 kilograms per hectare. Production estimates for 1976 indicate that more than 75,000 hectares are now under soybean cultivation, with an anticipated yield of 90,000 metric tons. Soybeans are grown primarily as an oil crop, although soybean cake, the by-product of oil extraction, is widely used as a rich source of protein for animal feed.

Over 75 percent of the soybean crop is cultivated in the northern littoral plains of Iran in the Caspian Sea area, particularly in Mazandaran and Gorgan Provinces. The remaining 25 percent is grown in the central plateau and western parts of the country. Irrigation is commonly used on the fertile, well-prepared soils. Yields of 3.0 to 3.5 tons per hectare are not unusual. The cultivars most frequently used are Hill in the Caspian Sea area and Clark 63 in the other regions.

The Ministry of Agriculture and the agricultural colleges have focused their attention on soybean research. Selection of high yielding varieties is done by means of yield evaluation experiments. The Seed and Plant Institute (SPI) and the agricultural colleges conduct experiments to determine planting dates, seeding rates, and water and fertilizer needs of the different varieties for various regions of the country.

The College of Agriculture, University of Tehran, is currently cooperating with INTSOY in carrying out soybean evaluation experiments, one set of trials having been run at the Karaj College farm and three conducted by SPI at three other locations. At the Karaj College farm ISVEX trial Amsoy 71, Corsoy, Beeson, and Wells yielded over 4 metric tons per hectare, a significant increase over yields from the other varieties used. Results of the ISVEX trial at Shahi Station showed that Calland and Clark 63 yielded more than the other varieties at that station. The trial at Dasht-Naz Station showed that Clark 63, Woodworth, and Williams were the top-yielding varieties, producing over 3.5 tons per hectare. In two local, uniform yield trials carried out by SPI, at ten stations and the other at four stations, the average best yields ranged from 3.2 kg per hectare at Moghan to 1.2 kg per hectare at Darab.

To determine the best row distance, SPI conducted a factorial trial at seven different stations, using four varieties planted at row spacings of 50 and 70 cm. The four varieties used were Clark, Hill, Lindarin, and Amsoy. Results of the experiment show that all four varieties produced the greatest yield at 50-cm row spacings at all seven stations. These varieties, planted on three to six different dates in six stations, produced the highest yield when planted at the earliest date. Planting took place from April 19 through July 6 at 15-day intervals.

Diseases and pests are not as yet serious problems in soybean production, but as production expands, these problems will undoubtedly increase. The Plant Protection Department of the College of Agriculture is currently carrying out experiments to determine the major diseases and pests of soybeans in Iran.

Other problems of equal importance now under consideration include: (a) fertilizer requirements and water needs of soybean varieties for the different soils and climatic conditions in the various regions in Iran; (b) the kinds of herbicides and the best methods of application for controlling weeds, particularly in humid regions; and (c) mechanization of soybean cultivation and harvesting.

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Soybean Production in Japan

Takashi Sanbuichi and Iwao Watanabe

Each year Japan produces approximately 120,000 metric tons of soybeans on 90,000 hectares. About 30 percent of this yield is raised on the northern island of Hokkaido, where large-scale farming is practiced. Especially in the northeastern part of Hokkaido, soybeans are a very important crop, together with several other crops with which they are planted in rotation. Throughout the country the average soybean yield is about 1.4 metric tons per hectare, but during the past four years production in the Tokachi District of Hokkaido has risen to between 1.8 and 2.0 metric tons per hectare. The use of new varieties and cultural methods has contributed to the increase in yields. Most of the soybeans grown in this area are marketed, whereas those produced in other regions are consumed primarily by the farmers themselves.

In Japan soybeans are used principally as a source of edible oil and protein foods, such as miso (bean paste), shoyu (soy sauce), tofu (soybean curd), and natto (fermented soybeans). The soybeans produced in Japan usually have large seeds, a high protein content, and are of a quality suitable for producing high quality soy products.

Japan is a chain of islands that stretches for hundreds of miles from north to south. Because climatic conditions, such as temperature and daylength, vary widely, it is not surprising that a large number of soybean varieties are cultivated and that there are considerable differences in the cultural methods used from region to region. In general, early varieties are cultivated in the high latitudes and late varieties in the low latitudes, but on the southern island of Kyushu early varieties are occasionally used. Known as summer soybeans, they are sown in the spring and harvested in the summer. Late varieties, which are called autumn soybeans, are sown in summer and harvested in the autumn. There are considerable differences in thermosensitivity between summer and autumn varieties.

Table 1 shows the main characteristics of the major varieties currently cultivated in Japan. As previously mentioned, most Japanese varieties produce large seeds, which does not cause an overall yield reduction as might be expected. On the contrary, results show that large-seeded varieties produce high yields.

Soybeans grown in the northern parts of Japan usually have larger seeds than those raised in southern areas. It is believed that the marked difference between day and night temperatures and the favorable soil moisture content during the early stages of plant growth account for the large size of soybean seeds grown in the north. The author observed a serious decrease in seed size when Japanese varieties were introduced into Thailand, probably because the day and night temperatures differ little during the rainy season, when much of the Thai crop is planted.

Most Japanese varieties are of determinate growth types. Indeterminate or semi-determinate varieties originating in or introduced from foreign countries usually show very poor pod setting and produce low yields under the cool weather conditions that sometimes cause severe damage to soybean crops in Hokkaido.

Soybeans are raised in several types of areas in Japan. Traditionally they have been planted beside the footpaths in paddy rice fields. Intercropping with wheat is another old cultural practice, although both practices are seldom used today. Because of the over-production of rice in Japan, the government has recently recommended that soybeans be cultivated in rice fields.

The cultural methods described in the concluding section of this report are those used primarily on Hokkaido. Soybeans are sown at the end of May and harvested from the middle to the end of October. The width between rows is usually 60 to 66 cm and 20 to 30 cm between hills. Two or three plants are grown on each hill. Fertilizer is commonly applied at the time of planting by means of a machine mounted to a tractor. Farmers usually use 10 to 30 kg of nitrogen, 100 to 150 kg of phosphate, and 50 to 80 kg of potash per hectare. Larger

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quantities are not used because it is thought that too much chemical nitrogen fertilizer will suppress the activity of nodule bacteria in soybeans. Research shows that the soybean yield does not increase as the supply of nitrogen fertilizer increases, unlike other crops, such as wheat, sugar beets, and potatoes, that produce increased yields with higher levels of nitrogen fertilizers. The use of barnyard and green manures is highly recommended because they stabilize soil fertility by maintaining the activity of nodule bacteria.

Weeds are controlled by means of herbicides and cultivation. Herbicides are applied before emergence, and cultivation is used three or four times during the early and middle stages of plant growth. Aphids, pod borers, cyst nematodes, Sclerotinia rot, and soybean dwarf virus are typical insect and disease pests found in Hokkaido. Farmers are now encouraged to use chemical control measures. Varieties resistant to the soybean cyst nematode are being used successfully in infested areas.

Most of the soybean crop is harvested by the bean harvester, a cutting machine mounted on a tractor. Compared with hand harvesting, the harvester reaps about five times faster. After being stacked and dried in the fields, soybeans are machine threshed.

Table 1. Main Characteristics of Major Local Varieties Cultivated in Japan

Variety	Growing period[a] (days)	Plant height (cm)	100-seed weight (g)	Cultivation area	Remarks
Toyosuzu	140	50	32	Hokkaido	Resistance to cyst nematode
Kita-musume	135	75	30	Hokkaido	Stability under the cool weather
Yuuzuru	150	70	42	Hokkaido	Very big size of seed
Raiden	135	70	25	Tohoku	Resistance to cyst nematode
Oku-shirome	150	85	22	Tohoku	Resistance to cyst nematode
Enrei	145	65	30	Tosan Hokuriku	Stiff stalk
Shirotae	145	70	32	Tokai Kinki	
Akiyoshi	95	55	28	Kyushu	

[a] Growing period only for the cultivation area indicated.

The Status of Soybean Production and Research in Korea

Hong Suk Lee, Keun Yong Park, Bong Jo Chung, Joong Su Park, and John M. Yohe

Good quality soybeans with large grain size have been cultivated for thousands of years in the middle and northern part of the east coast of Korea. Because soybeans have been grown primarily for subsistence, they have not been regarded as a cash crop by Korean farmers. Little progress was made in varietal improvement and the improvement of cultural practices until very recently. During the last ten years, however, there has been remarkable progress in increasing soybean productivity by the improvement of varieties and cultural practices. Soybean cultivation in 1974 was 286,188.4 hectares, thus making soybeans the third major crop of Korea in hectarage. Soybean hectarage is about 82 percent of the total hectarage of pulse crops, such as red beans, mung beans, kidney beans, peas, and peanuts.

The Republic of Korea is located between 33° and 38° north latitude. Average yearly temperatures range from 9.9°C at Chuncheon to 14.8°C at Cheju. The hours of sunshine per year vary from 1,815.2 hours at Pusan to 2,229.6 hours at Chuncheon. The total amount of rainfall per year ranges from the minimum of 1,103.3 mm in Chuncheon to a maximum of 1,730.1 mm in Kwangju. About 60 percent of the rain falls during the rainy season from late May to late July. The number of frost-free days also varies from location to location, with a range of 171 to 266 days.

Soybean production has gradually increased from 231,994 metric tons in 1970 up to 318,576 metric tons in 1974. Although total soybean production has increased, it has not kept up with demand as indicated by the fact that imports have increased from 36,291 metric tons in 1970 up to 66,370 metric tons in 1974. As a result, there is now greater awareness of the need to increase production in order to alleviate these production deficits.

Home consumption is the major area for soybean use, about 122,000 metric tons being consumed in 1974. Soybeans are prepared by mix-boiling with rice or vegetables, or are eaten in the form of curd, sprouts, sauce, paste, milk, and flour. The government uses soybeans primarily for military needs. Soybean oil is used for industrial purposes.

MAJOR PROBLEMS RELATED TO INCREASED SOYBEAN PRODUCTION

Even though Korea has made significant progress in increasing crop productivity during the last 10 years, yields have remained well below potential levels. Available evidence indicates genetic potential for high yield in today's varieties. However, further development of cultivars and cultural practices is needed to raise the average yields at both the experimental and farm levels. The following is a discussion of factors considered to be major constraints on increased soybean production. Some data related to those problems are also indicated.

Weather

In Korea the average monthly temperature during the soybean growing season, April to October, ranges from 10° to 26°C. In the high, mountainous regions the number of frost-free days ranges from 150 to 216 days. Therefore, yield is restricted by low temperatures and a limited number of frost-free days. Drought occurs frequently from early May to early or mid-June and during mid-August. From early May to early or mid-June is the time of planting, while in most cases the middle part of August is the time of flowering or pod set. On the other hand, from the middle part of June to late July rainfall is frequent, and generally excess soil moisture conditions prevail.

Varietal Improvement

As shown in Table 1, four of the 10 recommended varieties have been newly developed in Korea. Thus it will be quite possible to make greater contributions to increased production of soybeans through the breeding of

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Table 1. Recommended Soybean Varieties for Korea in 1975

Variety	Year released	Location investigated	Seeding time	Flowering time	1,000 grain weight	Mean grain yield (kg/ha)
Kwanggyo[a]	1969	Suweon	mid-June	July 28	18.4	1,997 (1968)
Bongeui[a]	1970	Chuncheon	mid-June	August 12	25.3	1,631 (1969)
Eundaidu[a]	1971	Cheju	late June	August 8	24.2	2,210 (1968–70)
Kanglim[a]	1974	Kwangju	late June	August 10	24.0	2,374 (1973)
Yukoo #3[b]	uncertain	Sosa	June 25	August 10	16.1	1,296 (1954–56)
Hill[b]	1968	Cheju	late June	August 8	14.4	2,730 (1965–67)
Donbuktai[b]	1974	Cheongju	late June	August 12	21.0	2,285 (1970–73)
Haman[c]	1930	Jinju	June 18	August 4	21.6	1,236 (1954–56)
Keumkangdarip[c]	1931	Chuncheon	May 15	July 28	37.8	1,258 (1954–56)
Buscog[c]	1948	Daiku	June 27	August 13	22.0	1,251 (1954–56)

[a] Varieties bred in Korea.
[b] Varieties introduced from abroad.
[c] Local varieties.

new cultivars. For this purpose we are maintaining 1,632 different lines in the *Glycine max* collection and 414 different lines in the wild soybean, *Glycine soja,* collection. This germ plasm bank will be instrumental in solving varietal problems that are barriers to increased production by providing: (a) high yielding cultivars widely adapted to different ecological conditions, (b) early-maturing cultivars adapted to double-cropping systems, and (c) cultivars that are resistant to lodging, diseases, insects, and nematodes.

Planting Time

The optimum planting date for maximum soybean yield in Korea is in May. However, most soybeans are planted from mid-June to early July because of double-cropping with barley or wheat. In Kangwon Province approximately 53 to 63 percent of the soybeans are produced under full-season cultivation, while 58 percent intercropping between barley is the usual practice in Kyunggi Province. On the other hand, in the southern plains area, such as Cheonnam and Cheonbuk Provinces, most of the soybeans are cultivated after barley.

Results of experiments in 1969 and 1970 showed a general decrease of yield by late planting (after May 25). Planting as late as July 10 resulted in yield losses up to 50 percent in most locations. Therefore, it is also necessary to develop varieties that will produce maximum yields under the ecological conditions and cropping patterns that prevail in Korea in order to achieve maximum production per unit area under multiple cropping systems.

Soil Fertility and pH

Although soils conducive to high soybean productivity occur naturally in Korea, improved practices of fertilization and liming are necessary to modify the existing low fertility conditions in certain areas. The largest responses from fertilizers generally occur on the least fertile soils. Fertility levels of soils in the Korean uplands, where most of the soybeans are grown, are generally low.

According to one of the tests by the Institute of Plant Environment (IPE) in 1970, adequate fertilization with 40 kg N/ha, 56 kg P_2O_5/ha, and 44 kg K_2O/ha resulted in a yield increase of 55 percent. As a result of demonstration trials reported in 1967, the Rural Guidance Bureau of the Office of Rural Development (ORD) found a 26 percent increase in yield with fertilizer application, and a 52 percent increase in yield with the addition of lime and fertilizer. According to the IPE survey of pH distribution of upland soils in 1964-1966, 36.3 percent of the upland soils were below a pH value of 5.4, and 70.1 percent were below a pH of 5.9. Only 15.8 percent of the soils were between a pH of 6.0 and 6.5, and only 14.1 percent were above a pH of 6.5.

Cultural Practices

At the present time the information available for the type of management practices necessary to maximize yields in Korea is inadequate. The following is a discussion of factors pertaining to the management of soybean culture in Korea.

Cropping systems. Typical cropping patterns are shown in Table 2, which indicates the importance of

Table 2. Soybean Cropping Patterns

Cropping system	Regions	April	May	June	July	Aug.	Sept.	Oct.
Full-season	northern mountainous	—	—	—	—	—	—	—
Intercropping with winter crops	northern to central plain		—	—	—	—	—	—
After barley	central and southern plain			—	—	—	—	—

soybeans in multiple cropping systems with wheat and barley. Estimates indicate that over 75 percent of the soybean crop in Korea is grown in multiple cropping patterns with barley and wheat. Soybean also compete with other food crops on upland soils for the limited amount of hectarage available. These competing crops can also be double-cropped after the winter cereal grains, i.e., wheat or barley. Intercropping between barley rows and mix-cropping of soybeans with sorghum, corn, sweet potatoes, sesame, and perilla are also common in Korea, particularly in the central part. This is one of the important constraints on increased yield.

Planting patterns. It is necessary to maintain relatively high soybean populations for maximum yield in the case of planting after barley. Because the growing time is not long enough when soybeans are planted after barley, yields are adversely affected. To maximize the growing time, mechanization for rapid planting may become more critical as farm labor supplies diminish and farm labor becomes more expensive. Furthermore, new varieties of a different plant type may be required. To date, the most appropriate row spacings, plant populations, types of weed control, and varieties that respond to different planting rates and row width have not been identified for the different ecological and climatological regions in Korea.

Seed treatment and inoculation. In new soybean production areas inoculation is a necessary first step in efficient, economical soybean management, but as yet there has been little or no research on inoculation in Korea. The need for inoculation will become more critical as average yields increase. Seeds visibly weathered or of poor quality, as demonstrated by poor germination and vigor in laboratory tests, may respond favorably to chemical fungicides. At present, because there is no laboratory where soybean seeds are routinely checked for germination, seed purity, or other quality characteristics, there is no control over seed quality. The Ministry of Agriculture and Fisheries is currently developing a new, certified seed program under the Office of Seed Production and Distribution. This program, funded by a World Bank loan, will initiate greater quality control over seed production and varietal identification. The major cereal grains (rice, barley, and wheat), along with soybeans and white potatoes, will be covered by this program.

Soybean Pathology and Entomology

Soybean pathology research has not been carried out extensively in Korea. The soybean diseases reported here are as follows: (a) virus disease: soybean mosaic virus; (b) bacterial diseases: bacterial blight and bacterial pustule; and (c) fungal diseases: brown spot, Ascochyta leaf spot, purple stain, frogeye spot, Sclerotium blight, pod and stem blight, Fusarium wilt, anthracnose, brown leaf spot, basal stem rot, downy mildew, rust, Phyllosticta leaf spot, and soybean scab. In Korea soybean mosaic and possibly other viruses are the major disease problems in soybeans today. According to the survey carried out by IPE in September 1974, the occurrence of soybean mosaic virus averaged 29.5 percent for eight provinces and was most severe in the two northern provinces as compared with the central and southern areas. Locally-adapted varieties resistant to soybean mosaic virus are in use, but the source or the genes for this resistance have not been identified.

The bacterial diseases, bacterial blight and bacterial pustule, are sometimes a serious problem. Of the fungal diseases, root rot, purple seed stain, anthracnose, and downy mildew are the most important. B. J. Chung and colleagues recently reported that bean yellow mosaic virus and alfalfa mosaic virus were detected serologically in crinkled soybean leaves. Soybean stunt virus was also detected from inoculation tests on clover indicator plants. Most recently a disastrous soybean virus disease, with symptoms similar to bud blight, was found in the leading soybean varieties. However, there appear to be some differences between this disease and bud blight, as demonstrated by differential host reactions.

The Institute of Agricultural Science, and ORD have screened the recommended Korean varieties for resistance to bacterial pustule, downy mildew, anthracnose, purple stain, and Fusarium wilt (Table 3).

Table 3. Reactions of Recommended Korean Varieties to Soybean Diseases

Varieties	Soybean disease reaction[a]				
	Bacterial pustule	Downy mildew	Anthracnose	Purple stain	Fusarium wilt
Buseog	MS	MS	R	MS	R
Kwanggyo	S	M	MR	MS	R
Keumgangdaerib	S	MR	MR	M	S
Hill	S	M	MR	M	S
Bongeui	S	M	MR	MS	R
Haman	S	M	MR	MS	MS
Kanglim	S	S	M	MS	S
Dongbuktai	S	M	R	MS	MS
Eundaedu	MS	M	M	M	MS

[a] R: resistant (0% disease)
M: medium (5.1-10% disease)
S: susceptible (more than 25.1% disease)
MR: moderately resistant (0.1-5% disease)
MS: moderately susceptible (10.1-25% disease)

The profuse foliage of soybeans attracts a large number of insects. Damage due to insect feeding can begin with planting and can continue until harvest. Insects and mites cause injury to soybeans in ways that vary with the particular feeding habits and ecological characteristics of each species. The major soybean insect pests that have been identified in Korea are as follows: (a) *Grapholitha leguminiverella* Matsumura, soybean pod borer; (b) *Sylepta ruralis* Scopoli, soybean webworm; (c) *Plusia erisoma* D., (d) *Aphis glycines* Matsumura; and (e) *Pepillia atrococerulea* Botes. During two years, 1969 and 1970, there was an average of 7.2 percent soybean seed damage caused by the soybean pod borer,

while 28.8 percent of the total foliage damage was caused by the soybean webworm.

More than 20 kinds of nematodes associated with soybeans have been identified, some of which are capable of inflicting heavy damage to the crop. Among the major nematodes attacking soybeans are the soybean cyst nematode and the root knot nematode. The soybean cyst nematode has been identified as a pest problem in Korea. Estimates indicate that losses due to nematodes can affect as much as 10 percent or more of the total crop. Resistance to the cyst nematode has been found in a Korean-bred line called Suweon strain 41 and in three introduced varieties (Peking, P.I. 84751, and P.I. 90763).

PRESENT AND FUTURE RESEARCH PROBLEMS

To increase soybean yields at both the farm and the experimental levels, three major areas must be considered. First, varietal improvement is needed to produce high-yielding, general purpose varieties with the following characteristics: (a) medium or large seed size; (b) early maturity or photo-insensitivity so as to permit adaptation to double-cropping; (c) more desirable plant types adapted to high population densities and to mechanization; (d) high protein content; (e) lodging resistance; and (f) resistance to pathogens and pests, such as soybean viruses, bacterial and fungal pathogens, soybean pod borers, soybean webworms, and cyst nematodes. In addition, researchers must also take into consideration genetics and breeding methods, collection and introduction of germ plasm, development of varieties for rice bund cultivation, and the need for varieties to be used as vegetables for sprouting or for mix-boiling with rice.

Second, soybean crop management programs and the collection of physiological data must expand to permit improvement in the following: (a) cultural practices, including fertilizer use, seeding time and method, cropping patterns, and acid soils; (b) seed quality; (c) nutrient efficiency and mineral nutrition of soybeans; (d) nodulation and nitrogen fixation; (e) weed control; (f) drying and storage; (g) mechanization; and (h) soil and water management, including soil-water problems, irrigation, and erosion control.

Third, soybean pest management programs must be developed to provide for the following: (a) identification and classification of soybean viruses, bacteria and fungi and major insect pests; (b) screening for sources of resistance to virus, bacterial, and fungal diseases, and insect damage; (c) development of sampling and screening methods; (d) control of bacterial and fungal diseases; (e) studies on insect-virus relationships, seasonal fluctuation and life cycles of major insects, pest resistance mechanisms, and chemical control of major insects; and (f) surveys of economic losses from yield reductions caused by various pests and diseases.

Soybeans in Malaysia

Abu Kassim b. Abu Bakar

Malaysia lies between the equator and 8° north latitude. East and West Malaysia are separated by the South China Sea. The average temperature is between 22° and 31°C throughout the year. Because little information on soybeans is available from East Malaysia, this report is confined to West Malaysia.

Soybeans appear to have been introduced into peninsular or West Malaysia about 50 years ago. The crop, which has been grown among young rubber plants or as a sole crop in rotation with other annual crops, is planted primarily on small farms. Last year, however, there was a move by a few enterprising organizations to try large-scale, commercial plantings.

Soybean products are consumed in various forms by both humans and livestock. The domestic demand greatly exceeds the local supply, which is therefore dependent upon importation. The possibility of expanding domestic production has become increasingly evident and research is being intensified to meet this end.

CURRENT STATUS

Statistical surveys show that the total area planted to soybeans fluctuates from year to year. In 1958 there were about 40.4 hectares (in terms of sole crop equivalent); 15 years later in 1973 the hectarage stood at 76. However, in 1974 as a result of government subsidies to small farmers, a substantial increase in production brought the total area to about 337.2 hectares.

Although soybeans can be grown throughout the country, a large percentage of the crop is raised in the east coast states of Kelantan, Pahang, and Trengganu of peninsular Malaysia. Because soybeans are a rain-fed crop, rainfall patterns have been a guide to determining the planting season, and generally two crops are possible each year on most parts of the peninsula.

Most of the research undertaken so far has been related to the selection of suitable and promising foreign varieties from the United States, SEARCA, and Taiwan. On the basis of research evaluations, workers have recommended several varieties and lines, viz., Hardee, Bossier, Palmetto, Disoy, 66D-2, KS 437, 66D-14, 66D-20, 64-64, Hua Lian 2, N44-92, Calland, L-114, TK5, CES 434, Clark 63, Bonus, and Improved Pelican. In experimental plots most of these varieties yield about 1,800 kilograms per hectare.

Very little work has been done on optimum plant spacing. However, a spacing of 60 x 10 cm has proved satisfactory for Palmetto, a tall variety, and 46 x 10 cm for 66D-14, a short variety. A spacing of 50 x 5 cm, which gives a density of about 400,000 plants per hectare, is also common. Fertilizer guidelines for soybeans intercropped with rubber differ somewhat for soybeans grown as a sole crop. For intercropping 560 kg of magnesium limestone, 33 to 45 kg of nitrogen, 65 to 90 kg of phosphate, and 45 to 65 kg of potash per hectare are recommended, while for sole cropping 1 ton magnesium limestone, 34 kg N, 56 kg P_2O_5, and 56 kg K_2O per hectare are recommended. The effectiveness of Rhizobium inoculation under Malaysian conditions is still uncertain, although there are indications that yields improve to some extent when there is nodulation.

Insect pests, diseases, and weeds are among the major soybean production problems. Of the several insect pests that have been identified, bean flies, pod borers, and leaf eaters are very destructive. Rust has caused crop failures, and bacterial pustule is widespread. Virus diseases are also a potential threat.

DOMESTIC MARKETS AND UTILIZATION

Peninsular Malaysia imports whole soybeans, as well as the flour, oil, and cake of the soybean. Until 1973 about 200,000 gallons of soy sauce were also imported, but in 1974 about 15,000 gallons were exported. However, the value of imports of soybeans and soybean products has increased from M$16.7 million in 1971 to M$28.6 million in 1974. Soybeans are used mainly to make bean milk, curd, sprouts, and other food products for human consumption. Soybean cake serves as a component of livestock feed, while soybean oil is used for industrial purposes.

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PROSPECTS FOR PRODUCTION

It has been estimated that the local consumption of soybeans per capita per year averaged 5.3 kg for the years 1971 to 1973. Based on assumptions of an annual population growth rate of 2.7 percent and a per capita consumption of 5 kg, the demand projected for 1976 is 65,000 metric tons, and for 1980, 71,000 tons. If this demand is to be met entirely by domestic sources, assuming a yield of 1,500 kg of soybeans per crop hectare and two crops per year, then the required soybean hectarage will have to be approximately 20,000 hectares for 1976 and 23,000 hectares by 1980.

CONCLUSION

Without doubt, domestic production of soybeans must be increased substantially and widespread cultivation promoted. At present, however, various problems exist and intensive research to solve these problems is imperative. The multitude and seriousness of pests and diseases under the prevailing conditions have to be among the major considerations in the research program. An accelerated schedule for selecting and screening varieties from various foreign sources is essential. The agronomic, breeding, and economic aspects of the crop need further, detailed studies in order to meet local conditions.

Soybean Production and Utilization in the Philippines

Federico B. Ballon

Soybeans are an important commodity in the Philippines. In 1974 the country imported about 60,012 metric tons of soybean meal from the United States and other countries at a cost of over US$16 million. This quantity was still far below the estimated requirement of 104,884 metric tons. The total registered production in 1975 was only 6,552 metric tons, although the estimated need was 115,152 tons. Domestic production constitutes only about 5.68 percent of the total requirement of the country.

Production per unit area is quite low compared with that of other countries producing soybeans, which can be accounted for to a great extent by the reluctance of farmers to grow soybeans. Because soybeans are a cheap source of quality protein for human food and animal feed and because they are a source of raw material for local industries, scientists are being mobilized as fast as possible to develop the necessary varieties and technology so as to make soybean production a more viable industry.

PRODUCTION

Soybeans are a new crop among Filipino farmers, and therefore production has not as yet gained headway. As of December 1975, the recorded area planted to soybeans was only 7,093 hectares, with a production of about 6,522 metric tons, or an average of 923.72 kilograms per hectare.

Varieties

At present there are five Philippine Seedboard soybean varieties planted commercially in the country (Table 1). These varieties were selected through the National Advance Yield Trials conducted in different regions of the country. Promising varieties or strains developed by the different institutions involved in varietal improvement research were grouped together and tested for yield performance and reaction to major diseases during two seasons in various regions. These varieties have a more or less wide range of adaptation to soil and climatic conditions in this country.

The Varietal Improvement Group is concentrating on the development of varieties with greater yield potential, greater responsiveness to added nutrients, good plant type, high protein content, and more resistance to major diseases, such as soybean rust (*Phakopsora pachyhrizi*) and bacterial pustule (*Xanthomonas phaseoli* var. *sojensis*). Varieties with more seed vigor and with longer viability are also being researched by the group.

With the organization of the National Soybean Working Group it became national policy that no new varieties should be released for commercial planting unless they are distinctly superior to the existing, recommended Seedboard varieties in one or more characters important to the crop and are at least satisfactory in other major requirements.

Inoculant

The use of inoculant is very important in soybean production in the Philippines. In areas where the crop was planted for the first time and inoculant was not used, production was lower than in areas where inoculant was used. A study at the University of the Philippines College of Agriculture, showed that the use of the Rhizobium bacterial strains Brasil 114, R11a, and CB 1809 as seed inoculants increased the yield from 305 to 1,012 kilograms per hectare. The peat carrier inoculant is the one most commonly used in the Philippines because it is easy to handle and because survival of the bacterium is better in the seeds and in the package. The Bureau of Soils of the Department of Agriculture is responsible for the low-cost production and distribution of inoculants to the farmers. The Bureau of Plant Industry of the same department recently identified a very promising Rhizobium strain from Giant Ipil-ipil.

Fertilizers

Rates of fertilizer application differ for different seasons in the Philippines. For dry season planting, three bags of ammonium phosphate (24 kg nitrogen and 30 kg phosphate) is recommended per hectare. If the seeds used are inoculated with Rhizobium, the use of fertilizer can be dispensed with in the wet season. Otherwise, two

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Table 1. Recommended Seedboard Soybean Varieties in the Philippines

Variety	Yield (ton/ha)	Seasonal adaptability	Maturity (days)		Special characteristics
			Wet season	Dry season	
CES-434	1.5	October	110-115	..	Very susceptible to bacterial pustule, nonshattering
Clark 63	2.0	May-June, October, February	80-90	95	Resistant to bacterial pustule, nonshattering, earliness, susceptible to rust
BPI L-114	1.5	October	110-115	..	Moderately resistant to rust, susceptible to bacterial pustule
TK-5	2.0	May-June, October, February	80-85	95	Resistant to shattering and a strain of rust, susceptible to bacterial pustule
UPLB Sy-2	2.0	May-June	86	86	Resistant to bacterial pustule and a strain of rust

bags of ammonium sulfate (21-0-0), 50 kilograms per bag, or one bag of urea (45-0-0) per hectare is suggested for application as a starter.

Water Management

Soybeans can be planted in any part of the Philippines, with the exception of some areas where the extremely heavy rainfall causes a high incidence of plant diseases and harvesting problems. The crop is usually planted two times a year, the first during May and June, and the second during October and November. February planting is also recommended for some varieties and regions of the country. Generally, the dry season planting requires supplemental irrigation, which is usually done three times. A water depth of 40 to 60 mm is recommended. The first irrigation is usually supplied after planting, and the other two during the flowering and pod-set stages.

Harvesting and Storage

Harvesting methods depend on the size of the farm. In small-scale farming the crop is harvested and threshed manually. On larger plantations it is harvested manually and threshed by a small machine thresher. On highly commercialized plantations the crop is harvested and threshed by combines.

At present soybean storage is not a problem in the Philippines because of the limited soybean production. However, the most common and practical method being practiced is piling the sacks. The ideal moisture content of dry soybean seeds for six months' storage is 12 to 13 percent and about 10 to 11 percent for storage of more than a year. Air passage is provided between individual sacks and between rows.

CROP PROTECTION

Weed Control

Weeds are one of the most destructive enemies of soybeans, because they serve as hosts to pests and diseases and compete with the crop for light, nutrients, and other growth requirements. The two methods of controlling weeds in the Philippines are by mechanical means and by the application of herbicides.

Diseases and Pests

The most common diseases affecting soybean crops in the Philippines are bacterial pustule and soybean rust. The most practical and the cheapest method of control being adapted in the country is the use of resistant varieties. The Varietal Improvement Group and plant pathologists are working hand in hand in the development of soybean varieties resistant to the different major diseases existing in the country.

Bean fly (*Ophiomyia* (*Melanogromyza*) *phaseoli* Tryon), leaf miner (*Stomopteryx subsecievella* (Zeller)), cutworm (*Spodoptera litura* (Fabricius)), corn earworm (*Heliothis armigera* Hubner), bean pod borer (*Maruca testulalis* (Geyer)), and other pests cause damage to the crop. These are easily controlled by the different insecticides available.

MARKETING

Because the soybean production industry is new in the Philippines, marketing problems have not yet reached major proportions. At present there is no organized marketing outlet for domestic soybeans. Marketing is, however, a serious problem for scattered, small plantation owners who must sell their produce directly from the farm or to buyers at their place of business. In some instances, farmers are victimized by unscrupulous middlemen. The large-scale planters are at an advantage because they usually deal directly with the processors. To protect the producers and encourage development of the infant industry, the President of the Republic of the Philippines issued a Letter of Instruction (No. 165), setting 2.20 Philippine pesos (US$0.26) per kilogram as the minimum price for soybean seeds. Through the Na-

tional Grain Authority the government will buy all soybeans, regardless of quantity, that cannot be absorbed by private merchants.

UTILIZATION

In the Philippines about 20 percent of the soybean supply is used for human food and about 80 percent for animal feed. Prepared in a variety of ways, soybeans are used in the manufacture of soy sauce, vegemeat (vegetable meat), soy flour and grits, soy protein concentrate, soymilk, and so forth. They are also consumed in the form of fermented products, such as tausi, tempeh, and pickling in miso. Rich in protein, soybeans are being introduced as a source of cheap protein for use in the daily diet of the Filipino people.

EXTENSION

Through the National Food and Agricultural Council (NFAC), a national coordinating agency, the government has launched a bold, grain production program known locally as "Masaganang Maisan." The objective of the program is to produce an adequate grain supply for domestic consumption and possibly for export. Under this program the government has assumed responsibility for making modern technology available to the farmers. Aside from the availability of production technology, farmers are assured of genetically pure seeds of the recommended Seedboard varieties. To make sure that farmers receive pure seeds, the Bureau of Plant Industry of the Department of Agriculture has nine Seed Testing Laboratories strategically located throughout the country and staffed by personnel trained both locally and abroad. Inspectors check the private seed growers to see that their seeds meet the field seed certification standard of the government. Soybean production technicians are trained locally in various phases of the program before being given field assignments.

There are three approaches to the implementation of the program: (a) the traditional, small-scale farm approach that encourages compact production rather than planting in fragmented areas; (b) Commercial/Integrated Farms Corporate Farming; and (c) the highly commercialized Joint Venture Project. Liberalized credit, including financing of post-harvest facilities, is provided for in all three approaches. As new varieties and innovations in production technology become available, farmers are informed of them through production technicians, radio, and other means of communication.

Soybean Research in the Kingdom of Saudi Arabia

Mohamad Al-arfag

At present soybeans are not grown commercially in the Kingdom of Saudi Arabia. Needless to say, successful local production of this crop would be of great benefit for human nutrition in this country, where the standard of living and the production of animal products are rapidly improving. Consequently, in 1973 the Crop Production Division, Agricultural Research and Development Department, Ministry of Agriculture and Water in Saudi Arabia felt it necessary to start serious field experimentation on soybeans in various locations in the Kingdom. Efforts were made to obtain soybean seeds from different sources, including Egypt, Taiwan, and the United States. This report summarizes the results of field plot observations, variety trials, and agronomic experiments conducted between 1973 and the present in order to explore the possibility of successfully growing this crop in Saudi Arabia.

VARIETY TRIALS AND OBSERVATION NURSERIES

Observation plots and field trials were planted at Uneizah, Qatif, Hofuf, and Hakma (Gizan) in 1973-74. Low yields, averaging well below 1,000 kg per hectare, were obtained at all sites. Reports from Uneizah indicated the presence of rust disease. At Qatif and Hofuf very poor plant growth was obtained. Seeds of 12 U.S. varieties, obtained from Egypt and Taiwan and planted at Hakma, produced the highest yields when planting was in December. Yields decreased and days to maturity increased if planting was delayed until February or April. When planted in December, plants reached maturity in about 60 days, but later sowing dates were accompanied by longer growth periods and the absence of nitrogen fixation bacteria. Early sowing dates were associated with higher yields; hence, sowing in April seems counterproductive. Some damage due to aphids and termites was recorded.

In 1974-75 our research program was expanded. Seeds were obtained from INTSOY (trials 032, 085, and 086) and also from Taiwan, the United States Department of Agriculture, and Lebanon. In the first INTSOY trial planted at Hakma on 30 November 1974, Jupiter, Calland, and Clark 63 gave yields above 1,000 kg per hectare. Clark 63 was the top yielder with the highest number of pods per plant and highest seed weight. While Jupiter ranked second in grain yield, it was not significantly lower than Clark 63.

INTSOY trial 085 was planted in May 1975 at Dirab. Jupiter was the highest yielding variety in this trial, followed by Hamptom 266A, Bossier, and Davis which also yielded over 1,000 kg of soybeans per hectare.

The highest soybean yields yet obtained in Saudi Arabia were from INTSOY trial 086, planted in February 1975 at Uneizah. Jupiter and Calland gave yields of over 2,100 kg per hectare, while Bragg, Forrest, Hill and Clark 63 all yielded over 1,000 kg per hectare. Promising yields were also obtained in a trial at Elkharj, while yields obtained in 1974-75 at Hakma were again generally very low.

The first observation nursery for selection of soybean lines adapted to conditions in Saudi Arabia was planted at Hofuf in February 1975. Over 550 lines were planted, from which 37 were chosen for further testing. In addition to these selections, further studies will be conducted with the varieties Jupiter, Bossier, Davis, Forrest, and Hampton 226A, all of which yielded above 1,500 kg per hectare in the 1975-76 INTSOY trial 086 planted at Hofuf in August 1975.

AGRONOMIC TRIALS

Two agronomic trials were carried out in 1974-75. The trials conducted at Hakma (Gizan) included six varieties and four levels of phosphate. The other trial, conducted at Dirab, included nine varieties and seven sowing dates.

Variety-Fertilizer Trial at Hakma (1974-75)

The purpose of this experiment was to determine the optimum dose of phosphate. The trial included six va-

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rieties and four levels of P_2O_5 (0, 120, 240, and 360 kg/ha). A basal dressing of nitrogen, phosphorus, and potash (60, 100, 60 kg/ha, respectively) was applied at planting; phosphate treatments were applied three weeks later. The experiment was in a split-plot design and was replicated four times. Ridges were 50 cm apart and plants were 5 cm apart. Sowing was on 16 November 1974, and the crop was harvested on 3 February 1975.

Data on plant height, flowering, maturity, pods per plant, and grain yield were recorded and analyzed. Significant effects from phosphate fertilizer were observed in all the above characters. As the level of fertilizer increased, plant height, pods per plant, and yield increased, while days to flowering and maturity decreased for the majority of the varieties. Table 1 shows the average grain yields.

Table 1. Effect of Phosphate Fertilizer on Soybean Yields at Hakma

Variety	Soybean yield (kg/ha) at four levels of phosphate (kg P_2O_5/ha)				
	0	120	240	360	Mean
Hampton 266A	610	1,044	1,236	1,712	1,151
Lee	625	1,164	1,356	1,636	1,195
Bragg	656	1,164	1,084	1,424	1,082
Tracy	568	992	1,424	1,180	1,041
Hutton	800	1,092	1,802	1,256	1,238
Dare	776	1,324	1,244	1,704	1,262
Mean	673	1,130	1,358	1,485	1,162
$LSD_{.05}$ variety 114					
$LSD_{.01}$ variety 179					
$LSD_{.05}$ fertilizer 74					
$LSD_{.01}$ fertilizer 101					

Varieties and Dates of Sowing Trial at Dirab in 1975

The purpose of this experiment was to observe the growth and yield of nine soybean varieties sown at Dirab on different dates from 20 February to 15 May at two-week intervals. The general performance of these varieties was rather poor with respect to plant height and grain yield. However, the best yields were associated with sowing in March. As expected, days to maturity increased as daylength increased.

PROBLEMS LIMITING SUCCESSFUL SOYBEAN PRODUCTION

The major factors limiting soybean production vary with the location at which trials were planted. At Qatif the major limitations were high salinity and low water table. Salinity was a major limiting factor at Elkharj also. At Hofuf the soybeans showed a serious chlorosis that has not yet been diagnosed. Finally, termite damage was serious at Hakma (Gizan). In general, no serious disease or pest problems were reported by the officers in charge of soybean experiments in Saudi Arabia. Also, reports from agronomists conducting these trials indicated that nitrogen-fixing bacteria were generally absent.

Credit should be given to research workers, experimental officers, and technical assistants who executed and reported the results of the soybean experiments presented in this report. Without the cooperation of INTSOY, most of the experiments carried out in Saudi Arabia would not have been possible. Special mention should also be given to the Chinese scientists who have shown so much interest in the soybean trials in the Kingdom of Saudi Arabia.

Cultivation and Uses of Soybeans in Sri Lanka

E. Herath

Plantation agriculture, with crops of tea, rubber, coconut, cocoa, and spices, forms the basis of Sri Lanka's economy. However, these crops, which are grown in the central highlands and in parts of the intermediate zones, comprise only a minor part of the total acreage of 16.2 million acres situated for the most part in the relatively underdeveloped dry zone. Rice, the traditional staple food, is grown under existing irrigation schemes during the *Yala* season (April to September), and also as a rain-fed crop in the *Maha* season (October to February). These two seasons correspond to the bimodal rainfall pattern experienced throughout the island when the southwest and northwest monsoons are active.

Apart from rice, which covers the largest acreage planted to a single crop, highland crops, such as corn, sorghum, hill millet, and pulses, are grown under rain-fed conditions in the *Maha* season. There is no traditional system of irrigated agriculture for these crops. The present emphasis of the Research and Extension Services of the Department of Agriculture is to develop and expand their cultivation in pilot projects under major and minor irrigation schemes in the dry zone.

Soybean is a relatively new crop, having been introduced to farmers only in 1972. At present the acreage under soybeans is negligible and is confined primarily to a few large, privately-owned farms and to many small, scattered plots in the dry and intermediate zones. Production areas should total nearly 8,000 acres for 1976. Minikits and production kits based on the system of popularising new varieties of rice have been tried with great success in the soybean extension programme. In addition, the Division of Extension hopes to extend cultivation to rice fields in the dry zone, where irrigation water is insufficient for a second rice crop.

CROPPING PATTERNS

There is no tradition of growing pulses or any other highland crop under a system of settled agriculture as in the case of rice. Shifting agriculture was practised for many centuries because new land was freely available. With increased demands for land and the introduction of farming systems, however, new concepts of crop husbandry have been developed. Where land is scarce, continuous cropping aided by irrigation is practised.

Most irrigation schemes have areas where the second crop of rice suffers from insufficient water. The extension division of the Department of Agriculture has planned a system to utilise the available water by encouraging farmers to grow grain legumes. The total requirement of irrigation water for a soybean crop is approximately one-third that for a crop of short-aged rice (three-month variety). The net income from an irrigated soybean crop is almost double that from rice. It is therefore not too difficult to convince enterprising farmers to raise soybeans. The greatest potential for increasing the acreage of grain legumes in general, and soybeans in particular, lies in this land use. Much of the present extension strategy is directed towards popularisation of rotating rice with one or two crops of grain legumes. Of the 12 million acres comprising the dry zone, about 1.5 million acres use existing irrigation schemes. A resource potential of 3.5 million acres of highland is available for rain-fed agriculture.

Intercropping soybeans with coconut, tea, and rubber has been tried but with little success. Since experienced agricultural personnel handle the plantation industry, this area has potential. Research has to be carried out to identify problems peculiar to this kind of mixed cropping. Intercropping with cassava, sugar cane, and other crops that remain in the field for many months is currently being studied. In the intermediate zone, rotating a three-year grass lea with soybeans has proved to be an excellent system of land use, giving consistently high yields of as much as 2,250 pounds per acre for the last three seasons.

CULTIVATION PRACTICES

The most significant contribution to soybean cultivation recently has been the introduction of commercial inoculants. Until this breakthrough soybean yields and performance were erratic because only a single strain had been used in the past. With these inoculants all soy-

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bean varieties performed significantly better, giving consistently high yields of up to 3,540 pounds per acre in research plots.

Most farmers utilise the residual effects of fertilizers applied to the previous crop to grow soybeans. In limited investigations conducted by the Research Division of the Department of Agriculture it was found that a basal dose of 20, 60, and 40 kg per hectare of nitrogen, phosphorous, and potassium, respectively, was beneficial under most conditions. The application of organic manure wherever available produced a better soil/water balance, seedling emergence, and nodulation. Straw mulching has also given excellent results.

HARVESTING AND STORAGE

For the most part, harvesting and threshing have been done manually, although there is a limited use of stationary threshers on the larger farms. If no rains interfere with harvesting or threshing, good seed with about 12 percent moisture can be obtained. In the *Maha* season, however, rain is not uncommon at harvest, and this can prove hazardous to large-scale farmers. At present seed is handled in the open market and very little storage is necessary, because the produce reaches the consumer in a short time. With increased production these problems will require special attention.

VARIETAL IMPROVEMENT

In the 1973 coordinated varietal trial, yields of 3,000 to 4,000 kg per hectare were recorded from the Asian variety Pb-1 and from the American varieties Hardee, Lee, Bragg, and Improved Pelican. In the wet zone during the southwest monsoon period, Hardee, Davis, Improved Pelican, Calland, Pickett 71, Hampton 266A, Pb-1, Jupiter, and Harosoy showed high yield responses. Bossier, a new entry in the INTSOY trials, performed well in almost all locations, and Forrest also showed promise in the first season it was tested.

Under wet-zone conditions during the *Maha* season all varieties matured earlier, probably because of their photosensitivity. Normal *Maha* seasons are characterised by short days and low light intensity at the time the monsoon is active. Higher nodule counts were also observed under irrigation than when soybeans were grown under rain-fed conditions. The following general observations are pertinent:

1. Irrigated soybeans performed better in most parts of Sri Lanka.
2. More studies must be done on planting dates, especially when the crop is rain-fed. This is also important for varieties that are sensitive to light intensity, latitudes, and light duration.
3. Higher soil pH appears to have better results.
4. Continuous cropping with soybeans tends to lower yields, which may be an allelopathic effect or may be caused by the lowering of soil nutrient levels.
5. Southern U.S. varieties in the late maturity groups and some of the Asian varieties, such as Pb-1 and SJ-2, seem to adapt better to local conditions than early maturity groups.
6. Bossier showed a wide range of adaptability under varying management levels. Very low variability in pod number, 100-seed weight, and yields was observed.

Objectives of the plant introduction programme in Sri Lanka include identifying high yielding varieties and building up a germ plasm collection that will aid breeders in evolving varieties for these latitudes. Close liaisons are being maintained with AVRDC, the breeders at Stoneville, Mississippi, and the University of Pantnagar.

FERTILIZER AND PLANT NUTRITION STUDIES

In *Maha* 1974 a study on phosphate utilisation was undertaken by four stations. Results made it apparent that high levels of phosphates are required to maintain high production. In February 1973 Sri Lanka contracted with the International Atomic Energy Agency to investigate the effects of fertilizers on a grain legume; soybeans were selected for this study. Initial research comparing methods of application of fertilizer P using tracer ^{32}P revealed the following:

1. Starter N with or without addition of fertilizer P increased grain yields, but the increase reached statistical significance only when P was added.
2. Application of P midway between rows or banding near the seeds gave higher yields than surface broadcasting or deep placement below the seeds.
3. Placement midway between rows gave the highest dry-matter yield and also the highest P in grain derived from fertilizer.

In a study of different levels of nitrogen (10 and 20 kg N/ha) with and without inoculation using three methods of application, the following results were recorded for the variety Bragg:

1. With inoculation, yields increased 7 percent over uninoculated soybeans. There was, however, no effect of inoculation on other yield components.
2. The use of 20 kg N/ha produced higher yields than 10 kg N/ha. Again, there was no significant difference on other yield components.
3. Application of N at planting produced the highest yield, whereas application at flowering produced somewhat lower yields. Results of these studies were inconclusive, however, since split application could not be properly carried out with the low levels used.

MICROBIOLOGICAL INVESTIGATIONS

These studies found that there was poor nodulation at high levels of nitrogen application. Effective nodulation occurred when up to 20 pounds of inorganic nitrogen per acre were applied, while the response to inorganic nitrogen without inoculation occurred only after larger quantities (up to 40 pounds per acre) were applied. These responses are recorded for basal application studies only.

Seeds treated with Malathion dust as an insecticide

and Ramrod as a preemergence herbicide were inoculated with Rhizobium and planted. At recommended rates these chemicals had no deterimental effect on nodulation. On the contrary, the use of 0.25 percent captan dust increased seedling emergence. A mixed Rhizobium culture applied at 10 locations gave significantly higher nodulation counts than when a single strain was used. Nodulation number and weight were positively correlated with yield.

CROP PHYSIOLOGY STUDIES

In crop density studies with plant populations of 500,000, 600,000, and 700,000 plants per hectare and using Lee 68, Bragg, and Improved Pelican at two levels of nitrogen (20 and 40 kg/ha), Lee 68 recorded the highest 100-seed weight and bean yield. An increase in plant population decreased pod and seed number per plant, 100-seed weight, and yield. The lower populations recorded higher yields, probably because of the increase in 100-seed weight.

Weed control research has shown that the preemergence weed killer Lasso gave effective control of most weeds and that yields obtained were as high as those from hand-weeded plots. Weed competition was critical only up to the thirtieth day, and hand weeding was not effective once flowering commenced. Most indeterminate varieties had the unique capacity to withstand heavy weed competition by continuing to flower and pod if weeds competed for light.

SEED STORAGE, QUALITY, VIABILITY, AND SEEDLING VIGOR

A storage trial was conducted under three storage conditions for 12 months. Seeds from 10 varieties were stored at 5°C, 25°C, and at room temperature. All varieties except Hardee showed germination counts above 85 percent for up to three months of storage. At 12 months six varieties under all three storage conditions gave counts below 75 percent. A study has also been initiated to determine the cause of poor germination in some varieties like Hardee. Since there is considerable variability in physiological maturity among varieties, the optimum stage of harvest for each variety needs to be determined.

UTILISATION RESEARCH

Soybean milk and milk products. Soybean milk was prepared in the laboratory using the traditional method, the Cornell University method, and the University of Illinois method. Milk prepared by the University of Illinois method was judged superior to the other two. Soymilk alone and in a blended form with cow's milk or buffalo milk was used to prepare a curd that compared favourably in texture and flavour with good quality curd made from buffalo milk. The curd was also processed into a palatable drink using seasonings to mask any beany flavour if present. The protein content of soymilk and soy curd was similar to that of cow's milk and curd made from cow's milk.

Soy flour. Soy flour was prepared in the laboratory by three methods: (a) the salt bed roaster method, which involves a quick, preliminary roasting using heated salt; (b) a slow roasting method; and (c) a parboiling treatment as an initial step in converting soybeans to flour. Flour prepared by the roasting method was found to be better in texture, colour, and shelf-life than flour made by first parboiling the beans. Up to 35 percent soy flour was combined with pure black gram flour to produce a good quality pappadum, which is higher in protein content and lower in cost than pappadum made with gram flour alone.

Soybean dhal. Soybeans show promise of being a good substitute for Mysore dhal if cooking time can be reduced. Preliminary experimentation has shown that a highly acceptable soy dhal can be prepared if the following steps are taken. First, using a coarse grinder, break up clean, dry beans into desired size, then soak freshly prepared dhal for 4 hours. Parboil for 30 minutes in 0.05 percent baking soda, and finally, dry in a dehydrating chamber at 50°C for approximately 12 hours. Dhal prepared in this way has a cooking time of 15 to 30 minutes, whereas one to one and a half hours are needed if precooking is omitted.

Cooking time and storage. Although there were no significant variations among 10 soybean varieties in the amount or rate of water absorption, it has been observed that older seeds require longer cooking. An investigation is being carried out to see whether there is a correlation between cooking time and water absorption with storage time. These studies will try to ascertain whether the physical condition of the seed coat or physiological conditions in the seed affect cooking time and water absorption.

Additional research planned. Ways of shortening cooking time by the use of meat tenderizers, such as pepsin from papaya and bromelic acid from pineapple juice, will be explored. A weaning food is to be developed using precooked soy meal, precooked rice flour, and skim milk fortified with vitamins. The use of partly dehydrated tropical fruits combined with soy flour in weaning foods will also be tested. An investigation will be carried out to detect the presence of trypsin inhibitors, if any, in "Those" (a soybean-cereal mixture now being marketed), as well as in other foods for which recipes have been developed by the Farm Women's Extension Unit.

EXTENSION

The Farm Women's Agricultural Extension Programme, assisted by FAO Rome and financed by the Freedom from Hunger Campaign, Australia, is an integral part of the total programme advanced by the Extension Division of the Department of Agriculture. During the past two years islandwide programmes were begun to popularise coarse grains, yams, and pulses as substitutes and supplements for rice and wheat flour. Preparation of dishes from soybeans and ways to combine them with other foods for a more nutritious diet were emphasised.

Soybean Production in Thailand

Amnuay Tongdee

Soybeans, one of Thailand's most important crops, have been grown here traditionally, although there is no evidence of when they were first introduced. After having been brought to this country, probably by migrating Chinese, soybeans became part of the Thai diet. They are processed into a variety of foods, including tou-hu tou-cheaw, and soy sauce. Freshly cooked pods, called tou-rae, are prepared for immediate consumption.

PRODUCTION AND PRODUCTION AREAS

In the past not many soybeans were grown because there was no export market. At present, however, production has been increasing as a result of the establishment of oil extraction factories and the higher demand for soybeans on the foreign market (Table 1). Looking at the data for soybean production during the past decade, one can see that between 1972 and 1974 the area planted to soybeans doubled, while the total production more than tripled, from 72,000 metric tons to 252,400 metric tons (Table 2).

Soybeans can be grown in every part of Thailand. In the northern part of the central highlands the principal growing areas are located primarily in Sukhothai, Pichit, and Nakernsawan. During the dry season Chiang Mai Province is also an important production area. Most of the soybeans produced in Thailand today are grown on small-scale, labor intensive plots, using traditional farming methods.

CULTIVATION

Soybeans are planted in both the dry season, from January through April, and in the rainy season, from May through July. In the dry season they are usually sown in rice fields after harvest. Farmers in the north practice this method in irrigated areas. Elsewhere in Thailand soybean production is expanding into irrigated areas, such as those in the central region and also in the Mekong Dam area to the northeast. Most of the areas engaged in soybean planting during the rainy season are to the north of the central region. Because the majority of farmers rely on natural rainfall, planting can be started only at the beginning of the rainy season or just before the end of this season, that is, between May and July.

In Chiang Mai Province, which was named a soybean production area in Thailand's five-year plan, most of those farmers who use irrigation start planting in December and January and harvest in April and May. In 1974 124,300 rais in the dry season and 63,125 rais in the rainy season were planted to soybeans. The total production area, 187,425 rais, produced 26,922 metric tons of soybean seed.

When soybeans are grown in rice paddies, the rice stubble, which has been left in the field after harvest, is cut to just above ground level. The straw is then tied together and burnt in the paddy. In this way the ashes are used as both mulch and fertilizer. Five or six seeds are dibbled into the soil at the base of the stubble or between the rows. Although seldom used, fertilizer can be applied after planting, following which the area is

Table 1. Price of Soybeans in Bangkok (1971-1975)

Month	Soybean prices (baht/metric ton)[a]				
	1971	1972	1973	1974	1975
Jan.	2,420	2,500	4,230	5,600	5,250
Feb.	2,380	2,750	4,770	5,660	4,900
Mar.	2,470	2,790	4,830	5,370	4,870
Apr.	2,580	2,780	4,730	5,330	4,570
May	2,620	2,970	4,860	4,820	5,150
June	2,640	3,220	6,420	4,930	5,090
July	2,750	3,460	7,430	4,650	....[b]
Aug.	2,790	3,330	6,600	5,120	....
Sep.	2,890	3,160	5,440	4,810	....
Oct.	2,880	2,970	5,070	4,800	....
Nov.	2,700	2,760	4,700	5,120	....
Dec.	2,420	3,550	5,220	4,900	....
Average	2,630	3,020	5,360	5,090	....

[a] 20 baht = one U.S. dollar.
[b] Figures not yet available.

Amnuay Tongdee: Mae-Jo Agricultural Experiment Station, Chiang Mai, Thailand.

Table 2. Area Planted to Soybeans and Total Soybean Production in Thailand

Year	Area (rais)[a]	Production (metric tons)
1964	213,000	31,300
1965	117,000	19,100
1966	285,000	37,900
1967	399,000	52,800
1968	329,000	44,500
1969	299,000	48,200
1970	368,000	50,400
1971	359,000	54,300
1972	500,000	72,000
1973	893,000	152,300
1974	1,016,000	252,400

[a] 6.25 rais = 1 hectare.

flooded. Watering is done every seven to ten days, or as needed, until harvesting. The plants require little attention throughout the growing period.

VARIETIES, FERTILIZERS, AND INOCULATION

Two recommended varieties are commonly grown in Thailand, SJ-1 during the rainy season and SJ-2 during the dry season. Farmers customarily use no fertilizer other than the burned rice straw; however, the 3-9-6 formula is suitable and extension workers have begun recommending its use to farmers in order to increase production. Inoculation is rarely used except in experimental fields.

DISEASE AND INSECT PESTS

Soybean rust is very severe, especially in the northern region during the rainy season. Root and stem diseases are considered of minor importance; consequently, very little attention has been given this potential problem. Disease-resistant varieties from breeding materials are being selected and will soon be released.

Insects are becoming a major problem in soybean production. The bean fly is the most significant, especially during the early stages of plant growth when it often kills the plant or causes severe damage. Of lesser importance are leaf rollers, leafhoppers, cutworms, armyworms, and leaf miners.

UTILIZATION

As indicated, the Thai people have been familiar with soybeans for many generations. A variety of traditional foods are prepared from soybeans for daily consumption. Recently many oil extraction factories have been installed, resulting in an increased demand for raw materials. An estimated 220,000 metric tons of soybeans are needed annually to meet this rising demand.

CLOSING ADDRESS

Solutions to Soybean Production Problems Through International Cooperation

R. W. Howell

I approach this assignment of presenting the concluding remarks with considerable humility. There are many people here at this conference who are wiser than I about the problems and opportunities in Asia, and so I cannot claim any special expertise. I hope you will judge my remarks as those of a person who has just been through a tremendous educational experience.

This week has indeed been educational, no doubt, for all of us. The final symposium was a fitting climax, for it focused on the major objective of the conference, "Expanding the Use of Soybeans." We are really talking about expanding the nutrition, and therefore the welfare and happiness, of our fellow human beings.

Dr. Riley's comments on the results of their survey on the goals of farmers in Taiwan reminded me of a story attributed to the president of the Eastman Kodak Company, although perhaps the story is apocryphal. In a staff meeting he asked, "What's the purpose of our company; what are we trying to make?" Some said film or cameras; others said chemicals — a whole range of products that particular corporation makes. He said, "You're all wrong. What we are trying to make is money." The farmer is also trying to make money. The point of the story is that we must not become so enraptured with our own commodities or with our own particular responsibilities that we lose sight of that objective.

This has been a truly international conference. Twenty-one countries, 16 of them in Asia or Oceania, are represented. The expertise of all the continents is also represented. Although we do not have delegates from South America or Africa, several people here have had extensive experience on both those continents, in addition to their experience in Asia, Australia, and North America. Over 230 people have attended, and there have been more than 80 presentations.

This conference, like similar conferences where colleagues get together, has given us the opportunity to renew friendships, a very warm experience for me. Even more important is the chance to make new friends. One of the real values of this kind of meeting is that we get to know one another as individuals, which makes it much easier to communicate and exchange ideas.

We wish to express our gratitude to the program committee, to the local committee, and to the hotel for the excellent arrangements that have made our visit so pleasant. From the sign at the airport in Bangkok — Soybean Conference, Check Over Here — and the banner and reception group at the airport in Chiang Mai, to a most notable evening in Old Chiang Mai at the cultural center, we have experienced nothing but genuine hospitality. And I am sure all of us have found that our personal wants as well as our professional needs were attended to promptly and pleasantly.

Let me give you some of my impressions of the conference. It would be presumptuous of me to undertake a review of every paper, but my impression is that a vast amount of talent and expertise is available to work on the problems for which soybeans may be a solution in this part of the world. The conferees are clearly well informed about the state of soybean technology. We have heard discussions of technology that is transferable from one country to another and discussions of situations where it is not. U.S. varieties, for example, have generally done well in variety trials, although this may not be true in a few years when these tests include larger numbers of improved lines from Asian countries. At present, however, this particular bit of technology appears to have transfer value. Certainly the principles of genetics, of storage and handling, of pest control, as well as some of the basic knowledge obtained in the preparation of food products are transferable, at least as a basis for developing the final product.

In other cases, available technology does not meet the requirements of conditions as we find them. We have no transferable countermeasures for certain pests and pestilences, such as soybean rust and the yellow mosaic virus, which we have not had to combat in the Western Hemisphere. Our contribution with respect to control of those two problems is possible only because colleagues in the Eastern Hemisphere have previously

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done research in this area. Also, certain insect problems have been identified. We know, for example, that the whitefly is a vector of the yellow mosaic virus. But undoubtedly there are insect problems that have yet to be identified.

The mechanics of planting, culture, harvesting, and processing all require imaginative, innovative solutions. As several speakers so eloquently pointed out during the extension panel this afternoon, conditions in this part of the world are considerably different. The situation of small farmers, small entrepreneurs, an abundant labor supply, a marketing system that still needs development has been impressed upon us throughout the week. But it is reassuring that important officials recognize the special nature of these problems and are dedicated to developing solutions that will be applicable to these particular conditions.

Earlier in the week Professor Amara emphasized the problems of the transfer of technology to people in small industries. This afternoon we heard a discussion of transfer to farmers. The conference began with Dr. Singh's report of his breeding program in India and a discussion of reasons why soybeans have not achieved the popularity hoped for. He pointed out that susceptibility to diseases and insects, and problems with seed quality are of major concern. Dr. Rathod added price and marketing problems to this list.

The big problems are being attacked directly. People have not merely wrung their hands, but have recognized the difficulties and have undertaken research designed to work out solutions. Research with respect to soybean rust is encouraging. Plant breeding programs are in progress in India, Taiwan, and Indonesia to find sources of genetic resistance. The evidence that resistance will not be extremely complex is encouraging. Incidentally, I would endorse the call made by one of the speakers for a conference dealing with the rust problem, which is of sufficient magnitude to deserve such attention.

This group is certainly convinced of the potential of soybeans. At times we have all wondered who listens in both my country and yours. But here we have seen and heard reassuring evidence that government is supportive of our efforts. The Sri Lanka program, in which the Sri Lanka Government, UNDP-FAO, and INTSOY have joined together, will be significant because of the concentrated strength it can bring to bear on problems in a representative environment. Here in Thailand soybean research is underway with assistance from Japan and Australia, as well as from international agencies.

An important survey of nutritional needs and protein status in Indonesia is planned. During the food science symposium Dr. Winarno enumerated three points of this program: first, educating people in the principles of nutrition and providing food for mothers and preschool children; second, establishing a food technology center; and third, directing a study of ways to transfer this information and technology to small industries.

We are reasonably confident that the technical problems will be solved. Good breeding programs are underway; advances are being made in pest control through exchange of information between workers. Problems are being identified and people in several countries are working on solutions.

But the problems get a little harder as we progress from storage, handling, and processing to food use and acceptability. In this stage, people problems are encountered. There are no people problems in breeding new soybeans because soybeans do not have any preferences; they are perfectly willing to be bred however you wish to breed them. But a whole new dimension of more difficult problems is encountered when attempts are made to involve people whose social and economic preferences must be considered. And yet — I shall speak my bias — I think people will adopt new foods if they are available, if they are good, and if the price is right. An educational program is necessary, but the task is not insurmountable.

The city of Chiang Mai offers interesting possibilities in this regard. The vast number of public eating establishments here is impressive. Vendors sell food not only in every establishment, but all along the curbs on many streets. Rather than prepare food at home, people in Chiang Mai eat out. This is the thing to do. In a sense, eating is institutionalized, and that offers opportunities for introducing new foods without having to reach all the homemakers in the city.

Earl Kellogg's lecture on basic economics appealed to me because I have always had a rather simplistic approach to economics and marketing. I think marketing means there must be a market; otherwise, why produce something. The market must provide a price that is profitable to the producer, the processor, and the retailer, and one that is attractive to the consumer as well. A good trade is one in which both parties think they got a bargain. If we can have a marketing system that will provide distribution at prices which insure an adequate reward for everyone in the production chain, and will also deliver a good product at a price the consumer considers reasonable, then there will be a market. So after all the economic jargon, that seems to me to be the essence of the problem.

The challenge of extension, which was the climax of the conference, is where the real rewards come. The program planners should be complimented for including the symposium on extension. Dr. Yookti's observation is especially apt: "Research without extension is meaningless; extension without research is empty." This calls for close work between research and extension people. As other speakers have pointed out, extension workers are the bridge between the researcher in his ivory tower and the clientele for whom we are all working. That bridge carries two-way traffic. Extension workers are more than mere conveyors of wisdom from the researchers to the farmers or small processors and homemakers. Extension workers can provide research workers with information about problems in the real world. In the laboratory, problems can be isolated, conditions defined, questions

stated to allow for precise answers. Appropriate equipment can be designed, the work can proceed in an orderly manner, and answers can be found. The real world, however, is more complex, and the role of extension is to help scientists keep in touch with that world. I would encourage you to accept this as a true partnership, one in which you both have something to give and something to gain.

In the same context, I would like to comment on a point touched on in the panel. There was a question as to whether extension work is being done by commercial companies rather than by government-supported extension programs. I do not want to offend anyone, but I consider that a nonquestion. My concept, which I believe reflects the general view of the Illinois extension service, is that companies are one of the channels through which extension people can work. We know, for example, that fertilizer companies and seed companies have salesmen who work hard to get information across to the farmer. We work closely with those people to be sure they have the latest information, and that the information they are giving the farmer is sound. A good company or a good salesman is not interested in just one profitable sale. They want to sell this year, and next year, and the year after that. For them to be able to do that, the farmer, that is, the customer, has to have confidence that what they sold him was good. This is why we work closely with the producers and sellers of pesticides, insecticides, and herbicides, and with seed company representatives. Because they supplement our program, we feel there is no conflict.

I want to say a little about learning from the farmers. Mr. Lockman told me it is important that we respect the farmers. I could not agree more. These farm leaders, leaders of the community, will not be sitting back waiting for us to tell them what to do. They will be trying things for themselves. There will be occasions when they have tried something and have a good idea that you may want to adopt in your extension program, something that may have a bearing on the direction of your research. Do not be afraid to learn from the farmers.

Finally, with regard to extension education, I am reminded of a slogan I learned in instructor training in the army: "If the student has not learned, the teacher has not taught." The only measure of success is that the students have learned, not how many meetings you had; not how many people came; not how many handouts you distributed; but how well the students have learned.

I will leave here inspired by the quality of the research talent in Asia and by the commitment for expanding the use of soybeans in Asia. From many years of experience I feel that our confidence in soybeans is not misplaced. I am confident also that this conference will prove to be an event of great significance in improving the diets, the health, and therefore the well-being of people on the most populous continent in the world. This experience has been very educational and very pleasant for me, as I hope it has been for you.

TITLES OF CONTRIBUTED PAPERS (in order of presentation)

Soybeans for Tropical Asia: Research and Problems
J. S. Russell, I. M. Wood, and D. F. Beech
Commonwealth Scientific and Industrial Research Organization, Australia

An Integrated Approach to the Introduction and Development of Soybean
R. N. Trikha and R. W. Nave
Soya Production and Research Association, India

Farm Level Soybean Cultivation: Survey of 140 Farmers
K. R. Huang and M. R. Menegay
AVRDC, Taiwan

Soybean Pests in Indonesia and Their Control
Dandi Soekarna
Central Research Institute for Agriculture, Indonesia

Rhizobium Strain Selection for Soybeans and Environmental Effects
Yenchai Vasuvat and Nanthakorn Boonkerd
Department of Agriculture, Thailand

Bionomics and Control of the Leaf Miner (*Stomopteryx subsceivella* Zell.) on Soybean
Pisit Sepsweasdi, Turnjit Statyavirut, and Aphirat Arunin
Department of Agriculture, Thailand

Genetic Susceptibility of Soybeans to Soybean Pod Borer (*Graphalitha glycinivorella*) in Korea
S. K. Kim, J. M. Yohe, K. Y. Park, and Y. H. Hwang
Crop Improvement Research Center, South Korea

Performance of Seventeen Introduced Soybean Varieties in Rezaiyeh, Iran
J. Carapetian and A. Mozafar
College of Agriculture and Animal Husbandry (Rezaiyeh), Iran

Microbiology of Soybean-Based Fermented Foods in Southeast Asia
H. C. Choke and K. C. Lek
University of Malaya, Malaysia

Microbial Fermentation and Browning of Soy Sauce
V. Prakash
University of Malaya, Malaysia

Soybean Projects and Soybean Insects in Iran
A. Parwin
Plant Pests and Diseases Research Institute, Iran

Occurrence of Soybean Bud Blight in Iran
F. Eskandari
University of Tehran, Iran

Survival of *Rhizobium japonicum* Serogroups in Some Iraqi Soils
S. M. Damirgi and R. K. Al-Rashidi
University of Baghdad, Iraq

Weeds and Chemical Weed Control in Soybeans in Iran
H. Mirkamali
Plant Pests and Diseases Research Institute, Iran

Defoliation Effect on Soybean Yield Under Four Different Population Densities
H. S. Lee
Seoul National University, South Korea

Selection of Tropical Rhizobium for Soybean Inoculation
W. J. Broughton and S. Padmanabhan
[illegible]

ABBREVIATIONS AND UNITS OF MEASURE

Av; av: average
bu: bushel; 1 bushel of soybeans equal to 27.3 kg; 1 bu/acre = 67 kg/hectare
cc: cubic centimeter
cm: centimeter
cm^2: square centimeter
CV: coefficient of variation
dm^2: square decimeter, or an area equal to 1/100th of a square meter
DMB: dry matter basis
DMRT: Duncan's Multiple Range Test
fl oz: fluid ounce, equal to 0.03 liter
FLSD: Fisher Least Significant Difference
ft-c: foot-candle, equal to 10.8 lux
g; gm: gram
ha: hectare, a unit of land area measurement equal to 10,000 square meters
hr: hour
IU: international unit
kg: kilogram
kg/ha: kilogram per hectare
lb: pound, equal to 453.6 grams
LSD: Least Significant Difference
lux: a unit of light intensity measurement equal to 1 lumen per square meter, or 0.0929 foot-candle
m: meter
m^2: square meter
mcg: microgram
meq: milliequivalent
mg: milligram
ml: milliliter
mm: millimeter
n: sample size
no.: number
NPU: net protein utilization
NS: not significant
O.M.: organic matter
oz: ounce, equal to 28.4 grams
pH: negative logarithm of the hydrogen ion concentration
ppm: parts per million
quintal: a metric unit of weight equal to 100 kilograms
rai: a unit of land area measurement used in Thailand; 16 rais = 1 hectare; 1 rai = $625m^2$
Rs: rupees
ton/acre: English short ton (2,000 pounds) per acre
ton/ha: metric ton (1,000 kilograms) per hectare
μ: micron
μg: microgram
wt: weight
$\bar{\bar{X}}$: mean value